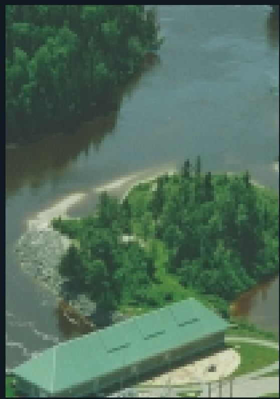


PRIMER ON THE TECHNOLOGIES OF RENEWABLE ENERGY

Pollution Probe
CLEAN AIR. CLEAN WATER.

POLLUTION PROBE IS A NON-PROFIT CHARITABLE ORGANIZATION THAT WORKS in partnership with all sectors of society to protect health by promoting clean air and clean water. Pollution Probe was established in 1969 following a gathering of 240 students and professors at the University of Toronto campus to discuss a series of disquieting pesticide-related stories that had appeared in the media. Early issues tackled by Pollution Probe included urging the Canadian government to ban DDT for almost all uses, and campaigning for the clean-up of the Don River in Toronto. We encouraged curbside recycling in 140 Ontario communities and supported the development of the Blue Box programme. Pollution Probe has published several books, including *Profit from Pollution Prevention*, *The Green Consumer Guide* (of which more than 225,000 copies were sold across Canada) and *Additive Alert*.

Since the 1990s, Pollution Probe has focused its programmes on issues related to air pollution, water pollution and human health, including a major programme to remove human sources of mercury from the environment. Pollution Probe's scope has recently expanded to new concerns, including the unique risks that environmental contaminants pose to children, the health risks related to exposures within indoor environments, and the development of innovative tools for promoting responsible environmental behaviour.

Since 1993, as part of our ongoing commitment to improving air quality, Pollution Probe has held an annual Clean Air Campaign during the month of June to raise awareness of the inter-relationships among vehicle emissions, smog, climate change and related human respiratory problems. The Clean Air Campaign helped the Ontario Ministry of the Environment develop a mandatory vehicle emissions testing programme, called Drive Clean.

Pollution Probe offers innovative and practical solutions to environmental issues pertaining to air and water pollution. In defining environmental problems and advocating practical solutions, we draw upon sound science and technology, mobilize scientists and other experts, and build partnerships with industry, governments and communities.

POLLUTION PROBE
CLEAN AIR. CLEAN WATER.

SEPTEMBER 2003

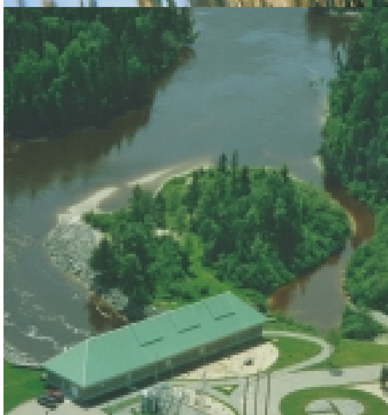
Pollution Probe is pleased to present this educational primer on renewable energy technologies. It has been developed to promote greater public understanding of the potential for shifting Canada's energy generation sources to cleaner and less greenhouse gas-intensive technologies. The primer can also be read in conjunction with Pollution Probe's complementary primers on smog, acid rain, climate change and mercury, as well as our guide for consumers on purchasing green power.

Pollution Probe is dedicated to ensuring that governments and industry implement policies and programmes that lead to a cleaner and safer environment. The support of an informed and active public is essential to accomplish this mission.

Your comments on this primer are welcome. We also appreciate feedback on the usefulness of the primer to you and others with whom you share it. Please let others know about the primer and its availability free-of-charge on our website (www.pollutionprobe.org/Publications/Energy.htm). Printed copies are also available for a small fee to cover printing and distribution costs.

K. B. Ogilvie

Ken Ogilvie
Executive Director
Pollution Probe



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Pollution Probe is solely responsible for the contents of this publication.

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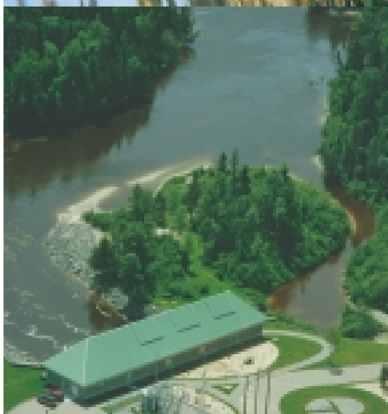


Atlantic Wind Test Site. Brian Simpson.

INTRODUCTION

Canadians are taking a new look at renewable energy technologies. Some of these technologies, such as those that generate hydroelectricity, are familiar sights in parts of Canada. Others, such as the technologies used to generate electricity from the wind and sun, are less common, but are seen more frequently today than even ten years ago.

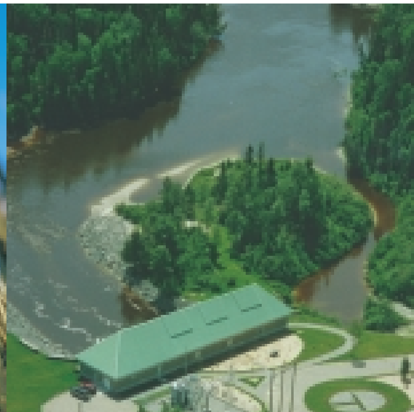
The purpose of Pollution Probe's *Primer on the Technologies of Renewable Energy* is to describe some of the more prominent technologies, particularly the ones either in use or being tested in pilot projects in Canada. The hope is to peak your interest in the possibilities of renewable energy, and to prompt you to support programmes that use renewable energy.

This primer is divided into six chapters. Chapter One explains what renewable energy is. For example, why is it called renewable, and why are Canadians taking a new look at renewable energy as a source of electricity, heat and, in some cases, fuel?

Chapter Two looks at water as a source of electrical power. This chapter is divided into four sections. The first section deals with large-capacity hydroelectric projects, which are probably what comes to mind when Canadians think of electricity from water. But almost half of the estimated 450 hydroelectric plants in Canada are relatively small-capacity plants, in the range of 20 to 25 megawatts, compared to the 1,577 megawatt capacity of Adam Beck II at Niagara Falls. The second section of this chapter explains how the smaller hydroelectric plants work. The third section looks at how tides are harnessed to generate electricity, and the fourth section explains how waves are used to generate electricity.

Chapter Three explains how wind is used to generate electricity and describes some of the wind turbine and wind farm projects that are either up and running or being tested in Canada.



Chapter Four is about biomass. This chapter describes the technologies used in Canada to turn energy from agricultural crops, fast-growing trees and mill waste into electricity, as well as to produce fuels for cars or trucks.

Chapter Five explains the technologies used to harness the sun's energy. This chapter is divided into two sections — solar thermal energy and photovoltaic energy. The first uses the sun's energy to heat water and air in buildings, as well as to generate electricity. The second captures the sun's energy in cells and converts it directly into electricity.

Finally, Chapter Six describes some of the technologies associated with geothermal energy to generate electricity and to heat air and water for houses, offices, schools and buildings.




Solar Power Tower. US Department of Energy.

WHAT IS RENEWABLE ENERGY? CHAPTER 1

Renewable energy is called renewable because the sources harnessed to create the energy renew and replenish themselves constantly and within a reasonably short period of time (i.e., months or years, not centuries). These sources of energy include water, wind, sun, biomass and heat from the Earth's interior.

The term renewable energy excludes energy created by nuclear fuels, such as uranium, and fossil fuels (oil, gas and coal) for two reasons. First, fossil fuels take millions of years to form, and once removed, require as many years to form again. Second, Canada's supplies, indeed the world's supplies, of uranium and fossil fuels are limited.

The term renewable energy is not always synonymous with what is often called "green" energy. Typically, green energy refers to energy from renewable sources that leave smaller environmental footprints than does conventional large-scale generation, including some renewable energy sources. For instance, although they utilize renewable energy and do not contribute to air pollution, some large-capacity hydroelectric projects require huge dams and reservoirs, which flood thousands of hectares of wilderness and disrupt the migration patterns of fish and wildlife. In contrast, some low-capacity, run-of-the-river hydroelectric projects use the flow of the water as it runs downstream to generate electricity and may result in little disruption to the environment or to local ecosystems.

There are two other important points about renewable energy. First, although quickly replenished, some of these forms of energy are intermittent on either a daily or a seasonal basis. There are days when the sun does not shine or the wind does not blow, and certainly it's rare that sunshine and wind are consistent throughout the day. In some instances, the technology requires a way of storing the power that is created. In most cases, the electricity generated from these intermittent renewable sources is supplemented by electricity generated by other, more dependable means, such as storage-based waterpower.

This leads to the second point. When renewable energy is used to create electricity, it often flows into a provincial or territorial power grid to become part of the pool of electricity generated from several sources, including non-renewable energy. Governments, utilities and many individual Canadians hope to increase the amount and overall proportion of electricity generated by low-impact renewable energy as an important way to protect human health and the environment.

Why Renewable Energy and Why Now?

Canadians are taking a new interest in renewable energy for several reasons. First, electricity from renewable energy produces fewer greenhouse gas emissions, which are associated with a changing climate, than electricity produced from burning fossil fuels. Similarly, renewable energy generally adds fewer other pollutants to the air, including the following:

- sulphur dioxide and nitrogen oxides that form acid rain;
- particulate matter, which along with ground-level ozone forms smog on hot, sunny summer days; and,
- mercury, which can be transformed in the environment to become highly toxic to people and animals.

For more information on the harmful effects of acid rain, smog and mercury please look for *The Acid Rain Primer, The Smog Primer* and *Mercury in the Environment: A Primer* at www.pollutionprobe.org/Publications/Index.htm.

Next, when Canadians use low-impact renewable energy, they help to protect the land and water. When large-scale energy projects are developed, they have the potential to drastically alter watersheds, migration routes, and wildlife and fish habitats. And, although many utilities have made major improvements in their practices and technologies, the effects on the environment can still be quite large.

Further, the supply of renewable energy is not only virtually unlimited (at the right price), it also offers the possibility of relatively stable prices. In the late 1990s and early years of the 21st century, Canadians watched as the prices of oil and gas soared, plummeted and then soared again, in part because of the weather and in part because of world politics. Increasing the use of locally generated renewable energy can help protect us from dramatic price swings.

In Ontario, Alberta and Nova Scotia, customers can now support the generation of electricity using renewable energy through several different plans. In most cases, the customers pay their regular electricity bills and support the use of green power to generate electricity through an additional fee or separate programme (see *The Consumer Guide to Purchasing Green Power* at www.pollutionprobe.org/Publications/Energy.htm).

Ontario Power Generation Inc. offers commercial, industrial and retail customers the opportunity to buy electricity created by green power under a programme called Evergreen. The power is generated using renewable energy resources, such as wind, biomass and low-impact hydro. Oakville Hydro Energy Services Inc. is making the Evergreen programme available to Ontario residents through its sale of Green Light Pacts, which customers purchase in addition to paying their electricity bills. Each full Green Light Pact ensures that 660 kilowatt-hours of Green Power are generated and distributed through the Ontario electricity grid. This is equivalent to approximately three weeks of electricity used by a typical home (see www.opg.com/envComm/E_greenPower.asp or www.oakvillehydro.com).

The Grey Bruce Renewable Energy Cooperative (GBREC) has developed a programme that sells Green Tags to support wind power generation in Ontario. GBREC buys Green Tags from wind energy generators, such as Sky Generation and the Port Albert Wind Farm, and sells them to Ontario residents and other

Canadians. Each Green Tag supports the generation of 1,000 kilowatt-hours of electricity through wind energy. The Green Tags are available directly from Green Tags Ontario and several community groups (see www.greentagsontario.com).

Another type of opportunity is offered by Windshare, a project developed by the Toronto Renewable Energy Cooperative (TREC) in a 50/50 partnership with Toronto Hydro Energy Services. Windshare has erected one wind turbine on the Toronto waterfront and has plans to erect a second turbine. To raise funds for its half of the project, TREC offers individuals and companies the opportunity to buy shares in the wind turbines and the electricity they generate (see www.windshare.ca).

In Alberta, Canadian Hydro Developers Inc. sells Renewable Energy Certificates, which are comparable to Green Tags. Also, ENMAX Energy Corporation offers its customers the opportunity to pay an additional fee on their electricity bills to support the purchase of wind-generated power in Alberta. Starting in 2005, the two companies will be providing green power to supply about 90 per cent of the electricity used in Alberta's government-owned facilities. The contracts were developed in response to a Request for Proposals issued by the Alberta government; when they come

What is a Power Grid?

A power grid is a network that includes the following:

- the power station where electricity is generated;
- the transformers by the station that boost the voltage or pressure of electricity so that it can travel long distances;
- the towers and high voltage wires that carry electricity across the countryside;
- the sub-stations close to the city or town, at which transformers reduce the voltage of the electricity for safe transmission on the distribution system within the municipality; and,
- the poles and wires that carry electricity through the city, town or village and eventually to industrial parks, local businesses and homes.

What are Watts?

The watt is a unit of power named after James Watt (1736–1819), the Scottish inventor, and is used to measure electricity. Watts are very small units. A light bulb is usually rated at 25, 40, 60 or 100 watts.

A kilowatt is 1,000 watts.

A kilowatt-hour is a unit of electrical energy, equivalent to one kilowatt of power used for one hour. It is equal to 1,000 watt-hours — the energy needed to turn on ten 100-watt light bulbs for one hour. A kilowatt-hour is the unit for which consumers are charged on electricity bills.

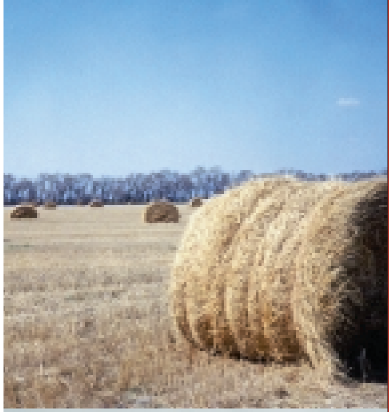
According to Ontario Power Generation, the average Ontario home uses about 11,600 kilowatt-hours each year, although new homes use closer to 7,000 kilowatt-hours a year.

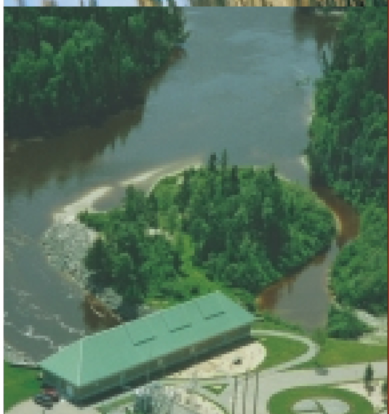
In 1999, the total use of electricity in Canada was 497,000,000,000 kilowatt-hours.

Utilities sometimes use kilowatt-hours when they list the amount of electricity a generating station is capable of producing in one year. For example, the Annapolis Tidal Generating Station in Nova Scotia is capable of producing 30 million kilowatt-hours per year.

into effect the contracts will result in annual savings of about four million dollars (see www.canhydro.com or www.enmax.com/doorway.htm).

On the east coast, Nova Scotia Power is offering its customers the opportunity to support wind generation of electricity by purchasing 125 kilowatt-hour blocks of Green Power, in addition to paying for their metered electricity use (see www.nspower.com).



What are Watts? (continued)

Most often, capacity levels of generating facilities are listed in megawatts. To get the theoretical amount of energy a station is capable of producing in a year, you take the capacity and multiply by the number of hours in a year and then apply a capacity factor (the amount of time the plant would be producing at full potential).

A megawatt is one million watts. Companies or utilities usually talk about the amount of electricity a generating station is capable of producing in megawatts. For example, the Annapolis Tidal Generating Station in Nova Scotia has a 20-megawatt capacity, which means it can generate 20 megawatts of electrical power at any one time.

A gigawatt is one billion watts or 1,000 megawatts.

A terawatt is one trillion watts or one million megawatts.

Wawatay Generating Station. Regional Power Inc.

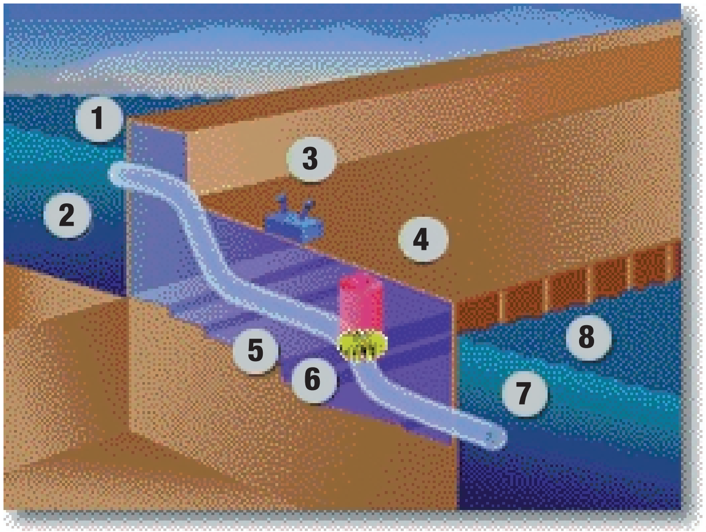
WATER CHAPTER 2

Societies have used water as a source of power for thousands of years. The first record of waterpower use comes from 250 BCE and refers to a water clock. In the 18th and 19th centuries, many communities grew up beside rivers because they provided the power needed to turn the waterwheel for the local mill. This chapter describes four ways in which the energy of moving water is used to create electricity — large-capacity hydro-electric plants and small-capacity hydroelectric plants, tidal generating stations and wave generating stations.

How Hydroelectric Plants Work

Large-capacity and small-capacity hydroelectric plants generate electricity in the same way. The difference between the two lies in the scale of the projects and the amount of electricity produced. Hydroelectric plants convert the potential energy of water to electrical energy by creating a drop in the elevation of the water. Some hydroelectric stations take advantage of a river's natural drop in elevation (for example, Ontario Power Generation's Sir Adam Beck generating station located at Niagara Falls). Many hydroelectric generating stations, however, use dams to raise water levels upstream of the station and increase the drop in height to produce more electricity and/or to store water and release it to produce electricity to match changes in demand.

FIGURE 1 **HOW HYDROELECTRIC GENERATION WORKS**



1 — Forebay
2 — Intake
3 — Transformer
4 — Generator
5 — Penstock
6 — Turbine
7 — Draft Tube
8 — Tailrace

Source: www.opg.com

The amount of electricity generated depends on the vertical distance that the water falls and the water's flow rate. Flow is a measure of the volume of water moving past a point during a certain amount of time, usually a second. Not surprisingly, large-capacity hydroelectric plants are often located where there is a large fall and/or a large quantity of water, while small-capacity hydroelectric plants are typically located where there is either a small fall or quantity of water.

- The water in the river or reservoir behind the dam flows through an opening, usually called an intake, and from there through a pipe called a penstock.
- The water flows through the penstock under pressure to its end, where there is a turbine.
- The force of the water turns the blades of the turbine, which turn the shaft inside the turbine.
- The turbine shaft is connected to a generator, which generates electricity.
- Once past the turbine, the water flows through a pipe, called a draft tube, out of the generating station into a channel, called the tailrace, and back to the river.

How Does a Water Turbine Generate Electricity?

In very simple terms, electricity is produced by spinning electro-magnets inside a coil of wire in a generator to create a flow of electrons. To keep the electro-magnets spinning, a hydroelectric station uses falling water. Water goes through the intake into a pipe that carries it down to the turbine. The turbine is connected to a generator. When the turbine is set in motion, it causes the generator to rotate, and electricity is produced.

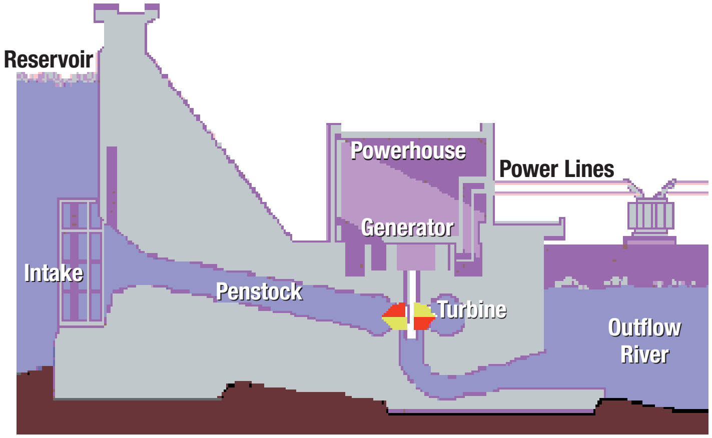
Large-capacity Hydroelectric Plants

In Canada, large-capacity hydroelectric plants are considered to be those with annual capacities of more than 20 to 25 megawatts. There are three common types of large-capacity hydroelectric plants, with variations on each: dam and reservoir, run-of-the-river and pumped storage.

Dam and reservoir. Many large-capacity hydroelectric generating stations use a dam to increase the height of the water and a reservoir to store water backed up behind the dam. The reservoir gives utilities a reliable source of water, allowing them to adjust the amount of electricity generated to meet daily, weekly and seasonal demand, and in some cases, demand in wet and dry years. When demand rises for a given utility, the utility responds by increasing the flow of water to the turbine.

Run-of-the-river. Some large-capacity hydroelectric generating stations use a combination of large flow rates and high natural waterfalls. Typically, a small dam or weir is used to divert the water to the hydropower plant. (A weir is a diversion structure where excess flow spills over the top.) In some cases, a dam or weir is not used, and a portion of the water is allowed to flow naturally through the river. When a dam or weir is not used, or is very small, hydroelectric plants cannot store water for long periods of time. These plants, which use the flow of the river in a manner that does not appreciably alter the existing flows and water levels, are called run-of-the-river plants. Because these plants rely primarily on the river's natural flow of water, the amount of electricity the stations generate varies from day-to-day, season-to-season, and year-to-year, depending on the volume of water in the river. (The Sir Adam Beck generating stations on the Niagara River are examples of large-capacity run-of-the-river plants.)

FIGURE 2 **TYPICAL LARGE-CAPACITY HYDROELECTRIC PLANT WITH DAM AND RESERVOIR**



Source: US Geological Survey. Water Science for Schools.

- **Dam and reservoir —** The dam increases the height of the water and the reservoir stores the water for future use.
- **Water intake —** Gravity causes the water to flow through the intake.
- **Penstock —** The water that goes through the intake flows under pressure through a pipe called the penstock.
- **Turbine —** The force of the water flowing down the penstock turns the turbine.
- **Generator —** The shaft of the turbine goes into the generator, which generates the electricity.
- **Transmission lines —** The transmission lines carry the electricity to where it is needed.

Pumped storage. Some electricity producers also use a hydroelectric generating system called pumped storage. In this case, they use excess electrical capacity generated by the turbines, which is generally available at night, to pump water from one reservoir to another at a higher elevation. During periods of peak demand, the producer releases stored water from the higher reservoir through the penstock to the turbines and then to the lower reservoir. Pumped storage sites actually use more electricity to pump the water from the lower to the upper reservoir than they generate. But these sites are useful because they allow producers to generate electricity when demand is high, for example, in the early morning or early evening. The ability to use pumped storage is even more valuable if the producer uses sources of renewable energy that are intermittent, such as the sun or the wind.

Cascade systems. Many waterpower facilities are organized in cascade systems, such that the water storage on the river system is "cascaded" through multiple facilities. The water released from an upstream reservoir will move through successive downstream stations with a time delay corresponding to distances between facilities and flow rates. Downstream facilities are therefore not necessarily operated independently; facilities on the system generate electricity from the same initial release of stored water, rather than from their own storage reservoirs, and must be operated to respond in a similar, coordinated fashion to the original release. Variations on this approach occur when facilities within the system have extra storage capacity in individual impoundments, or have alternative sources of water, such as significant tributaries.

Considerations. Large-capacity hydroelectric plants, indeed all hydroelectric plants, produce electricity relatively efficiently. In fact, they convert about 90 per cent of the available energy — from water — into electricity; this is more efficient than any other method of generating electricity. Waterpower plants with dams and reservoirs are also reliable producers of electricity because they have readily available sources of stored water.

Even though large-capacity hydroelectric plants use water as the source of power, they often require dams that may cause extensive flooding of environmentally sensitive areas. The dams and reservoirs may also destroy or alter fish habitat and migration routes for fish and wildlife, as well as require people to relocate their communities. Typically, large-capacity hydroelectric plants have a larger environmental footprint than small-capacity plants.

Small-capacity Hydroelectric Plants

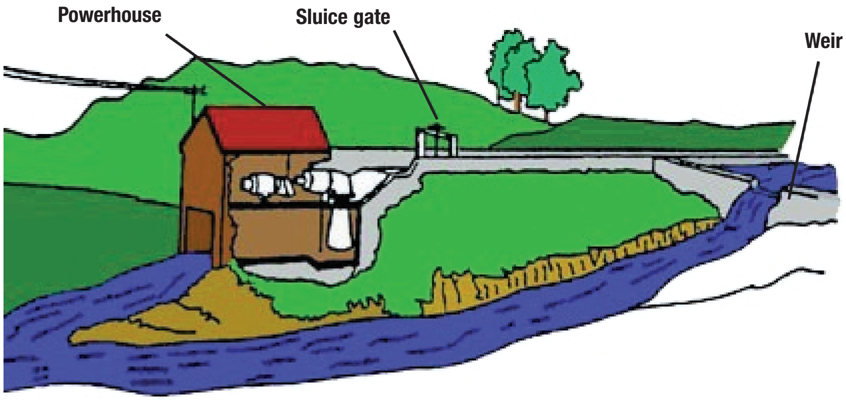
There is no consensus in Canada or, for that matter, in the world about what constitutes a small-capacity hydroelectric plant. In Ontario, for example, there is no definition of "small." In Quebec, small refers to plants with capacities of less than 25 megawatts, and in British Columbia, small refers to plants with capacities ranging between two megawatts and 50 megawatts. Internationally, small often refers to plants with capacities of 10 megawatts or less. Hydroelectric plants with capacities between 100 kilowatts and one megawatt are sometimes referred to as mini-hydroelectric plants, and hydroelectric plants with capacities of less than 100 kilowatts are often referred to as micro-hydroelectric plants. In British Columbia, however, micro-hydroelectric plants are defined as those with capacities of less than two megawatts.

Despite the differences in definition, the important environmental distinction for hydroelectric plants is not the size of the project, but instead the potential local and cumulative effects of waterpower facilities on the environment.

There are two types of small-capacity hydroelectric plants: those using weirs and dams, and run-of-the river facilities.

Weirs and dams. Most small-capacity hydroelectric plants rely on low dams, weirs or diversions, but do not cause substantial flooding. If a small-capacity hydroelectric plant does need to store water, it is usually a minor amount and is stored in an existing upstream lake for a relatively short period of time.

FIGURE 3 **SMALL-CAPACITY HYDROELECTRIC PLANT WITH WEIR**



Source: http://acre.murdoch.edu.au

- **Dam or weir —** If there is a dam or weir, it is low, simply constructed, and used to direct the water into the canal or penstock.
- **Intake or sluice gate —** The water flows from the river or stream through the intake, which includes a trashrack that collects trash and debris from the stream or river.
- **Turbine —** The force of the water flow causes the turbine blades and shaft to turn.
- **Generator or powerhouse —** The turbine shaft is connected to the generator, which generates electricity.
- **Tailrace —** The tailrace carries the water back to the river.

Run-of-the-river. Run-of-the-river hydroelectric plants divert the water, typically at a small dam or weir, sending it through a canal or penstock to the generating station and then back into the river without appreciably altering existing flow rates or water levels.

Considerations. As with large-capacity hydroelectric plants, small-capacity hydroelectric plants generate low-cost electricity very efficiently. However, if the plant does not store water in a nearby lake or small reservoir, then the amount of energy that can be generated is not as reliable and will vary from day-to-day, season-to-season, and year-to-year. For example, in dry years, the station will not generate as much electricity as it does in wet years; during a day of heavy rain the plant will generate more electricity than during a day without rain. The cost of small-capacity hydropower is typically higher than large-capacity hydropower because of economies of scale.

The environmental impacts of small-capacity hydroelectric plants can be smaller than those of their larger counterparts. Good design and planning can often mitigate the stresses a small-capacity hydroelectric plant places on the environment. For instance, a fish ladder can allow fish to swim around the station unharmed. It is possible, however, that the cumulative effect on the environment of many small hydroelectric plants on a given river system could be significant. Even small-capacity hydroelectric plants cannot be looked at in isolation.

Quick Facts

The word “hydro” comes from the Greek word “hydra,” which means water.

The first hydroelectric generating station in Canada was built in 1882 at Chaudière Falls on the Ottawa River. The station supplied electricity to two arc lamps for a sawmill in Ottawa.

The first high-voltage, long-distance transmission line began carrying electricity in 1897. The 29-kilometre long, 11,000-volt line transmitted electricity from an 895-kilowatt plant on the Bratiscan River to Trois Rivières in Quebec.

Tides

Every day, twice a day, the tides rise and fall, in some places by only a metre or so, and in others, such as the Bay of Fundy on Canada’s east coast, by as much as 6.3 metres (21 feet). The earliest evidence that people harnessed the power and regularity of the tides to do work comes from the tenth century. Coastal inhabitants built dams across the openings of basins in such a way that the water could flow in when the tide came in, but not out when the tide fell. Instead, the stored water flowed through waterwheels or paddle wheels, which turned grindstones that ground grain into flour.

The French built the first commercial-scale tidal generating plant in the 1960s near St. Malo on the north coast of France. With a capacity of 240 megawatts, the La Rance plant is the world’s largest tidal plant. Canada followed in 1984 with the Annapolis Tidal Generating Station in the Annapolis Basin in Nova Scotia. This plant has a capacity of 20 megawatts. The other tidal generating station operating today is located in Kislaya Guba, near Murmansk on the White Sea in Russia. This plant has a capacity of 0.5 megawatts.

Although the tides rise and fall twice a day in all coastal areas, there must be a difference of at least five metres between high and low tides for a tidal generating station to create cost-effective electricity. Today, about 40 areas in the world are considered suitable for tidal generating stations.

How the technology works — In some cases, the technology works today as it did more than 1,000 years ago — by harnessing the power of the changing tides using dams, which are often called barrages or fences.

Barrage. The simplest and oldest technology involves building a dam, known as a barrage, across a bay or estuary that has large differences in elevation between high and low tides. When the tide comes in, the water fills the area behind the barrage. When the tide starts to ebb, the gates of the barrage shut to hold back the water at its maximum height. Once the tide is out, the water is allowed to flow through holes near the bottom of the barrage where the turbine is located. The water, now running with great energy, turns the blades of the turbine that, in turn, generate electricity. The tidal generating station in the Annapolis Basin uses this method.

The Annapolis Tidal Generating Station.
The Annapolis Tidal Generating Station is located in the Annapolis Basin near the mouth of the Annapolis River between Granville Ferry and Annapolis Royal. The Annapolis Basin opens into the Bay of Fundy, which has the highest tides in the world.

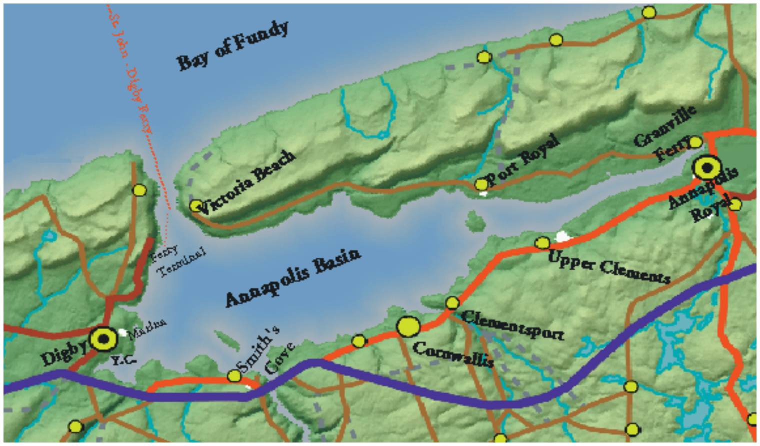
Quick Facts

Today, Canada has 450 large- and small-capacity hydroelectric plants, with a combined capacity of 65,678 megawatts.

Ontario has about 200 hydroelectric generating plants.

Canada's hydroelectric plants generate about 60 per cent of the country's electrical power and account for 13 per cent of the world's electricity generation from water-power.

FIGURE 4 **MAP OF THE ANNAPOLIS BASIN**

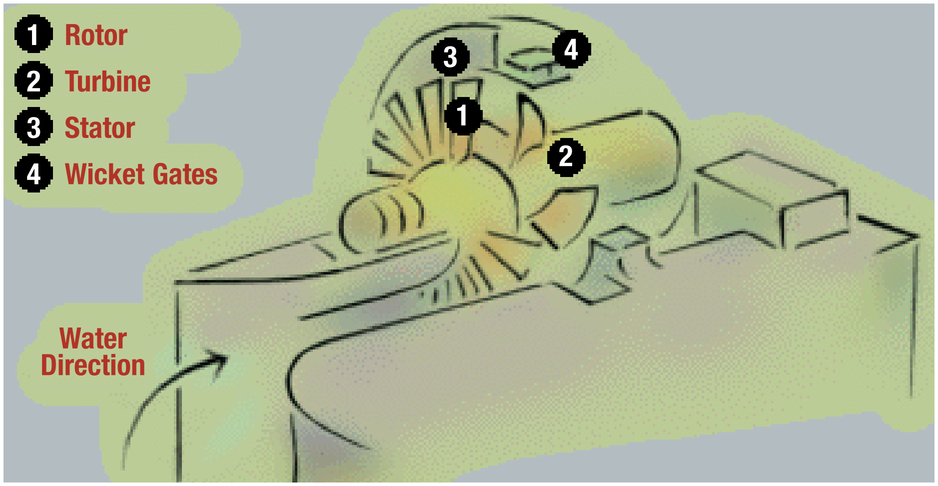


Source: www.annapolisbasin.com

The turbine in this station is a single-effect turbine, which means that it generates electricity only when the flow of the water is towards the sea or, in this case, the Bay of Fundy.

- When the tide comes in, the water flows through the sluice gates into the area behind the barrage.
- When the tide starts to go out, and the water level drops, the station's wicket gates open.
- Water rushes past the turbine at a rate of about 400 cubic metres per second.
- The turbine causes the generator to create electricity, which is then transmitted down the line and throughout Nova Scotia.
- The station is capable of producing 30 million kilowatt-hours a year, which is enough electricity to power 4,500 homes.

FIGURE 5 **TIDAL POWER GENERATION**



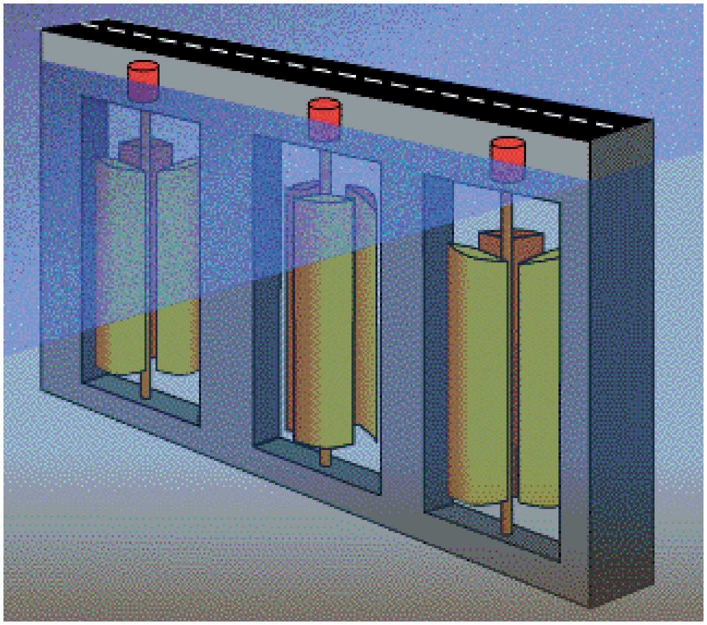
As the runner turns, the rotors' magnets sweep past the wire coils in the stator, creating an electromagnetic current, which is tapped and converted into useable electricity at a nearby station.

Source: www.nspower.ca

Two other methods of turning the power of tides into electricity include the tidal fence and the tidal turbine.

Tidal Fence. A Canadian company is working on a tidal power plant on the southern side of the San Bernadino Strait in the Philippines that will use a tidal fence. A tidal fence includes a series of vertical axis turbines that are mounted within the fence, which in the industry is known as a caisson. The advantage of tidal fences is that they can be used in unconfined areas, such as channels, or, in the case of the fences proposed for San Bernadino Strait, between islands.

FIGURE 6 **TIDAL FENCE**



Source: www.fujitaresearch.com

Tidal Turbine. Although they were proposed during the oil crisis of the 1970s, the first tidal turbines did not begin operating until the mid-1990s when a 15-kilowatt tidal turbine was installed in Loch Linnhe on the west coast of Scotland, north of Glasgow. Now, a company in the United Kingdom is working on a 300-kilowatt tidal turbine to generate electricity at Lydmouth in North Devon. Tidal turbines resemble wind turbines, except that the blades or rotors are about one-third of the way up the structure and are completely submerged in water. These turbines use the currents of tides that have velocities of between two and three metres per second to turn the rotors or blades. Currents of more than three metres per second put too much stress on the blades in the same way that gale force winds damage wind turbines.

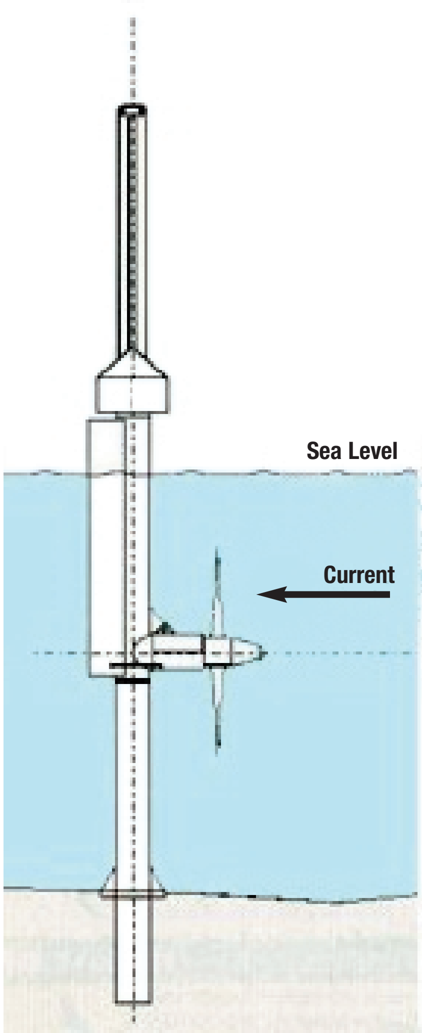
Considerations. Tides are a source of renewable power that is free, reliable and available 365 days a year. The technologies used to harness that power and generate electricity, however, are expensive. Further, some of the technologies, such as the ones that require barrages or dams, have the potential to disrupt local ecosystems and, if the barrage is large enough, to alter local tides.

Waves

About two-thirds of the Earth is covered by oceans. Winds blowing along the surface of the oceans create waves. Although the energy in waves is usually spread out along thousands of kilometres of shoreline, in some coastal areas the "energy density" is enough to produce electricity economically. Good sites for wave energy are generally found along the western coasts of North America and northern Europe, which face open oceans.

How the technology works — The technologies that harness the power in waves are only 30 to 35

FIGURE 7 **TIDAL TURBINE**



Source: http://acre.murdoch.edu.au
(Copyright IT Power Ltd.)

years old. England and Japan were the first to develop methods to capture the power of waves. Today, companies have built or are building installations that convert the energy of the waves into electricity in Scotland, Portugal, Norway, the United States, Australia, India and China.

Basically, wave energy converters rely on the up and down motion of waves to generate electricity. There are several types of systems. Some systems extract the energy from surface waves, and other systems use the energy from pressure fluctuations below the water's surface or from the wave itself. Some systems are fixed in position, while others move with the waves. The more common methods used to capture the energy from waves include

- the oscillating water column system;
- the float system; and,
- the channel system.

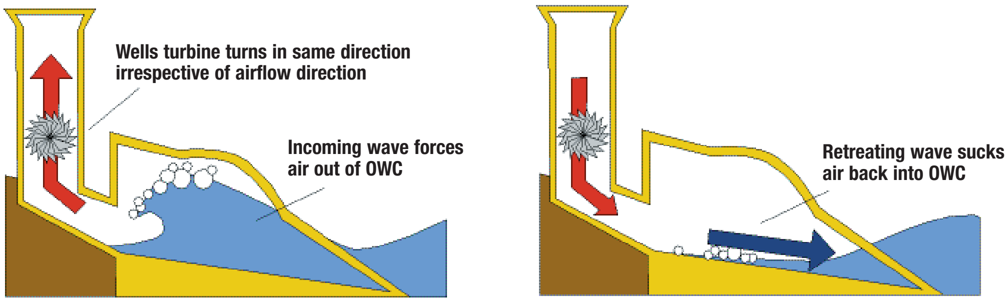
Oscillating water column system. The oscillating water column features a parabola, the two arms of which face out into the water, and a partially submerged structure. The column has an opening to the sea below the water line and a closed top above the water's surface, which means the air inside is trapped. The oscillating water column generates electricity in a two-step process. As a wave enters the column, it forces the air in the column up the closed column past a turbine, and increases the pressure within the column. As the wave retreats, the air is drawn back past the turbine due to the reduced air pressure on the ocean side of turbine.

Parabola — The wave enters the parabola, which focuses the wave, increasing its height and the pressure the water exerts on the air in the column.

***Column* —** The column is open at the bottom to allow the wave to enter and is closed at the top to keep the air in and under pressure.

***Turbine* —** As the wave enters the column it compresses and forces the air up the column and past the turbine, causing it to spin. A generator connected to the turbine produces electricity. When the wave retreats, the air in the column decompresses and is drawn down past the turbine again.

FIGURE 8 **OSCILLATING WATER COLUMN**

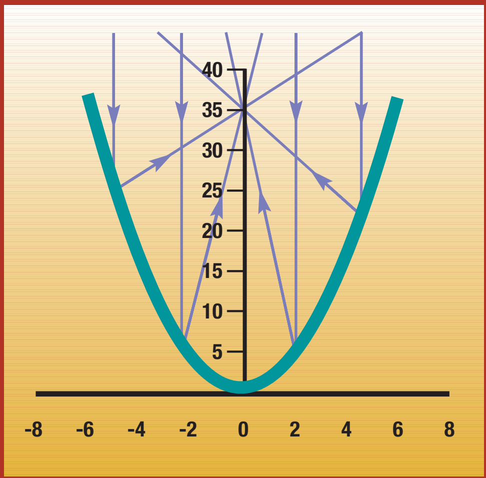


Source: http://acre.murdoch.edu.au

Floating devices. There are several types of floating wave energy devices (e.g., the Salter Duck, Clam and Archimedes wave swing) that generate electricity through the harmonic motion of the floating part of the device, as opposed to fixed systems that use a fixed turbine powered by the motion of the wave. In these systems, the devices rise and fall according to the motion of the wave and electricity is generated through their motion.

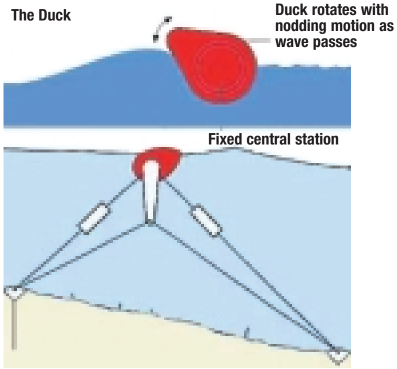
Parabola

A parabola has a curve that focuses all waves to a single point.



Source: http://acre.murdoch.edu.au

FIGURE 9 **THE SALTER DUCK WAVE ENERGY CONVERSION DEVICE**



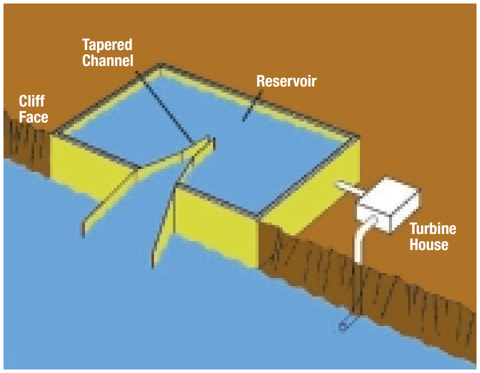
Source: www.fujitaresearch.com

Channel Systems. Tapered channel systems, or TAPCHAN systems, operate much like a hydroelectric generating station, with a dam to elevate the water and a reservoir to store it. In this case though, the water comes from the ocean in the form of waves. The waves are directed into an elevated reservoir on shore by a channel, which is tapered with the widest end opening into the ocean.

- The taper in the channel increases the height and the energy of the waves as the water rushes into the reservoir.
- The reservoir is elevated on the shoreline, sometimes against a cliff face.
- The energy of the moving wave is captured as potential energy when the water is stored in the reservoir.

- As with hydroelectric generating stations, the turbine turns when the system channels the stored water past the turbine, which is connected to a generator that creates electricity.

FIGURE 10 **TAPERED CHANNEL SYSTEM**



Source: G. Boyle. 1996. Renewable Energy: Power for a Sustainable Future.

Considerations. The channel system has the advantage of few moving parts and the ability to produce power on demand. But it needs coastal areas that have consistent waves and a suitable location for the reservoir. Shore-based systems, such as the channel system and, in some cases, the oscillating water column system, can provide energy for local needs, such as those of an island's population.

Wave energy systems do not need fuel to operate and do not produce polluting emissions. But they do have to be durable enough to withstand the beatings they take during severe storms. Some systems, such as the ones that focus waves, may change the height of waves and so alter sedimentation and erosion patterns in the affected area. Others, such as the ones that are offshore, use visual and radar devices as navigational aids to boats and ships to avoid potential collisions.

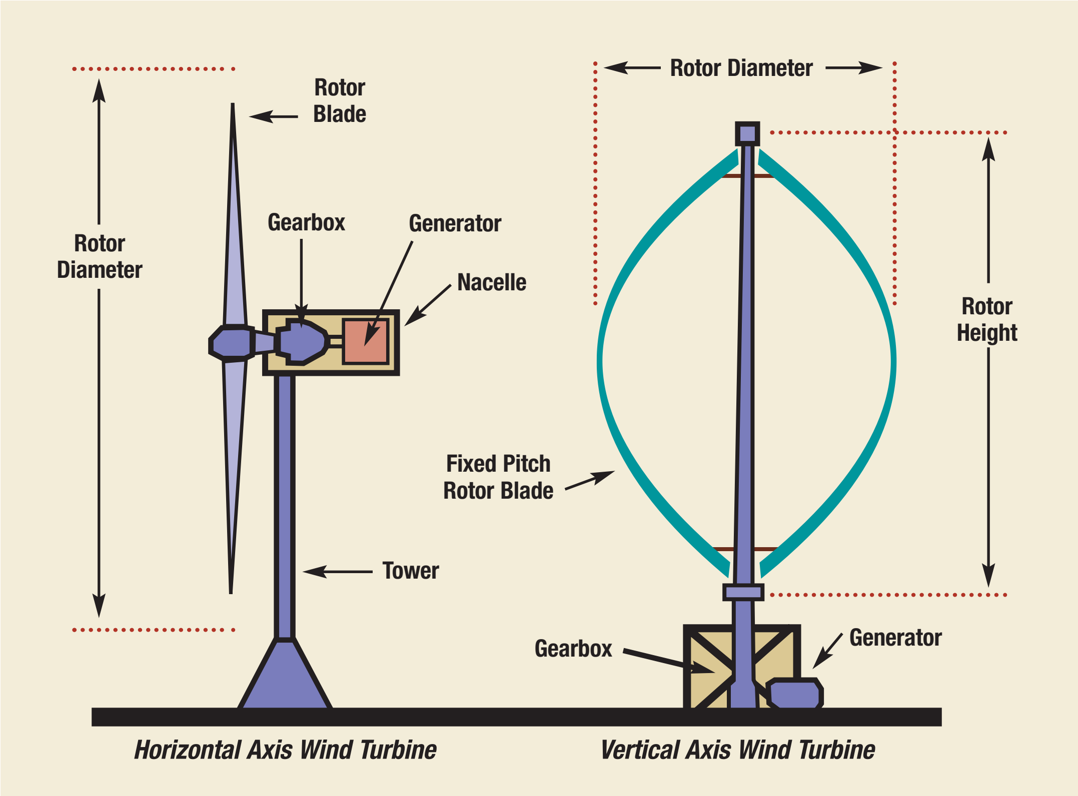
SunBridge Wind Power. Suncor Energy.

WIND CHAPTER 3

Societies have been using wind for power for more than 2,000 years. Until the industrial revolution in the 18th and 19th centuries, windmills were used to pump water and grind grain. In Ontario, some farmers used windmills to pump water until the early years of the 20th century. As with waves, wind as a source of renewable energy for commercial electricity production did not come into its own until the early 1970s when the cost of oil and gas rose quickly, and people began looking at other sources of power. The modern versions of windmills are called wind turbines. At the beginning of 2002, wind turbines produced about 449,000,000 kilowatt-hours of electricity per year in Canada, or enough to supply about 56,000 homes.

There are two primary designs for wind turbines — horizontal and vertical axis turbines.

FIGURE 11 **TWO TYPES OF WIND TURBINES**



Source: Office of Conservation and Renewable Energy. 1990.
Renewable Energy Technology Evolution Rationales.

Horizontal Axis Turbine

The horizontal axis turbine looks more like a windmill with two, but more often three, rotor blades affixed like a propeller to the front of the tower at its top. In some turbines of this design, the rotor blades can lie flat and tip forward and backward (or "pitch") to catch the wind. These are called variable pitch wind turbines.

In the horizontal axis wind turbine, the gearbox, brake and generator are housed in a casing or nacelle behind the rotor blades at the top of the tower. Most wind turbines in Canada are of this design. One of the largest turbines is located near Pickering, Ontario. The Pickering Wind Generating Station stands some 117 metres (30 storeys) high from the base to the blade tip and has a capacity of 1.8 megawatts. It produces enough electricity to supply approximately 600 homes for a year.

Vertical Axis Turbine

The vertical axis turbine looks like an eggbeater. The rotor blades are attached at the top and close to the bottom of the tower and bulge out in the middle. The gearbox and generator are housed in a protective structure at the tower's base.

How the technology works — Despite the differences in appearance of the two turbine designs, the mechanics are similar. Typically, the tower is 30 or more metres high to catch the best winds, since they blow more constantly and smoothly and with more force at this height than they do at ground level.

- The wind passes over the rotor blades, causing them to turn.
- The shaft of the rotor may go into a gearbox, which can increase the speed, or may go directly into the generator and create electricity.

- The harder the wind blows, the more energy that can be captured and the more electricity that can be generated. If the wind is too strong, then the turbine will shut down by turning out of the wind and applying a braking mechanism that prevents the blades from turning too quickly and being damaged.

Wind turbines today come in a range of sizes, from the ten-kilowatt turbine, designed to provide power to a cottage, to huge turbines, such as the one at Pickering. Wind turbines generally produce electricity when winds blow at more than 13 kilometres an hour. Production increases until it hits a maximum power at about 55 kilometres an hour. When winds blow at 90 kilometres an hour or more, most large wind turbines shut down for safety reasons.

Some wind turbines stand on their own. Others are grouped together at wind farms. At wind farms, wind turbines need to be spaced at five and a half times the diameter of the rotor blades to prevent the turbulence or “wake” of one turbine from affecting (robbing) the flow of wind at another. There are several wind farms in Canada. One of the biggest wind farms is at Le Nordais. It has 133 turbines on two sites, one near Cap-Chat in the Gaspé and the other near Matane in the Lower St. Lawrence region in Quebec. The wind turbines at those sites have three rotor blades of about 48 metres in diameter that are mounted on towers nearly 55 metres high. The two sites generate about 99,750 kilowatts of electricity each year. Ontario’s first commercial wind farm is located near Kincardine and was jointly developed by Ontario Power Generation and British Energy Canada. It contains five, 1.8-megawatt Vestas turbine units and can produce enough electricity annually to supply about 3,000 Ontario homes.

FIGURE 12 **LE NORDAIS WIND FARM AT CAP-CHAT (AXOR AS DEVELOPER)**

Source: www.axor.com/ancien

Most electricity generated by wind turbines in Canada flows into provincial or territorial grids and from there to homes and businesses. In Alberta, the electricity from some wind turbines is driving Calgary Transit's C-Train, making it the first transit system powered by wind. The programme, called Ride the Wind, is a joint venture with Calgary Transit, Vision Quest Windelectric Inc. (now a subsidiary of TransAlta Corp.), and Enmax Corporation, Calgary's municipal utility. To meet the C-Train's annual demand for 21,000 megawatts of electricity, Vision Quest will install ten more wind turbines at its wind farm in southern Alberta and sell the power to Enmax.

Quick Facts

Canada has utility scale wind turbines in Alberta, Saskatchewan, Ontario, Quebec, Prince Edward Island, the Yukon and Nova Scotia.

BC Hydro is planning to develop a ten-megawatt wind demonstration project on north Vancouver Island on Rumble Ridge, northwest of Port Alice. The proposed project calls for eight to 15 wind turbines, depending on the capacity selected.

Considerations. Wind is an intermittent source of energy because it does not always blow at the speed required to generate electricity. Wind turbines generally capture an average of 15 to 40 per cent of the total rated electricity generation capacity of the wind turbine. In most cases the electricity created by wind turbines, at least the utility grade turbines, flows into the grid and becomes part of the overall pool of electricity available for use.

As with electricity created by tides and waves, there are no significant air pollution and greenhouse gas emissions associated with this form of renewable energy. There is some noise, however, created by the rotor blades as they cut through the air. But slower rotor speeds (15 to 25 rpm) and new designs and materials have significantly reduced the noise level in the past several years. Today, the noise level at 250 metres can be as low as 42 to 43 decibels, which is less than the average background level of noise in city residential areas. Similarly, results of studies show that wind turbines have little effect on the population of birds, in part because utilities and private companies go to great lengths to make sure they do not site wind farms in the middle of migratory flight paths, and in part because in most areas the migratory flight paths of birds are higher than the turbines or the reach of the blades. The slower, constant blade speeds and solid tower designs that typify today's wind turbines also serve to lessen the potential for bird impingement impacts.




Soft Core Bales. Bio-Products Saskatchewan Inc.

BIOMASS CHAPTER 4

For thousands of years, the world's economy has been based in part on what is today called biomass energy. Simply put, many societies burn wood and peat to warm their homes, cook their food and forge their utensils. Today, we also use biomass to generate electricity and to fuel vehicles. In Canada, biomass supplies 5.9 per cent of primary energy demand. Worldwide, biomass supplies about 15 per cent of the world's energy and about 35 per cent of the energy needs in developing countries.

From Biomass to Electricity and Heat

Biomass is a blanket term that refers to organic matter and includes plants, trees, residues from crops, such as corn stalks and wheat straw, organic waste from municipalities, and waste from forestry operations, including sawdust, timber slash and mill waste. There are several ways of turning biomass into heat and electricity, including direct combustion, anaerobic digestion, co-firing, pyrolysis and gasification.

When biomass is converted to energy it does not add more carbon dioxide to the air than it sequestered when it was growing. In other words, energy from biomass is considered greenhouse gas neutral.

Direct combustion. The simplest way of generating energy from biomass is to burn it. This is called direct combustion. Any organic material that is dry enough can be burned. The heat is used to boil water to produce steam, which turns a turbine attached to a generator to create electricity. In some instances, the heat from the process is also diverted to heat buildings and water. The three examples below describe how communities and companies have used biomass to generate electricity and heat.

Williams Lake Generating Station — In the late 1980s, the residents of Williams Lake, BC, south of Prince George, decided to do something about the smoke from the wood waste burners at five area sawmills. The community residents, the local utility, sawmill owners and the provincial government met, and the result was the Williams Lake generating station. It burns 550,000 green tonnes annually of wood waste, including bark, chips and sawdust from area sawmills to generate electricity. Today, the plant has a capacity of 60 megawatts, of which BC Hydro buys 55 megawatts under contract. The town's air is clear of the smoke and fine ash that used to hang over it.

Oujé-Bougoumou — This Cree community of 650 people has invested in a district heating system that is fuelled by wood waste from nearby sawmills. (A district heating system uses one system to provide heat or electricity, and sometimes both, to a number of buildings.) The community, which is about 850 kilometres north of Montreal in Quebec, wanted to cut the cost of heating by reducing the residents' dependence on fossil fuels (diesel fuel) that had to be trucked in at great expense. With the help of Natural Resources Canada and Hydro-Québec, the Oujé-Bougoumou community built a district heating system that consists of two plants — one with two biomass boilers that burn wood waste, and one with two oil-burning boilers for back-up — and a network of pipes that distribute the heat to community homes and offices. In the future, community residents may plant fast-growing poplar trees on their land so they will not have to depend on wood waste from mills. While still in the process of making a decision about the heating system, the community sent a delegation of four people to Charlottetown, Prince Edward Island, to look at its district heating system.

Charlottetown — The city of Charlottetown wanted to reduce its dependence on imported oil and electricity. Like most Canadian cities in the 1970s, Charlottetown had an abundance of municipal waste. So city officials decided to go with the raw material they had at hand and build an energy-from-waste plant, which converts waste into steam. Three years later the city added a district hot water system fuelled by wood chips from local woodlots. Today, the energy-from-waste plant converts about 30,000 tonnes of municipal waste into steam, which, with the heat from the wood-waste burning plant, provides heat to more than 80 buildings in the area and generates electricity for use in the plant and the local grid. Plants such as Charlottetown's that produce heat and electricity at the same time are called co-generation plants.

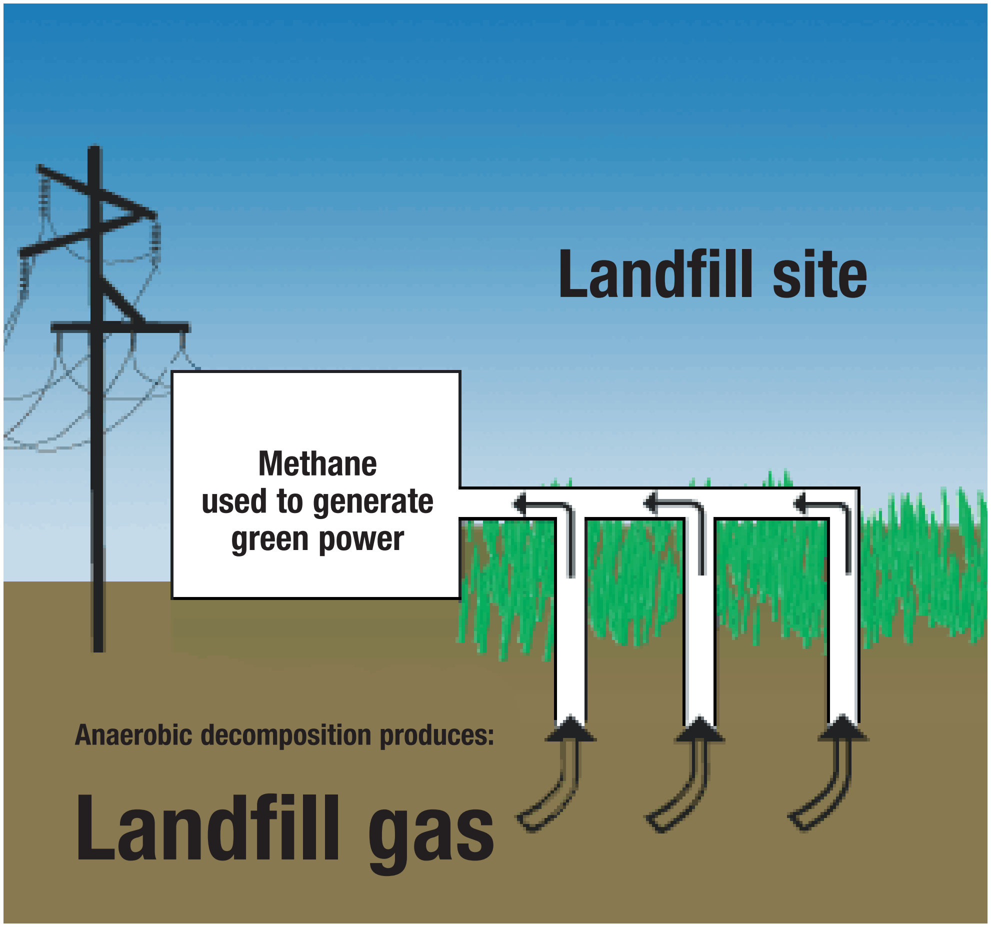
FIGURE 13 **THE PRINCE EDWARD ISLAND HOME BOILER PLANT**

Source: www.nrcan.gc.ca

Anaerobic digestion. Anaerobic digestion is a process that breaks down organic matter, such as the organic portion of municipal waste, in a tank, container or lagoon that doesn't have any oxygen in it. The waste contains microorganisms that, when they digest biomass, such as manure, organic waste or waste in a landfill site, produce a combustible gas. The gas is composed primarily of methane and carbon dioxide and is called biogas. This biogas, which is a reasonably clean fuel, can be used in an electrical generating plant. The digestion process also produces a "digestate" that can be separated into a liquid component, which can be used as a fertilizer, and a solid component, which can be used as a soil conditioner.

For instance, in Ontario, CCI Newmarket Ltd. has a plant that feeds organic waste into an anaerobic digestion process to produce compost and create biogas, which is used to generate electricity. At full capacity the plant will produce 2,500 kilowatts of electricity and 60,000 tonnes of compost. In a variation of the process, the Regional Municipality of Kitchener-Waterloo and Toromont Energy have a facility using landfill gases, created by a natural anaerobic digestion process that occurs as wastes decay in a landfill site, to produce electricity. In the past, the gases were simply burned off. Today, a network of pipes collects the landfill gases, composed of methane, sulphur dioxide and nitrous oxide, and uses them to fuel an electrical generating station. Ontario Power Generation buys electricity from this plant and the one in Newmarket as part of the company's green power programme.

FIGURE 14 **HOW LANDFILL GAS PLANTS WORK**



Source: www.torontohydro.com

Co-firing, pyrolysis and gasification. Co-firing refers to the practice of introducing biomass into the boilers of coal-fired electricity plants. Adding biomass as a source of fuel helps to reduce the use of coal.

Pyrolysis refers to the thermo-chemical process used to convert solid biomass to liquid fuel. During the process, biomass is heated in an oxygen-free tank to produce a gas that is rich in hydrocarbons, which is then quickly cooled to an oil-like liquid and a solid residue, or char, which is usually called charcoal and used for burning. Pyrolysis offers the advantage of producing renewable liquid fuels that can be more easily stored, transported and burned than solid wood wastes.

Gasification is a form of pyrolysis. It uses more air than pyrolysis when the biomass is heated. The resulting gas, called producer gas, is a mixture of carbon monoxide, hydrogen and methane, as well as carbon dioxide and nitrogen. This gas is burned to produce steam, or used in gas turbines to produce electricity.

Biomass as Fuel

Ethanol. When Henry Ford made the Model T, drivers fuelled up with ethanol. Later gasoline became the fuel of choice, but today drivers are looking again at ethanol. More than 130 million litres of grain-based fuel ethanol is made in Canada each year. Right now, ethanol is used as an additive, usually mixed with gasoline in a blend of ten per cent ethanol and 90 per cent gasoline. This is called E10. Drivers can use it in recent model cars without modifying the engines and can buy it at more than 1,000 filling stations in Canada.

Most of the ethanol made today is the result of a fermentation process using corn, grains, potatoes, sugar beets or sugar cane.

- In the process, wheat or corn is ground in a hammermill to expose the starch.
- The ground grain is mixed with water and briefly cooked.
- Enzymes are added to convert the starch to sugar using a chemical reaction called hydrolysis.
- Yeast is added to ferment the sugars to ethanol.
- The ethanol is separated from the mixture by distilling it.
- The water is removed from the mixture by dehydrating it.

One company in Canada, Iogen Corporation, is working on a process to make ethanol from the cellulose components of wood, hay and straw. This method is similar to the traditional process, but is more difficult because the wood, hay and straw require more complex treatment before the sugars can be fermented to ethanol.

Bio-diesel. Bio-diesel is made from renewable sources, such as vegetable oils from canola seeds, corn seeds, sunflower seeds or flax seeds. These can be treated to create a clean-burning fuel known as bio-diesel. The most direct way to extract the oil from the seeds is to use mechanical or mechanical/solvent extraction. Bio-diesel is produced and used in Europe and is also produced in the United States, but is not used extensively there.

In Canada, bio-diesel fuel is not produced commercially, but tests are under way, such as the one Toronto Hydro is conducting for its fleet. As of July 2002, Toronto Hydro's entire diesel fleet of 400 cars, vans and trucks were powered by a vegetable-based, bio-diesel fuel. At present, the utility is using a blend of 20 per cent bio-diesel and 80 per cent regular diesel, with hopes of using blends containing as much as 50 per cent bio-diesel in the future.

Considerations. Using biomass to generate electricity has many benefits, as shown by the stories of the communities of Williams Lake, Oujé-Bougoumou and Charlottetown. At Williams Lake, the electrical generating station has helped to clean the air. At Oujé-Bougoumou, the district heating system fuelled by wood waste has helped to cut the community's dependence on expensive fossil fuels, reduced the cost of heating homes and buildings, and kept the money that used to go into buying fossil fuels in the community. In Charlottetown, the city's energy-from-waste plant has added years to the life of the local landfill site and cut the community's dependence on imported fossil fuels. Similarly, using ethanol to fuel vehicles reduces drivers' dependence on gasoline, which is not a renewable fuel, and cuts emissions of carbon dioxide and some pollutants associated with smog.

Concerns have been expressed that to ensure a constant supply of raw material to produce ethanol a company might buy up vast tracts of land to grow crops needed as feedstock. This may jeopardize an area's biodiversity as these tracts of land are devoted to one crop. There are also concerns that crops once used to feed people may be diverted to industry and that soil quality may deteriorate because parts of plants or trees once left behind to nourish the soil will now be used as raw materials in bio-products. These, and other, concerns are valid factors to consider when expanding ethanol production.

In conclusion, if biomass resources are managed wisely and resulting combustion emissions are properly controlled, biomass has the potential to provide significant amounts of energy more cleanly and with much lower greenhouse gas emissions than non-renewable fossil fuels, such as coal and oil. The direct combustion of biomass, however, can result in air emissions of concern. As with any energy generation technology, all environmental aspects must be considered before final decisions are taken.

Solar Panels. Canadian Solar Industries Association.

THE SUN CHAPTER 5

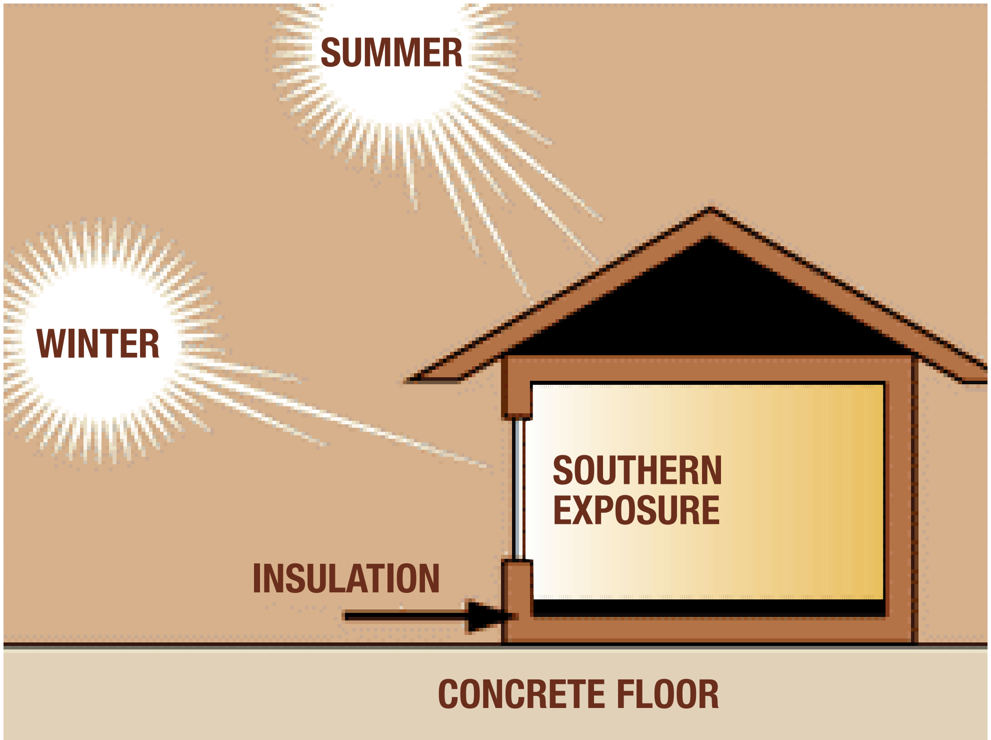
The sun is a renewable source of energy that is plentiful and environmentally friendly. Today, we harness the energy of the sun to warm houses, heat water and generate electricity using three different methods or technologies: passive solar energy, active solar energy and photovoltaic energy.

Passive Solar Energy

The term passive refers to the techniques used to capture the energy. These techniques rely on the design of buildings and the types of materials used to construct them, rather than on mechanical equipment. Passive solar design is not new. One hundred years ago, families painted tanks black and placed them in sunny areas to heat water for the household. The black surfaces absorbed the heat, which was transferred through the metal of the tanks to the water. This method of heating water is still used in warm countries, and in Canada during the summer at cottages and campgrounds, often with a back-up water heater.

Today, passive solar design uses the basic elements of a building — the walls, roof and windows — to control the amount of the sun's energy that is absorbed or lost. For instance, in Canada in the winter, a window that faces south or southwest captures the sun's energy, in the form of heat, reasonably efficiently. Windowpanes allow the sun's energy to come through. Well-insulated windowpanes keep the energy inside in the form of heat. Heavy mass materials, such as stone or quarry tiles in the floor and double layers of gypsum on the walls, absorb the heat and keep the room warm, but prevent it from becoming unbearably hot during the day. They then radiate the heat back out when the sun has set.

FIGURE 15 **PASSIVE SOLAR DESIGN**



Source: www.solarenergysociety.ca

Passive solar design also helps to keep a house cool in the summer. For example, painting a house white or a light colour reflects the sunlight. Long overhangs on a roof, as well as shutters and awnings on windows, help to block the sun's rays, as do leafy trees and tall shrubs, which also help to keep a house warm in the winter by acting as windbreaks.

Solariums

Solariums are glass-enclosed rooms that can be added onto houses or built into them during construction. Basically, the solarium is a passive solar collector that homeowners can use, at least in the morning on a hot summer's day. The sun's radiation in the solarium heats the air, which is either stored and circulated through the rest of the house in the evening or, in the winter, continuously circulated through the house by convection currents or forced ventilation.

Daylighting is a relatively new term that refers to using the day's light to light a house or office building as much as possible. This form of passive solar design places windows to take advantage of natural light, but does not expose them to the afternoon sun in the summer or the prevailing winds in the winter.

Active Solar Energy

Active solar energy systems use solar collectors to capture the sun's energy and to generate electricity to power pumps and fans that distribute heated air and water. In Canada, the most widely used technologies heat air and water for use in houses, offices, factories and apartment buildings.

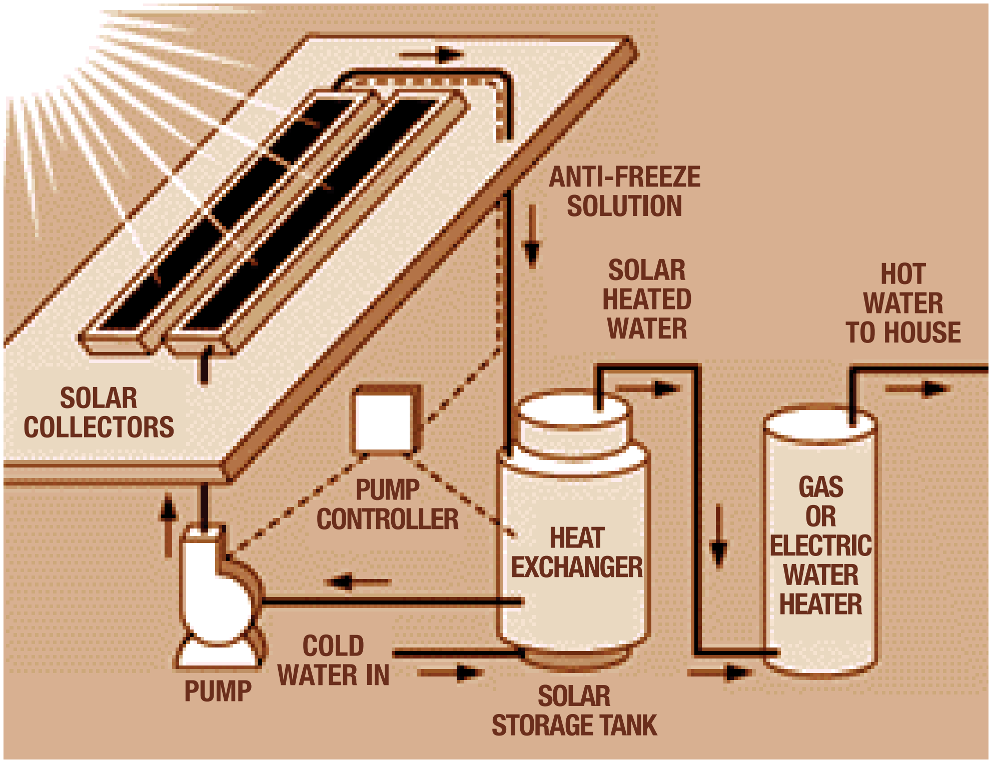
Solar water heating. One method of heating water uses glazed or unglazed collectors.

- The collector includes a black absorber that absorbs the radiation from the sun. The sun's energy warms a heat-transfer liquid that flows through a tube, or tubes, on the collector. In glazed collectors, the absorber and tubes are placed between a glazing, often glass, and an insulated panel. This type of collector is used to heat water when its temperature must be in the 30 to 70°C range. In contrast, unglazed collectors are not insulated and are used to heat water for indoor and outdoor swimming pools, where the temperature of the water must be below 30°C.

- The heat-transfer liquid can be water, anti-freeze or thermal oil. It flows into a tank below the collector.
- The tank contains water that the heat-transfer liquid warms up.
- The warmed water flows into the building's hot water tank where it is ready to be used, or sometimes warmed further.

Homeowners often use solar water heaters in conjunction with a back-up electric or gas water heater. A typical solar hot water system will provide 50 to 75 per cent of a family's hot water. Owners of buildings often use solar water heaters to pre-heat the water before it is pumped into the hot water tank to be warmed up.

FIGURE 16 **SOLAR WATER HEATING**



Source: www.solarenergysociety.ca

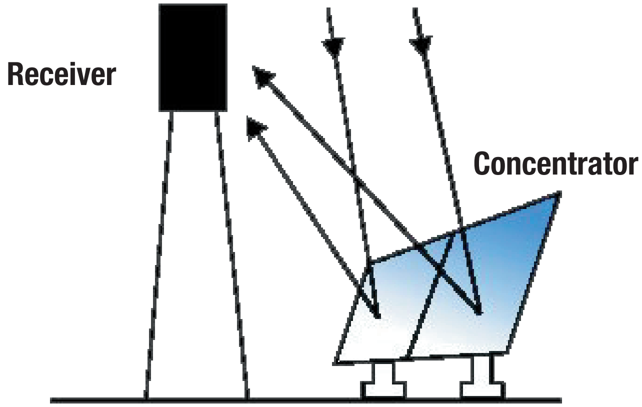
Solar space heating and ventilation. One method of heating air also uses glazed collectors, while another uses perforated cladding (a covering that protects the outside of a building) and fans.

Glazed collectors — As with the hot water systems, the glazed collectors warm a heat-transfer liquid, which flows into a tank, such as the one used in the water heating system. The liquid from the tank is then pumped through the heating system, which may be a radiant floor heating system or a baseboard radiant heating system.

Perforated cladding — This method uses perforated cladding that has been painted black and installed on a wall that faces south. The Ford Motor Company of Canada Ltd., for example, installed cladding on the south wall of one of its assembly plants in Oakville, Ontario. The wall is made up of 16 perforated aluminum panels that have been painted black. The company retrofitted the cladding to an existing south wall, leaving an air space of about 30 centimetres. Sixteen fans draw in fresh air through the perforations in the aluminum cladding. The fresh air heats up in the 30-centimetre space between the cladding and the building's wall. The heated air is mixed with re-circulated air from the plant and then distributed throughout the building using ducts.

Solar generating stations. In Australia and the American southwest, universities, companies and research laboratories are testing systems that concentrate the solar radiation in one spot. These systems include a power tower, parabolic trough and parabolic dish systems.

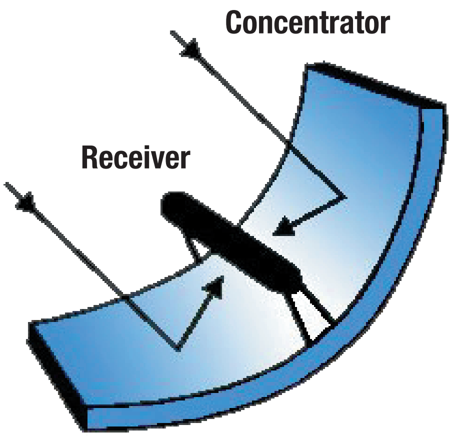
FIGURE 17 **POWER TOWER**



Source: http://acre.murdoch.edu.au

Power Tower — A power tower uses a number of large, sun-tracking, flat-plane mirrors to focus the sun's light onto a central receiver at the top of a tower. The system pumps a fluid, either a high temperature synthetic oil or molten salt, through the receiver where it is heated to 550°C and then used to generate electricity.

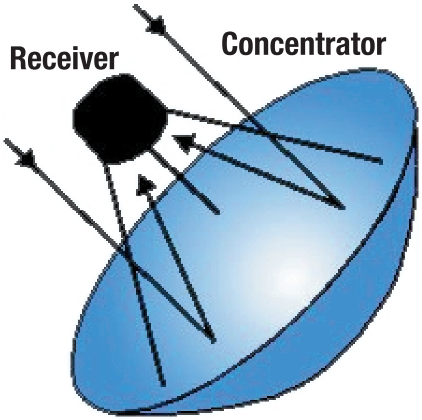
FIGURE 18 **PARABOLIC TROUGH SYSTEM**



Source: http://acre.murdoch.edu.au

Parabolic Trough Systems — As the name suggests, this system uses a series of long troughs in the shape of a parabola. The parabola concentrates the light onto a receiver tube that is positioned along the focal line of the parabolic trough. Temperatures at the receivers can reach 400°C and produce steam for generating electricity. Usually, but not always, the troughs track the sun as it moves during the day. In California, companies are building multi-megawatt power plants that use parabolic troughs and gas turbines.

FIGURE 19 **PARABOLIC DISH SYSTEM**



Source: http://acre.murdoch.edu.au

Parabolic Dish Systems — A parabolic dish system uses parabolic dish-shaped mirrors to focus the sun's radiation onto a receiver positioned at the focal point of the disk. There is fluid in the receiver, which, when the sun's rays hit it, heats up to 750 to 1,000°C. The very hot fluid is then used to generate electricity in a small engine attached to the receiver. Like the parabolic trough, a parabolic dish also tracks the sun's movements.

Considerations. As with the wind, the sun's energy is free-of-charge, and neither passive nor active solar technologies pollute the air with noxious emissions during their operation (however, emissions are created when the technologies are being manufactured). Although the initial cost of installing some of the technologies may be steep, home and building owners can get back some or all of their investments over time in lower energy bills. The sun does not always shine, so solar heating systems for air and water usually require some form of back-up heating.

Photovoltaic Energy

The photovoltaic process turns the radiant energy of the sun into direct current electrical energy. The French physicist Edmond Becquerel (the father of Antoine Henri Becquerel, who is known for his discovery of radioactivity) described the effect in 1839, but practical photovoltaic cells did not come onto the market until the mid- to late-1950s.

In Canada today, systems using photovoltaic technology are especially useful in remote areas of the country. Some researchers who spend the summer in the high Arctic use photovoltaic systems, instead of non-rechargeable batteries, to power their laptop computers. Similarly, the Canadian Coast Guard uses photovoltaic systems to light navigational aids, such as buoys. In Ellesmere Island National Park, the wardens rely on photovoltaic energy to provide half of their station's electricity — at least in the summer. The warden's station uses a wind turbine and diesel generator to meet the other half of its electricity needs in the summer.

Facts about Solar Electricity

- Solar panels are becoming reliable means of generating electricity and are designed to work in most hostile and/or remote locations.
- Solar panels can provide enough electricity to power lights, water pumps, satellite receivers, stereos, vacuums, washers, refrigerators, microwaves, computers, fax machines, power tools and more.
- Solar power is most effective when used in conjunction with energy conservation techniques, energy-efficient appliances and other sources of renewable energy.
- Initially solar panels require a high investment, but will pay for themselves in cost savings over time.

The Solar Industry in Canada

- There are currently 110 photovoltaic solar systems in Canada, representing 352 kilowatts of power from solar electricity.
- There was a 12 per cent growth in solar energy in 2002.

The Solar Industry Worldwide

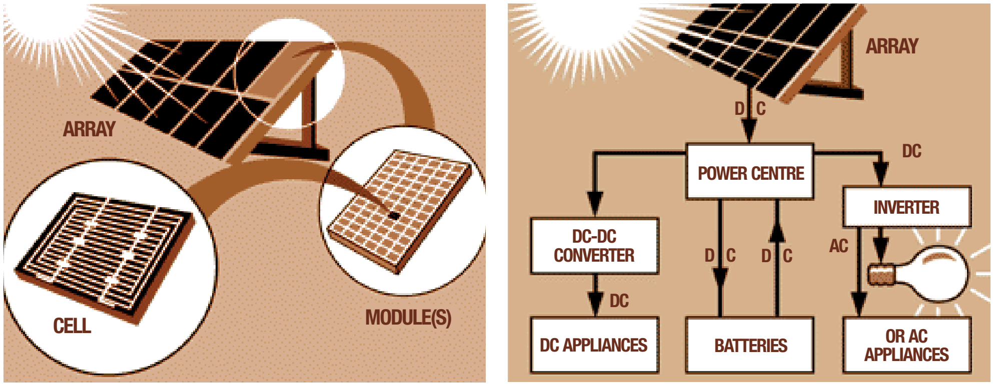
- Total installed capacity of grid-connected photovoltaic systems was 669 megawatts at the end of 2001.
- The solar industry grew 49 per cent in 2001 — with an additional 220 megawatts of power being added.
- Every year, 25,000 solar photovoltaic homes are being added to Japan's electricity grid.

Photovoltaic cell. Photovoltaic or solar cells are small semiconductor devices. They are usually ten centimetres by ten centimetres in dimension and are often made of silicon. As long as the sun shines on a photovoltaic cell, it produces a small flow of electricity — about 0.5 volts. To produce electricity in useful amounts, the cells are usually grouped together in panels. An array of panels consists of single panels linked together. On the roof of its main office building in downtown Toronto, Ontario Power Generation has installed a 4.8-kilowatt system consisting of 48 100-watt panels of solar cells. This array of panels produces enough electricity to power one household.

There are three other interesting facts related to photovoltaic cells. First, they only work when the sun shines, so some photovoltaic systems include batteries that store power so it can be used at night or on cloudy days. Second, photovoltaic cells produce direct current electricity. Most electric lights, appliances and computers run on alternating current electricity, so photovoltaic systems often include a device called an inverter to convert direct current to alternating current electricity.

Third, photovoltaic cells are not very efficient. They convert only 12 to 15 per cent of the sun's light into electricity.

FIGURE 20 **PHOTOVOLTAIC CELLS AND ARRAY**



Source: www.solarenergysociety.ca

- The heat-transfer liquid can be water, anti-freeze or thermal oil. It flows into a tank below the collector.
- The sunlight hits the photovoltaic cells, which are grouped in a module or panel.
- The cells generate electricity.
- The electricity flows into a controller or power centre.
- Some electricity flows directly into a battery where it is stored for future use.
- Some electricity flows into an inverter to be converted from direct current to alternating current so it can be used in offices and households.

Sizing a Photovoltaic System for the Home or Cottage

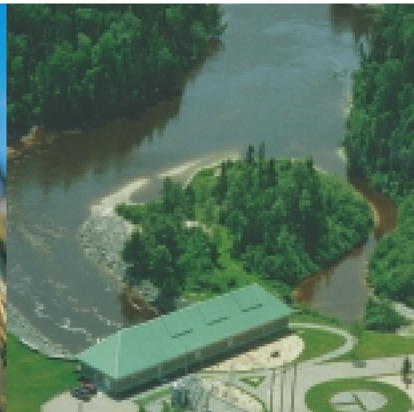
To work out the size of the photovoltaic system you need for your home or cottage, multiply the watts required by your appliances or electrical devices by the number of hours you expect to have them on. For example, a 100-watt light bulb that is left on for ten hours a day uses 1,000 kilowatt-hours of electricity. Do that for every appliance in the house or cottage and add up the results. The photovoltaic system should supply all the kilowatt-hours you expect to use, plus more if you are planning to buy new appliances.

In Canada, there is a slowly growing interest in integrating photovoltaic arrays in the windows, roofs and walls of houses and office buildings. This use of photovoltaic energy is called building-integrated photovoltaics. These systems can be stand-alone, only providing power to the house or building, or can be connected to the electricity grid. Although these systems are new to Canada, some companies have integrated them into their building designs.

In British Columbia, BC Hydro and the British Columbia Institute of Technology are working together to demonstrate the use of building-integrated photovoltaic panels as a building material and a source of electricity at two sites on the Institute's campus in Burnaby. The first site is the Technology Centre building where ten vertical photovoltaic panels that can generate one kilowatt of peak power have been installed. Another set of panels has been installed on the Technology Place building. These panels are capable of producing four kilowatts of peak power and are used to light the building.

Considerations. Photovoltaic panels and arrays do not produce emissions when they create electricity and need only the energy from the sun to power them. In remote areas of the county, photovoltaic panels are a cost-effective source of power that save governments and companies the expense of flying in batteries or diesel fuel for generators. Although there is a misperception that Canada does not receive enough sunlight to generate electricity from photovoltaic panels, they are catching on as a useful source of power in schools, hospitals, government offices and other buildings. Photovoltaic cells are often used in conjunction with other sources of power. Even though there have been relatively high costs involved in setting up photovoltaic panels, prices for the equipment are dropping, and home and building owners often recover their investments over the years in savings on electricity bills.



Kilauea Volcano in Hawaii. US Department of Interior, US Geological Survey.

THE EARTH CHAPTER 6

In late October 2002, Mount Etna in Sicily erupted, shooting rocks and lava into the air and down the mountain. The volcano was a dramatic reminder of the stores of energy that lie beneath the Earth's surface. At the surface, and to a depth of about 500 metres, the temperature of the Earth ranges from 7 to 15°C. Scientists who have drilled deep holes into the Earth have discovered that the temperature increases at a rate of about 15 to 30°C for every 1,000 metres. At 2,000 metres, the temperature is estimated to be 65 to 75°C.

Scientists use the term “geothermal gradient” when talking about the increase of temperature with depth in the Earth’s crust. The geothermal gradient is not uniform around the world. There are areas, such as in British Columbia, where geothermal gradients are higher. The temperature increases more rapidly with depth. One company is currently investigating the possibility of generating electricity from the geothermal reservoir of hot water in Meager Mountain, BC. Many companies and individuals, however, are already tapping into the energy stored just beneath the Earth’s surface to heat air and water for houses, schools and office buildings.

Heating and Cooling Using Heat Pumps

The warmth of the Earth, groundwater and water in lakes can be used to heat the air and water in buildings. Systems that do this are sometimes referred to as earth energy systems. There are closed-loop systems and open-loop systems. Both systems use pipes and heat pumps. Closed-loop systems usually use a heat transfer liquid that circulates continually through the loops of pipe. In closed-loop systems, the pipes are laid either horizontally or vertically (e.g., straight down for 30 to 100 metres). Open-loop systems are often used to draw on the heat in water from a lake or aquifer. These systems are called open because the water, once used, leaves the system and is piped into a discharge well.

Closed-loop system using pipes underground. The system is called closed because the liquid that absorbs the Earth’s heat stays within the system.

FIGURE 21 **CLOSED-LOOP SYSTEM**

Source: www.canren.gc.ca

Pipes — The pipes are the legs of the system. They are usually plastic and are either laid in the ground horizontally or pushed down into holes vertically. Vertical pipes can go down into the soil to a depth of 30 to 100 metres. Horizontal pipes are laid out in long loops using lengths of straight pipe, or short loops using coiled pipes (sometimes called slinky or spiral pipes). If the pipes are laid horizontally, then they need to be at least a metre below the frost line. In both cases, the pipes are (ideally) about three metres apart to make sure heat from the Earth can be transferred.

Fluid — There is fluid in the pipes that absorbs the heat from the ground. The manufacturer of the pipe usually specifies appropriate heat transfer liquids to be used. The most common are denatured ethanol and methanol. (Methanol is not approved for use in Ontario.) As the fluid flows through the pipes, it absorbs heat from the Earth.

Heat pump — The warmed heat transfer fluid returns to the building where a heat pump transfers the heat from the fluid to air or water.

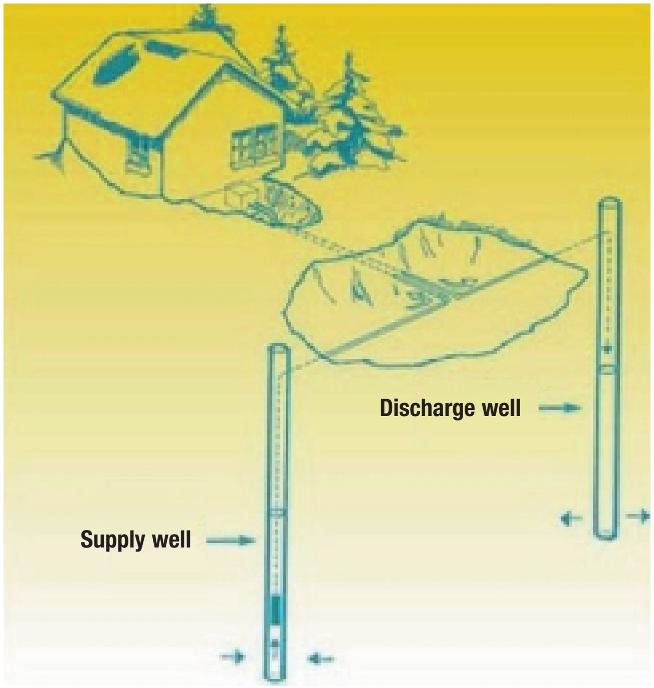
Compressor — The compressor warms the air or water further.

Ducts and radiators — The warm air or water is circulated through ducts (if air) or radiators (if water).

Open-loop system using pipes underground or in the water.

An open-loop system works because the water in a lake, pond or deep well changes temperature more slowly than the air above it.

FIGURE 22 **OPEN-LOOP SYSTEM**



Source: www.canren.gc.ca

- The open-loop system draws water from a lake, pond or well to the building.
- A heat pump extracts the warmth from the water and transfers it to air or water within the building.
- The cool water is then sent to a discharge well.

Not surprisingly, this type of system depends on local environmental regulations that govern how the water can be returned to the ground. Note that the water for these systems has to be free of contaminants, such as chlorides and metals, which can damage the heat pump. This system can be reversed in the summer to cool buildings.

Creating Electricity

Meager Mountain lies 150 kilometres north of Vancouver in British Columbia and is a volcanic complex with eight vents. The volcano last erupted 2,400 years ago. During the oil crisis of the 1970s, BC Hydro, along with the Geological Survey of Canada and Energy, Mines and Resources Canada, launched a geothermal survey in the province and identified Meager Mountain as a possible site to produce geothermal energy.

In the late 1990s, North Pacific GeoPower Corporation began to explore the possibility of using geothermal energy in the area north of Vancouver to generate electricity. Specifically, the company was looking for confirmation of reservoirs of water circulating within rock fractures still hot from the volcanic activity. North Pacific plans to bring the water to the surface to drive steam turbines and generate electricity. The water will be returned through re-injection wells. In the early months of 2002, the company recorded a temperature of 212°C at a depth of only 550 metres.

Although Meager Mountain is the only geothermal site under active study in Canada, other countries, such as the United States and Iceland, have used geothermal energy for many years to drive turbines and to heat houses and buildings.

Considerations. Earth energy systems that transfer heat from areas close to the Earth's surface to heat air and water do not produce harmful emissions and are relatively inexpensive to operate, depending on how the electricity used to run them is generated. Further, geothermal energy is a constant, rather than intermittent, form of energy. At present, the capital costs of installing an earth energy system can be higher than installing a furnace and central air conditioning system using traditional energy sources. There are, however, more than 30,000 Earth energy systems in Canada today, and, as more are installed, the costs will come down.

Although most systems that draw water from wells, ponds and lakes comply with environmental regulations of the province or territory, there have been cases in which groundwater was not put back into the aquifers, but was dumped into sewers. Consequently, in some areas the water tables dropped. There are also concerns about the hot water drawn up from deep within rock fissures to generate electricity. If released, the silica, sulphates, sulphides, carbonates, silicates and halides naturally present in this water may corrode equipment and harm the environment. Companies using this source of energy try to contain the water within closed systems.

Deep Lake Water Cooling

Toronto sits on the shore of Lake Ontario, which is 270 kilometres long and 74.2 kilometres wide and has an average depth of 81.5 metres. Enwave District Energy Limited has proposed to lay a new water intake pipe extending five kilometres into Lake Ontario. The pipe will lie on the lakebed to draw in water that is at a temperature of about 4˚C. This system will use Lake Ontario's naturally cold water as a starting point to provide air conditioning to Toronto's office towers, sports and entertainment complexes, and proposed waterfront developments.

Breaking Waves. Getty Images.

CONCLUDING STATEMENT

This educational primer on renewable energy technologies has been produced to promote greater public understanding of the potential for shifting Canada's energy generation sources to cleaner and less greenhouse gas-intensive technologies. The primer can also be read in conjunction with our complementary primers on smog, acid rain, climate change and mercury, as well as with our green power research reports (including our guide for consumers on purchasing green power).

Pollution Probe is dedicated to ensuring that governments and industry implement policies and programmes that lead to a cleaner and safer environment. The support of an informed and active public is essential to accomplish this mission. The primer series is an important part of Pollution Probe's public education and outreach programme, and we urge all readers of this primer to support the increased use of renewable energy in Canada.

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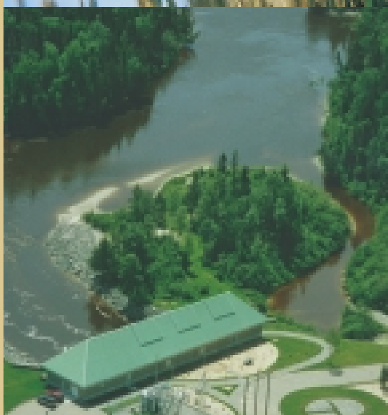

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