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

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Remote aboriginal communities in Canada's Northwest Territories are starting an energy transition from high cost, carbon-intensive diesel powered electricity to greater local reliance on renewable sources of electricity. This paper reviews 25 remote communities' electricity systems, past renewable electricity projects, as well as provincial targets and policies for the introduction of renewable electricity alternatives. Besides small hydro-electricity projects and the future extension and interconnection of the two local grids, the transition to cleaner electricity systems is promoted through climate change policy emission targets and financial incentives focusing on solar photovoltaic applications (up to 20% of local generation capacity in the short term). The development of solar projects in 19 remote communities between 2009 and 2016, mainly under net metering agreements, in addition to two recent utility owned solar installations developed in cooperation with communities, and a community owned solar plant under a power purchase agreement with the local utility, represent successful deployment models that increase community benefits and improve environmental performance. Finally, the private sector has demonstrated the financial feasibility of commercial scale wind technology at the remote Diavik diamond mine, documented the diesel and carbon savings and enabled these lessons to be transferred to future developments.

Keywords: Northwest Territories, remote aboriginal communities, indigenous communities, diesel, renewable electricity, energy transition, climate action

Introduction

Remote aboriginal[1] communities in the Northwest Territories (NWT) and the Territorial Government are looking to change their sources of electricity from fossil fuel (diesel and natural gas) based generators to renewable energy sources. The high dependence on fossil fuels in remote communities is contrasted with hydro-electricity as the main source of electricity for the larger Snare and Taltson grids. The NWT electricity system faces significant challenges due to the small number of customers, harsh winter conditions, isolated diesel fueled plants, and limited economies of scale resulting in high electricity costs (GNWT, 2009a). The extensive use of fossil fuels for remote electricity generation increased interest in introducing renewable alternatives to reduce greenhouse gas emissions to help mitigate climate change (NT Energy, 2013). Mini-hydro, biomass cogeneration, wind and solar applications under community ownership are

[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.

considered as options to reduce electricity cost structures (GNWT, 2009a). Other potential benefits include improving environmental performance by reducing emissions and increasing local self-sufficiency. The next sections of this paper provide an overview of the population served in NWT remote communities, the capacity and type of current electricity 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.

Table 1: Remote Aboriginal communities in NWT

	Community name	Population 2014	Diesel and natural gas plant capacity (MW)	Annual electricity demand (2012) (MWh)
1	Aklavik	691	1.280	2,890
2	Colville Lake	158	0.240	406
3	Deline	514	1.440	2,533
4	Fort Good Hope	560	1.230	2,650
5	Fort Liard	619	1.320	2,727
6	Fort McPherson	792	1.825	7,636
7	Fort Providence	815	1.480	2,942
8	Fort Simpson	1,244	3.210	7,636
9	Gameti	296	0.612	970
10	Jean Marie River FN	71	0.230	248
11	Inuvik	3,396	D:7.8 NG:7.7	28,327
12	Kakisa-Kaagee Tu FN	45[2]	0.300	358
13	Lutselk'e	299	0.820	1,460
14	Nahanni Butte- Deh Cho FN	97	0.230	397
15	Norman Wells	766	D: 2.120	D: 388 NG: 8,402
16	Paulatuk	304	0.840	1,385
17	Sachs Harbour	128	0.795	929
18	Trout Lake-Sambaa K'e Dene	104	0.397	447
19	Tsiigehtchic	160	0.500	664
20	Tuktoyaktuk	962	2.205	3,662
21	Tulita	562	1.100	2,172
22	Ulukhaktok (previously Holman)	465	1.160	1,833
23	Wekweeti	142	0.380	610
24	Whati	497	0.975	1,570
25	Wringley- Pehdzeh Ki FN	146	0.781	642
	Total	13,788	40.97	83,884

Abreviations: D=Diesel, NG=natural gas

Source: GNWT (2015); NT Energy (2013); AANDC and NRCan (2011).

Population

[2] Population for 2011: https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6104005&Geo2=PR&Code2=01&Data=Count&SearchText=Kakisa&SearchType=Contains&SearchPR=61&B1=All&Custom=&TABID=1

NWT's 33 remote communities had a total population of 44,088 in 2015. There were 15 communities with a population below 350, 12 communities with a population up to 1,000, and six communities with over 1,000 people. The total aboriginal population was estimated at 22,050, while there were 22,038 non-aboriginal residents. Yellowknife is the territorial capital and has a population of 20,637, of which approximately 15,000 are non-aboriginal (GNWT, 2015). There are 25 remote communities that are not connected to the two electricity grids with a combined population of approximately 14,000 people (Table 1).

Electricity system

Electricity in NWT is generated mainly from three sources: natural gas, hydro-electricity and diesel fuel. It is supplied by NT Hydro, a public agency established in 2007 under the Northwest Territories Hydro Corporation Act, and fully owned by the Government of the Northwest Territories (GNWT) (NTPC, October 2011). NT Hydro fully owns Northwest Territories Power Corporation (NTPC), which operates hydro-electric, diesel, natural gas, solar power generation facilities, and transmission systems to provide electricity services in the Northwest Territories. The NWT electrical system is presented in Figure 1.

Figure 1: The electrical system in Northwest Territories

Source: NT Energy (2013, p. iii).

There are two main electrical grids, the Snare grid servicing Yellowknife, Dettah, N'Dilo and Behchokö, and the Taltson grid servicing Fort Resolution, Fort Smith, Hay River and Enterprise. Electricity in the two grids is generated mainly by hydroelectric plants backed by diesel generators. The rest of the communities use diesel generated electricity, except Norman Wells and Inuvik, where both diesel and natural gas are used. Renewable energy projects are also deployed in NWT communities, as will be discussed in the next sections (NT Energy, 2013).

The generation and distribution structure of NWT electrical system is presented in Table 2. NTPC generates and distributes electricity to 25 of the 33 communities in NWT and supplies electricity on a wholesale basis to Northland Utilities (NUL) owned by ATCO (NT Energy, 2013). NTPC activities are subject to regulation by the Northwest Territories Public Utilities Board (PUB). NTPC owns almost all the electricity generation assets in NWT and distributes power to approximately 45% of the population.

Table 2: NWT electricity service providers and generation source

Service Provider	Community	Generation source
NTPC Generation and distribution NUL Distribution	Dettah, Fort Resolution, Fort Smith, Behchokö Hay River, Hay River Dene Reserve, Enterprise and Yellowknife	Hydro-electricity (8 communities)
NTPC Generation and distribution	Aklavik, Colville Lake, Deline, Fort Good Hope, Fort Liard, Fort McPherson, Fort Simpson, Jean Marie River, Lutselk'e, Nahanni Butte, Paulatuk, Gameti, Sachs Harbour, Tsiigehtchic, Tuktoyaktuk, Tulita, Ulukhaktok, Whati, Wrigley	Diesel (23 communities)
NUL Generation and distribution	Kakisa, Fort Providence, Trout Lake, Wekweètì	
NTPC	Inuvik, Norman Wells	Natural gas and diesel (2 communities)

Source: adapted from GNWT (2008, p.4); GNWT (2009, p.99).

NUL consists of Northland Utilities (Yellowknife) Ltd., which distributes hydroelectric power in Yellowknife (Hay River, Hay River Dene Reserve, Enterprise and Yellowknife), and Northland Utilities (NWT) Ltd., which generates and distributes diesel-electric power to four isolated communities in the South Slave (Kakisa, Fort Providence, Trout Lake, Wekweètì). NUL serves almost 55% of the population located in the largest NWT communities. Imperial Oil Ltd is a utility company that sells natural gas fired electricity to NTPC for distribution in Norman Wells (GNWT, 2012a; GNWT, 2009a; GNWT, 2008).

The total installed capacity of NWT power plants in 2012 was 148 MW, with hydro-electricity accounting for 54.8 MW, diesel 78.3 MW (of which 35 MW represent communities' diesel generators and 43.3 MW industrial generators), and natural gas 14.5 MW. Total community related generation for 2010 was 309 GWh (75% or 228.66 GWh hydroelectric, 17% or 52.53 GWh diesel, and 9% or 27.81 GWh natural gas), while the total NWT electricity generation including the industrial consumers was 722 GWh (GNWT, 2012a; NT Energy, 2013). Diesel electricity generation related emissions from communities and mines were 437,000 tonnes $CO_{2,eq}$

in 2010 and 482,800 tonnes $CO_{2,eq}$ in 2011 (or 36% of total emissions of 1,220 kT $CO_{2,eq}$ in 2010 and 34% of 1,420 kT $CO_{2,eq}$ in 2011 respectively) (GNWT, 2011a; GNWT, 2013).

Table 3: NWT residential electricity rates, 2015

Community	Zone	Residential Electricity Rate (¢/kWh)		Actual cost
Colville Lake, Nahanni Butte, Sachs Harbour, Jean Marie River, Gameti, Paulatuk, Wrigley, Tsiigehtchic, Tulita, Whati, Deline, Lutsel K'e, Fort McPherson, Ulukhaktok, Fort Good Hope, Tuktoyaktuk, Fort Liard, Fort Simpson, Aklavik, Inuvik	NTPC Thermal	For the first 1000 kWh[3] Each additional kWh	29.73 c/ kWh 60.83 c/ kWh	60.83 c/kWh
Norman Wells	NTPC Norman Wells	For the first 1000 kWh Each additional kWh	29.73 c/ kWh 47.54 c/ kWh	47.54c/kWh
Fort Smith, Fort Resolution, Hay River	NTPC Taltson	For the first 1000 kWh Each additional kWh	21 c/ kWh 21 c/ kWh	31.1 c/kWh
Dettah, Behchoko, Yellowknife	NTPC Snare	For the first 1000 kWh Each additional kWh	29.73 c/ kWh 31.1 c/ kWh	21 c/kWh
Fort Providence, Dory Point/Kakisa, Wekweeti, Trout Lake	NUL (NWT) Thermal	47.39*		
Hay River, Hay River Reserve, Enterprise	NUL (NWT) Hydro	27.21*		
Yellowknife	NUL (YK)	23.72*		

* Indicates 2012 rates for the communities served by NUL[4].
Source: NTPC (2016); GNWT (2012a).

Electricity rates

Electricity costs in NWT are high due to the limited number of communities connected to the two local hydroelectric grids, high fixed and operating costs, and isolated diesel plants (GNWT, 2009a). Additionally, the communities' small customer base, small size diesel plants and fuel imports reduce the possibility for economies of scale and increase electricity costs and rates (GNWT, 2008). The 2010 Electricity Review changed the Territorial Power Subsidy Program (TPSP) and increased the applied subsidy from 700 kWh to 1,000 kWh per month during the winter months and 600 kWh in the summer months, and equalized residential rates within these remote communities to Yellowknife's rate. The residential electricity rates in NWT's remote communities start at 29.73 c/kWh for the first 1,000 kWh, with additional charges for excess use depending on the electricity generation cost in each community (Table 3).

[3] For the winter months (September to March). In the summer months (April to August) the rates apply for the first 600 kWh and above 600 kWh respectively.
[4] See GNWT (2012a).

Future power requirements and plans

NWT's electricity system has been the focus of numerous reviews aimed at addressing the primary northern related issues of reliability, affordability, environmental impacts, economic development and job creation, aboriginal involvement and energy self-sufficiency (GNWT, 2008; GNWT, 2009a; GNWT, 2009b; NT Energy, 2013). Public consultation initiated between 2008 and 2010 resulted in nineteen actions that changed the structure of the electrical system described in the 2010 Electricity Review (GNWT, 2010); three of the main changes were the reduction of the number of rate schedules from 33 to seven (described previously), the advancement of conservation measures, and the promotion of alternative (natural gas) and renewable energy generation options.

Electrical demand growth in NWT is driven by residential, commercial and industrial load increases (NT 2103). Residential electricity demand has increased due to population growth and increases in per capita household appliance use with approximately one-half (0.5) percent growth per year between 2007 and 2013. Future industrial load increases may result from oil exploration projects in the Sahtu region and mining activities in the North and South Slave regions, which currently host two of the four mines in operation in NWT, the Diavik and Ekati mines, while the Snap Lake mine was recently shut down[5] (NT Energy, 2013). Both the Snare and Taltson grids can meet future demand in the case of future mine operation in the area[6]. In the case of diesel communities, the existing diesel plants are adequately sized to meet future community demands.

Resource options to address electricity generation issues and future load growth include diesel, liquefied natural gas (LNG), solar, wind, biomass, hydro-electricity, expansion of the transmission system to connect the remote communities and mines to the grid[7], and finally, the interconnection of the NWT transmission system with one or more of the Saskatchewan, Alberta or British Columbia provincial grids (NT Energy, 2013). A review of the costs and benefits of available options indicates that medium sized (10 MW scale) hydro-electric projects, such as the La Martre Falls, Snare Site 7, and the Taltson Expansion, together with the expansion and interconnection of the two local grids, represent the biggest options for the NWT electrical system to maximize provincial economic development by providing access to low cost hydro resources to support future industrial loads and the potential for exports in the case of potential interconnection(s) to the continental grids (NT Energy, 2013).

Availability of renewable energy sources in NWT

As mentioned, the available resources to offset diesel generation in NWT remote communities include solar, wind, and small hydro. NWT's potential hydro-electric resources are estimated at

[5] See http://www.cbc.ca/news/canada/north/snap-lake-shutdown-layoffs-1.3353295
[6] The proposed Tamerlane and Avalon mining projects (NT Energy, 2013).
[7] In this case the interconnected grid will be based on the Taltson and Snare grids.

11,000 MW, of which only 55 MW are developed (Snare and Taltson), and 69 MW (La Martre and Taltson expansion) are proposed for future development (GNWT, 2011a). Solar resources in NWT are considered good due to long hours of sunlight during the spring and summer months, providing electrical generation between 800 and 1,200 kWh/kW (GNWT, 2012b). Although wind resources are available in northern NWT communities, wind speeds are considered low, ranging from 5.4 m/s in Yellowknife to 6.5 m/s in Sachs Harbour and 6.7 m/s in Ulukhaktok (GNWT, 2011a). Extensive wind studies in NWT communities have been conducted by the Aurora Institute (ARI, 2016), but the majority of the communities lack sites with wind potential of over 6-7 m/s, which is considered necessary for a financially viable project in the difficult conditions of the NWT arctic environment (Pinard J. , 2007).

Renewable energy policy and promotion

The installation of solar photovoltaic projects in NWT was initiated in the 1980s and some continue to operate thirty years later (Carpenter, 2013). The 2011 "Greenhouse Gas Strategy for the NWT 2011-2015" (GNWT, 2011b) identified solar energy as a potential means to reduce communities' emissions. The "2012 NWT Solar Energy Strategy" (GNWT, 2012b) established steps and actions to increase solar project implementation to supply up to 20% of the average load of the 25 diesel powered communities, and targeted a 10% displacement of annual diesel generated electricity. As a result, there are more than 200 solar installations in NWT communities and 25 grid connected solar photovoltaic systems, while it is estimated that the planned 1.8 MW of solar PV installations to be deployed over the next five years will displace 570,000 litres of diesel per year and reduce emissions by 1,660 tonnes $CO_{2,eq}$ per year[8] (GNWT, 2012b). Finally, the NWT's "2013 Energy Action Plan" focused on developing local renewable energy resources, such as biomass, solar and wind, to create sustainable communities, the interconnection of NWT local grids and linkages to mineral development, as well as hydro-electric developments and transmission projects in the communities of Whati, Kakisa and Fort Providence (GNWT, 2013; NT Energy, 2013).

The promotion of solar projects is supported by incentives in the form of rebates and financial support. The first incentive program for solar photovoltaic applications in the NWT was the RETCAP (2001-2003) with the primary goal to displace diesel and reduce noise from generators. The program provided a 50% rebate on panels and balance of system costs, and during its two-year period led to the installation of 36 solar systems in off grid homes, houseboats and remote lodges, with a total of 204 kW in 16 communities, namely in Hay River, Yellowknife, Jean Marie River, Innuvik, Sachs Harbor, Wekweeti, Nahanni Butte, Behchoko, Paulatuk, Fort Smith, Norman Wells, Gameti, Whati, Edzo, Fort Good Hope and Fort Simpson (Carpenter, 2013). More recently, the Alternative Energy Technologies (AET) program, administered by the Arctic Energy Alliance (AEA)[9], provides funding for communities, businesses and residents for the

[8] This equals to $2.8X10^{-3}$ tonnes $CO_{2,eq}$/ litre diesel or 0.0008 tonnes $CO_{2,eq}$/kWh with an average diesel engine efficiency of 3.6 kWh/litre diesel.
[9] See http://aea.nt.ca/programs/alternative-energy-technologies-program

installation of renewable energy technologies, including solar, hot water heating systems, wind turbines, and solar photovoltaic panels, to reduce fuel consumption and lower the cost of their operations. The program is split into the Residential Renewable Energy Fund (RREF), the Business Renewable Energy Fund (BREF) and the Community Renewable Energy Fund (CREF). The CREF assists with the installation of larger, community systems of renewable energy or the conversion of an existing conventional energy system to a system using an alternative energy technology. It provides up to one-half of the cost of a community-based alternative energy project, up to a maximum of $50,000 annually. Eligible community entities include aboriginal communities and governments, GNWT departments, boards and agencies, and non-profit organizations (GNWT, 2013).

Renewable energy projects in remote communities

NWT's 25 remote communities are powered by isolated diesel generators (and natural gas plants in two communities) with a total capacity of 41 MW. The power plants generate approximately 84,000 MWh/year, consume approximately 23,330,000 litres/year of diesel fuel and contribute 67,000 tonnes/year $CO_{2,eq}$ emissions[10] (Table 1).

There is one 50 kW wind turbine, developed in 1998, and 29 solar photovoltaic installations in 19 remote communities with a total renewable capacity of 524.3 kW (Table 4). Of these projects, 17 have less than 10 kW capacity, 10 are larger than 10 kW but less than 20 kW capacity, and three have a capacity larger than 20 KW. Most solar projects are deployed on community buildings reducing diesel consumption and expenses for the local governments.

Table 4: Renewable energy projects in remote communities. Northwest Territories

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Aklavik			15	2015	

[10] 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).

2	Colville Lake		135.5	2014	Pembina (n.d. (a)); see also[11]
3	Deline		-		
4	Fort Good Hope		5	2013	
5	Fort Liard		10.5	2014	
6	Fort McPherson		-		
7	Fort Providence		15	2013	
8	Fort Simpson		104	2013	See also[12]
			5	2013	
			5	2013	
9	Gameti		5	2012	
			17	2015	
10	Jean Marie River FN		1.3	2006	
				2016	
11	Inuvik		5	2009	Dignard, Martel, & Ross (1998)
			7	2009	
			1	2011	
			3.5	2011	
			10	2013	
			1.7	2013	
12	Kakisa-Kaagee Tu FN		-		
13	Lutsel'Ke		35	2015	AEA (2016); CBC (2016b)
14	Nahanni Butte- Deh Cho FN		4.8	2011	
15	Norman Wells		4.8	2011	
16	Paulatuk		5	2011	
			1.7	2011	
17	Sachs Harbour	50	4.3	1998	Pinard & Weis (2003); Carpenter
				2010	(2013)
18	Trout Lake-Sambaa K'e Dene		-		
19	Tsiigehtchic		18	2015	
20	Tuktoyaktuk		-		
21	Tulita		10	2013	
22	Ulukhaktok		-		
23	Wekweeti		4.2	2010	Carpenter (2013)
24	Whati		5	2012	
			16	2015	
25	Wringley- Pehdzeh Ki FN		19	2015	
	Total	**50**	**474.3**		
Proposed projects					
1	Aklavik		10	2016	
2	Fort Simpson		10	2016	
3	Jean-Marie River		6	2016	For all proposed projects see[13]
4	Norman Wells		10	2016	
5	Whati		5	2016	
	Total	**-**	**41**		

Source: For all existing projects see Carpenter (2013); Cherniak, Dufresne, Keyte, Mallett, & Scott (September 2015); GNWT (2012b); Prieur (2015).

Five additional solar projects with a total capacity of 41 kW are planned for the communities of Aklavik, Fort Simpson, Jean Marie River, Norman Wells and Whati. The solar panels are to be

[11] https://www.ntpc.com/smart-energy/how-to-save-energy/colville-lake-solar-project

[12] http://www.skyfireenergy.com/solar-commercial/grid-tied-electric-systems/104kw-diesel-offset-solar-photovoltaic-system-fort-simpson-northwest-territories/

[13] http://aea.nt.ca/blog/2016/02/request-for-proposals-community-government-building-solar-projects

deployed on community buildings under a net metering agreement[14], and they will reduce diesel consumption and community electricity expenses[15].

Diavik mine also introduced renewables to reduce its combustion of diesel to generate electricity. The $31 million investment in four wind turbines (9 MW) resulted in savings of $5 million in reduced diesel purchases (4 million litres) in its first year of operation thereby reducing the expected payback period from 8 to 6 years (Varga, 2014). After the success of Diavik's 9 MW wind hybrid system (DDC, 2014; CANWEA, 2014), a 1.8 MW wind project is considered for Storm Hills outside of Inuvik, which could meet approximately 18% of Inuvik's annual electricity demand (Matangi, 2014). Finally, pilot projects are being developed for biomass in Dettah and geothermal technologies in Fort Liard (GNWT, 2013).

Conclusion

The 25 remote aboriginal communities in NWT are undergoing an energy transition through the introduction of mainly solar photovoltaic installations into the diesel powered electrical systems, new small hydro-electricity projects, and the future extension and interconnection of the two local grids. The Government of NWT has established provincial targets and supported investment in photovoltaic systems with financial incentives to reduce diesel consumption and encourage community participation in electricity generation. As a result, 28 solar photovoltaic projects were deployed in 19 remote communities between 2009 and 2016. Most of the projects were developed under net metering agreements that reduced community electricity expenses while displacing diesel. The success of two community scale projects developed by NTPC in cooperation with communities, as well as Lutselk'e's community owned and operated solar installation under a PPA agreement, provide successful models for future deployment of renewable electricity in remote communities with increased community benefits, reduced costs and improved environmental performance.

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[14] "Net metering" allows residential and commercial customers who generate their own electricity from renewable electricity technologies to feed excess electricity generated back into the grid. See, for example, http://www.ntpc.com/docs/default-source/default-document-library/ntpc-net-metering-13-08-14.pdf?sfvrsn=2.
[15] http://aea.nt.ca/blog/2016/02/request-for-proposals-community-government-building-solar-projects

References

AANDC and NRCan. (2011). *Status of Remote/Off-Grid Communities in Canada.* Ottawa: Aboriginal Affairs and Northern Development Canada (AANDC) and Natural Resources Canada (NRCan).

AEA. (2016, 03 17). *News-Lutsel K'e 35 kW Solar PV Installation*. Retrieved from Arctic Energy Alliance: http://aea.nt.ca/blog/2015/05/lutsel-ke-35-kw-solar-pv-installation.

ARI. (2016, Jan. 2016). *Wind and Solar Energy Potential* . Retrieved from Aurora Research Institute: http://nwtresearch.com/projects/energy/wind-and-solar-energy-potential.

CANWEA. (2014). *Diavik Wind Farm: Wind energy helps reduce carbon footprint.* Retrieved from CANWEA: http://canwea.ca/wp-content/uploads/2013/12/canwea-casestudy-DiavikMine-e-web2.pdf.

Carpenter, W. (2013). Solar Energy in the Northwest Territories. *Renewables in Remote Microgrids Conference.* Toronto. Retrieved 15 Oct. 2015 from: https://wise.uwaterloo.ca/documents/events/public/renewable_in_remote_microgrids_conference/solarenergyinthenorthwestterritorieswadecarpentergovernmentofnwtpdf.

CBC. (2016b, April 18). *Lutsel K'e, N.W.T., wins award for solar power project*. Retrieved from CBC News: http://www.cbc.ca/news/canada/north/lutsel-k-e-n-w-t-wins-award-for-solar-power-project-1.3013118.

Cherniak, D., Dufresne, V., Keyte, L., Mallett, A., & Scott, S. (September 2015). *Report on the State of Alternative Energy in the Arctic.* Ottawa: School of Public Policy and Administration, Carleton University.

DDC. (2014). *Wind farm.* Retrieved 29 Dec.2014 from Diavik Diamond Corporation: http://www.diavik.ca/ENG/ouroperations/565_wind_farm.asp.

GNWT. (2008). *A Review of Electricity Regulation, Rates and Subsidy Programs in the Northwest Territories.* Government of Northwest Territories.

GNWT. (2009a). *Creating a brighter future: a review of electricity regulation, rates and subsidy programs in the Northwest Territories.* Government of Northwest Territories.

GNWT. (2009b). *Electricity review: A discussion about electricity with northeners.* Government of Northwestern Territories.

GNWT. (2010). *Efficient, Affordable and Equitable: Creating a Brighter Future for the Northwest Territories' Electricity System.* Government of Northwest Territories.

GNWT. (2011a). *Northwest Territories Energy Report.* Government of Northwest Territories.

GNWT. (2011b). *A Greenhouse Gas Strategy for the Northwest Territories 2011-2015.* Government of Northwest Territories.

GNWT. (2012a). *Northwest Territories energy facts-electrical generation.* Retrieved 22 Oct. 2015 from Government of Northwest Territories: http://www.iti.gov.nt.ca/sites/default/files/2012_ELECTRICAL_GENERATION_V2.pdf .

GNWT. (2012b). *Northwest Territories Solar Energy Strategy 2012-2017.* Government of Northwest Territories.

GNWT. (2013). *Northwest Territories Energy Action Plan.* Retrieved 05 Feb. 2015 from Government of Northwest Territories: http://www.iti.gov.nt.ca/sites/default/files/energy_action_plan_web_feb_20.pdf.

GNWT. (2015). *Population Estimates*. Retrieved 15 Dec.2015 from Northwest Territories-Bureau of Statistics: http://www.statsnwt.ca/population/population-estimates/

HORCI. (2012). *2011 Greenhouse Gas Inventory Report and Action Plan.* Thunder Bay: Hydro One Remote Communities Inc.

Matangi, A. (2014). *Wind resource assessment Storm Hills, NWT.* Sea Breeze Power Corp. Retrieved 20 Jan. 2017 from: https://nwtresearch.com/sites/default/files/2014-06-11_storm_hills_nwt_wra.pdf.

NT Energy. (2013). *A vision for the NWT Power System Plan.* Retrieved 05 Feb. 2015 from: http://www.iti.gov.nt.ca/sites/default/files/nwt_power_systems_plan_december2013.pdf.

NTPC. (2016, Jan. 06). *Residential electrical rates effective September 1, 2015*. Retrieved from Northwest Territories Power Corporation: https://www.ntpc.com/customer-service/residential-service/what-is-my-power-rate.

NTPC. (October 2011). *Northwest Territories Power Corporation Strategic Plan 2012 - 2014.* Northwest Territories Power Corporation.

Pembina. (n.d. (a)). *Solar PV Case Study. Collville Lake, NWT.* Pembina Institute: Retrieved 02 May 2016 from: http://www.bullfrogpower.com/wp-content/uploads/2015/09/Colville_Lake-Solar.pdf.

Pinard, J. (2007). *Executive progress report for wind energy monitoring in six communities in the NWT.* Inuvik, NWT: Aurora Research Institute.

Pinard, J., & Weis, T. (2003). *Pre-Feasibility Analysis of Wind Energy for Inuvialuit Region in Northwest Territories.* Retrieved 29 Dec. 2014 from Aurora Research Institute:

https://nwtresearch.com/sites/default/files/inuvialuit-region-wind-energy-pre-feasibility-study.pdf.

Prieur, A. (2015). *Remote Northern Microgrids in Canada-International Microgrid Symposium.* Retrieved from http://microgrid-symposiums.org/wp-content/uploads/2015/10/25-Prieur-Remote-Northern-Microgrids-20150817.pdf.

Varga, P. (2014, April 11). *Diavik mine's wind-driven power saves $5 million a year in diesel costs*. Retrieved from Nunatsiaq Online: http://www.nunatsiaqonline.ca/stories/article/65674diavik_mines_wind-driven_power_saves_5_million_in_diesel_costs/.