

University of Alberta Future Energy Systems

Quebec Energy Market Profile

Measuring the Costs and Benefits of Energy Transitions

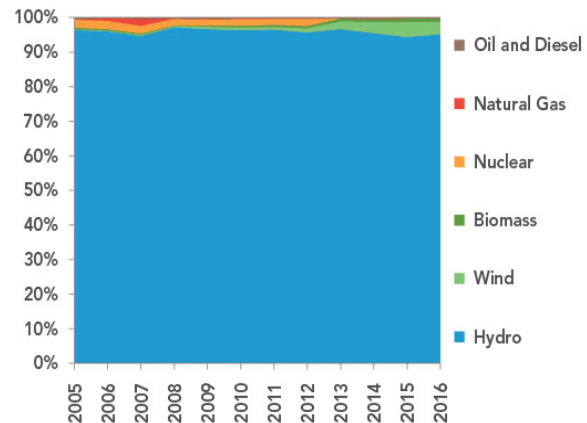
Elizabeth Dowdell and Sonak Patel
8-23-2018



Context

Quebec generates 99.8% of the province's electricity from renewable sources, with 95.2% provided by hydro resources, followed by a small but growing share of wind and biomass (NEB, 2017). Renewable capacity reached over 44,000 MW in 2016, while generation reached 206,696 GWh (NEB, 2017).

HydroQuebec, a provincially-owned Crown corporation, is responsible for the majority of electricity generation, transmission, and distribution in the province, however a handful of independent power producers operate privately-owned wind (39 projects), hydroelectricity (5 projects), and thermal power plants (7 biomass, 3 biogas), that retail to HydroQuebec (NEB, 2018a, HydroQuebec 2018a). Electricity was not always publicly owned, with the province nationalizing the resource through the purchase of several private energy companies in 1944 and 1963 (HydroQuebec, 2018b). Both reservoir and run-of-river hydro facilities are common across Quebec, and range in age from legacy (Trois Riviere c.1900) to current developments (la Romaine expected 2020) (HydroQuebec, 2018b). HydroQuebec also services the remote, off-grid communities of northeastern Quebec, providing power to 39 communities (15,300 customers) in five regions, through the operation of two generating stations with non-integrated transmission/distribution networks (Canadian Off Grid Utilities Association, nd).



Electricity Generation by Source in Quebec
Source: NEB, 2017

Quebec Demographics

2016 Census Profile (Statistics Canada, 2017)

- **Population:** 8,164,361
- **Average age:** 41.9 years
- **Working age distribution:** 65.4%
- **Private dwellings:** 3,858,943
- **Private dwellings occupied by usual residents:** 3,531,663

Quebec Consumption & Trade

Quebec is ranked #1 in Canada for per capita electricity consumption at 21.1 MWh with some of the lowest residential electricity prices in the country. This high ranking is largely due to energy-intensive industries like aluminum smelting, while the low cost is due to abundant resources and strict market regulation. Quebec is a large electricity exporter, with interconnections to Ontario, New Brunswick, and the Northeast United States. A net exporter, Quebec traded 12.6 TWh in 2016 (NEB, 2018b). Part of the province's 2030 energy policy is to further develop wind energy, explicitly for export (Government of Quebec, nd)

Energy Generation Regulations

HydroQuebec customers are eligible to participate in the utilities net metering program, producing renewable electricity for their own consumption, and returning any extra to the grid for credit on future withdrawals. Net metering is limited to renewable energy and includes wind, solar, hydro, geothermal (electricity generation only), and bioenergy. Generation must connect at the location listed on the customers delivery contract and cannot exceed 50 kW annually. A participating customer must be the owner and occupant of the dwelling/business, submit a technical report, undergo connection inspection, and pay a \$400 fee. HydroQuebec offers no reimbursement for expenses, but does provide a dual register meter free of charge. Credits expire every 24 months (HydroQuebec, nd).

For those looking to produce larger quantities of power, the Government of Quebec in their 2006-2015 Energy Strategy, developed a standardized application process to support Aboriginal and community waterpower projects under 50 MW utilizing crown resources (Government of Quebec, nd).

HydroQuebec publishes a procurement plan every three years, covering the next ten years of service, with a mandate to enter into contract for electricity purchases following tender if annual demand exceeds 165 TWh; HydroQuebec's 'heritage supply'. Electricity purchase programs have, since early 2000, focused on wind, biomass, and small hydro, at the request of the Government of Quebec (HydroQuebec, 2018c), with reference guides developed to support community and Aboriginal waterpower projects under 50 MW (Government of Quebec, nd) There are currently no calls for power in progress for HydroQuebec's integrated network, while the non-integrated network is in the process of increasing supply through private production, with a 6 MW wind project selected to receive a power purchase agreement as recently as March 2018 (HydroQuebec, 2018d).

Policy, Legislation, & Targets

The most recent energy use and development guide comes from *Energy in Quebec: A Source of Growth*, the provinces 2030 energy policy document. Targets include:

- Enhance energy efficiency by 15%
- Reduce petroleum product consumption by 40%
- Eliminate thermal coal
- Increase renewable share in total energy production by 25%
- Increase bioenergy production by 50%

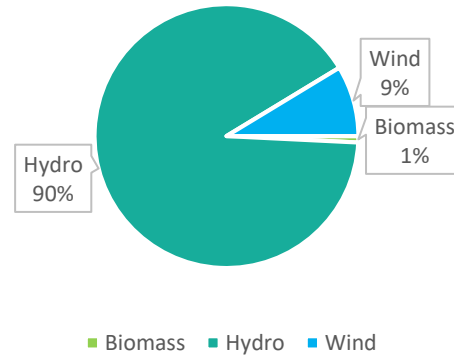
While these goals are defined by the province as 'ambitious', they come with a strategic framework and funding, and a strong desire from Quebec to be a leader in renewable energy and innovation (Government of Quebec, 2016).

Renewable Projects Overview & Dataset

A dataset of 208 renewable energy projects, in both operation and development, have been identified in

Quebec from two sources: Government of Canada - Renewable Energy Powerplants, 1 MW or more, and Atlas of Canada - Clean Energy Resources Projects. Out of a total of 44,761.9 MW renewable projects in the portfolio, 90% (40,532.4 MW) are hydroelectric projects, 9% (3,882.2 MW) are wind projects, and the remaining 1% (347.3 MW) is from biomass energy. No solar energy projects were identified at the commercial level, however, it should be noted that this list does not include Net Metering participants. Of the 208 renewable projects identified, a number of community-based projects were identified, including 14 municipally owned projects, 18 jointly owned projects, and 2 First Nations owned projects.

Renewable Projects in Operation by Type

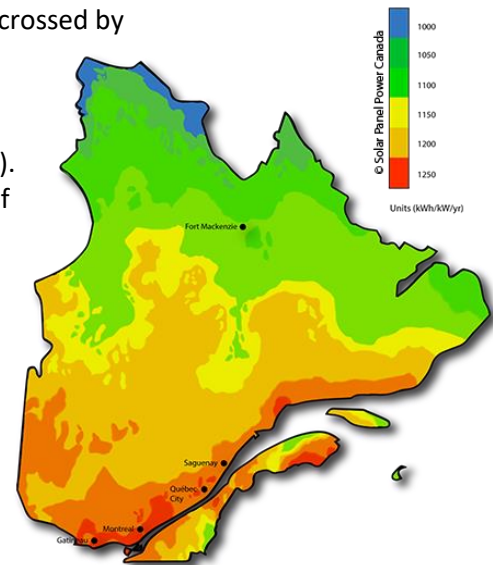


Renewable Energy Potential

Quebec is located on the Canadian Shield, a mostly flat landscape crossed by multiple lakes and rivers. The province extends from the densely-populated Great Lakes region in the south, up to the remote, northern Ungava peninsula. Low mountain ranges border the southern and northern reaches of the province (World Atlas, 2018). This mix of geographic and population features supports a range of renewable energies, especially hydroelectric, wind, and biomass.

Solar

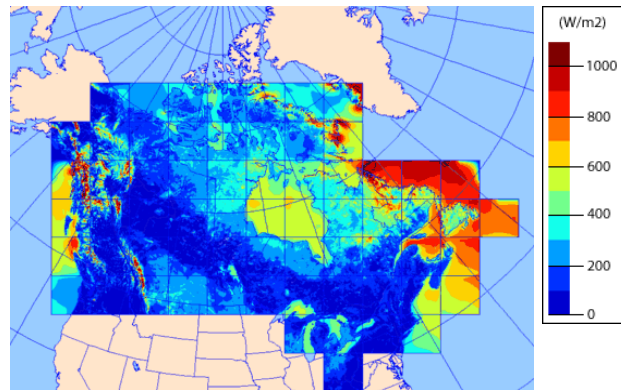
Quebec is characterized as having quality solar resources, and ranked fifth in Canada in terms of potential for private business/residential installation due to supportive government policy and incentives. The average solar system (5 kW) is expected to produce 5,766 kWh of electricity per year. However, there is little commercial incentive to adopt solar energy production as Net Metering provides only a two-year credit and no payment for excess energy, with no call for solar power or purchase agreements issued by HydroQuebec (Solar Panel Power Canada, 2018). Geographically, solar potential is the greatest in the southern portion of the province but both north and south have issues with snow accumulation during the winter.



Average Annual Solar Energy Generation per kW Installed
Source: <https://solarpanelpower.ca/quebec/>

Wind

Quebec has excellent wind potential due to the large and sparsely populated nature of the province as a whole. Since the first farm was built in 1998, the province has been increasing the mix of wind in its renewable electricity production through a series of calls for tender with current capacity meeting approximately 3,878.9 MW of a 4,000 MW goal. Uncaptured potential energy estimates for the province in 2005 range from 3,600 MW (Quebec Government Department of Natural Resources and Wildlife (MRNF), 2005) to 100,000 MW (Hélimax cited by Association Québécois de la Production d'Énergie Renouvelable (AQPER), nd) depending on the location and technical feasibility of connecting to HydroQuebec's existing grid and the grid's ability to utilize this energy. In the same Hélimax report, 400,000 MW is estimated to be Quebec's raw wind energy potential, a number that may never be realized without further investment in transmission infrastructure.



Annual Mean Wind Speed at 50 m

Source: <http://www.windatlas.ca/maps-en.php>

In a 2015 national study by Barrington-Leigh & Ouliaris, wind potentials across the nation were measured to determine the feasible generation. Using GIS, high wind potentials were identified using wind speeds of 7 m/s at a height of 80 m. The study excluded protected lands, inland water bodies, First Nations land, and a 5 km buffer around population centres. The remaining lands were then amended to only include lands near transmission lines (Barrington-Leigh & Ouliaris, 2015). Assuming that 25% of the remaining high potential areas are utilised, which accounts for competing land uses, Quebec could generate 190 TWh per year. Of Quebec's total 2015 energy demand of 447 TWh per year, wind energy could account for 42% of Quebec's total energy generation (Barrington-Leigh & Ouliaris, 2015).

Quebec also has some potential for offshore wind energy as well, based in the Great Lakes. Barrington-Leigh & Ouliaris (2015) evaluated the potential for offshore wind across the nation. Offshore wind benefits from higher wind speeds, but is challenged by higher construction costs, higher maintenance costs due to seawater corrosion, and higher transmission costs (Barrington-Leigh & Ouliaris, 2015). When examining feasible lands for offshore wind, areas near the shore and water bodies near population centres or transmission lines were considered feasible. Areas with high potential were off the coast of British Columbia, on the Great Lakes, on the Gulf of St. Lawrence, and Bay of Fundy. High potential sites do not account for shipping lanes and environmentally sensitive areas. Assuming a 50% utilization of high potential areas, it was determined that offshore wind farms in Quebec could produce 13 TWh per year, meeting 2% of the total energy demand in Quebec of 447 TWh per year (Barrington-Leigh & Ouliaris, 2015).

Hydroelectricity

Hydroelectricity is the primary source of renewable energy currently developed in Quebec, due in large part to a geography rich with lakes and rivers, 500,00 and 4,500 respectively, and a history of

hydroelectric production dating back to the 19th century (HydroQuebec, 2018e). According to the Government of Quebec, while ~47,000 MW of hydraulic resources have been developed, another ~45,000 MW remain untapped, with only ~20,000 MW currently economically viable (Government of Quebec, 2012). While resources are vast, they are not always located convenient to the provinces integrated or non-integrated transmission centers. Further development of hydro potential is largely encouraged through the private sector, with government support for smaller, run of river projects owned by community and Indigenous proponents in Quebec.

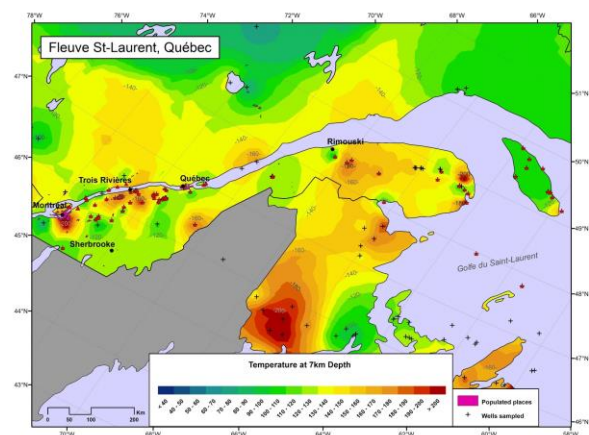
Barrington-Leigh & Ouliaris (2015) used the technical feasibility of hydroelectric resources and assumed a 60% capacity to generation ratio and 60% of feasible sites are developed to determine the feasibility of energy generation from hydroelectric sources. Quebec could produce 308 TWh per year, which could meet 69% of the total 447 TWh per year demand.

Geothermal

Located mostly on the Canadian Shield, Quebec has limited geothermal resources. While HydroQuebec does provide information to customers on installing geothermal heating/cooling, no electricity generation facilities currently exist or are being contemplated. Deep geothermal potential has been researched in the southeastern part of the province, with water temperatures in the 150°C range, theoretically supporting electricity generation, estimated at 2-5 MW per facility (HydroQuebec, 2018f).

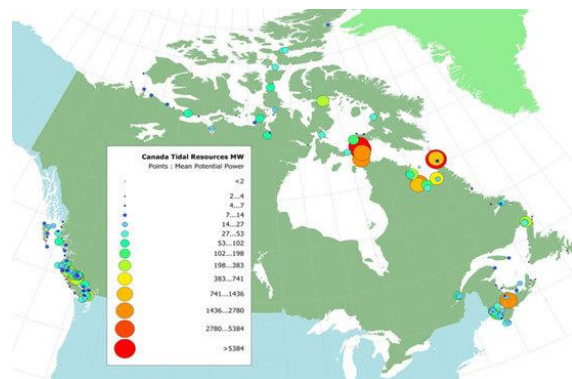
Ocean

The hydrokinetic energy of wave, tidal, and river currents are currently under investigation but not yet commercialized in Quebec. While river currents, even strong ones, do not seem to provide much return (400 kWh or less), tidal projects are more promising. A demonstration turbine was installed in the St. Lawrence seaway from 2010 to 2013 producing energy for the HydroQuebec grid in the range of 100 kW. Raw river current potential is estimated at 5,250 MW in Quebec, with 525 to 788 MW feasible based on a 10-15% return. Tidal projects fare better, with theoretical potential estimated at 4,288 MW however, the best tidal resources are located in northern Quebec, along the Ungava peninsula, far from any transmission infrastructure and therefore presently inaccessible (HydroQuebec, 2018g).



Temperature at 7 km depth

Source: <http://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/17114>



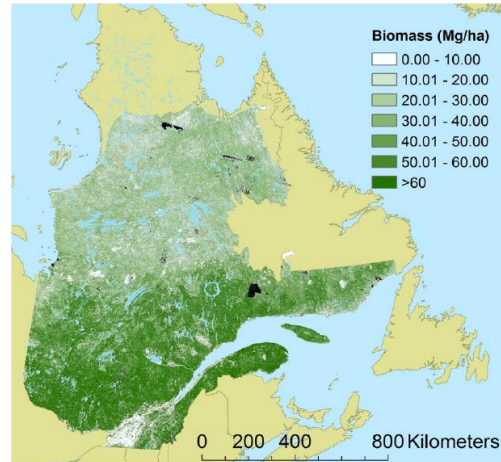
Tidal Feasibility in Canada

Source: <https://www.nrcan.gc.ca/energy/renewable-electricity/marine-energy/7371>

Barrington-Leigh & Ouliaris (2015) used the technical feasibility of tidal power and assumed 15% of it could be extracted using existing technology. Using this parameter, it was determined that Quebec could generate 3.94 TWh per year, meeting 0.88% of the total 447 TWh per year energy demand in Quebec (Barrington-Leigh & Ouliaris, 2015).

Biomass

Residual forest biomass is the most commonly used feedstock for electricity generation in Quebec with this renewable showing growth thanks to government investment and re-investment in business, institutional, and community biomass programs. In March, 2017 the Government of Quebec re-launched its Residual Forest Biomass Program with \$19 million available for new infrastructure projects, closing the program again in March, 2018 (AQPER, 2017). In 2011, HydroQuebec estimated total dry matter reserves at 19.5 million metric tonnes with a technical potential of 30-35% electricity recovery in a forest biomass facility (HydroQuebec, 2018h). HydroQuebec notes that only forest biomass, specifically slash, has been demonstrated to reliably produce electricity generation but no estimate of annual slash feedstocks could be obtained.



Biomass in Quebec

Map Source: Boudreau, J, Nelson, R, Margolis, H, Beaudoin, A, Guindon, L & S. Kimes, D. (2008). *Regional aboveground forest biomass using airborne and spaceborne LiDAR in Quebec*. Remote Sensing of Environment. 112. 3876-3890. 10.1016/j.rse.2008.06.003.

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