<u>The State of Hydro</u>

A General Briefing
November 2004

Manitoba Wildlands

Contents

I. Global context

Electricity is most commonly produced by using a source of heat to create steam which powers turbines. This is called thermal generation. Heat sources include coal, natural gas, oil, nuclear reactors, wood and garbage.[1] About 80% of electricity production in the world is from thermal plants.

Roughly 15% of global electricity production is from hydroelectric generating plants in which water running through turbines in a dam spins a generator. (See Part V for an explanation of how hydroelectric generating systems work.)

A small but growing percentage of electricity production comes from solar panels, wind turbines, biogass plants and geothermal plants. These all fall under the category of renewable energy production.

Global electricity production by generation method:[2]

Coal:	38.1%	Natural gas:	18.4%
Nuclear:	16.3%	Hydroelectric:	15.0%
Oil:	7.6%	Renewables:	4.0%[3]

Hydroelectricity

Canada is the world's largest producer of hydroelectricity, accounting for 13% of global output.[4]

Table 1 - International Hydroelectricity Comparison 2002[5]

	Production TWh*	Capacity MW*
Canada	353	67,100
United States	300	76,000
Brazil	300	64,000
China	258	82,700
Russia	174	44,700
Norway	121	27,600

[1]Combined cycle natural gas power plants burn gas in a turbine comparable to a jet engine which spins a generator directly, and also utilizes waste heat/exhaust to produce steam which turns a conventional steam generator. Greater efficiency is achieved in this way.

[2]Source: US Dept. of Energy <http://www.eia.doe.gov/oiaf/ieo/electricity.html>; and Canadian Hydropower Association <http://www.canhydropower.org/hydro_e/pdf/Quick_Facts_2004.pdf>,

[3]Hydroelectricity is sometimes categorized as a renewable. Due to the severe environmental impacts often resulting from hydroelectric systems, hydroelectricity is increasingly left out of the renewable category.

[4]Presentation by Pierre Fortin, Executive Director, Canadian Hydropower Association, June 22, 2004, Winnipeg, Manitoba. Accessed at <http://www.canhydropower.org/hydro_e/ppt/2>.

[5]International hydroelectricity data was taken from the World Atlas and Industry Guide, *International Journal on Hydropower and Dams.* Aqua-Media International, UK, 2003.

World Total	**2,740**	**729,000**

**Note:*
*Terawatt hours (TWh) are a measure of amount of energy produced or used over time (A monthly electric bill is measured in watt hours (or kilowatt hours); a single 100 watt light bulb switched on for one hour uses 100 watt hours (100 W * 1 hr). 1 Terawatt hour (TWh) = 1,000,000,000 watt hours).*

Megawatts are a measure of power (or capacity) similar to horsepower. 1 Megawatt (MW) = 1,000,000 watts. The MW rating of a dam is like the horsepower rating of an engine. "Capacity" is measured in watts/megawatts. "Peak load" or "peak demand" is also measured in MW. Peak demand generally refers to the maximum output required at the moment of highest demand in a year. It is not the total amount used or produced in a year, but the greatest amount of power the must be available. If peak demand (perhaps on the hottest or coldest day of the year) is 10,000 MW and a utility does not have the ability to provide 10,000 MW, there will be blackouts.

- Largest hydroelectric dams in the world:[6]

1) Itaipu	Brazil/Paraguay	12,600 MW
2) Guri	Venezuela	10,300 MW
3) Sayano-Shushensk	Russia	6,400 MW
4) Grand Coulee	USA	6,180 MW
5) Krasnoyarsk	Russia	6,000 MW
6) Churchill Falls	Canada (Labrador)	5,428 MW
7) La Grande 2	Canada (Quebec)	5,328 MW
15)Mica	Canada (B.C.)	2,660 MW
16)La Grande 4	Canada (Quebec)	2,650 MW
20)W.A.C. Bennet	Canada (B.C.)	2,416 MW [7]

<u>Three Gorges Dam</u>
If completed, it would be the largest hydroelectric dam in the world. It would produce 18,200 MW, displace almost 1.9 million people, cost over US$24 billion and take some 20 years (starting in 1994) to build. (See footnote 7.)

- Estimated number of people displaced by dams (hydroelectric dams and dams built for other purposes) around the world: 40-80 million.[8]

<u>Global Energy Consumption:</u>
- 13,290 TWh (2001) Note: Africa accounts for less than 400 TWh of this.
- Predicted to grow by an average of 2.3% per year, hitting 23,000 TWh by 2025.

(Source: Canadian Hydropower Association (see footnote) and Energy Information Administration, US Dept. of Energy <http://www.eia.doe.gov/oiaf/ieo/electricity.html>.

[6] International Water Power & Dam Construction Handbook, IWPDC, Sutton, UK, 1995 (cited in *Silenced Rivers*, Patrick McCully, Zed Books, 2001, p.6.)
[7] International Rivers Network, Berkeley, CA <http://www.irn.org/programs/threeg/index.shtml>.
[8] World Commission on Dams, cited in *Silenced Rivers*, Patrick McCully, Zed Books, 2001, p.xxxi.

II. Hydroelectric production in Canada and the US

In Canada, hydropower accounts for about 60% of total electric production.[9] Though the US produces almost as much hydroelectricity as Canada, due to its much higher total demand for energy, hydropower accounts for only 8 to 12% of total electricity production in the US.[10]

- Total ***hydro***electric production in Canada: 353 TWh. (2003)[11]
  in the US: 300 TWh (2002)[12]

- Electricity production from all sources in Canada: 563 TWh (2003)[13]
  in the US: 3,848 TWh (2003)[14]

- Total installed ***hydro***electric capacity in Canada: 69,205 MW (2002)[15]
  in the US: 79,400 MW (2003)[16]*

- Installed electric generation capacity in Canada:** 118,000 MW (2003)[17]
  in the US: 953,200 MW (2003)[18]

- There are 475 hydroelectric generation stations in Canada. 233 of these (those with capacity of 10MW or more) account for 99% of total capacity.[19]

* ***NOTE****: In addition to this figure, the US has 20,400 MW of pumped storage hydro capacity. A pumped-storage hydroelectric plant functions by pumping water from a lower reservoir to an upper reservoir when demand for electricity is low. Water is stored in an upper reservoir for release to generate power during periods of peak demand. For example, in the summer water is released during the day for generating power to satisfy the high demand for electricity for air conditioning. At night, when demand decreases, the water is pumped back to the upper reservoir for use the next day. In essence, it is a way of storing electricity (in the form of water) from low demand times to be used in high demand times.*

(Definition adapted from the US Federal Energy Regulatory Commission; see <http://www.ferc.gov/industries/hydropower/gen-info/water-power/wp-pump.asp>)

** ***NOTE****: Capacity refers to electrical power output. The capacity of a dam is the maximum power output, usually measured in megawatts (MW). It is like the horsepower rating of an engine. Installed capacity is the capacity at existing generation stations; as opposed to potential capacity that is as yet undeveloped.*

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[9] Canadian Hydropower Association <http://www.canhydropower.org/hydro_e/pdf/Quick_Facts_2004.pdf >; Canadian Electricity Association <http://www.canelect.ca/english/electricity_in_canada_snapshot_Demand_1.html>; National Energy Board of Canada <http://www.neb-one.gc.ca/newsroom/speeches/GCEnergyInQuebec_3rdEnergyForum_2004_09_20_e.htm#S27>.

[10] National Hydropower Association <http://www.hydro.org/hydrofacts/facts.asp>.

[11] See footnote #4 Note: one terawatt hour (TWh) equals 1000 gigawatt hours (GWh).

[12] See footnote #4.

[13] National Energy Board of Canada <http://www.neb-one.gc.ca/newsroom/speeches/GCEnergyInQuebec_3rdEnergyForum_2004_09_20_e.htm#S26>.

[14] US Dept. of Energy, Energy Information Administration <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_5.pdf>.

[15] Canadian Hydropower Association <http://www.canhydropower.org/hydro_e/pdf/Quick_Facts_2004.pdf>.

[16] US Dept. of Energy, Energy Information Administration <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_5.pdf>. NOTE: Though the US has higher capacity (total "horsepower") its total production is less than Canada's (300 TWh vs. 353 TWh). This discrepancy is due largely to the fact that no dam runs at maximum output 24 hours a day, 365 days a year. Water flows are not that steady and demand is not that constant. Canadian dams generally run at a higher percentage of maximum output for a higher percentage of the time than do US dams. This is due in part to reservoir storage capacity in Canada.

[17] National Energy Board of Canada <http://www.neb-one.gc.ca/newsroom/speeches/GCEnergyInQuebec_3rdEnergyForum_2004_09_20_e.htm#S27>.

[18] US Dept. of Energy, Energy Information Administration <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_42.pdf>.

[19] Presentation by Canadian Hydropower Association Exec. Dir. Pierre Fortin to the Energy Council of Canada, Winnipeg, MB, June 22, 2004. Accessed at <http://www.canhydropower.org/hydro_e/p_what.htm>, Oct. 13, 2004.

- **Installed hydroelectric capacity by province:**

Quebec:	31,346 MW	170.5 TWh (2003)[20]
BC:	10,207 MW	44.5 TWh (for year ended Mar 31, 2004)[21]
Ontario:	8,150 MW[22]	32.4 TWh (2003)[23]
Nfld/Labrador:	6,367 MW	37.8 TWh (2003)[24]
Manitoba:	4,999 MW	18.5 TWh (for year ended Mar 31, 2004)[25]

III. Canadian exports of electricity

- Canada is one of the largest exporters of hydroelectricity in the world. [26]
- Canada exports 7-9% of total electricity production to the US.[27]
- Roughly 60% of Canadian electricity exports are from hydroelectric sources.[28]
- In 2002 Canada exported CDN$1.8 billion worth of electricity.[29]
- Canadian exports of electricity make up less than 1% of total US electricity consumption.
- Canadian exports and imports of electricity 1999-2003[30]

Year	Exports (TWh)	Imports (TWh)	Net Exports (TWh)
1999	43.7	14.6	29.1
2000	49.8	13.7	36.1
2001	40.2	17.9	22.3
2002	35.7	15.6	20.0
2003	26.1	19.6	6.6

[20] Hydro Quebec 2003 Annual Report <http://www.hydroquebec.com/publications/en/annual_report/2003/pdf/hydro2003en_complete.pdf>.
[21] BC Hydro 2004 Annual Report <http://www.bchydro.com/rx_files/info/info12355.pdf>.
[22] Ontario Waterpower Association <http://www.owa.ca/renew.html>.
[23] Ontario Power Generation 2003 Annual Report <http://www.opg.com/ir/reports/2003AnnualEng.pdf>.
[24] Newfoundland and Labrador Hydro 2003 Annual Report <http://www.nlh.nf.ca/Annual%20Reports/2003%20NLH%20Annual%20Report.pdf>.
[25] Manitoba Hydro 2004 Annual Report <http://www.hydro.mb.ca/about_us/ar_2003/ar_2003_report.shtml>.
[26] See footnote #15.
[27] National Energy Board of Canada <http://www.neb-one.gc.ca/newsroom/speeches/GCEnergyInQuebec_3rdEnergyForum_2004_09_20_e.htm#S30>.
[28] See footnote #14.
[29] Presentation by Pierre Fortin, Executive Director, Canadian Hydropower Association, June 22, 2004, Winnipeg, Manitoba. Accessed at <http://www.canhydropower.org/hydro_e/ppt/4>.
[30] National Energy Board of Canada <http://www.neb-one.gc.ca/Statistics/ElectricityExportsImports/elx0312_e.pdf>.

IV. Potential Hydroelectric expansion in Canada and the US

Parts of Canada and the US are facing significant electricity shortages in coming years. As a result the push is on to increase electricity generation, including hydroelectric dams. Expansion of hydroelectric capacity in Canada is intended largely to supply the US market.

- Technically, the undeveloped hydroelectric potential in Canada is: 118,000 MW[31]
  in the US: 73,200 MW[32]

- Amount of undeveloped potential considered practical after considering environmental and economic feasibility in Canada: 34,371 MW[33]
  in the US: 29,780 MW[34]

Projects under construction or consideration in Canada:

British Columbia[35]

- Site C Project on the Peace River (under consideration)
  900 MW
  CDN$2.1 billion projected cost

Alberta[36]

- Dunvegan Hydro Project
  100 MW

Ontario

- "The Ontario Waterpower Association estimates that 1200 to 4000 MW of additional water power potential exists in the Province."[37]
- Other estimates are in the general range of 5000 MW of practically viable potential development.[38]

Manitoba[39]

- Manitoba Hydro and the Manitoba Government state that there is 5000 MW of undeveloped hydroelectric potential in northern Manitoba.
- Wuskwatim (public hearings have been held)
  200 MW
  CDN$900 million

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[31] Canadian Hydropower Association <http://www.canhydropower.org/hydro_e/pdf/Quick_Facts_2004.pdf >.

[32] *Hydroelectric Power Resources of the United States; Developed and Undeveloped*, Federal Energy Regulatory Commission, Washington, DC, January 1, 1992, p. xi; accessed at <http://www.hydro.org/hydrofacts/forecast.asp>.

[33] Natural Resources Canada <http://www.canren.gc.ca/tech_appl/index.asp?CaId=4&PgId=26>.

[34] NOTE: Over half of this potential is at existing irrigation or flood control dams that are currently without generating equipment. Source: National Hydropower Association <http://www.hydro.org/hydrofacts/facts.asp>.

[35] *BC Hydro resurrects Site C dam proposal*, Scott Simpson, Vancouver Sun, April 2, 2004, accessed at <http://www.ippbc.com/details.asp?id=3254>. Also, author's telephone conversation with BC Hydro spokesperson, Sept. 20, 2004.

[36] Canadian Hydro Developers Inc. <http://www.canhydro.com/dunvegan/dhp.html>.

[37] Electricity Conservation and Supply Task Force, Final Report to the Minister, January 2004, p. 50; <http://www.energy.gov.on.ca/english/pdf/electricity/TaskForceReport.pdf>.

[38] *Smart Generation: Powering Ontario with Renewable Energy*, David Suzuki Foundation, Vancouver, 2004, pp. 38-9.

[39] Sources include: *The Hydro Province*, Manitoba Hydro, undated; Manitoba Hydro <http://www.hydro.mb.ca/issues/transmission_projects/transmission_projects.shtml>; Government of Manitoba <http://www.gov.mb.ca/est/energy/power/generating.html>; Tataskweyak Journal, Special Edition, June 2004; *Doer hopes to supply Ontario with hydro*, WINNIPEG.CBC.CA, Sept. 30, 2004.

- Conawapa (feasability studies underway)
  1250 MW
  CDN$5 billion (estimates are as high as $10 billion, including transmission)
- Gull/Keeyask (technical studies underway)
  620 MW
  CDN$2.5 billion
- Gillam Island: 1,000 MW
- First Rapids: 210 MW
- Manasan: 265 MW
- Early Morning: 70 MW
- Red Rock: 340 MW
- Whitemud: 310 MW
- Kelsey extension: 200 MW
- Bonald: 120 MW
- Granville: 125 MW

Newfoundland and Labrador[40]

- Gull Island Project
  2000 MW
  CDN$4 billion (including transmission facilities)

Quebec[41]

- There is 5930 MW of potential development not including refurbishments to existing dams (361 MW) and projects currently not considered viable (5800 MW).
- Eastmain-Rupert Project (under construction)
  1250 MW (Eastmain-1 480 MW, and Eastmain-1-A 770 MW)
  CDN$4.9 billion
- Toulnustouc Project (under construction)
  526 MW
  CDN$900 million
- Peribonka Project (public hearings have been held)
  385 MW
  CDN$1.1 billion
- Rocher-de-Grand-Mere (underway)
  220 MW
  CDN$454 million
- Romaine River projects (technical studies have been conducted)
  total of 1500 MW between 4 dams
  CDN$5 billion
- Petit Mecatina River projects
  total of 1500 MW available on the river
- Mercier Project (under construction)
  50.5 MW
- 500 MW Nastapoka River (considered marginally profitable)

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[40] Government of Newfoundland and Labrador, Press Release, Aug. 1, 2002; <http://www.gov.nf.ca/releases/2002/exec/0801n05.htm>.
[41] Hydro Quebec 2003 Annual report <http://www.hydroquebec.com/publications/en/annual_report/2003/pdf/hydro2003en_complete.pdf>; Hydro Quebec Strategic Plan 2004-2008 <http://www.hydroquebec.com/publications/en/strategic_plan/2004-2008/pdf/3.pdf>.

- 1,600 MW Caniapiscau River (not currently profitable)
- 3,100 MW George River (currently not environmentally or economically viable)
- 1,100 MW A la Baleine River (not currently viable)
- La Tuque refurbishment (underway)
  51 MW in addition to existing capacity
  CDN$179 million
- Outardes 3 refurbishment (underway)
  254 MW in addition to existing capacity
  CDN$143 million
- Outardes 4 refurbishment (underway)
  56 MW in addition to existing capacity
  CDN$141 million

Other provinces

- Negligible amounts

V. How hydroelectric generation works

The production of electricity requires a force to spin a generator. The generator then converts that force into electricity that can be sent along a wire. A hydroelectric generating station uses the force of flowing water to spin a large propeller which turns the generator (see diagrams).

"Head"

The difference in water level behind the dam and downstream of the dam (called "head") is what provides the flow of water through turbines in the dam.

Liquid Batteries

The storage of water in a reservoir behind a dam is an important factor in hydroelectric generation. It is not possible to store large amounts of electric energy but it is possible to store large amounts of water. This is important because the demand for energy varies by season and by time of day. Water can be stored during low demand seasons and times of day to be released when demand is high. Storage reservoirs behind dams act as batteries.

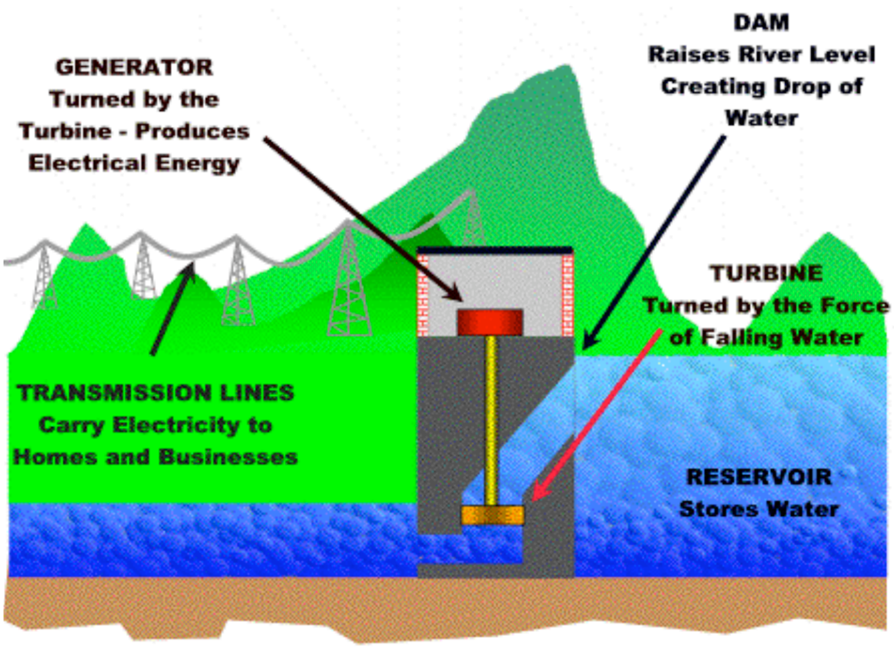
Adjustability

One unique feature of hydroelectric dams with reservoirs—in comparison to other electric generation methods—is that energy output from a dam can be adjusted from moment to moment. This is in contrast to coal fired plants which take considerable time to fire up, nuclear plants which can take days to fire up, and wind generation which varies according to wind patterns. This means hydroelectric plants are well suited to providing energy particularly at times of the year and the day when it is most needed ("peaking power"). It also means they work well in conjunction with wind energy as wind energy is highly variable and hydro energy can be used to fill in the gaps.

Run of the river

Hydroelectric dams without reservoirs are called "run of the river" dams. Rather than storing water they simply make use of the water flows as nature provides them. Flows upstream and downstream of a run of the river dam remain very similar to what they would be in the state of nature. Previous alterations of the flow of a river when the generating station are first built on the river are often considered to be natural or 'baseline'.

See: Dams Lite? Run of River Projects No Panacea.
www.irn.org/pubs/wrr/issues/WRR.V16.N4.pdf



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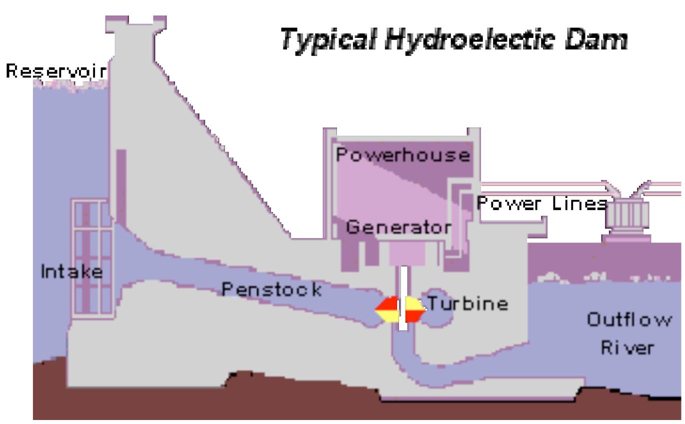

http://ga.water.usgs.gov/edu/hyhowworks.html