Hydropower in Canada

Past Present and Future

Acknowledgements

The Canadian Hydropower Association would like to thank the many people who contributed to the production of this brochure. Thank you to our reviewers and editors who devoted many hours to locating information and photographs, reviewing several drafts and providing guidance and valuable insight: André Bolduc, Dawn Dalley, Claude Demers, John Evans, Michel Famery, Gilles Favreau, Luc Gagnon, Richard Goulet, Kathleen Hart, William Henderson, Bill McKinley, Jacques Mailhot, Debra Martens, Nathalie Noël, Paul Norris, Richard Prokopanko, Audrey Repin, Roger Schetagne, Glenn Schneider, Alexis Segal, Margot Tapp, Thomas Taylor, Gaëtan Thibault, Louise Verreault, and Chris Weyell.

Thanks to Ruth Holtz, Bracebridge Public Library, for locating the original newspaper article.

Thank you to the Board of Directors for their many helpful suggestions.

Thanks to Margot Lacroix for her translation and Francine Gravel for the graphic design.

Special thanks to Pierre Fortin, founding president of the Canadian Hydropower Association, for initiating this project, and to Gabrielle Collu for her research and writing.

Finally, we would like to thank the members of the Canadian Hydropower Association, whose support made this publication possible.

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Hydropower in Canada
Past Present and Future

Legal deposit: 2008
Library and Archives Canada
Bibliothèque et Archives nationales du Québec
ISBN 978-0-9810346-0-7

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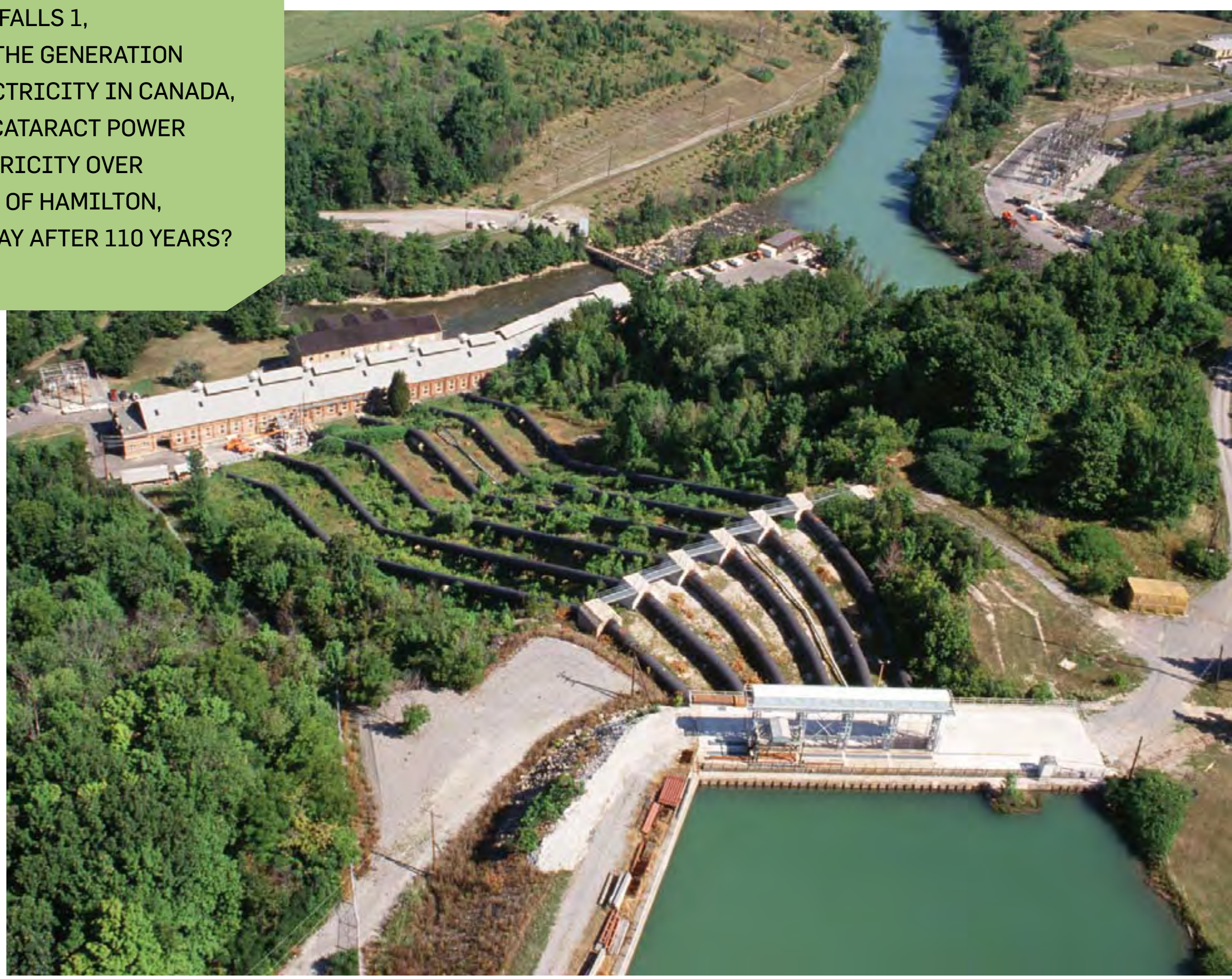
Building a country

From the late 1800s onward, hydropower stations have been constructed from coast to coast in Canada. Just as the construction of the national railway helped to define Canada as a country, so too did hydropower development.

Hydropower has enabled Canadians to meet their need for energy, making life easier and safer. Having opened up remote regions, attracted industries, stimulated economic growth, nurtured innovation, and created world-class expertise, hydropower has founded a modern economy. Drawing on the renewable resource of water, hydropower has contributed all of this without adding to air or water pollution.

In Canada, the first use of water to produce electricity was for a wheel built by the Ottawa Electric Light Company at Chaudières Falls in 1881. It was used to power street lights and local mills. A few years later, street lamps on the Terrasse Dufferin in Québec City were powered by a plant at Montmorency Falls, while lamps were lit in Montréal by a plant on the Lachine rapids. In southern Ontario, the oldest high-head hydropower generating station in Canada opened at DeCew Falls.

DID YOU KNOW THAT DECEW FALLS 1, A PIONEERING PROJECT IN THE GENERATION AND TRANSMISSION OF ELECTRICITY IN CANADA, DEVELOPED IN 1898 BY THE CATARACT POWER COMPANY TO DELIVER ELECTRICITY OVER 56 KILOMETRES TO THE CITY OF HAMILTON, IS STILL IN OPERATION TODAY AFTER 110 YEARS?



DeCew Falls 1; Courtesy of Ontario Power Generation.

Hydropower highlights

- **1750** St-Maurice Forges, Canada's 1st industry, on banks of St-Maurice R. in Québec.
- **1849** Invention of Francis turbine.
- **1870** Pulp & paper companies settle along St-Maurice R.
- **1873** Arc light demonstration in Winnipeg, Manitoba.
- **1880** Invention of Pelton turbine.
- **1881** Canada's 1st hydraulic generator: Ottawa Electric Light Co.'s waterwheel, Chaudière Falls.
- **1885** Montmorency Falls powers 35 street lamps on Terrasse Dufferin in Québec City.
- **1888** 1st hydropower plant in British Columbia: Nanaimo Electric Light, Power & Heating Co., Millstream R.
- **1893** Queenston-Chippawa railway powered by two 1,000 horsepower units at Niagara Falls; 1st hydro station at Niagara Falls in Ontario.
- **1897** 1st long-distance electricity transmission in British Empire: 27 km from St-Narcisse on Batiscan R. to Trois-Rivières in Québec.
- **1898** 1st hydropower plant in Newfoundland, on Black R., Placentia Bay.
  1st major industrial hydropower plant in British Columbia: Lower Bonnington on Kootenay R.
  DeCew Falls 1, delivers power over 56 km to Hamilton, Ontario.
- **1900** Manitoba's 1st hydropower plant: on Minnedosa R.
  Petty Harbour hydropower plant supplies electricity to street railway system, St. John's, Newfoundland & Labrador.
- **1901** 1st aluminum smelter in Canada, powered by Shawinigan Water & Power Co.
  1st transmission line between Canada and USA at Niagara Falls.
- **1903** 1st major hydropower development in Québec: Shawinigan-1, two 5,000 horsepower units on St-Maurice R.
- **1904** 1st hydropower plant in New Brunswick on the Meduxnekeag R.
- **1906** Manitoba's 1st year-round hydropower plant: Pinawa on Winnipeg R.
  1st publicly-owned electric utility in world: Hydro-Electric Power Commission of Ontario.
- **1911** Pointe du Bois on Winnipeg R. in Manitoba.
  Shawinigan-2, five 15,000 kW units, St-Maurice R.
- **1912** Invention of Kaplan turbine.
- **1913** Dominion Government study of hydropower potential of Nelson R. and Churchill R. in Manitoba.
- **1920** Hydropower represents more than 97% of electricity in Canada.
- **1922** Queenston-Chippawa, on Niagara R. in Ontario in service; renamed Sir Adam Beck 1 in 1950.
- **1923** Great Falls on Winnipeg R. in Manitoba.
- **1925** Alcan (now Rio Tinto Alcan) settles in Saguenay-Lac-St-Jean, Québec.
- **1926** Isle-Maligne, Rio Tinto Alcan's 1st hydropower plant in Saguenay-Lac-St-Jean.
- **1928** 1st interprovincial transmission line between Paugan Falls, Québec and Toronto, Ontario.
- **1929** Largest run-of-river facility in Canada: Beauharnois, St. Lawrence R., Québec.
- **1931** Seven Sisters and Slave Falls plants in service in Manitoba.
- **1936** Manitoba exports hydropower to USA.
- **1943** Rio Tinto Alcan's largest hydropower plant in Canada: Shipshaw, Saguenay-Lac-St-Jean.
- **1944** Creation of Québec Hydro-Electric Commission, now known as Hydro-Québec.
- **1945** Farm electrification in Manitoba.
- **1949** Construction of Nechako reservoir, British Columbia, begins.
- **1954** 1st unit at Sir Adam Beck 2 in service.
  1st hydropower station in Labrador at Menihek Lake to meet needs of Iron Ore Co.'s Schefferville mine in Québec.
  Kitimat aluminum smelter uses hydropower from Kemano in British Columbia.
  McArthur on Winnipeg R. in Manitoba, largest in world operating with such a low head (seven metres).
  Creation of Newfoundland Power Commission.
- **1956** 1st transmission line between Manitoba and Ontario.
- **1957** 1st and only pumped storage plant in Canada: Sir Adam Beck Pump Generating Station at Niagara Falls, Ontario.
- **1958** 1st unit in service at R.H. Saunders plant, St. Lawrence R., Ontario.
- **1959** Saskatchewan's 1st major hydropower plant: Squaw Rapids.
- **1960** Kelsey on Nelson R. in northern Manitoba powers International Nickel Co.
- **1961** Creation of Manitoba Hydro.
- **1962** Creation of BC Hydro.
- **1963** Nationalization of electricity in Québec.
- **1964** Columbia R. Treaty ratified, with provision for construction of 3 hydropower dams in British Columbia.
- **1965** World's 1st 735-kV transmission line links Manicouagan and Outardes plants to Québec City and Montréal.
- **1967** Bay d'Espoir plant in service, Newfoundland & Labrador.
- **1968** British Columbia's greatest hydropower plant: G. M. Shrum, fed by W.A.C. Bennett Dam at head of Peace R.
- **1969** World's largest multiple-arch-and-buttress dam: Daniel-Johnson in Québec, feeding Manic-5 and Manic-5-PA power plants.
- **1971** Newfoundland & Labrador's largest hydropower plant: Churchill Falls.
  Nelson R. High Voltage Direct Current line, 900 km from Gillam, Manitoba to Winnipeg.
- **1972** Completion of Mica Dam, Columbia R., British Columbia.
- **1973** Construction of La Grande complex at James Bay begins; in 2008 the complex represents nearly 25% of Canada's hydropower capacity.
- **1975** Creation of Newfoundland & Labrador Hydroelectric Co.
  1st modern land claim settlement in Canada: James Bay & Northern Québec Agreement, signed by Cree, Inuit, Hydro-Québec, governments of Québec and Canada.
- **1977** Northern Flood Agreement signed by 5 First Nations, Manitoba Hydro, governments of Manitoba and Canada.
- **1981** World's largest underground hydropower plant, Robert-Bourassa, in service.
- **1983** Longest high-voltage submarine line links Vancouver Island to the continent.
- **1984** 1st tidal power plant in North America at Annapolis Royal in Nova Scotia.
- **1990** Manitoba Hydro's largest hydropower plant: Limestone run-of-river.
- **1995** Columbia Basin Trust, for promotion of social, economic and environmental well-being of region most affected by Columbia R. Treaty.
- **1997** Kyoto Protocol signed by 180 countries.
- **1998** Creation of Canadian Hydropower Association.
- **2002** Paix des braves agreement between Cree and government of Québec.
- **2003** Ste-Marguerite-3 in Québec.
- **2006** Wuskwatim Project Development Agreement in Manitoba.
  Eastmain-1 at James Bay in service.
- **2008** Péribonka on the Manouane R. in Québec in service.
  Construction of Eastmain-1-A-Sarcelle-Rupert in Québec begins.

735-kV transmission line;
Courtesy of Hydro-Québec.

Overcoming **distance**

Late nineteenth century Canadian and American industrialists were awed by the potential hydro energy of Shawinigan Falls in Québec and Niagara Falls in Ontario. The technology to transport that energy any significant distance, however, did not yet exist. Because electricity could only be used where it was generated, industries set up their factories near power sources.

The first long-distance electricity transmission in Canada began delivering power over 27 kilometres from the Saint-Narcisse generating station to the city of Trois-Rivières in 1897. One year later, the Lower Bonnington hydropower station on the Kootenay River in British Columbia's southern interior began transmitting power to the gold, silver, zinc, and lead mines in Rossland, 51 kilometres away.

The advent of long-distance electricity transmission opened up new markets for hydropower.

Although energy-intensive industries such as aluminum smelting or pulp and paper continued to be attracted to hydro-rich regions such as Québec's Mauricie or Saguenay-Lac-Saint-Jean, cities could now draw on electricity several kilometres away from the source.

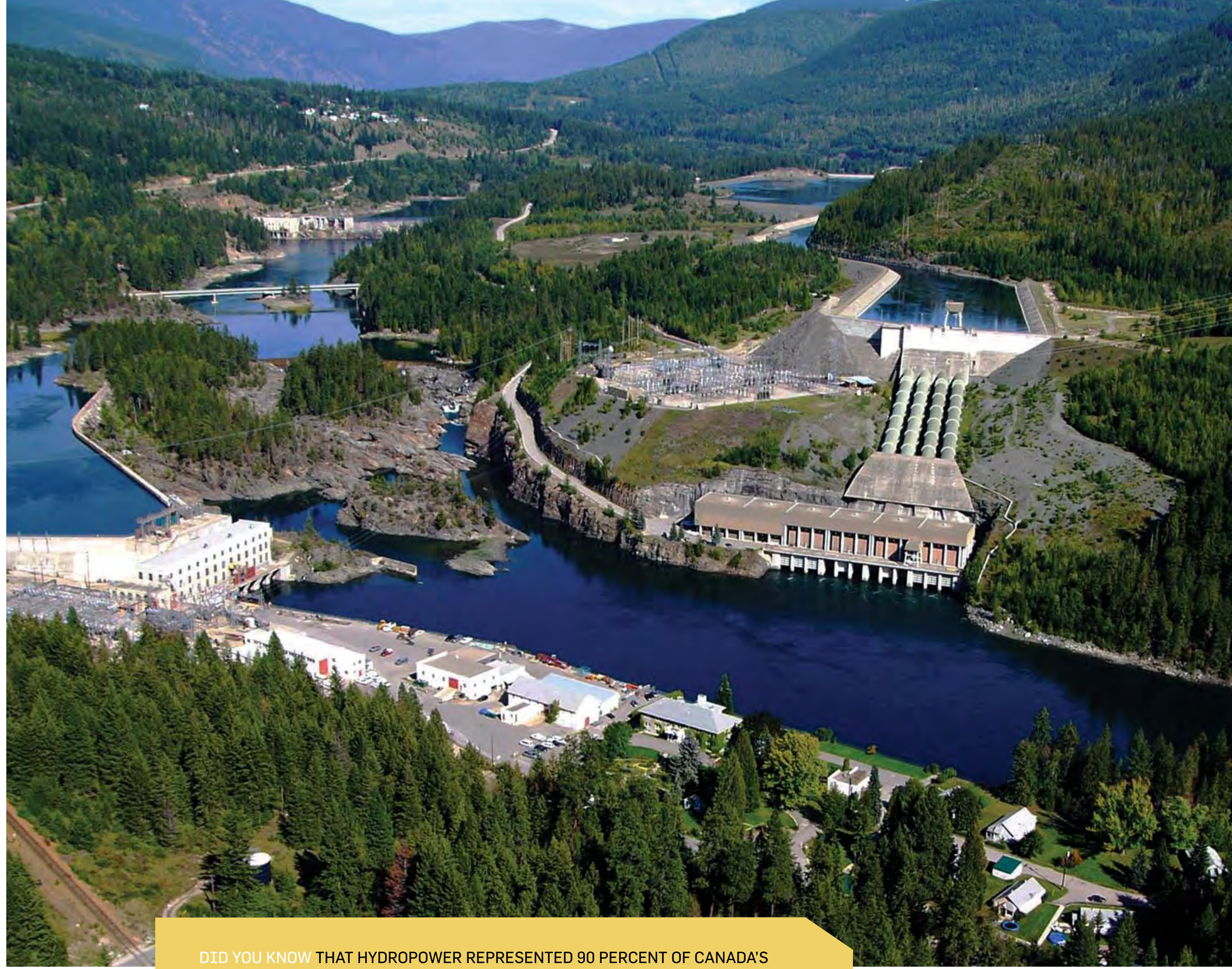
The power of water also led to a major innovation in long-distance transmission. The Manicouagan and the Outardes rivers on the North Shore of the Saint Lawrence River in Québec had huge potential; however, carrying that energy from the North Shore to the province's urban centres without losing power over hundreds of kilometres of distance was a major challenge. And without the ability to transport the electricity, there was no reason to develop the power of these rivers.

In 1965, the world's first 735-kilovolt power transmission line ever built, about 600 kilometres long, linked the Manicouagan and Outardes generating stations to the metropolitan areas of Québec City and Montréal. A few years later, in 1971, Manitoba followed suit with the development of the High Voltage Direct Current line running 900 kilometres from Gillam to Winnipeg.

This high voltage transmission technology, recognized by the Commission for the Centennial of Engineering in Canada as one of the ten major engineering feats in Canada in the twentieth century, revolutionized the electric industry and made it possible to exploit hydroelectric resources across Canada. It has also been applied to hydropower projects in countries around the world, for example for the transmission line designed by a consortium of Canadian companies between the Guri dam and the city of Caracas in Venezuela, or the one joining the electric utility Hydro-Québec and the New York Power Authority.

Existing hydropower stations can operate for decades while improving their efficiency with upgrades. New projects are being developed across the country. In this way, hydropower will continue to contribute to Canada's growth far into the future, providing clean electricity for both domestic and industrial use.

Jean-Jacques Archambault, Québec engineer known for his work on the 735 kV electric transmission technology. Archambault developed the idea, which was approved by the Québec Hydro-Electric Commission in 1962 and integrated in the Manicouagan-Outardes hydropower complex. Courtesy of Hydro-Québec.



DID YOU KNOW THAT HYDROPOWER REPRESENTED 90 PERCENT OF CANADA'S ELECTRICITY IN 1950? TODAY, IT REMAINS THE LEADING SOURCE AT 60 PERCENT. IT REPRESENTS 97 PERCENT OF OUR RENEWABLE ELECTRICITY.

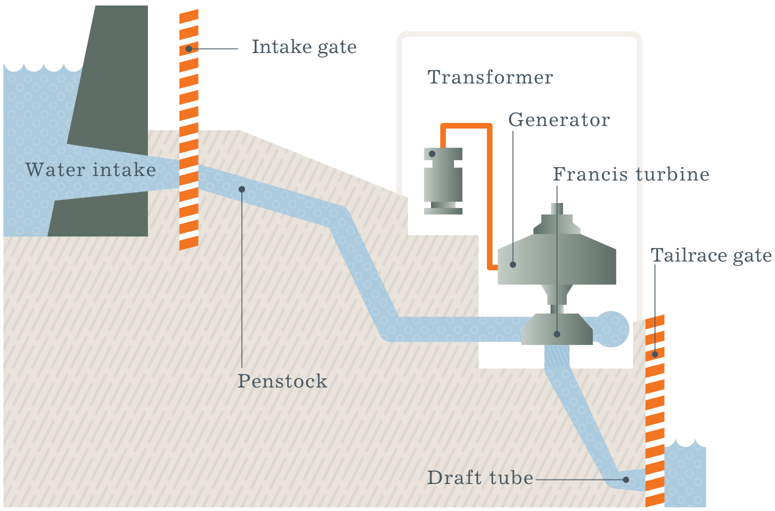
Dams of the Columbia Basin on the Kootenay River. Right: BC Hydro's Kootenay Canal facility. In the background: Fortis BC's Lower Bonnington Dam; Courtesy of BC Hydro.

What is hydropower?

Hydropower, or hydroelectricity, comes from the energy created by falling or moving water. The energy is produced by the fall of water turning the blades of a turbine. The turbine is connected to a generator that converts the energy into electricity.

The amount of electricity a hydropower facility can produce depends on the quantity of water passing through a turbine (the volume of water flow) and the height from which the water falls (the head). The greater the flow and the head, the more electricity is produced.

Hydropower converts the natural flow of water into electricity to light our homes and power our industries without depleting or polluting water resources in the process.



Undeveloped hydro potential

Provinces / Territories	Technical potential in megawatts (MW)[1]
Québec	44,100
British Columbia	33,137
Yukon	17,664
Alberta	11,775
Northwest Territories	11,524
Ontario	10,270
Manitoba	8,785
Newfoundland & Labrador	8,540
Nova Scotia	8,499
Nunavut	4,307
Saskatchewan	3,955
New Brunswick	614
Prince Edward Island	3
Canada	**163,173**

Study of the Hydropower Potential in Canada, report by ÉEM, March 2006.

[1] *These estimates of technical potential are based on data obtained from various utility companies, associations, and government reports. They refer to capacity that can technically be developed. Feasibility factors, such as economic or social aspects, have not been considered in this assessment. Further assessment must be conducted to confirm exact numbers.*

DID YOU KNOW THAT TO REPLACE THE ELECTRICITY PRODUCED BY HYDROPOWER IN CANADA TODAY WOULD REQUIRE ANNUALLY 560 MILLION BARRELS OF OIL? AN ADDITIONAL 250 MILLION TONNES OF GREENHOUSE GASES PER YEAR WOULD BE EMITTED, EQUAL TO A THIRD OF THE COUNTRY'S CURRENT EMISSIONS.

"The opening of the third electric power plant was celebrated by the town in royal style last Thursday afternoon. The wheel through which the machinery was set in motion was turned by Mayor Armstrong in the presence of over a hundred prominent citizens. In a happy speech the Mayor reviewed the work connected with the building of the plant, and said that it was now a heritage of the people and for their benefit as long as the river bed contained water."

Muskoka Herald, January 5, 1911.

Péribonka hydropower facility; Courtesy of Hydro-Québec.

Leading source of electricity

The sources for electricity generation in Canada are diverse. They include natural gas, oil, coal, nuclear power, biomass, solar and wind power, and water. Over the years, hydropower has been the leading source of electricity in Canada, and its predominance continues today.

More than 70,000 megawatts of hydropower have already been developed in Canada. Approximately 475 hydroelectric generating plants across the country produce an average of 355 terawatt hours per year — one terawatt hour represents enough electricity to heat and power 40,000 houses.

Canada generates most of its electricity with water for five main reasons:

1. water is abundant,
2. the technology is efficient,
3. the service life of stations is long,
4. the cost is competitive
5. and the electricity produced is renewable and clean.

With many rivers across the country, Canada has hydropower in all regions. The top producing provinces are Québec, British Columbia, Manitoba, Ontario, and Newfoundland and Labrador, with over 95 percent of the total hydropower generation in Canada.

Canada still has immense undeveloped potential – over twice the current capacity – and all provinces and territories have some hydropower potential.

Hydropower developments are being studied and planned throughout the country. They range from major projects to smaller ones, from run-of-river to pumped storage, and from well established and proven technologies to new technologies using tidal and wave power.

MEASURING POWER AND ENERGY

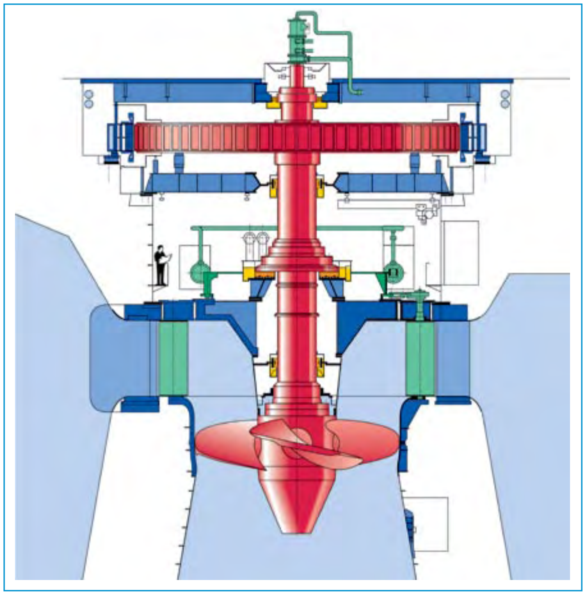
- The basic unit of power is the watt (W), as in a 100-watt light bulb.
- In the case of hydropower utilities, much larger units are required: a megawatt (MW) is one million watts, a gigawatt (GW) is one billion watts, or a terawatt (TW) is one trillion watts.
- The unit to measure energy is the kilowatt hour (kWh): the total amount of energy produced in one hour by a one-kilowatt source of power. The same formula holds true for a megawatt hour (MWh), a gigawatt hour (GWh), and a terawatt hour (TWh).
- A kWh will keep a 100 watt bulb going for ten hours.
- The standard unit for measuring the force or voltage of electricity is the volt. One kilovolt (kV) is equal to 1,000 volts.

W.A.C. Bennett, premier of British Columbia from 1952 to 1972. The longest-serving premier in the province's history, Bennett played an influential role in the creation of BC Hydro and the development of hydropower on the Peace and Columbia Rivers. Courtesy of BC Hydro.

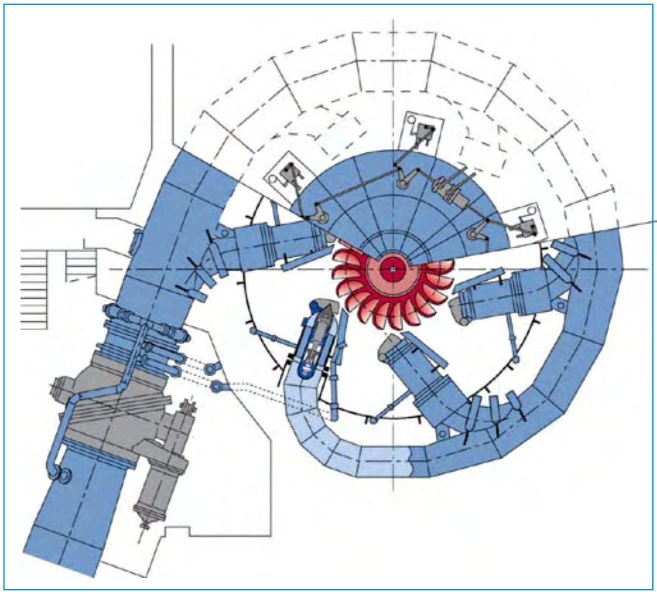
DID YOU KNOW THAT NOVA SCOTIA IS HOME TO ONE OF ONLY THREE TIDAL POWER PLANTS IN THE WORLD? THE ANNAPOLIS GENERATING STATION BEGAN OPERATING IN 1984. IT CHANNELS THE MASSIVE TIDAL POWER OF THE BAY OF FUNDY, WHICH HAS THE HIGHEST TIDES IN THE WORLD.

Different waterfalls, different turbines

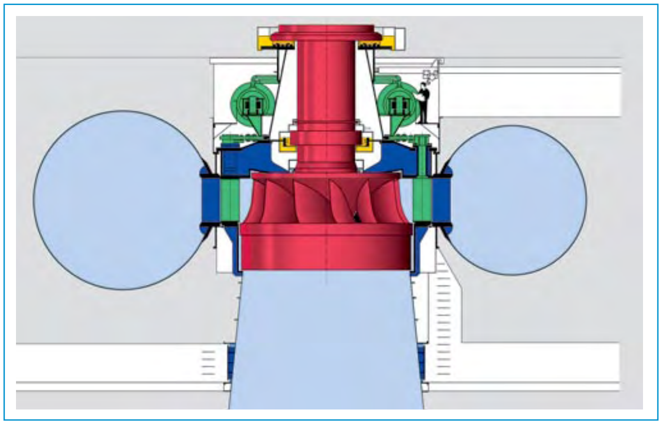
There are several different types of turbines; each is chosen to most efficiently convert the water flow into electricity depending on the available head.



The Kaplan is a propeller-type turbine with adjustable blades. It allows for efficient power production in low head applications.



The Pelton uses the impulse of water falling in buckets. It is the turbine of choice for high head sites.



The Francis turbine is the most common turbine today. It operates in a head range of ten metres to several hundred metres.

Courtesy of Voith Siemens Hydro Power Generation.

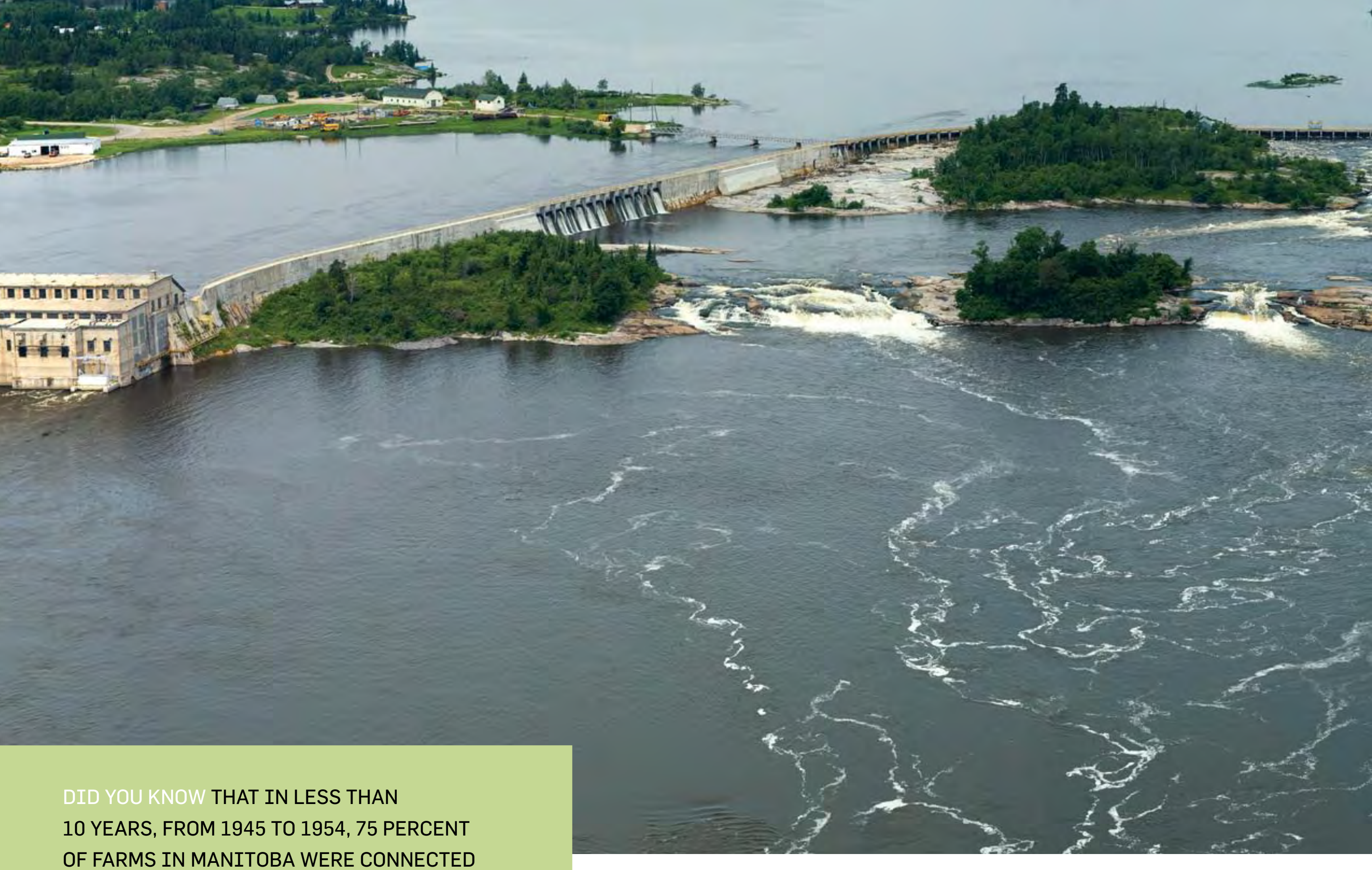
Pointe de Bois generating station; Courtesy of Manitoba Hydro.

Waste not, want not

Hydropower is one of the most efficient sources of energy. Modern hydropower stations can convert more than 95 percent of the available energy in the river into electricity, while the best fossil fuel power plants, the combined cycle cogeneration plants, are only about 60 percent efficient. Most conventional fossil fuel plants are less than 30 percent efficient. For example, when coal is burned to generate power, two-thirds of its energy is wasted. In addition, fossil fuels are not renewable, while water is renewed through the natural water (hydrologic) cycle.

Hydropower stations have a very long service life, which can be extended further with refurbishment works. DeCew Falls 1 in Ontario was commissioned in 1898 and is still operating today; Pointe de Bois in Manitoba, commissioned in 1911, is still producing power; and Beauharnois in Québec recently celebrated 75 years of operation.

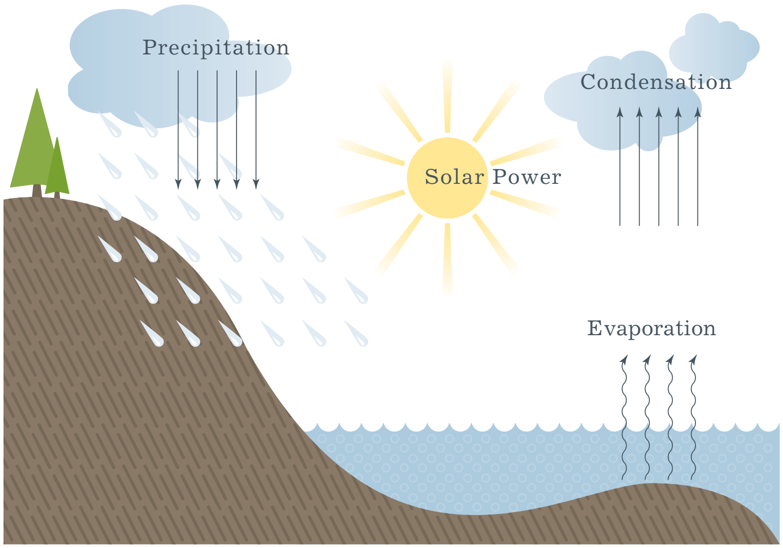
In addition to extending the service life of hydropower facilities by decades, the rehabilitation of installations can provide an opportunity to improve the efficiency of facilities and increase their capacity to meet peak power demand.

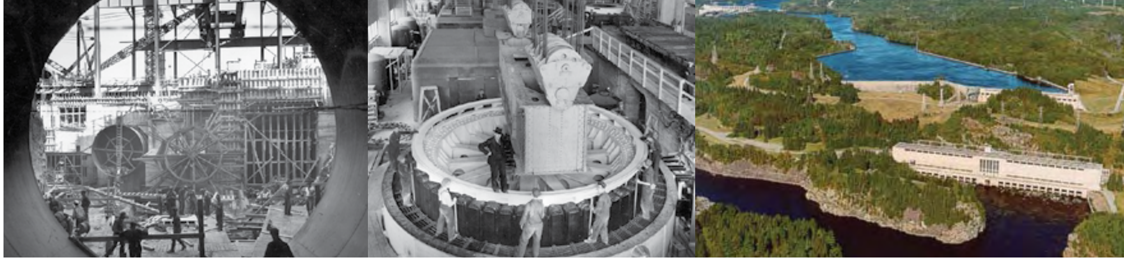


DID YOU KNOW THAT IN LESS THAN 10 YEARS, FROM 1945 TO 1954, 75 PERCENT OF FARMS IN MANITOBA WERE CONNECTED TO THE PROVINCIAL POWER SYSTEM, GREATLY IMPROVING PRODUCTIVITY AND QUALITY OF LIFE?

The water cycle

The water on earth constantly moves through a natural cycle that is perpetually driven by the sun's power. It evaporates from lakes, oceans and rivers, cools and condenses to form clouds, precipitates into rain or snow, falls and flows back to the rivers and oceans.





Shipshaw generating station; Courtesy of Rio Tinto Alcan.

DID YOU KNOW THAT SEVERAL HYDROPOWER PLANTS WERE BUILT DURING THE SECOND WORLD WAR TO MEET SKYROCKETING DEMAND FOR ELECTRICITY TO PRODUCE THE ALUMINUM FOR PLANES AND MUNITIONS? AMONG THESE, THE SHIPSHAW GENERATING STATION WAS BUILT IN A RECORD EIGHTEEN MONTHS BY 15,000 WORKERS.

Same water, more power

As part of the major overhaul of its hydroelectric facilities in the Saguenay-Lac-Saint-Jean region, Rio Tinto Alcan has replaced most of its 43 turbine-generator units, gaining an average of two megawatts per unit with the same amount of water. The company plans to add a new turbine to its largest generating station in Canada, Shipshaw, which will increase its capacity to a total of 1,145 megawatts.

Renewable, in all types and sizes

Hydropower facilities in Canada come in a variety of types and sizes, ranging from micro hydro plants, like the 70 kW Pickerton power plant in Ontario, which provides electricity for only a few homes, to very large installations, like the 5,428 megawatt Churchill Falls in Labrador, which produces enough power to light three cities the size of Vancouver.

Regardless of size, all are sources of renewable power.

Renewable: *adj.* – **1** able to be renewed. **2** (of a source of material or energy) not depleted by utilization

n. a renewable source of material or energy

Oxford Canadian Dictionary

DID YOU KNOW THAT MANY HYDROPOWER FACILITIES IN CANADA ARE USED FOR MULTIPLE PURPOSES SUCH AS NAVIGATION, RECREATION, IRRIGATION, FLOOD CONTROL, AS WELL AS HYDROPOWER PRODUCTION?

Churchill River; Courtesy of Newfoundland and Labrador Hydro.

Some hydropower facilities include dams to increase the head of a waterfall or to control the flow of water through reservoirs that can store the water for future energy use (storage hydropower). Others produce electricity by immediately using a river's water flow (run-of-river). Some hydropower plants also use pumped storage systems, which hold the water for reuse in the production of electricity during periods of high demand.

Run-of-river

A run-of-river facility uses the river directly without modifying the flow and has little or no water storage capacity. The amount of electricity produced varies according to the flow. In springtime when the river fills up with melted snow and ice, the power production is high, and in winter when the river freezes up, or at the end of the summer when it dries up, the power is low.

In Canada, there are several large run-of-river facilities, such as the 1,600-megawatt Sir Adam Beck 1 on the Niagara River in Ontario and the beautiful art-deco 1,673-megawatt Beauharnois on the Saint Lawrence River in Québec. There are also run-of-river facilities that are developed as part of a cascade system, such as the 1,436-megawatt La Grande-1 at James Bay, and many smaller run-of-river plants, such as Waterton in Alberta and Upper Mamquam in British Columbia.

Beauharnois generating station; Courtesy of Hydro-Québec.

Storage

A storage facility includes a reservoir. A hydropower facility with storage generally produces more energy than a run-of-river project of the same size because it saves water when it is plentiful, for use in periods when it is scarce.

Storage hydropower is unique among energy sources for its operational flexibility. If there is an increased electricity demand, a plant can respond almost immediately by releasing more water through the turbines. In contrast, the process of starting up a nuclear reactor takes 24 hours and a coal-fired plant 12 hours. When the demand is low, a hydropower plant can store water for future electricity requirements.

Hugh Keenleyside Dam and Arrow Lakes Generating Station on the Arrow Lakes Reservoir; Courtesy of Columbia Power.

Additional power stations can be located downstream of a reservoir in a cascade development. Each downstream station can then use the water stored in the reservoir when it is released. The Manic stations on the north shore in Québec are a good example of a cascade development with storage.

Because hydropower maintains the balance between electricity supply and demand, it can support the development of other renewable but intermittent sources such as wind and solar. Hydropower and wind energy in particular are a great match because their peak production times complement each other. As additional wind or solar energy is integrated in the electricity grid, more storage capacity will be needed.

In addition to producing clean renewable electricity all year round, reservoirs have other practical and recreational uses. They help manage seasonal floods, protecting people and property, and provide a steady source of water for drinking and irrigation. Reservoirs are also used for fishing and boating, as well as skiing and snowmobiling in winter.

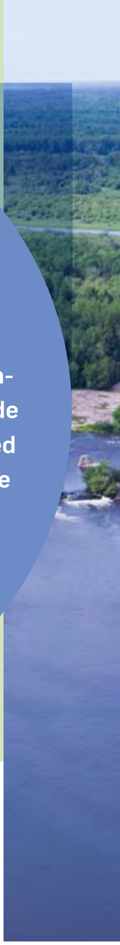
While it is true that reservoirs modify natural habitats, these habitats have the ability to adapt to change. Reservoirs soon become resting and feeding points for migratory birds and waterfowl. They also support a significant fish population, and frequently become valuable and popular recreational areas. In fact, reservoirs can become as much a part of the ecosystem as the neighbouring lakes.

Not only are reservoirs designed and operated to reduce risks such as water shortage or flooding, they are monitored to ensure their longevity, safety, and site security.

The Columbia River Treaty was ratified in 1964 by Canada and the United States to prevent periodic and sometimes devastating floods, and to meet the need for additional power.

In return for building the Duncan (1967), Keenleyside (1968), and Mica (1973) dams to provide water storage for power generation in the United States, British Columbia is entitled to half the additional power generated in the United States.

Today the Columbia River basin provides half of the electricity produced in the province.

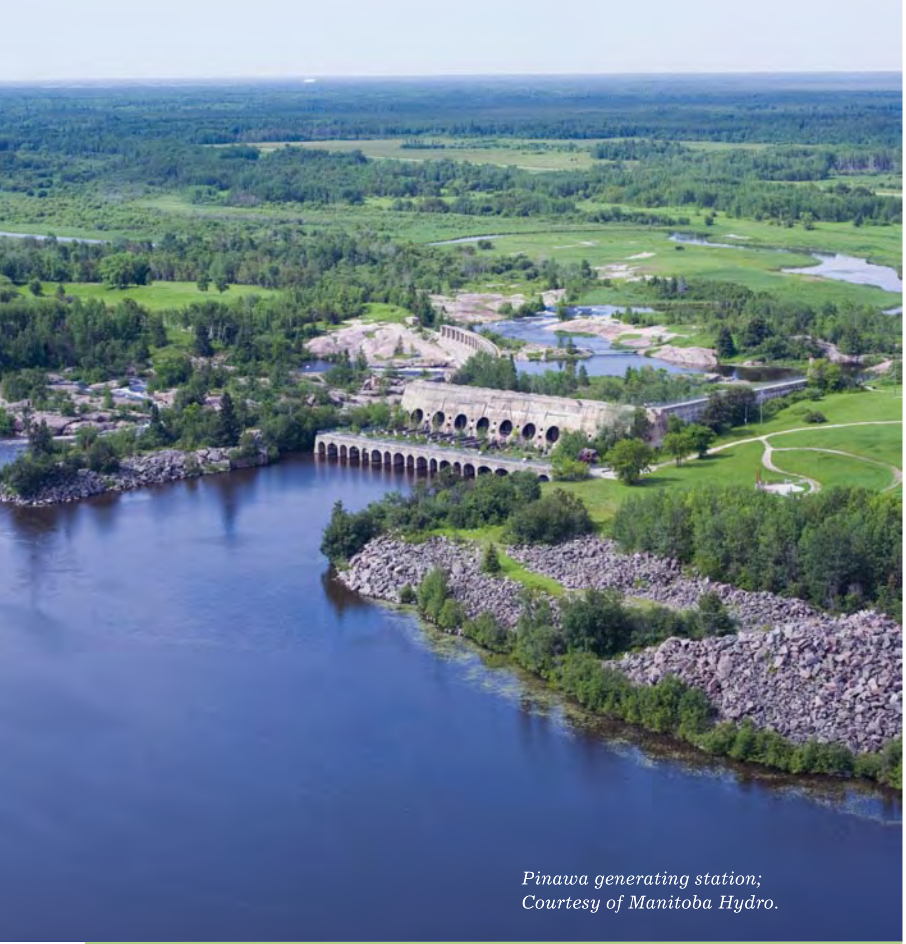


Pumped storage

Pumped storage is an efficient way to store energy for future use. Excess electrical energy (for example, energy generated at night) is used to pump water uphill to a storage reservoir. During the day, or at other times when energy is needed, the water is released and converted back into electricity in the hydro station. Pumped storage facilities, like all storage facilities, can respond to changing electricity demand within seconds, making them an ideal backup for variable wind and tidal power.

Adam Beck 1 and 2 generating stations; Courtesy of Ontario Power Generation.

In Canada, there is one pumped storage facility, the 174-megawatt Sir Adam Beck Pump Generating Station at Niagara Falls in Ontario. The pumped storage station built in 1957 enables Ontario Power Generation to make more effective use of the water that is available by pumping it into a reservoir during low demand and running it through the turbines for electricity during high demand. The changeover from turbine to pumping is accomplished in a matter of minutes and can occur several times each day. It is expected that more pumped storage plants will be developed in Ontario to meet peak demand.



Pinawa generating station; Courtesy of Manitoba Hydro.

DID YOU KNOW THAT PINAWA GENERATING STATION ON THE WINNIPEG RIVER WAS THE FIRST HYDROPOWER PLANT IN MANITOBA TO OPERATE ALL YEAR ROUND? WINNIPEG'S POPULATION QUADRUPLED OVER THE 10 YEARS AFTER THE GENERATING STATION OPENED, MARKING THE GREATEST PERIOD OF EXPANSION IN THE CITY'S HISTORY.
IN ADDITION, ELECTRICITY RATES FELL FROM 20 CENTS PER KILOWATT HOUR TO 3.3 CENTS. MANITOBA STILL HAS AMONG THE LOWEST RATES IN THE WORLD.

Courtesy of Columbia Power.

Powering the economy

Since the development of the first hydropower facilities at the end of the nineteenth century, hydropower has contributed to building a prosperous and energy-rich nation. Water power brought clean electricity, thereby supporting the development of industry and commerce, which in turn nurtured the local economy through improved access to health, education, and enhanced quality of life.

Shawinigan Water and Power Company harnessed the potential of the 400-kilometre Saint-Maurice River in the early 1900s. Not only did it give birth to a city, it also attracted several important industries to the region, including pulp and paper and aluminum. Eventually, electricity from Shawinigan was distributed over a vast territory. Thanks to the power of the falls, Shawinigan became the most modern city in the Commonwealth. For a while, it shared with Paris the title – City of Light.

Several companies, such as the Northern Aluminum Company (now Rio Tinto Alcan), the Belgo-Canadian Pulp and Paper Company (now AbitibiBowater), and the Canada Carbide Company, were drawn to Shawinigan by the abundance of water and electricity.

This pattern of water drawing industry to regions, and industry supporting hydropower development, is repeated in many regions across the country: Nechako River in British Columbia, Saguenay-Lac-Saint-Jean in Québec, Niagara Falls in Ontario, and Grand Falls, Bishop's Falls and Deer Lake in Newfoundland and Labrador, to name just a few.

The hydropower industry also contributes to the Canadian economy by creating tens of thousands of jobs for the maintenance, upkeep, and refurbishment of hydropower installations, which represents hundreds of millions of dollars annually. In 2006 alone, Hydro-Québec carried out refurbishment work worth a total of $441 million.

World-renowned expertise

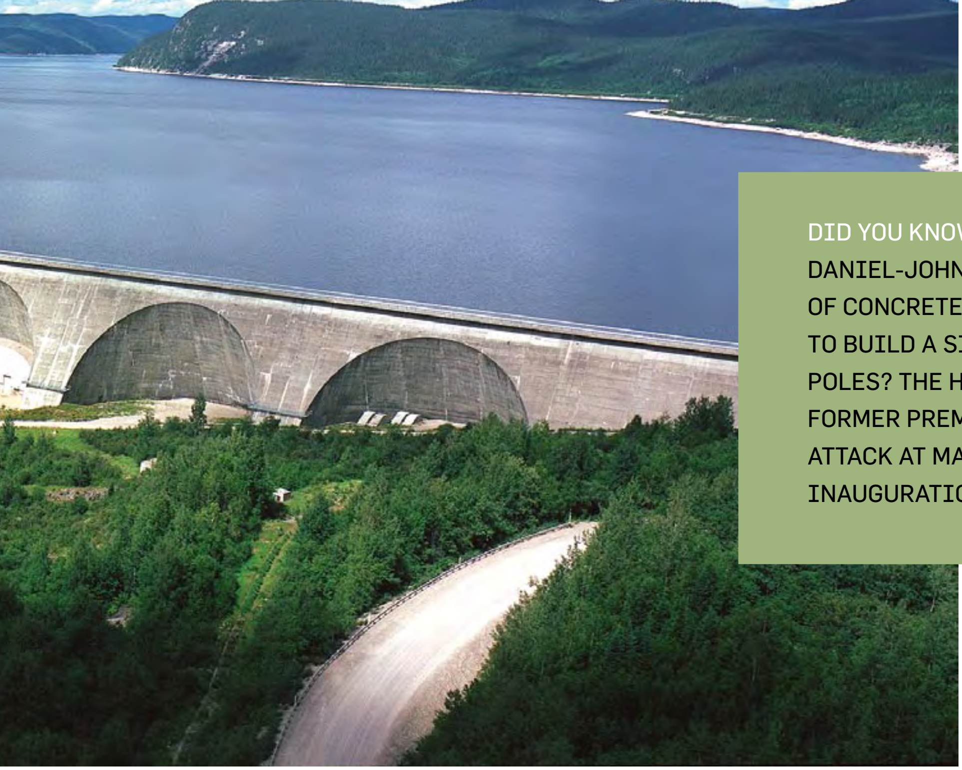
Provided with the opportunities presented by an abundance of natural water resources, the Canadian energy industry has developed an expertise in the generation and transmission of electricity, particularly clean, reliable, renewable hydropower.

Over the years, Canada has also developed a world-renowned skill in hydropower project design and construction.

Some of the largest and most efficient hydropower facilities in the world have been developed thanks to Canadians. Some examples of hydropower projects involving Canadian expertise are: Alto Anchicaya in Colombia, Bayano in Panama, Kpong in Ghana, Manantali in Mali, Nalubaale in Uganda, Bersia and Kenering in Malaysia, Magat in the Philippines, Idukki and Chamera in India, Balambano and Karebbe in Indonesia, and Karun 3 in Iran.

Here in Canada, the Daniel-Johnson dam on the Manicouagan River in Québec is the world's largest multiple arch-and-buttress dam, with a height of 214 metres and a length of 1,300 metres. The 5,616-megawatt Robert-Bourassa generating station in James Bay in Northern Québec is the world's largest underground power station, closely followed by Churchill Falls in Newfoundland and Labrador. Located 137 metres underground, Robert-Bourassa is 483 metres long, 17 metres deep, and generates enough electricity to meet the needs of 1.4 million people. The Churchill Falls powerhouse, located approximately 300 metres underground, is 296 metres long, 25 metres wide and 47 metres deep – equivalent to a 15 story building – and has an installed capacity of 5,428 megawatts.

Canadian companies have also developed expertise in the life extension and upgrade of hydropower facilities. Demand for rehabilitation work will increase in Canada and in countries around the world as facilities age.



Daniel-Johnson Dam; Courtesy of Hydro-Québec.

DID YOU KNOW THAT IT TOOK 10 YEARS TO BUILD THE DANIEL-JOHNSON DAM, AND 2.2 MILLION CUBIC METRES OF CONCRETE – THE AMOUNT THAT WOULD BE NEEDED TO BUILD A SIDEWALK LINKING THE NORTH AND SOUTH POLES? THE HYDROPOWER DAM IS NAMED AFTER THE FORMER PREMIER OF QUÉBEC, WHO DIED OF A HEART ATTACK AT MANICOUAGAN WHILE ATTENDING THE INAUGURATION CEREMONY IN 1968.

Hydro superpower

With nearly 12 percent of global output, Canada surpasses almost all countries in hydropower production.

Sir Adam Beck, architect and first chairman of the Hydro-Electric Power Commission of Ontario, which became Ontario Hydro in 1974 and was split up into five separate entities in 1999. Beck served as Chairman until his death in 1925. He was instrumental in developing the 450-MW Queenston-Chippawa generating station at Niagara, now renamed in his honour. Courtesy of Ontario Power Generation.

Hydro superpower

	Country	Production (TWh/year)	Installed capacity (MW)
1	China	440	130,000
2	Canada	355	70,858
3	Brazil	351	73,678
4	USA	270	90,090
5	Russia	168	46,100
6	Norway	119	28,691
7	India	105	35,000
8	Japan	92	22,134
9	Venezuela	81	14,596
10	Sweden	62	16,300

World Atlas & Industry Guide, 2007 and U.S. Energy Information Administration.

Capacity and energy

Energy represents the amount of electricity produced over a certain period of time. Installed capacity or power is the maximum capacity that hydropower facilities can produce.

The United States has more hydropower capacity than Canada available to respond to peak demand; Canada, however, produces more hydropower energy on an annual basis.

Five reasons to develop hydropower

1 ~ Clean – Hydropower is a clean renewable source of energy.

2 ~ Best long-term investment – Hydropower plants have low operational and maintenance costs. In addition, they have a very long service life, lasting an average of 30 years before the first refurbishment.

Facilities can easily be upgraded to take advantage of the latest technologies. Therefore, despite high initial investment costs, hydropower remains economical in comparison to other large-scale generating options.

3 ~ Competitive prices – Because water from rivers is a domestic resource that is not subject to fluctuations in fuel prices, hydropower fosters energy independence and security. Manitoba, British Columbia and Québec, which produce most of their electricity from water, have the lowest electricity rates in North America.

4 ~ Good for the economy – As Canada's main source of electricity, hydropower is crucial to our economy. It helps create and maintain high valued-added jobs and major investments, generates considerable electricity revenues, and develops an internationally sought-after expertise.

For over 125 years, hydropower has made a significant contribution to Canada's economic growth and prosperity by providing a reliable and affordable energy source, supporting regional economic development, and promoting the growth and competitiveness of countless industries, including the aluminum, pulp and paper, and agri-food sectors.

5 ~ Jobs – The hydropower industry employs tens of thousands of people: engineers, geologists, electricians, mechanics, accountants, construction workers, technical specialists, environmental specialists, and many other trade workers.

Major hydropower construction projects generate hundreds of jobs that extend for years. This contributes to regional economic growth in the form of direct and indirect income and provides local training and business opportunities.

DID YOU KNOW THAT THE EASTMAIN-1-A-SARCELLE-RUPERT HYDROPOWER INSTALLATION IN QUÉBEC WILL CREATE 33,000 PERSON-YEARS OF WORK OVER THE COURSE OF ITS DEVELOPMENT? APPROXIMATELY FOUR PERCENT OF THESE JOBS WILL BE IN ABORIGINAL COMMUNITIES.

Renewable, clean power

All human activity affects the environment. The production of energy is no different. However, some forms of energy are less damaging to the environment by virtue of being renewable and clean.

Rivers are a powerful source of clean and renewable energy. They can provide us with abundant, efficient, reliable, and affordable electricity. Relying on a clean and renewable resource – water – hydropower converts its natural flow into electricity without wasting or depleting water in the production of energy.

Although hydropower facilities in their construction phase can affect the local environment, such as modifying fish habitat and flooding lands, with careful planning their environmental footprint can be minimized. Mitigation and environmental enhancement measures, such as reforestation, wetland establishment, and fish reclamation, are implemented where necessary. When impacts cannot be mitigated, compensation schemes such as investing in the improvement of existing habitats are applied.

Granite Canal; Courtesy of Newfoundland and Labrador Hydro.

■ The Granite Canal Hydroelectric Development, located in south-central Newfoundland, includes a fish habitat compensation facility providing 45,000 square metres of spawning and rearing habitat for tens of thousands of ouananiche (land-locked Atlantic salmon) and brook trout displaced following the Granite Canal diversion.

■ The Exploits River Hydro Partnership Development, located in central Newfoundland, includes fishway installations that allow passage for salmon in the river while avoiding the hydropower facilities at Grand Falls-Windsor. The safe passage of the salmon, together with the release of water from storage in dry periods, has contributed to the rebirth of the Exploits River as one of the most outstanding salmon rivers in North America.

■ Lac Saint-Jean, a natural lake in Québec, is used as a reservoir to generate electricity for aluminum production, resulting in fluctuating water levels that affect the lake's shorelines. In collaboration with the local community, Rio Tinto Alcan has undertaken to preserve the shoreline by raising breakwaters, planting vegetation, and building dikes to protect marshland, which is a nesting and spawning ground for birds and fish.

"This agreement is a wonderful and important milestone in the long history of the Nisichawayasihk Cree Nation that I believe will usher in a new era of economic development and prosperity for our members along with greater independence.

The project truly represents a 21st century opportunity for our First Nation to continue to live off the land – but in a new way – by developing and using our water resources sustainably and with minimal environmental impact."

Former NCN Chief, Jerry Primrose

Partnering for sustainable development

Because the development of hydropower facilities has an impact on the environment, the key to sustainable hydropower lies in developing well planned and well managed projects that work to optimize economic, social and environmental benefits while minimizing adverse effects.

In Canada, environmental legislation covers all stages of hydropower development, from planning through construction to operation.

The legislation requires the participation of stakeholders, including the population that might be directly affected by the project.

A facility is only developed when it has gone through a complete environmental assessment process and is deemed economically viable, environmentally sound and socially acceptable. The hydropower industry works closely with host communities in the planning, construction, and development of projects to alleviate some of the negative impacts of a project and ensure that local communities benefit from the project, through improved quality of life, employment and business opportunities, and long-term revenues.

From left to right: then NCN Councillor W. Elvis Thomas, former NCN Chief Jerry Primrose, Manitoba Hydro President and CEO Bob Brennan, and Manitoba Hydro's Ed Wojczynski at March 30, 2006 announcement of successful conclusion of the negotiation of the Wuskwatim Project Development Agreement. Courtesy of Manitoba Hydro.

"**sustainable development**, which implies meeting the needs of the present without compromising the ability of future generations to meet their own needs, should become a central guiding principle of the United Nations, Governments and private institutions, organizations and enterprises..."

World Commission on Environment and Development, 1987.

Benefit sharing

Manitoba Hydro and the Nisichawayasihk Cree Nation (NCN) signed an agreement, the Wuskwatim Power Limited Partnership, to develop the Wuskwatim generating station. This agreement, the first of its kind between a utility and a First Nation, offers a model for future hydropower developments that focus on maximizing business training, job opportunities and dividends for local communities. It incorporates both traditional and conventional knowledge in the planning and design of projects.

Under the agreement, Manitoba Hydro builds, manages and operates Wuskwatim, while NCN plays a fundamental role in environmental monitoring and stewardship. Furthermore, NCN has the opportunity to own up to 33 percent of the project.

The Eastmain-1-A-Sarcelle-Rupert project is another good example of the new relationship based on mutual respect and benefit sharing being established between the hydropower industry and Aboriginal communities.

This project resulted from the Paix des braves, the Peace among Braves, a historic agreement between the James Bay Cree and the government of Québec.

The Cree have been involved in the hydropower project every step of the way, from preliminary studies to project development. According to Ashley Iserhoff, Deputy Grand Chief of the Grand Council of the Crees (Eeyou Istchee), "Hydro Quebec has [...] made a serious commitment to the preservation of fish and wildlife, to respect our way of life and to find mechanisms to have the least environmental and social impact on our people."

The Eastmain-1-A-Sarcelle-Rupert project calls for exceptional environmental protection and impact prevention measures: redeveloping spawning grounds for fish (lake sturgeon, lake trout and multiple spawning grounds), seeding plants (grasses on the Rupert River's de-watered embankments to counter erosion), and building rises on the Rupert to maintain navigation and traditional local hunting and fishing activities. These environmental measures are estimated at $260 million.

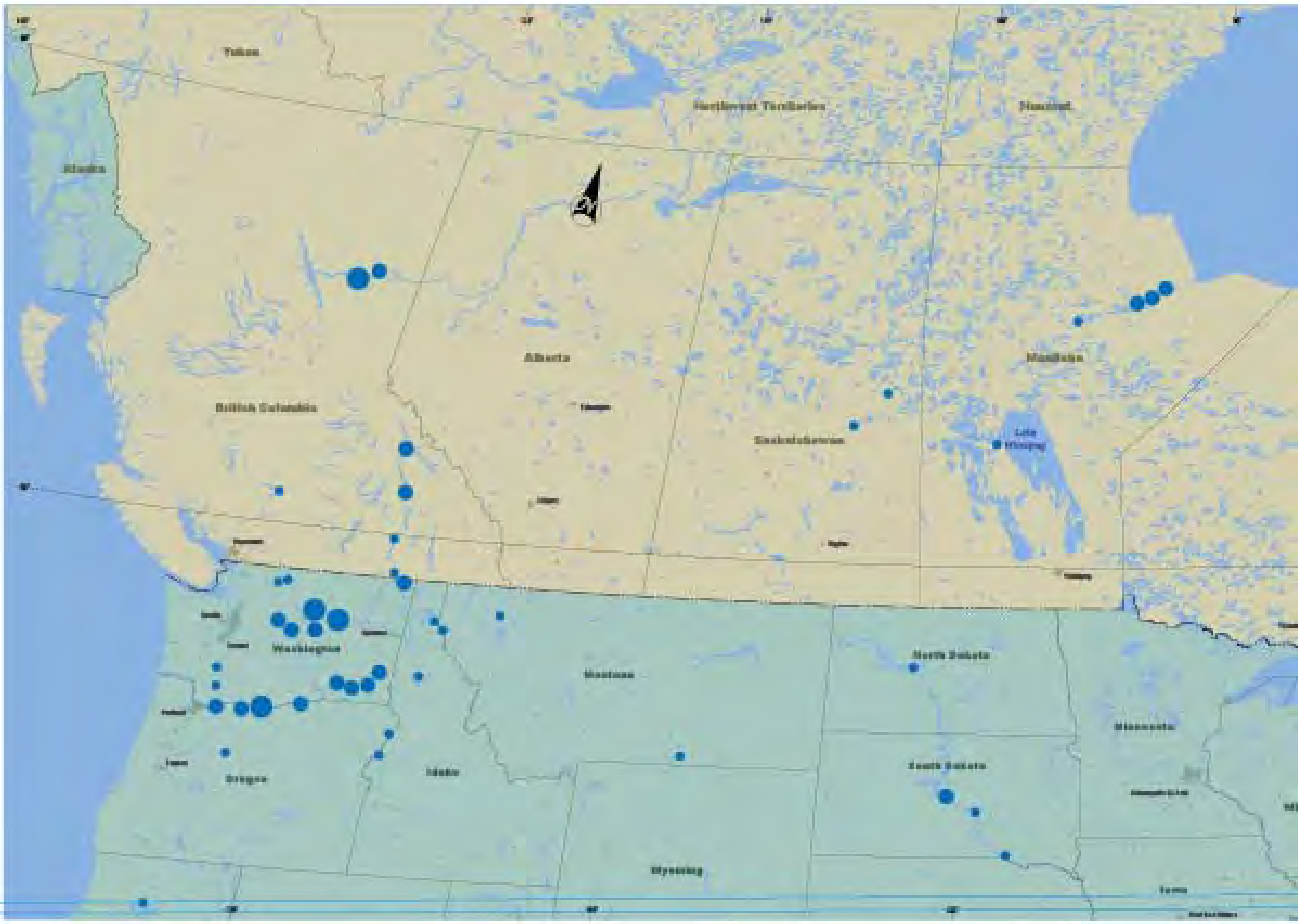
DID YOU KNOW THAT THE DEVELOPMENT OF LA GRANDE HYDROELECTRIC COMPLEX IN NORTHERN QUÉBEC LED TO THE SIGNING OF THE FIRST MODERN LAND CLAIM SETTLEMENT IN CANADA, THE JAMES BAY AND NORTHERN QUÉBEC AGREEMENT OF 1975?

Key solution to air pollution and climate change

Hydropower produces no air pollutants that cause acid rain and smog, no polluting or toxic waste by-products, and a small amount of greenhouse gas emissions. Greenhouse gas emissions from hydropower projects in Canada are at least 60 times less than those from coal-fired plants and 18-30 times less than natural gas power plants.

Hydropower reservoirs can emit small amounts of greenhouse gases from decomposing vegetation and other natural reactions, as do natural lakes and rivers. In boreal regions, such as Canada, these amounts are significantly lower than those produced by natural gas, oil or coal-fired plants, and are comparable, under a life-cycle (from cradle to grave) assessment, to those of other renewable sources of electricity, such as wind power.

Flooding large expanses of land can increase mercury circulation and make it more available for assimilation by fish.
Fish found in new hydropower reservoirs can contain higher levels of mercury for this reason; however, these levels decrease after 20 to 30 years, reaching levels similar to those found in surrounding natural lakes.

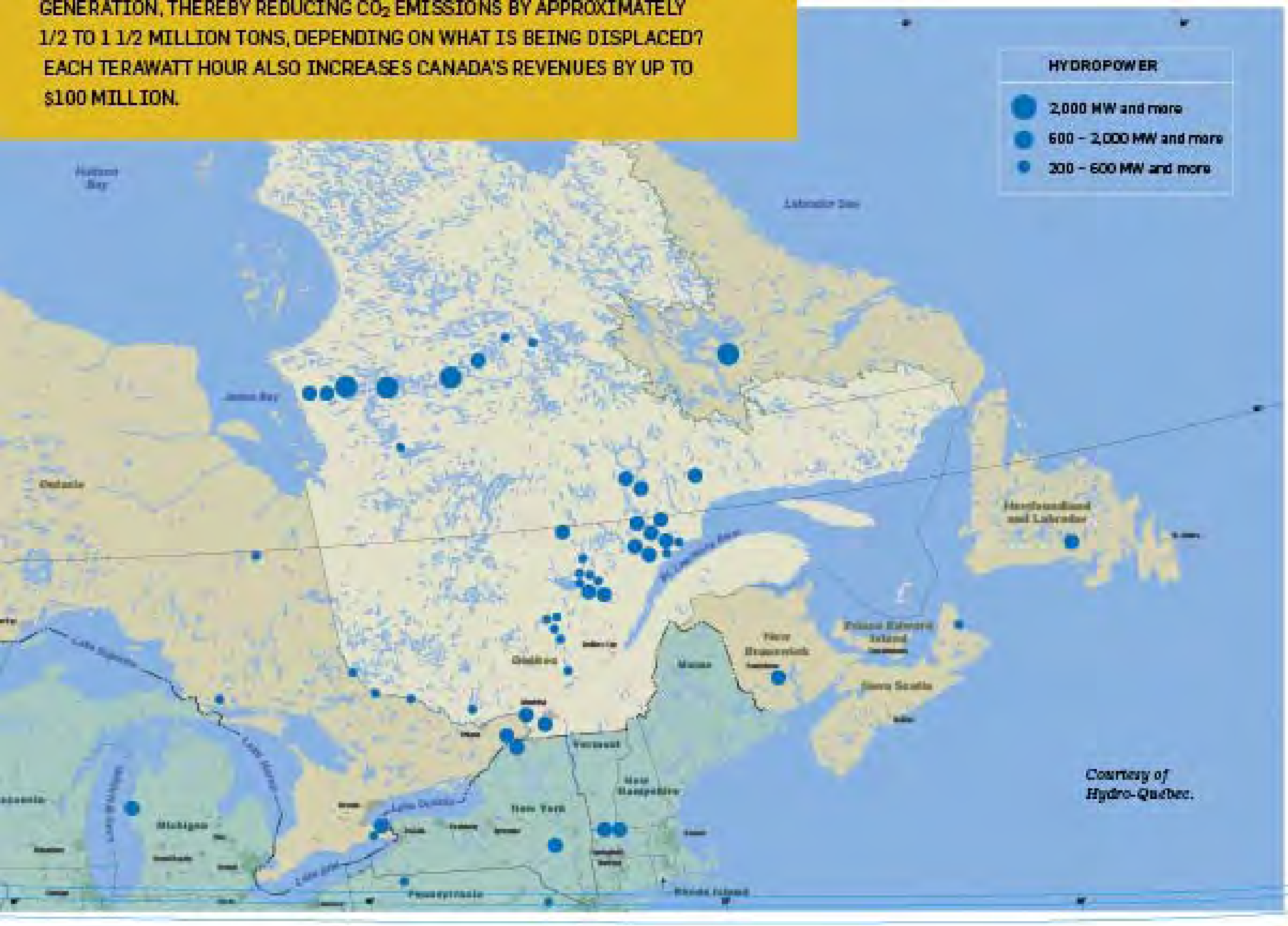


But where does this mercury come from in the first place? It is estimated that about two thirds of the mercury currently found in the environment comes from smelters, incinerators, and coal and oil-fired plants, while about a third is naturally occurring.

That mercury particles are dispersed in the atmosphere and accumulate in the environment, including bodies of water, is a North American issue, which hydropower can help address. By displacing coal and oil-fired electricity plants, hydropower can in fact contribute to the reduction of continental mercury contamination.

Not only does hydropower help avoid greenhouse gas emissions and improve air quality, it also reduces continental emissions and pollutants. Canada is one of the world's largest exporters of clean electricity. Canada exports significant amounts of electricity to the United States, an average of 40 terawatt hours a year, primarily to markets that rely on coal-fired power plants. Most of that electricity comes from clean, renewable hydropower.

DID YOU KNOW THAT EACH TERAWATT HOUR OF HYDROPOWER EXPORTED TO THE UNITED STATES GENERALLY REPLACES COAL, OIL, OR NATURAL GAS-FIRED GENERATION, THEREBY REDUCING CO_2 EMISSIONS BY APPROXIMATELY 1/2 TO 1 1/2 MILLION TONS, DEPENDING ON WHAT IS BEING DISPLACED? EACH TERAWATT HOUR ALSO INCREASES CANADA'S REVENUES BY UP TO $100 MILLION.



Courtesy of Hydro-Québec.

Looking ahead

Canada needs clean, reliable hydropower for future growth.

Even with significant efforts to reduce our consumption and to integrate more efficient technologies, electricity demand will continue to grow by about 1.2 percent annually over the coming decades because of population and economic growth. This could lead to further pressure on our environment.

Today, transportation and electricity, or more specifically the burning of coal and natural gas, are responsible for over half of Canada's greenhouse gas emissions.

Hydropower can play a role in reducing emissions in both sectors.

Electricity is a very efficient way of powering cars, trains and subways. When the source of power is water, not only is it efficient, but it is clean. Both Vancouver's Sky Train and vast trolley bus network, and Montréal's subway and train, already work on hydropower, which has contributed to reducing emissions in these two cities. Imagine what the integration of electric cars could do.

Heating and air conditioning are huge consumers of electricity. Again, hydropower is a key solution. Manitoba and Québec have among the lowest per capita greenhouse gas emissions in Canada - twice as low as in the United States - thanks to hydropower's predominant role in the energy supply of both provinces.

DID YOU KNOW THAT HYDROPOWER IS SUSTAINABLE DEVELOPMENT AT ITS BEST BECAUSE IT MEETS CANADA'S ELECTRICITY NEEDS TODAY WITHOUT MORTGAGING THE ENVIRONMENT OF FUTURE GENERATIONS?

Fortunately, there is still the technical potential to more than double the existing hydropower capacity in Canada.

Not all of the available potential will be developed, because of technical challenges, cost, or unacceptable environmental trade-offs. Despite that, a significant amount will be developed. Why? Because clean, renewable hydropower is one of the best sources of electricity available from a technical, environmental, social, and economic perspective.

Hydropower can play a key role in meeting Canada's growing electricity needs while reducing air pollutants and greenhouse gas emissions.

A clean and renewable power source, hydropower will continue to be Canada's preferred source of electricity.