Recent Developments in Renewable Energy in Remote Aboriginal Communities, Quebec, Canada

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Northern Quebec's 14 remote aboriginal communities are dispersed through the land of Nunavik and are entirely reliant on diesel for their electricity needs. This paper reviews Nunavik communities' electrical systems, past renewable electricity projects, as well as available renewable resources for electricity generation. One renewable project was installed in Kuujjuaq in 1986, but despite the availability of wind and hydroelectricity resources, there were no subsequent renewable electricity installations in Nunavik. However, the need for alternatives to diesel powered electricity is recognized and communities are examining two options: the potential connection to the provincial grid to access reliable and clean electricity and the integration of renewable applications into local community diesel systems. The success of the Mesgi'g Ugju's'n wind farm partnership with Mi'gmaq communities in Gaspe, and the Raglan Mine community scale wind turbine, combined with falling storage prices and technological advancements in controller design, could provide an opportunity for the development of high penetration wind projects in locations with high wind regimes, including some of Nunavik's aboriginal communities.

Keywords: Quebec, remote aboriginal communities, indigenous communities, renewable electricity, community ownership, wind projects

Introduction

There are 44 remote communities in Quebec served by autonomous electricity grids based on hydroelectric and thermal power plants. Northern Quebec's 14 remote aboriginal[1] communities are dispersed through the land of Nunavik and are entirely reliant on diesel for their electricity needs (AANDC, 2012b). Although one of the first wind-diesel projects in Canada was installed in Kuujjuaq in 1986 (Ah-You & Leng, 1999; Hydro Quebec, 2016) to reduce both the need for diesel and greenhouse gas emissions, and despite the availability of wind and hydroelectricity resources in the proximity of communities, there were no subsequent renewable electricity installations in Nunavik. However, the need for alternatives to diesel powered electricity is recognized and communities are examining the potential connection to the provincial grid to access reliable and clean electricity to improve their socioeconomic conditions. The next sections provide an overview of the population served in Nunavik's 14 remote aboriginal communities, the capacity and type of current electricity generation systems, electricity price and rate

[1] The term aboriginal community is used in this paper. It is recognized that some communities prefer the term indigenous community while others prefer aboriginal community and that both are used in the literature.

structures, future demand expectations, renewable resource availability, as well as Quebec's policies, and Nunavik's plans to support community participation in renewable electricity generation.

Population

According to AANDC and NRCan (2011), in 2011 there were 44 remote communities in Quebec with a total population of approximately 35,000, of which 25 are non-aboriginal communities with a population of approximately 20,000, and 19 are aboriginal communities with a population of approximately 15,000. The community of Whapmagoostui FN is serviced by the diesel plant in Kuujjuaraapik and the community of Obedjiwan is part of the diesel grid of Haute Maurice. The community of La Romaine (home of the Innu Montagnais de Unamen Shipu) is part of the Basse-Côte-Nord grid and powered by a 5.7 MW diesel generator. There are no data available for the communities of Rapid Lake and Grand Lac Victoria. The remaining 14 communities are the Inuit communities in Nunavik (Akulivik, Aupaluk, Inukjuak, Ivujivik, Kangiqsualujjuaq, Kangiqsujuaq, Kangirsuk, Kuujjuaq, Kuujjuaraapik, Puvirnituq, Quaqtaq, Salluit, Tasiujaq, Umiujaq) with a population of approximately 12,090 people in 2011 (CRC-CAC, 2015; RRSSSN, 2011) (Table 1).

Table 1: Remote aboriginal communities, Nunavik

	Community Name	Population 2011[2]	Diesel plant capacity in 2000 kW[3]	Annual electricity demand in 2000 MWh[4]
1	Akulivik	615	850	2,016
2	Aupaluk	195	550	1,020
3	Inukjuak	1597	2,990	5,744
4	Ivujivik	370	1,050	1,264
5	Kangiqsualujjuaq	874	1,760	3,394
6	Kangiqsujuaq	696	1,520	2,342
7	Kangirsuk	549	1,050	2,349
8	Kuujjuaq	2375	3,935	11,973
9	Kuujjuaraapik	657	3,405	7,976
10	Puvirnituq	1692	2,870	6,077
11	Quaqtaq	376	1,045	1,448
12	Salluit	1347	2,000	4,419
13	Tasiujaq	303	850	1,493
14	Umiujaq	444	1,050	1,643
	Total	**12,090**	**24,325**	**53,158**

Source: AANDC (2012b); CRC-CAC (2015); Hydro Quebec (2002).

Electricity system

Hydro Quebec has an installed capacity of 36,912 MW from 87 generating stations and over 99% of its supply is hydroelectricity (Hydro Quebec, 2015). Hydro Quebec is the main

[2] http://pse5-esd5.aadnc-aandc.gc.ca/fnp/Main/Search/FNPopulation.aspx?BAND_NUMBER=540&lang=eng
[3] Hydro Quebec (2002, p.11). The 2011 AANDC and NRCan (2011) study features the same generators capacity.
[4] Hydro Quebec (2002, p.11)

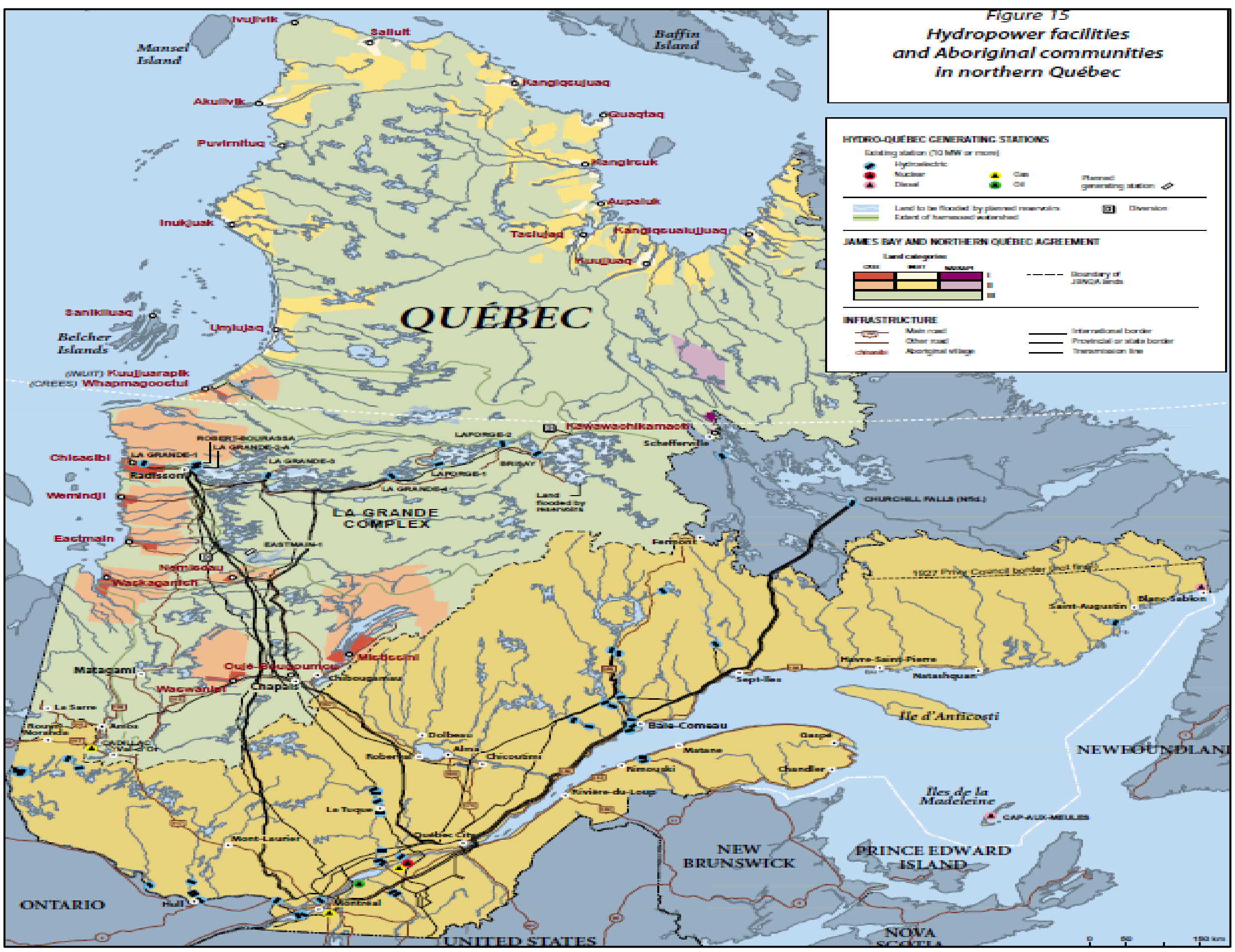
distributor of electricity for the five autonomous grids in Quebec, namely the Îles-de-la-Madeleine, Haute-Mauricie, Schefferville, Basse-Côte-Nord (including Anticosti Island), and Nunavik, which serve in total approximately 35,000 residents (Table 2 and Figure 1). Total power requirements for the isolated grids in 2012 were 93 MW, supplying 412 GWh to approximately 17,600 customers (Hydro Quebec, 2013). In 2015 there were 23 plants in off grid systems with a total capacity of 131 MW (Hydro Quebec, 2015).

Table 2: Quebec's autonomous electrical grids

	Autonomous electrical grids in Quebec	Power plant type
1	Îles-de-la-Madeleine	Light/heavy diesel
2	Haute-Mauricie	Diesel plants
3	Schefferville	Menihek hydroelectric station in Labrador and diesel plants
4	Basse-Côte-Nord (including Anticosti Island)	Lac-Robertson hydroelectric station and diesel back-up
5	Nunavik	Isolated diesel power plants

Source: Hydro Quebec (2013).

Figure 1: Hydro Quebec's electricity system and Nunavik's remote communities



Source: Hayeur (2001, p. 69).

The largest of Quebec's autonomous grids is the Îles-de-la-Madeleine grid, serving approximately 43% of all autonomous grid customers using two thermal power stations, one on Île-d'Entrée using light diesel, and one at Cap-aux-Meules using heavy fuel oil. In 2012 the power requirements were 42.1 MW and electricity consumption was 187 GWh, while the 2012 annual emissions exceeded 125,000 tonnes $CO_{2,\ eq}$ annually (Hydro Quebec, 2013). The small grid of Haute-Mauricie comprises of the communities of Opiticiwan and Clova, each supplied by a diesel-fired thermal power station, which generate a total of 10.8 GWh. The Schefferville grid is powered by the Menihek hydroelectricity plant in Labrador, and serves the communities of Schefferville, Matimékush-Lac-John and Kawawachikamach, which consume approximately 43.4 GWh. The Basse-Côte-Nord grid is powered by the Lac-Robertson hydroelectric generating station with an installed capacity of 33.7 MW that provides approximately 80% of the grid, and two thermal power stations, 2.8 and 5.7 MW, installed in the Port-Menier and La Romaine communities respectively. The grid serves communities from La Romaine to Blanc-Sablon and the community of Port-Menier on Anticosti Island and its power requirements were 86.4 GWh in 2012 (Hydro Quebec, 2013). Nunavik's isolated diesel communities are described in the next sections.

Electricity rates

Electricity rates in Quebec are currently the lowest in Canada, due to Quebec's vast hydroelectricity resources (Hydro Quebec, 2015). Although the cost of electricity generation in Nunavik's communities is significant and ranges between 65 c/kWh and 132.4 c/kWh (see Table 3) (GQ, 2014; Cherniak, Dufresne, Keyte, Mallett, & Scott, 2015), electricity rates in remote communities are heavily subsidized to as low as 5.71 c/kWh for the first 900 kWh/month and 37.62 c/kWh for any additional kWh (Hydro Quebec, 2016).

Table 3: Electricity cost in Nunavik's remote aboriginal communities

	Community Name	**Total electricity cost, 2013 (c/kWh)**
1	Akulivik	109.7
2	Aupaluk	119.4
3	Inukjuak	77.7
4	Ivujivik	132.4
5	Kangiqsualujjuaq	78.8
6	Kangiqsujuaq	85.2
7	Kangirsuk	78.9
8	Kuujjuaq	86
9	Kuujjuaraapik	70.4
10	Puvirnituq	66.2
11	Quaqtaq	95.4
12	Salluit	65
13	Tasiujaq	90.6
14	Umiujaq	95.9

Source: GQ (2014, p. 16).

Future power requirements and resources availability in Nunavik communities

Electricity generation in the Nunavik communities increased at an average 3.6% annually from 53,158 MWh in 2000 (Hydro Quebec, 2002) to approximately 82,400 MWh in 2012 (Hydro Quebec, 2013) and 85,500 MWh in 2013 (GQ, 2014). Hydro Quebec estimates future electricity demand increase for the fourteen Nunavik communities between 2% and 4% annually for the period 2005 to 2024, due to anticipated population, dwellings, and community building increases (Hydro Quebec, 2003). Local governments estimate that by 2025 the annual peak demand will reach 110 MW (NRBHSS, 2014; NRBHSS, 2013).

The need to address future community load increases, provision of clean electricity, and economic development is examined in "Plan Nunavik" (KRG, 2012). The plan proposes the interconnection to Hydro Quebec's provincial electricity grid as the main alternative for communities to reduce their dependence on diesel for both electricity and heating, and to improve their socioeconomic conditions through low cost, locally sourced, clean hydroelectricity. The transmission line to connect all 14 communities and the Raglan Mine is estimated to cost between $900 to $1,600 million with a construction period of 6 to 14 years (KRG, 2012; George, 2011). Communities plan to use local resources for community owned, hydroelectricity generation and transmission facilities that will cover regional demand including the extensions of the Raglan and Nunavik Nickel mining sites, and attract future mining exploration projects in the area (GQ, 2006; KRG, 2012; NRBHSS, 2014). Aboriginal governments identify Nunavik's hydroelectricity resources as able to support from 6,300 to 7,200 MW of renewable electricity generation, and the existence of significant tidal power potential in the Ungava Bay. However, there is a lack of studies on the economic, technical and environmental potential of these resources (MC-KRG-GQ, n.d.; George, 2011).

Renewable energy policies and promotion in Nunavik communities

Quebec's 2006-2012 Action Plan included an energy strategy focused on the provision of low cost electricity to support industrial development and electricity exports through the addition of 4,500 MW of hydroelectricity and the development of 4,000 MW of wind potential by 2015 (GQ, 2008). Communities (including aboriginal communities) are encouraged to participate in privately owned generating stations under 50 MW to promote social and economic development (GQ, 2006; GQ, 2015). To support the creation of aboriginal renewable generation assets and to help meet community socioeconomic needs, Hydro Quebec made available 250 MW of renewable electricity procurement, and prioritized aboriginal consultation and the development of energy projects in cooperation with communities (GQ, 2016). The largest of these grid connected projects is the 150 MW Mesgi'g Ugju's'n (MU) Wind Farm, a 50-50 partnership between the three Mi'gmaq communities of Gesgapegiag, Gespeg and Listuguj and the independent renewable power producer, Innergex (MU, 2016a). The benefits to the Mi'gmaq communities include equal membership on the board of directors, direct employment (110 out of the 300 construction workers and four of the eight operational workers were from the communities), an indexed social development fund of $75,000/year and estimated profits of $200 million over the 20-year contract period (MU, 2016b).

Table 4: Renewable energy projects in remote Nunavik communities

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Akulivik					
2	Aupaluk					
3	Inukjuak					
4	Ivujivik					
5	Kangiqsualujjuaq					
6	Kangiqsujuaq					
7	Kangirsuk					
8	Kuujjuaq		65		1986	INAC(2004); Ah-You & Leng (1999). See also[5].
9	Kuujjuaraapik					
10	Puvirnituq					
11	Quaqtaq					
12	Salluit					
13	Tasiujaq					
14	Umiujaq					
	Total		**65**			

The 14 northern communities of Nunavik are powered by isolated diesel generators with a total capacity of 24.325 MW, generated approximately 82,400 MWh/year in 2012, consumed approximately 23,000,000 litres/year of diesel fuel, and contributed 65,000 tonnes/year $CO_{2,eq}$ emissions[6] (Table 1) (KRG, 2012; Hydro Quebec, 2013). Although renewable electricity projects for Canadian remote communities were initiated in Quebec, starting with the first 230 kW wind turbine installed in Îles-de-la-Madeleine in 1976 (Adamek & Tudor, 2009), there has been only one 65 kW wind turbine installed in the Nunavik community of Kuujjuaq in 1986[7] (Table 4).

The potential for wind-diesel projects in Nunavik's communities was examined by the Institut de Recherche d' Hydro-Québec (IREQ) (Krohn, 2005) and through the installation of wind measurement equipment in Inukjuak, Whapmagoostui, Akulivik, and Kangiqsualujjuaq by Hydro Quebec (Hydro Quebec, 2003; Hydro Quebec, 2007). Studies indicate wind resources higher than 7 m/s for all 14 Nunavik communities (Weis & Ilinca, 2008; Weis & Ilinca, 2010; Krohn, 2005). Simulation studies, performed for all communities, indicated that wind-diesel projects, under certain assumptions, could be economically viable for the communities of Inukjuak, Kuujjuaraapik, Kangiqsualujjuaq, Kangirsuk, Kangiqsujuaq, Umiujaq, and Akulivik, with the greatest potential identified in the community of Inukjuak (Hydro Quebec, 2007). An 8

[5] http://www.hydroquebec.com/learning/eolienne/historique-eolien-hydro-quebec.html
[6] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 ton $CO_{2,eq}$ for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).
[7] The Kuujjuaq wind turbine is currently not operational and used for educational purposes at the Cégep de la Gaspésie et des Îles. See footnote 4.

MW hydroelectricity project was also examined for Inukjuak (George, 2011; Atagotaluuk, 2016).

Despite the considerable number of wind studies for the 14 Nunavik communities conducted between 2003 and 2008 (see Maissan (2006a); Krohn (2005)) and past announcement for governmental support for the development of wind-diesel projects in the autonomous grids (including Nunavik) to reduce the use of costly and greenhouse gas emissions intensive diesel generation (GQ, 2006) there has been no renewable electricity applications installed in Nunavik's aboriginal communities. High deployment costs, communities' vested interests in diesel generation, equipment availability, and resistance to change from Hydro Quebec are the main reasons identified as barriers to wind deployment in Quebec's remote communities (Weis, 2014; GQ, 2014). Recent Hydro Quebec announcements state that wind and hydroelectricity projects are not financially viable under current economic conditions (Rogers, 2014).

However, the installation of a wind-hydrogen-smart grid system at Nunavik's Glencore's Raglan Mine in 2016 signals the potential of community scale wind applications in remote locations. The project used an Arctic grade wind turbine, hydrogen storage technologies, an advanced controller, and low environmental impact foundations at a Canadian Arctic mine location, and displaced 3.4 million liters of diesel and 10,200 tons of greenhouse gases within its first 18 months of operation, or 2.2 million liters of diesel per year (Tugliq Energy, n.d.; NRCan, 2017). The project's successful deployment demonstrates the potential for wind power to displace diesel consumption in remote communities (NRCan, 2017).

Conclusion

Remote communities in Nunavik are entirely dependent on diesel fuel for electricity, heating and transportation. Communities are examining the introduction of wind power into communities' local diesel generation operations and potential connections to the provincial grid as alternatives to reduce diesel dependency and to improve socioeconomic conditions. The success of the Mesgi'g Ugju's'n wind farm partnership with Mi'gmaq communities in Gaspe may provide valuable lessons for projects in the north. However, despite available wind resources and Hydro Quebec's experience in wind-diesel hybrid systems, wind deployment is currently considered not financially viable for the Nunavik communities. Recent successful deployment of a community scale wind turbine in Raglan Mine, combined with falling storage prices and technological advancements in controller design, could enhance the feasibility of high penetration wind projects in locations with high wind regimes, including some of Nunavik's aboriginal communities. An alternative pathway to clean, reliable electricity is the connection to the provincial grid that could also provide multiple benefits to the communities through local hydroelectricity or wind generation and transmission to existing and future mining development in Nunavik.

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