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

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Remote aboriginal communities in Nunavut are entirely dependent on diesel powered electricity. This paper reviews the electricity systems in 25 remote communities, past renewable electricity projects and available renewable resources. Despite past efforts to introduce renewable energy into these communities, alternative energy generation is limited to a few district heating installations, and wind and solar demonstration projects. The high cost of deployment of renewable technologies in Nunavut's isolated locations and limited government financial resources hinder communities' participation in renewable electricity generation. However, growing demand and the necessity for diesel plant replacements or upgrades in 17 of the 25 communities, combined with recent decreases in the cost of solar and battery storage technologies, provide an opportunity for communities with high wind resources to integrate wind and solar projects into their electricity systems and to reduce dependence on fossil fuels.

Keywords: Nunavut, remote aboriginal communities, indigenous communities, diesel, renewable electricity, wind, solar

Introduction

Each of Nunavut's 25 communities is remote and isolated with no road or electricity grid connecting them. They are entirely dependent on diesel generated electricity with diesel delivered in the summer and stored in tanks for use throughout the year. The result is a high cost, carbon-intensive system. Efforts have been made to introduce renewable energy in the past (Ah-You & Leng, 1999), but renewable electricity generation is limited to a few wind and solar demonstration projects (Senate Canada, 2014a). System efficiency has been improved with district heating systems in ten communities that use residual or waste heat from the diesel plants (Senate Canada, 2014a). Although there are hydroelectricity resources capable of reducing Nunavut's diesel consumption, the necessity of upgrading the outdated diesel generators and the Government of Nunavut's limited financial resources restrict the deployment of renewable electricity projects (Senate Canada, 2014a). However, the need for change is recognised and new interest has arisen in the potential for renewable resources to displace diesel through the integration of wind, solar and battery storage in the local systems as old diesel plants are upgraded (Das & Canizares, 2016). The next sections provide an overview of the population served in Nunavut's remote aboriginal[1] communities, the capacity and type of current electricity

[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.

generation systems, electricity price and rate structures, future demand expectations, renewable resource availability, as well as policies, plans and pilot projects to support renewable electricity generation in the remote communities.

Population

Nunavut has 25 communities[2] with a 2014 population of approximately 36,500 (Table 1), of which approximately one third (or 11,389 people) is under the age of 15. Nunavut's population increased at an average annual growth rate of 2.3% from 2006 to 2014. The capital Iqaluit has a population of 7,542 and the communities of Arviat and Rankin Inlet follow with populations of 2,611 and 2,820 respectively (NBS, 2014).

Table 1: Remote aboriginal communities, Nunavut

	Community name	Population 2014	Diesel plant capacity (MW)[3]	Annual electricity demand (2013) in MWh
1	Arctic Bay (Ikpiarjuk)	875	1.07	3,008
2	Arviat	2,611	2.24	8,028
3	Baker Lake (Qamanittuaq)	2,164	2.24	8,938
4	Cambridge Bay (Ikaluktutiak)	1,684	3.11	9,144
5	Cape Dorset (Kinngait)	1,508	1.80	6,110
6	Chesterfield Inlet (Igluligaarjuk)	387	0.81	2,002
7	Clyde River (Kangiqtugaapik)	1,039	1.35	3,681
8	Coral Harbour (Sallit)	961	1.31	3,367
9	Gjoa Haven (Uqsuqtuuq)	1,370	1.65	5,009
10	Grise Fiord (Aujuittut)	163	0.465	1,250
11	Hall Beach (Sanirajak)	895	1.345	3,257
12	Igloolik	2,007	1.74	6,183
13	Iqaluit	7,542	15.10	56,888
14	Kimmirut	481	0.93	2,.062
15	Kugaaruk (formerly Pelle Bay)	953	0.835	2,653
16	Kugluktuk (Qurluqtuq)	1,591	2.22	5,576
17	Pangnirtung (Pangniqtuuq)	1,613	2.22	6,477
18	Pond Inlet (Mittimatalik)	1,673	2.25	5,993
19	Qikiqtarjuaq (formerly Broughton Island)	526	1.305	2,531
20	Rankin Inlet (Kangiqiniq)	2,820	3.55	17,396
21	Repulse Bay (Naujaat)	1,068	0.99	3,584
22	Resolute (Qausiuttuq)	247	2.05	4,778
23	Sanikiluaq	924	1.2	3,483
24	Taloyoak (Talujuaq)	998	1.5	3,418
25	Whale Cove (Tikirarjuaq)	456	0.75	1,753
	Total	**36,556**	**54.03**	**174,507**

Source: AANDC (2012b); NBS (2014); QEC (2013).

[2] AANDC (AANDC, 2012b) mentions 26 communities and includes the community of Bathurst Inlet (Kingoak), which currently has zero population, see https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6208065&Geo2=PR&Code2=01&Data=Count&SearchText=Bathurst%20Inlet&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=6208065&TABID=1

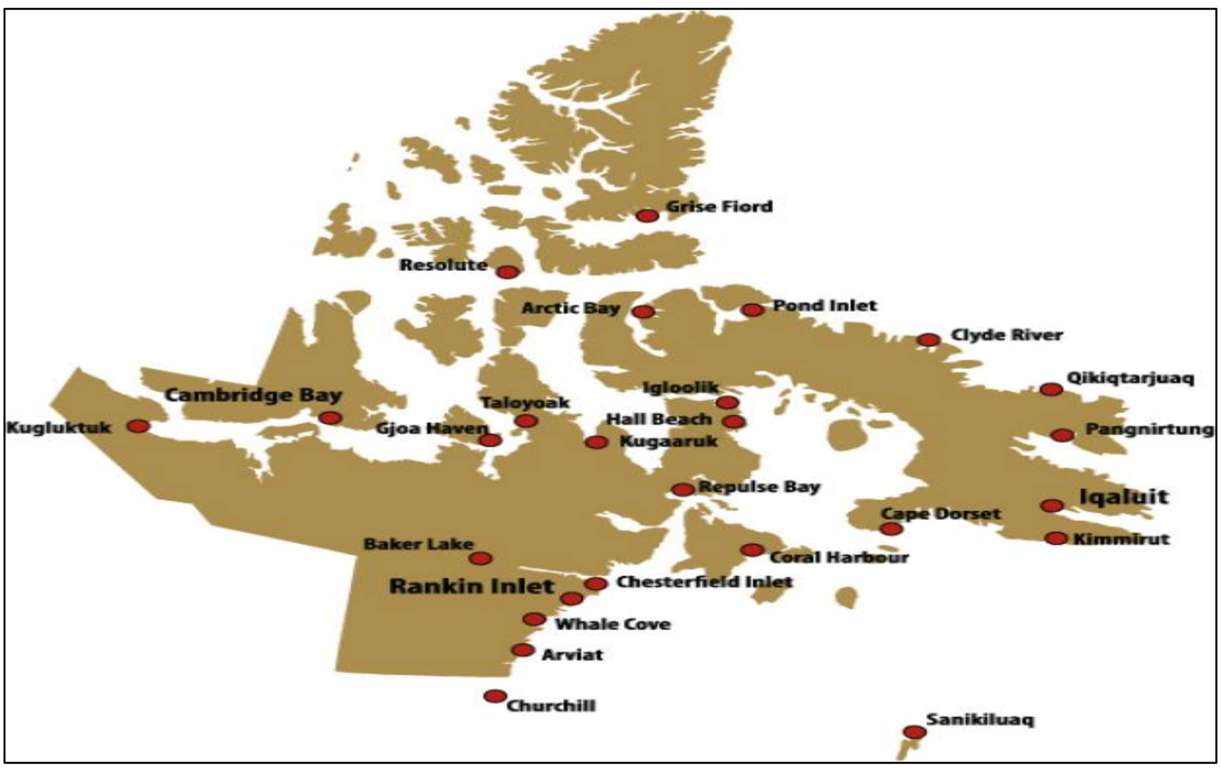
[3] https://en.wikipedia.org/wiki/List_of_generating_stations_in_Nunavut and the Nunavut power archives, such as http://web.archive.org/web/20040829121348/http://www.nunavutpower.com/communities/chester.html in the case of Chesterfield inlet for example. See also AANDC and NRCan (2011).

Electricity system

Electricity generation in Nunavut was the responsibility of Northern Canada Power Commission (NCPC) from 1949-1988, followed by Northwest Territories Power Corporation (NTPC) until 2001 (NTPC, 2016). Following the creation of the new territory, new arrangements were made with power generation being provided by Qulliq Energy Corporation (QEC), a corporation owned by the Government of Nunavut (QEC, 2015a). QEC generates, transmits and distributes electricity through 26 stand-alone diesel plants in 25 communities (there are two diesel plants in Iqaluit) and approximately 275 km of distribution lines, with a total installed capacity of 54 MW, serving approximately 14,400 electrical customers (Figure 1) (GN, 2015).

Diesel generated electricity in Nunavut was 176,850 MWh in 2013[4] and was projected to increase by 2.3% to 187,610 kWh in 2014/2015. Electricity generation in 2013 was fueled by approximately 48 million liters of diesel resulting in an average efficiency of 3.69 kWh/liter, at an average cost of 0.91 $/lit (QEC, 2013). Diesel fuel is shipped in bulk during the summer and stored in fuel tank facilities in each community (QEC, 2014; GN, 2015). Electricity related greenhouse gas emissions for 2013 were estimated at approximately 116,000 tonnes CO_{2eq}, while total emissions (electricity, heating and transportation) were 473,813 tonnes of CO_{2eq} , an increase of 14,941 tonnes since 2009 (GN, 2015).

Figure 1: Electricity system in Nunavut: communities with diesel generators



Source: QEC (2013).

[4] QEC 2014/2015 General Rate Application, Vol 1, p.45/372.

Electricity rates

The cost of electricity in Nunavut depends on the community and the rate class, which in turn is based on the distinction between residential, government and commercial customers. Residential rates in 2014 ranged from 62.23 c/kWh in Rankin Inlet to as high as 114.16 c/kWh in Kugaaruk or 144.80 c/kWh for government accounts in Whale Cove (QEC, 2015b) (Table 2). Residential and small commercial consumption are subsidized through the Nunavut Electricity Subsidy Program. For small commercial enterprises subsidization applies to the first 1,000 kWh of monthly consumption, while residential customers are subsidized for the first 1,000 kWh during the October to March period and the first 700 kWh during the April to September period; in this case all consumers pay the same rate, which is 50 percent of Iqaluit's base rate, or 30.15 c/kWh (GN, 2015c; CBC News, 2014). Excess consumption is billed at the electricity rate of each community presented in Table 2.

Table 2: Qulliq Energy Corporation (QEC) electricity rate schedule, May 2014

	Community	Domestic		Commercial	
		Non-government c/kWh	Government	Non-government c/kWh	Government
1	Arctic Bay (Ikpiarjuk)	87.87	87.87	78.97	78.97
2	Arviat	79.14	79.14	74.03	74.03
3	Baker Lake (Qamanittuaq)	70.31	70.31	66.09	66.09
4	Cambridge Bay (Ikaluktutiak)	76.06	76.06	66.07	66.07
5	Cape Dorset (Kinngait)	68.59	71.87	64.47	71.87
6	Chesterfield Inlet (Igluligaarjuk)	97.54	97.54	91.14	91.14
7	Clyde River (Kangiqtugaapik)	78.19	78.67	69.66	69.66
8	Coral Harbour (Sallit)	94.66	94.66	87.11	87.11
9	Gjoa Haven (Uqsuqtuuq)	89.45	92.28	85.96	85.96
10	Grise Fiord (Aujuittut)	92.09	110.79	105.92	105.92
11	Hall Beach (Sanirajak)	89.03	92.32	85.91	85.91
12	Igloolik	63.23	63.23	58.35	58.35
13	Iqaluit	60.29	60.29	50.68	52.04
14	Kimmirut	103.74	103.51	87.70	88.13
15	Kugaaruk (formerly Pelle Bay)	114.16	114.16	101.77	101.77
16	Kugluktuk (Qurluqtuq)	93.32	98.68	87.19	87.19
17	Pangnirtung (Pangniqtuuq)	65.74	70.13	58.66	64.26
18	Pond Inlet (Mittimatalik)	89.95	97.29	82.88	82.88
19	Qikiqtarjuaq (formerly Broughton Island)	77.92	88.71	74.06	88.71
20	Rankin Inlet (Kangiqiniq)	62.23	62.23	55.04	60.64
21	Repulse Bay (Naujaat)	85.06	85.06	75.30	75.30
22	Resolute (Qausiuttuq)	101.35	103.15	96.81	96.81
23	Sanikiluaq	82.25	82.25	79.01	79.01
24	Taloyoak (Talujuaq)	98.36	106.46	96.78	96.78
25	Whale Cove (Tikirarjuaq)	90.42	144.80	111.18	122.71

Source: QEC (2015b).

Future power requirements and plans

Electricity load growth is forecasted for all Nunavut communities due to new housing, territorial and federal government driven major projects, and exploration activities in the mining sector (QEC, 2015a). Load growth for Iqaluit is forecasted to average 3-4% annually. Rapid growth is expected in Cambridge Bay due to the creation of the Canadian High Arctic Research Station (CHARS) campus, which will be responsible for a 75% increase in the community's electricity demand. Although QEC aims to participate in mining driven generation projects, its main objective remains the affordable and reliable supply of electricity to residential and commercial customers (QEC, 2015a).

The need for an energy strategy in Nunavut was first examined in the Ikuma report (GN, 2001) and outlined in Ikummatiit (GN, 2007). Nunavut's goal was (a) to reduce diesel consumption that reached approximately 172 million liters in 2006, of which 40% was accounted for by transportation, 37% for heat and hot water and 23% for electricity generation, and (b) to develop alternative forms of energy such as hydroelectricity, wind power and solar power, complemented with energy efficiency measures. In the case of electricity generation, the strategic plan included the development of studies for renewable energy generation and the creation of an Independent Power Purchase Policy to encourage the private sector to undertake renewable energy projects and then sell surpluses to QEC (GN, 2007).

Recent reports and discussions focus on the urgent need for replacement and updates of QEC diesel plants, since 17 out of 25 facilities have reached the end of their designed service life[5] (Senate Canada, 2014b; Bell, 2015). There is also a need for infrastructure investments in hydroelectricity projects to power Nunavut's potential mining operations and to reduce diesel consumption (Senate Canada, 2014a; Windeyer, 2015).

Hydroelectricity investment studies have focused on a project outside of Iqaluit, which could address increasing loads and infrastructure upgrades issues, as well as replacing 15 million liters of diesel fuel (GN, 2015; Senate Canada, 2014b). The project has been postponed due to its high projected cost ($250 to 500 million) and the limited ability of Nunavut government to add additional debt (Rohner, 2015). Other renewable options include run-of-the-river facilities at locations near Iqaluit, at Akulikutaq, Tungatalik and Qairulituq (GN, 2007; NWT, 2011; Northern Vision, 2014). Finally, although past wind projects in Kugluktuk, Cambridge Bay and Rankin Inlet exhibited high costs and limited performance[6] (Weis, Ilinca, & Pinard, 2008; George, 2012), a wind-hydrogen-diesel project has been examined for Cape Dorset (Northern Premiers Forum, 2014; Senate Canada, 2014b).

Another option is the proposed connection of the five Nunavut communities (Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet and Baker Lake) in the Kivalliq region to Manitoba's electrical grid (Senate Canada, 2014b). A recent study estimated the cost of the 1,000 km transmission line at approximately 900 million with potential savings of $40 million a year from the replacement of diesel with clean hydroelectric power, and additional benefits of future load growth coverage (from 38 GWh to 185 GWh by 2035), lower electricity costs (from an average

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[5] http://www.nunatsiaqonline.ca/stories/article/65674senate_study_nunavuts_power_generation_system_unsustainable/
[6] http://www.nunatsiaqonline.ca/stories/article/65674wind_power_for_nunavut_dont_hold_your_breath_qec_boss_says/

of 75 c/kWh to 13 c/kWh), reduced emissions, and the foundation for fibre-optic infrastructure (Rogers, 2015) .

Availability of renewable energy sources in Nunavut

Alternatives to diesel fueled electricity examined for Nunavut include locally discovered resources of oil and gas, renewable resources, grid connection, and small nuclear power plants (Senate Canada, 2014b). Solar potential in Nunavut is estimated to range from 567 - 691 kWh/kWp in Iqaluit (Poissant, Thevenard, & Turcotte, 2004) to 1,158 kWh/kWp in Chesterfield Inlet (GN, 2015), while average wind speeds in the area of communities range from 5 m/s in Coral Harbour to 7.7 m/s in Whale Cove. Wind resources with average wind speeds higher than 7 m/s are present in the communities of Arviat, Chesterfield Inlet, Clyde River, and Whale Cove (Weis & Ilinca, 2008; Weis & Ilinca, 2010). A recent study indicates that significant savings in diesel consumption and operation and maintenance costs could be achieved through the introduction of wind and solar applications into local diesel systems for the communities of Sanikiluaq, Iqaluit, Rankin Inlet, Arviat, and Baker Lake (Das & Canizares, 2016).

Renewable energy policies and promotion

Although renewable energy projects are technically viable in Nunavut, there is a lack of territorial programs supporting such high capital cost alternatives due to limited financing (McDonald & Pearce, 2012). At the federal level the program ecoENERGY for Aboriginal and Northern Communities Program (EANCP), established with the objective to support renewable energy projects for greenhouse gas emissions reductions, attracted five applications during the 2007-2011 period and six applications during the 2011-2014 period from Nunavut, in comparison to seven and twelve applications respectively from Northwest Territories (AANDC, 2014b). Recent federal budget commitments of $10.7 million over two years for developing renewable projects in northern aboriginal communities could assist Nunavut's communities to examine RETs applications for diesel displacement (DFC, 2016; CBC News, 2016).

The 25 remote communities of Nunavut are powered by diesel generators with a total capacity of 54 MW, generated approximately 174,000 MWh in 2013 (Table 1), and consumed 48,000,000 litres of diesel, resulting in the emissions of approximately 116,000 tonnes CO_{2eq} (QEC, 2014; GN, 2015). Starting in the 1987 a number of renewable energy technologies in the form of solar photovoltaics, solar water heating, and wind turbines have been installed (Table 3). Projects included a 3.2 kW solar photovoltaic system on the Arctic College in Iqaluit in 1995 (INAC, 2004; Poissant, Thevenard, & Turcotte, 2004), solar photovoltaics in 1998 and a 66 kW wind turbine in 2000 in Rankin Inlet (INAC, 2004; Dignard, Martel, & Ross, 1998), a 80 kW wind turbine in Cambridge Bay in 1994, and two 80 kW turbines in Kugluktuk installed in 1996 (QEC, 2002; INAC, 2004). The three wind projects encountered equipment malfunctions and maintenance issues so were decommissioned (GN, 2016).

Table 3: Renewable electricity projects in remote communities, Nunavut

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Arctic Bay (Ikpiarjuk)					
2	Arviat					
3	Baker Lake (Qamanittuaq)					
4	Cambridge Bay (Ikaluktutiak)		100		1987	Ah-You & Leng (1999); Weis & Ilinca (2008)
			80		1994	
5	Cape Dorset (Kinngait)					
6	Chesterfield Inlet (Igluligaarjuk)					
7	Clyde River (Kangiqtugaapik)					
8	Coral Harbour (Sallit)					
9	Gjoa Haven (Uqsuqtuuq)					
10	Grise Fiord (Aujuittut)					
11	Hall Beach (Sanirajak)					
12	Igloolik		20		1988	Ah-You & Leng (1999); Weis & Ilinca (2008)
13	Iqaluit			3.2	1995	Poissant, Thevenard, & Turcotte (2004); INAC (2004)
14	Kimmirut					
15	Kugaaruk (formerly Pelle Bay)			4	2014	See[7]
16	Kugluktuk (Qurluqtuq)		160		1996	Ah-You & Leng (1999); Pinard & Weis (2003)
17	Pangnirtung (Pangniqtuuq)					
18	Pond Inlet (Mittimatalik)					
19	Qikiqtarjuaq (formerly Broughton Island)					
20	Rankin Inlet (Kangiqiniq)		50		1998	Ah-You & Leng (1999); Weis & Ilinca (2008)
21	Repulse Bay (Naujaat)					
22	Resolute (Qausiuttuq)					
23	Sanikiluaq					
24	Taloyoak (Talujuaq)					
25	Whale Cove (Tikirarjuaq)					
	Total		**410**	**7.2**		
Proposed projects						
1	Arviat			10		See[8]
2	Iqaluit			2.86		Murray (2015)
	Total			**12.86**		

Source: Nunavut Power (n.d.); Ah-You & Leng (1999).

Future renewable electricity applications include a 4 kW photovoltaic system to be installed on the local hockey arena in Kugaaruk to reduce the electricity consumption of community's freezer during the summer months (Rogers, 2014), a 2.86 kW solar system to be installed in Qulliq Energy Corporation's Iqaluit plant (Murray, 2015), and a 10 kW solar photovoltaic system to be installed on the Arviat recreation center (Table 3) (GN, 2015).

Conclusion

Remote communities in Nunavut are entirely dependent on diesel fuel for electricity, heating and transportation. The Government of Nunavut, Qulliq Energy Corporation and the communities are interested in renewable energy to reduce diesel dependence and to increase local self-reliance.

[7] http://www.nunavutenergy.ca/en/Nunavuts_Energy_System; http://www.nnsl.com/frames/newspapers/2014-08/aug11_14ae.html
[8] http://www.nunavutenergy.ca/en/Nunavuts_Energy_System

However, the high cost of deployment of renewable technologies in Nunavut's isolated locations and limited government financial resources restrict communities' investment in renewable electricity generation. Local interest in renewables is supported by external groups. For example, the environmental group, World Wildlife Fund – Canada (WWF), is promoting a shift to renewables in Nunavut and supported the pre-feasibility study by Das and Canizares (2016) that found renewables to be financially feasible in selected communities (WWF, 2016). Given, recent decreases in the cost of solar technology and battery storage applications combined with the necessity for diesel plant replacements or upgrades in 17 of the 25 communities, an opportunity has arisen to consider the potential for renewables to be integrated into the electricity systems of Nunavut's remote communities, to build local capacity and to reduce the communities' dependence on fossil fuels.

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