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

Konstantinos Karanasios and Paul Parker

Remote aboriginal communities in Canada's Yukon Territory are undergoing a transition from carbon-intensive diesel generated electricity to low carbon, renewable sources of electricity. Hydroelectricity is the main source of power in the territorial grid so the extension of the grid and the addition of new hydroelectricity sources offers one path to low carbon electricity future for some communities. In more remote parts of the territory, wind, solar and smaller hydroelectric generation projects are considered to reduce diesel consumption and the associated greenhouse gas emissions. Yukon's Climate Change Action Plan promotes cutting the carbon intensity of electricity. This paper reviews community electricity systems, past renewable electricity projects, as well as available renewable resources, generation alternatives, and policies, plans and proposed future projects that could help transform the supply of electricity in the remote communities. The transition to cleaner electricity systems also creates an opportunity for new investment models and development options where communities or private parties may replace public utilities as investors in new generation technologies. Government supports for the transition of communities from greenhouse gas intensive diesel generation to low carbon renewable sources of electricity include the microgeneration and Independent Power Producer policies. Initial success with small renewable energy projects in the remote Yukon communities is leading to additional and larger projects being planned.

Keywords: Yukon, remote aboriginal communities, indigenous communities, diesel, renewable electricity, energy transition, climate action policies

Introduction

Renewable energy (hydroelectricity) has a long tradition in the Yukon as the main source of electricity for Whitehorse and the local grid connected communities. New interest has arisen in the potential for renewable energy to displace diesel in Yukon's remote aboriginal[1] communities to achieve environmental, economic and social goals. The shifting of electricity generation from diesel to renewables is identified as an immediate step to reduce greenhouse gas emissions to help mitigate climate change (GY, 2015). However, advocates for renewable energy in aboriginal communities argue that these projects can be part of broader changes to empower aboriginal communities and to build local capacity for community development (Henderson, 2013). Before reviewing recent climate and energy policies in the Yukon and identifying the

[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.

communities with the greatest opportunities for investment in renewable energy, this paper sets the context by providing an overview of the population served in 23 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 renewables in the remote communities.

Population

There are 23 remote communities in Yukon with a total population of approximately 37,000 people in 2014 (YBC, 2014). The majority of the population (approximately 28,000 people) is gathered in Whitehorse, with Dawson City and Watson Lake being the next largest communities with populations of 2,000 and 1,500 respectively. The First Nation population in Yukon was estimated at 7,650 people, representing approximately 21% of the total population, of which 4,130 resided in Whitehorse and the rest in rural communities (YBC, 2014). There are five remote communities that are not connected to the territorial grid with a population of approximately 2,000 people (Table 1).

Table 1: Remote Aboriginal communities, Yukon

Nr	Community name	Population 2014	Diesel plant capacity (MW)	Annual electricity demand (2012) (MWh)
1	Destruction Bay/ Burwash Landing-Kluane FN[2]	147	0.9	1,996
2	Beaver Creek- White River FN	112	1.0	1,897
3	Swift River	10	0.2	263
4	Watson Lake	1,496	5.3	15,024
5	Old Crow- Vuntut Gwitchin FN	254	1.1	2,083
	Total	**2,009**	**8.5**	**21,263**

Source: YBC (2014); YEC (2013, p. 114).

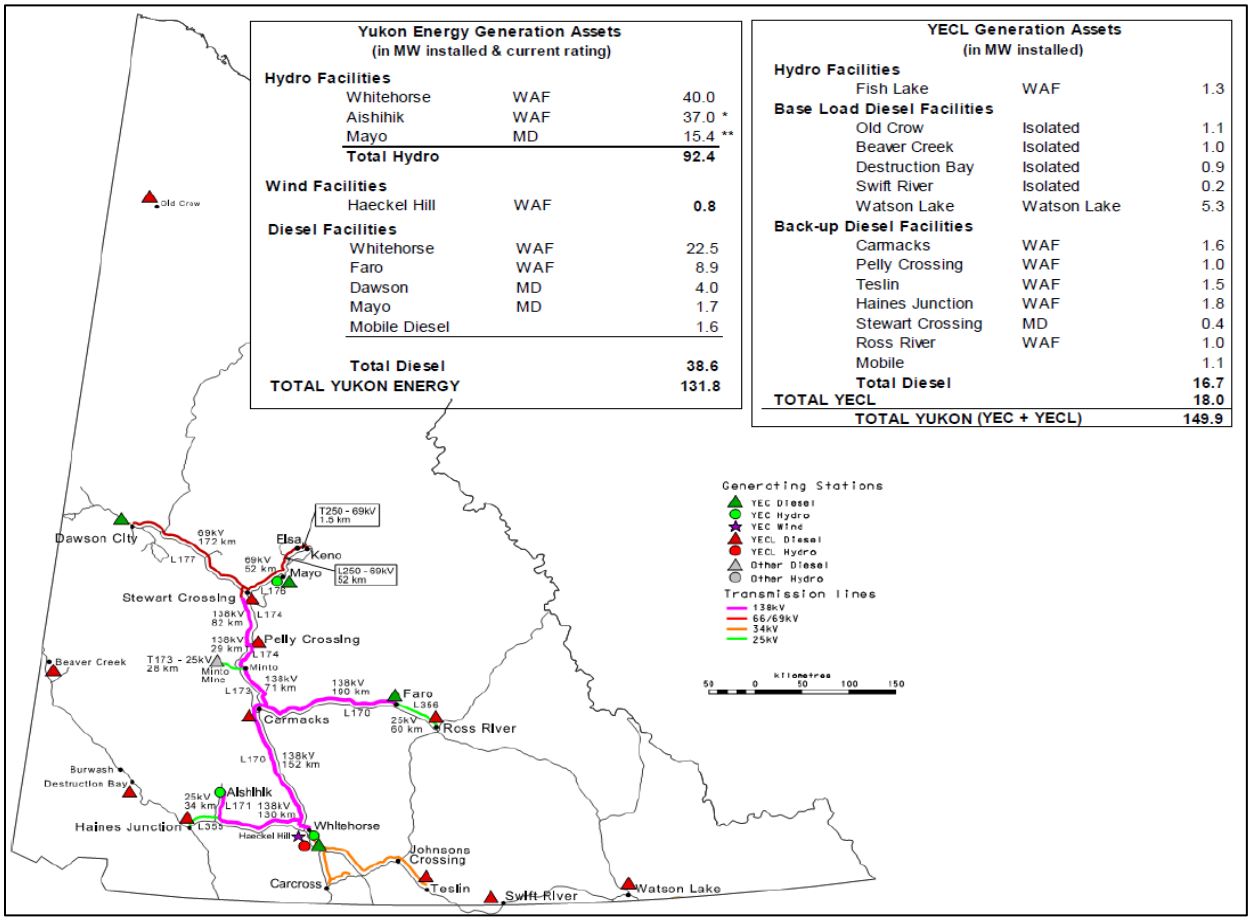
Electricity system

Electricity is supplied by the Yukon Energy Corporation (YEC), established in 1987 as a publicly owned business operating at "arm's length" from the Yukon government. Yukon Energy directly serves about 1,700 customers, most of whom live in and around Dawson City, Mayo and Faro, and provides power to many other Yukon communities through the Yukon Electrical Company Limited (YECL), recently renamed as ATCO Electric Yukon[3] (Yukon Energy, 2015). ATCO Electric Yukon (AEY) is a private investor-owned utility and a member of the ATCO Group of Companies with head office and service centre in Whitehorse. ATCO Electric Yukon purchases power from YEC for distribution to 17,000 customers in 19 communities from south of the Yukon border to north of the Arctic Circle (ATCO, 2015).

[2] Destruction Bay and Burwash Landing share the same generator in Destruction Bay.
[3] The Yukon Electrical Company Limited (YECL) or recently renamed as ATCO Electric Yukon. Figure 5 mentions YECL instead of ATCO Electric Yukon.

Yukon's electricity system, presented in Figure 1, consists of one large hydroelectricity based grid called the Yukon Integrated System (YIS), and five isolated diesel powered communities (Watson Lake, Swift River, Destruction Bay/Burwash Landing, Beaver Creek, and Old Crow). Yukon Energy has the capacity to generate approximately 132 megawatts of power; 92 MW are provided by hydro facilities in Whitehorse, Mayo and Aishihik Lake (40 MW at Whitehorse, 37 MW at Aishihik and 15 MW at Mayo), 39 MW by diesel generators (used currently only as back-up generators), and 0.8 MW by two wind turbines located on Haeckel Hill near Whitehorse (Yukon Energy, 2016). ATCO Electric Yukon owns and operates the 1.3 MW Fish Lake Hydro plant, on the outskirts of Whitehorse, and maintains 8 MW back-up generating plants in Carmacks, Teslin, Haines Junction and Ross River in the event of a power interruption. Additionally, ATCO Electric Yukon serves five off grid communities with 8.4 MW of diesel generation (5.3 MW in Watson Lake, 2.0 MW in total for the Destruction Bay, Beaver Creek, and Swift River communities along the Alaska Highway, and 1.1 MW in Old Crow). All these communities are accessed by roads except the community of Old Crow, home of the Vuntut Gwitchin First Nation (ATCO, 2015; Yukon Energy, 2012)

Figure 1: Yukon's electricity system



Source: Osler (2011, p. 22)-modified.

Yukon's total electricity generation in 2013 was 424,720 MWh from hydro (94.8%), 23,215 MWh from thermal plants (5.2%) and 277 MWh from wind generation (0.1%) (YBS, 2013). Total diesel electricity generation for the five communities in 2010 was 20,000 MWh, of which approximately 70% was for Watson Lake (Yukon Energy, 2012). Since approximately 95% of Yukon's electricity was provided from renewable resources, total diesel electricity generated GHG emissions in Yukon in 2010 were 30,726 tonnes, of which approximately 13,500 tonnes were from the diesel plants in the five off-grid communities (Yukon Energy, 2012). Utility power generation in Yukon accounts for only about 3% of GHG emissions, while transportation and building heating account for over 85% of GHG emissions (Yukon Energy, December 2011, p. 51).

Electricity rates

Yukon electricity rates are considered the lowest in Northern Canada due to the legacy hydro assets of Mayo, Aishihik and Whitehorse (Yukon Energy, April 2012). For residential consumers Yukon has a single rate zone with the same rate of 12.14 c/kWh[4] for the first 1,000 kWh per month, and a high of 13.99 c/kWh for consumption over 2,500 kWh, except Old Crow which has a rate of 30.77 c/kWh (Table 2). The same rates apply for residential government rates and general services rates (both non-government and municipal) with the highest rate being 41.45 c/kWh for residential government services in the community of Old Crow (Yukon Energy, June 2011). Residential consumption is subsidized through the Interim Electrical Rebate, which provides residential customers with a maximum rebate of $26.62 per month for the first 1,000 kilowatt hours of power used (Yukon Energy, 2015). In 2013 the average residential electricity consumption was approximately 10,200 kWh with an average consumer cost of 14.16 c/kWh, which is higher than the cost in Southern Canada, but low in comparison to the average cost in NWT and Nunavut (YBS, 2013).

Table 2: Yukon residential electricity rates 2015

Rate schedule	All communities (except Old Crow)	Old Crow Community
For the first 1,000 kWh/month	12.14 c/kWh	12.14 c/kWh
Between 1,001-2,500 kWh/month	12.82 c/kWh	12.82 c/kWh
Over 2,500 kWh/month	13.99 c/kWh	30.77 c/kWh

Source: Yukon Energy (2016).

Recent grid extensions and future load growth

Yukon's energy development is subject to challenges associated with cyclical mining development and population growth. Yukon's electricity system enhancements are to be designed with the following objectives: to secure ratepayers against financial risks and potential rate increases, to address sustainability issues, to reduce diesel generation and to meet its service

[4] All prices in Canadian currency (CAD).

criteria of affordability, reliability, flexibility and environmental responsibility (Yukon Energy, April 2012).

Two major extensions of Yukon's electricity infrastructure were undertaken in the last decade to address mining development and grid access, as well as power balance requirements between the previously separate Whitehorse-Aishihik-Faro and Mayo/Dawson power grids. First, the 2008 connection of Minto copper-gold mine to the Yukon electrical grid benefitted Little Salmon Carmacks First Nation, Selkirk First Nation and Na-Cho Nyak Dun First Nation along the path of the transmission line. The benefits of the grid extension for the communities included construction related employment, elimination of expenses for diesel purchases and increased sales of surplus hydroelectricity. The reduced electricity rates increased profit margins for the Minto mine leading to higher royalties and taxes for the Yukon Government and Selkirk First Nation (CMC, 2008). Second, the Carmacks Stewart Transmission project in 2011, was built to meet new demand by current and proposed mining projects located in the proximity of remote communities. It connected the Whitehorse-Aishihik-Faro and Mayo/Dawson power grids through a new 138 kV transmission line running generally along the Klondike Highway, providing grid electricity to the remote community of Pelly Crossing and encouraging economic development along the corridor (Yukon Energy, 2012; Yukon Energy, 2006).

Yukon expects a significant power load increase in the next 40-year period. According to Yukon Energy (2012), diesel load is forecast to increase from 58 GWh in 2011 to 1,442 GWh in 2030 mainly due to the increase of off-grid mine loads from 37 GWh to 1,337 GWh, which are expected to rely on diesel or LNG supply options. Non-industrial loads are forecast to increase a moderate 2.26% over the same period. In the case of the five diesel powered communities, load growth is projected to rise from 20 GWh in 2011 to 22 GWh by 2030, and GHG emissions are expected to increase from 13,900 tonnes to 15,473 tonnes respectively.

Yukon plans to address future power load growth mainly through enhancements of current hydroelectric facilities and the development of new hydroelectric projects, while other options include Demand Side Management (DSM) and Supply Side Management (SSM) programs, solar applications, natural gas developments and potential connection to the Alaska Highway Pipeline, as well as the option of extending the current grid and connect to the BC or Alaska electrical grid (Yukon Energy, 2012; Yukon Energy, April 2012).

Availability of renewable energy sources in Yukon

According to Yukon Energy (2012), Yukon plans to address future power demand mainly through hydroelectricity "short term" enhancements and new 'long term" project developments; total potential supply is expected to exceed 6,800 GWh/year with estimated full utilization costs (including transmission) below 15 c/kWh (in 2009). It is assumed that the Yukon Integrated System (YIS) will be able to accommodate only one wind project at Mount Sumanik of approximately 20 MW (Yukon Energy, 2012, p. 18), given the non-dispatchable character of

wind and the higher costs, for which a feasibility assessment is already available (Yukon Energy, January 2009). Although solar photovoltaic applications are limited in Yukon, solar irradiance data are measured on three grid connected solar electric demonstration sites, namely a 4.0 kW installation at the Yukon government's Main Administration Building and a 1.5 kW system at Yukon College, both in Whitehorse, and a 4.4 kW system in Yukon's Northern Lights Space and Science Centre located in the community of Watson Lake. The results indicate photovoltaic performance ranging between 825-1,069 kWh/kWp.year, which combined with installation costs of approximately $ 5/Watt and modest predictions on diesel fuel increases, could result in competitive costs for solar electricity in the community of Old Crow, which has higher electricity rates (YGESC, 2014).

Renewable energy policies and promotion

In 2009 the Yukon Government released its Climate Change Action Plan (GY, 2009) aiming to reduce GHG emissions from the government's internal operations by setting a cap on GHG emissions in 2010, reducing GHG emissions by 20% by 2015 and becoming carbon neutral by 2020. Mechanisms to achieve these targets include the reduction of emission intensity of on-grid diesel power generation by 20% by 2020, and the reduction of energy use through demand-side management programs by 5 GWh by 2016 (GY, 2015).

To achieve these targets, Yukon's 2009 energy strategy promoted a target of 20% increase of renewable energy supply by 2020, the development of a policy framework for geothermal applications, support for projects in off grid diesel communities, and promotion of renewable sources for heating and transportation (GY, January 2009). The development of renewable energy projects was to be facilitated through the Independent Power Producers (IPP) purchase policy, the net metering policy for small producers (now called the microgeneration policy), and incentives for demand management (GY, November 2009). The IPP policy (GY, October 2015) promotes three approaches for renewable projects: the Call for Power (CFP) program, which applies to large IPP projects to be integrated into YIS, requires a government approval, and aims at addressing future electrical needs as previously described; the Standing Offer (SOP) program promotes the development of new, small projects (up to 10,000 MWh for the YIS and 2,100 MWh for the Watson Lake grid) that will sell electricity to Yukon Energy Corporation in the YIS and to ATCO Electric Yukon in the diesel grid in Watson Lake; finally, the third approach of Unsolicited Proposal covers projects that are larger than the SOP limits, which will be assessed based on the territory's needs.

Three diesel powered aboriginal communities (Old Crow, Beaver Creek and Destruction Bay/Burwash Landing) are encouraged to work in cooperation with ATCO Electric Yukon and develop their own community owned IPP projects to acquire economic benefits, improve self-reliance and address environmental issues through the Unsolicited Proposal process, while

projects up to 50 kW are eligible under the microgeneration policy. The microgeneration policy[5] includes projects offsetting electricity consumption by connecting renewables to homes or businesses under all rates classes. In the case of communities connected to Yukon Integrated System the applicable rate is $0.21/kWh, while the rate for diesel powered communities is $0.30/kWh (GY, October 2013).

Renewable projects in remote communities

Yukon's remote communities of Destruction Bay/ Burwash Landing, Beaver Creek, Swift River, Watson Lake and Old Crow are not connected to the local grid. Instead, they are powered by five diesel plants[6] with a total capacity of 8.5 MW serving approximately 2,000 people in 2014. The power plants generate approximately 21,263 MWh/year, consume approximately 6 million litres/year of diesel fuel and contribute 17,000 tonnes/year in $CO_{2,eq}$ emissions[7] (Table 1).

Three of the five diesel powered communities in Yukon are considering the displacement of diesel through the development of renewable energy projects (Table 3). The community of Watson Lake has been monitoring solar resources and photovoltaic performance under the cold conditions since 2011 through a 4.4 kW solar system installed on Yukon's Northern Lights Space and Science Centre. It also examined local hydroelectricity options: a feasibility study conducted in 2014 concluded that two potential sites could provide electricity at a cost of 0.18-0.21 $/kWh and create annual savings of $1.3- $2.4 million in comparison to the current diesel based electricity generation system (Morissette, 2014).

[5] http://www.energy.gov.yk.ca/microgeneration.html
[6] Destruction Bay and Burwash Landing, home of the Kluane First Nation, are served by the same diesel generator in Destruction Bay.
[7] Assuming an average efficiency rate of 3.6 kWh/litre for the diesel engines and an average of 0.00080 tonnes $CO_{2,eq}$/kWh, for direct carbon emissions (emissions resulting from diesel and natural gas combustion only). See HORCI (2012).

Table 3: Renewable electricity projects in remote communities, Yukon

	Community	Hydro MW	Wind kW	Solar kW	Year	Source
Existing projects						
1	Destruction Bay/ Burwash Landing	-	-	4.7	2012	Pinard (2013); Tobin (2016)
2	Beaver Creek- White River FN	-	-	-		
3	Swift River	-	-	-		
4	Watson Lake	-	-	4.4	2011	YGESC (2014)
5	Old Crow- Vuntut Gwitchin FN	-	-	3.6	2011	Cherniak, Dufresne, Keyte, Mallett, & Scott (September 2015)
				12.1	2011	See [8]
	Total			**24.8**		
Proposed projects						
1	Destruction Bay/ Burwash Landing	-	300	42		Pinard (2013); Tobin (2016)
2	Beaver Creek- White River FN		-	-		
3	Swift River		-	-		
4	Watson Lake	1.5	-	-		Morissette (2014)
5	Old Crow- Vuntut Gwitchin FN	-	-	330		Cherniak, Dufresne, Keyte, Mallett, & Scott (September 2015)
	Total	**1.5**	**300**	**372**		

The Kluane First Nation, based in the remote communities of Burwash Landing and Destruction Bay, is directly involved in renewable energy projects. In addition to a 4.7 kW roof mounted solar project installed in 2012, they are planning the development 42 kW of solar panels on three community buildings to displace diesel under a "net metering" agreement (Tobin, 2016). Additionally, the community wants to develop a 300 kW community owned wind project at Kluane Lake (Pinard J. , 2013; Pinard J. , 2014; Tobin, 2016) to generate and sell electricity to ATCO Electric Yukon under the IPP policy and a Power Purchase Agreement (PPA) (Tobin, 2016). The project is being developed using federal and provincial capital funding, as well as financial support from Bullfrog Power (GY, 2015; BP, 2017).

Similarly, the community of Old Crow, home of the Vuntut Gwitchin FN, wants to reduce its dependence on diesel and has installed solar panels on two of its community buildings (Vuntut Gwitchin First Nation, 2002; Ronson, 2014). Old Crow plans to develop a community owned 330 kW solar-diesel-storage hybrid energy system[9] that will displace approximately 98,000 litres of diesel annually and generate revenue for the community under a PPA agreement with ATCO Electric Yukon (Tukker, 2016).

[8] kza.yk.ca/wp-content/uploads/2011/08/OldCrowResearch1.pdf
[9] See also: www.arcticinspirationprize.ca/docs/2014-aip-laureates-en.pdf; http://www.yukon-news.com/news/old-crow-wants-to-build-yukons-largest-solar-plant/

Finally, the commercial viability of solar applications in Yukon has been confirmed by private sector projects. Northwestel, a communications company, successfully deployed four 10 kW photovoltaic arrays in 2014 for the operation of its microwave sites in remote locations, and reduced its diesel consumption by 20,000 litres [10] (Northwestel, 2015; GY, 2015). This combination of private and public success with initial projects is leading to proposals for larger renewable energy projects in remote Yukon locations.

Conclusion

Remote aboriginal communities in the Yukon are undergoing an energy transition from GHG intensive diesel generation to low carbon renewable sources of electricity. The transition is being achieved in two ways: grid expansion and local renewable energy projects. The community of Pelly Crossing has been connected to the territorial grid which is primarily supplied by hydroelectricity. In addition to the environmental benefits of lower GHG emissions, the community gains increased opportunities for economic and social development with lower electricity prices and increased supply capacity. In the remote diesel powered communities, the Yukon Government has promoted investment in renewable energy with supportive policies including the microgeneration policy (<50kW) and Independent Power Producer policy to reduce diesel consumption and to encourage community participation and ownership of electricity generation assets. Initial success with renewable energy projects in the remote Yukon communities is leading to additional and larger projects being planned.

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[10] See also: NorthwesTel Remote Station Solar/Diesel Hybrid Feasibility study, in http://www.energy.gov.yk.ca/publications.html.

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