C33

Renewables for Decarbonization and Resiliency of Remote and Arctic Communities in Canada: Policy and Economics Review

Heather Hayne, MEng, PEng
Member ASHRAE

Carsen Banister, PhD
Member ASHRAE

Nika Martinussen

ABSTRACT

Most remote and Arctic communities in Canada have the highest carbon intensity of electricity and heating in the country. There is increased interest from many individuals and organizations to successfully integrate renewable energy systems, but many policy and technical barriers persist. This paper presents the current state of the policies and economics affecting the successful installation and operation of renewable energy projects in the three territories in Canada, the northernmost regions. There is a companion paper in the same conference proceedings focusing on the technical and logistical challenges of renewable energy in these locations.

Successfully growing the installed capacity of renewable energy in these regions will lead to substantial decarbonization of the energy supply and improve resiliency. This paper summarizes available sources estimating the installation and operating and maintenance costs of solar photovoltaic and wind turbine systems in northern and remote communities in contrast to locations in southern Canada and also in contrast to the cost of diesel-generated electricity. An overview of funding programs is presented, along with description of some of the issues that arise in interfacing funding with current policies. The policies enabling or inhibiting the generation of electricity by independent producers are reviewed in detail, including personal experiences of multiple applicants. Shortcomings and issues with the policies are examined, with recommendations to better enable decarbonization and increased resiliency of building energy in remote and Arctic communities in Canada.

Keywords: renewable energy, remote communities, Arctic, decarbonization, resiliency

INTRODUCTION

This study focuses on the current state of renewables and policy challenges to their implementation in Canada's three northern Territories: Yukon, Northwest Territories, and Nunavut. This paper is published along with a companion paper focusing on the technical and logistical challenges of renewable energy in remote and Arctic communities in Canada, with both papers in the same conference proceedings. The background information is included in both papers for the reader's convenience.

Fossil fuels have traditionally been used in the North for building heating, and, where hydroelectric power is not available, for electrical generation. In the last decades, the use of renewable energy sources, especially solar and wind, have

Heather Hayne is an instructor in the Mechanical and Aerospace Engineering Department, Carleton University, Ottawa, Canada.
Carsen Banister is a Research Officer at the Construction Research Centre, National Research Council Canada, Ottawa, Canada.
Nika Martinussen is an undergraduate student in Engineering Physics, University of British Columbia, Vancouver, Canada.

increased in the North, yet still make up only a small fraction of the overall energy supply. In the move to decarbonization, adoption of renewable energy is particularly important for small diesel-dependent communities, not only to reduce fossil fuel use and greenhouse gas emissions, but also to improve resiliency, community self-sufficiency, economics, health, and the environment. While there are policy drivers and economic incentives to install and operate renewable energy technologies, significant challenges still persist.

This paper discusses installation, operating and maintenance costs of solar photovoltaic and wind turbine systems in northern and remote communities, in contrast to locations in southern Canada, and also with regard to the cost of diesel-generated electricity. An overview of funding programs is presented, along with a description of issues that arise in interfacing funding with current policies. The policies enabling or inhibiting the generation of electricity by independent producers are reviewed in detail, including personal experiences of multiple applicants. Shortcomings and issues with the policies are examined, with recommendations to enable decarbonization and increased resiliency of building energy in remote and Arctic communities in Canada.

BACKGROUND

To set the context, the three territories of Canada encompass an enormous area (approximately 3.9 million square kilometres) above 60° N latitude, with a total population of about 136,000. While all Yukon (YT) communities, save one, have year-round road access, one third of Northwest Territories (NT) communities lack this, as do all in Nunavut (NU). Most remote communities rely on diesel for electricity generation by public utilities. There is no grid connection between the territories and the rest of Canada, nor, in almost all cases, between territorial communities, all of which Figure 1 illustrates.

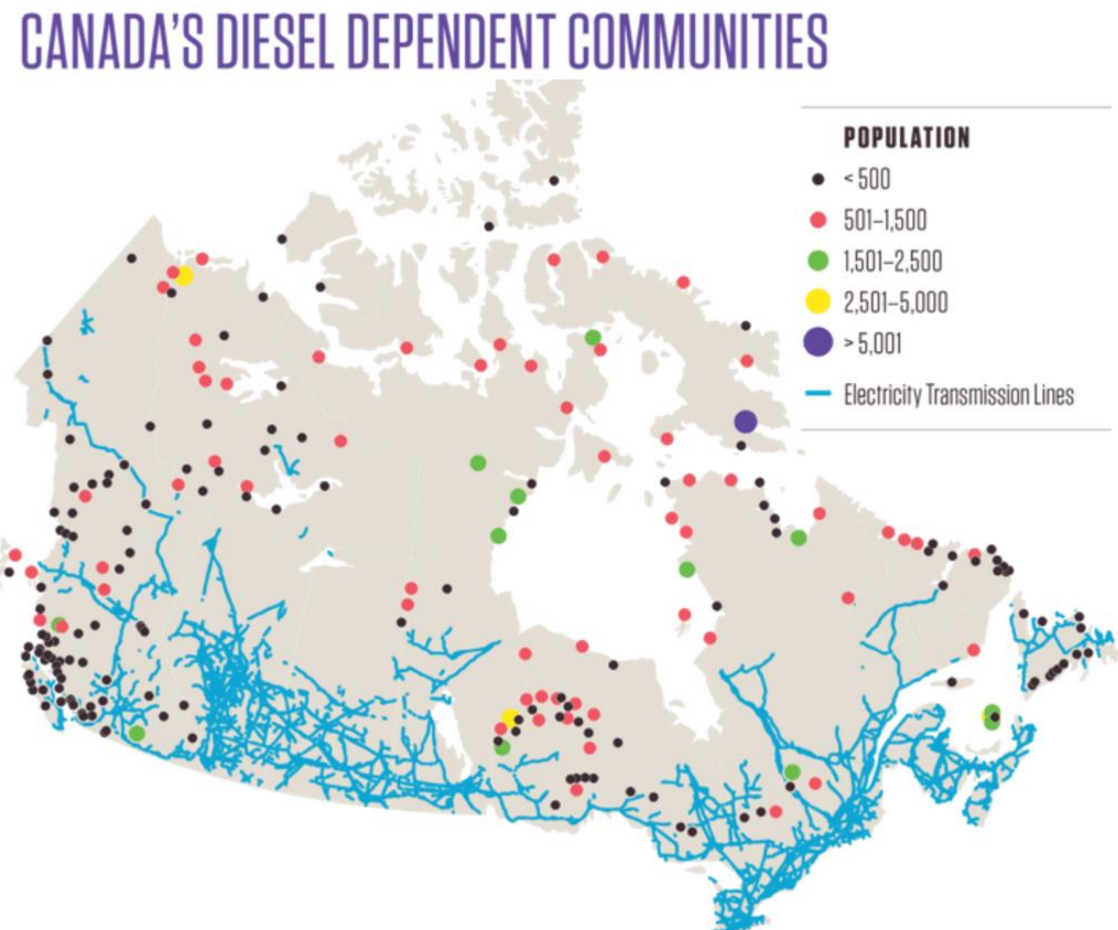

Fig. 1. Canada's diesel dependent communities (Natural Resources Canada 2012; Arriaga, M. et al. 2014)

Nunavut generates 100% of its electricity from petroleum; in 2021 Yukon generated 20% of its electricity from natural gas and 80% from hydro, and the Northwest Territories generated 14% of its electricity from natural gas, 47% from hydro, and 37% from petroleum. Wind powered two percent of NT's 2021 electrical generation (at one mine, Diavik).

Per capita energy use and GHG emissions are sizeable because of space heating and transportation. Even in hydro-generation communities, fossil fuels are commonly used for building heating and domestic hot water. Compared to the 2020 national annual average of 17.7 tonnes CO2e per person per year for all sources, Yukon and Nunavut rates were 14.2 tonnes and 15.4 tonnes respectively, despite having little industry. The NT's annual per capita GHG emission rate reached 30.9 tonnes (Canada Energy Regulator 2022) due to its mining industry.

In communities with existing diesel plants, integration of solar, or solar and wind, is highly feasible and already underway in several locations. Recently, small-scale solar and wind projects have been seen in Yukon and NT, with large wind turbines at Diavik mine and sizeable solar projects in Yukon. Indigenous communities have been proactive in implementing renewables projects, being the largest owners of clean energy assets besides private utilities and the federal government (Morrison 2021).

INSTALLATION, OPERATING, AND MAINTENANCE COSTS

Cost of Diesel

In comparing the cost of renewables and diesel, one must recognize that despite being a default "inexpensive" fuel in the past, its cost to the consumer does not represent the total true cost. Diesel fuel subsidies are applied by the Federal and Territorial governments. At production level, there are various Federal tax and non-tax subsidies (International Institute for Sustainable Development, 2020). "In each Territory the territorial governments subsidize the energy costs to residential customers, either directly (through government grants) or though rate equalization measures (Gwich'in Council International 2017). Commercial or industrial customers are also rebated, but not to the same extent.

Even so, electricity costs more in the Territories than elsewhere in Canada. In 2021, the national average cost was 17.9 cents per kWh. (Note: unless otherwise specified, all costs are in Canadian dollars). Residential power costs in the NT averaged 37 to 38 cents per kWh, and in Yukon, 18.7 cents per kWh. Nunavut residential power costs were levelized in late 2022 at 62 and 93 cents per kWh, (non-government and government) with non-government residential customers paying half the 62 cent rate with some usage limits (Qulliq Energy 2022). The cheapest electricity in Canada, in Quebec, cost about 7 cents per kWh (Energy Hub 2021). Cost of fossil-fuelled power, even if negotiated in advance, does increase, for various reasons. Diesel oil costs have recently doubled across Canada, to over $2.00 per litre (Statistics Canada 2022). "A large portion (e.g., 50% or more) of current delivered fuel prices for thermal power generation in these (remote) communities is for refining, processing, taxes and transportation, i.e., costs separate from the basic oil or natural gas commodity price" (Gwich'in Council International 2017). Other costs of producing power, such as operational and maintenance costs, tend to rise as well. Many diesel generating plants in remote communities are old and in need of replacement or updating.

In the Northwest Territories, most communities are served by power plants owned and operated by the Northwest Territories Power Corporation (NTPC). Two-thirds of these are thermal plants (diesel, natural gas, or liquefied natural gas). NTPC power rates are higher in thermal communities, but the difference is subsidized by the Territorial government. For example, residential and small customers in thermal communities pay only half of the 70.16 cents per kWh cost of generation (Northwest Territories Power Corporation 2022).

All Nunavut communities are all on diesel power provided by Qulliq Energy Corporation.. Territory-wide rates have replaced the previous rate structure which varied by community. Those not living in public housing receive monthly subsidies up to a certain threshold (Qulliq Energy Corporation 2019).

Yukon's power, provided by the publicly-owned utility Yukon Energy, has numerous categories of customer cost each consistent across the territory. For example, residential service, non-government, is 12.14 cents for the first 1000 kWh (plus a monthly customer charge) (Yukon Energy N.D.).

A 2017 study prepared for the Gwich'in Council International of power costs in nine northern communities from 2014 to 2016 breaks down the cost of diesel and diesel-generated power on a kilowatt-hour basis. For example, in 2016/17, the delivered cost of diesel fuel in Iqaluit was $1.11 per litre. As noted above, the actual cost of the diesel fuel is only about half that of the delivered cost. With a power plant efficiency of 3.82 kWh/L, the cost of the fuel used to produce electricity was

$0.29/kWh. (As with all conversion of thermal energy to electricity, diesel generation is not particularly efficient and for diesel, 40% efficiency is considered good.) Other expenses included operations and maintenance costs. Adding depreciation and financing costs, the total cost was $0.50/kWh – the carbon charge was not yet in effect at the time of this study (Gwich'in Council International, 2017). Based upon these numbers, diesel electrical generation costs per MWh were in the realm of $500 to $800 at the time of writing.

Cost of Renewables

Traditionally the subsidized costs of diesel-generated electricity were cheaper than renewables, but recently this has changed. However, wind and solar are not yet common at a utility scale in the North. The 3.5 MW Inuvik turbine (now in construction) will be the first large scale public installation, expected to lower fuel costs by $3 million per year (The Energy Mix 2022). At Haeckel Hill in Yukon, four turbines are now being installed with a potential to save 40 milion litres of diesel fuel over their lifetime (Government of Canada, 2022)

Capital costs to install solar and wind power in Canada are decreasing and are expected to continue downwards in inflation-adjusted terms. "In 2017, capital costs for utility-scale wind and solar projects in Canada *(overall)* were CAD$1,600 per kW and CAD$1,800 per kW (in 2016 dollars), respectively" (Canada Energy Regulator 2022). Considering that renewables projects in the North cost more and may require more maintenance than similar projects in the South, the cost of renewables is comparable to, or less than that of diesel. Installed costs in 2021 for solar projects in the North were around $3,000 per kW (Energy Hub, 2021). For wind, capital "cost approximations show that potential wind energy projects in the Arctic would be two to three times more expensive than those in temperate regions. The price per kW installed capacity is between 2,500 and 7,000 USD" (de Witt 2021). Actual installed cost of wind in the North varies by location, size, and equipment.

The four Diavik 2.3 MW turbines cost $31 million (in 2013), or about $3,300 per kW (CBC News, 2013). Larger turbines are much cheaper to install per kilowatt than the smaller turbines needed in remote communities. The levelized cost of producing renewable power across Canada in 2017 was about $130/MWh for wind and $58/MWh for solar, and expected to continue decreasing (Canada Energy Regulator 2022). These costs are already lower than that of diesel generation, at $500 to $800 per MWh (Gwich'in Council International, 2017). Battery costs have also reduced drastically in cost over the past decade (Lee 2020). Since many wind and solar installations in the North are small and relatively new there is little available information on their levelized production costs.

Looking at lifecycle costs, renewable power is cheaper than diesel power despite the larger capital cost, since no fuel is required for operation. Diesel systems can last 40 or 50 years, solar about 25 years, and wind turbines up to 20 years (Boggon 2019; TWI N.D.). All systems require maintenance, but solar panels require little apart from snow clearing and sometimes cleaning of dirt and other debris. Photovoltaic panels have no moving parts, and degradation is mostly due to UV radiation. For Arctic wind turbines, there is little reported information on actual operations and maintenance costs. In 2016, J.P. Pinard estimated an annual operations and maintenance (O&M) cost of $10,000 for a Nunavut 250 kW turbine such as the Northwind 100 at $1 million installed cost, and $40,000 per year for one Enercon E70 2.4 MW turbine costing $2.5 million. (Pinard 2016).

Cost and lifecycle considerations include decommissioning and recycling. No facilities exist to recycle solar panels in Canada. For wind turbines, it is preferable to "repower" (replace or retrofit components) than to decommission them, which can entail significant expense and environmental damage.

Solar Power. The rationale for using a particular renewable energy source depends not only on its availability and the diesel offset, but also on its cost compared with alternatives. A quick analysis tool for determining the economics of solar is found in "Market Snapshot: Residential solar is financially viable in some provinces and territories, but not in others" from Canada Energy Regulator (CER) (Canada Energy Regulator 2018). Although solar PV energy is now the world's cheapest source of electricity, Canada's installed costs are higher than many other countries' (Wood 2019). The average Canadian installation cost in 2021 was $3.01 per Watt. In the Northwest Territories, installed cost was $2.74 to $3.35 per Watt, in Yukon, $2.29 to $2.81, and Nunavut, over $4.00 (Energy Hub 2021). There are well over 100 solar installations in the Northwest Territories. In Yukon, one company alone, has performed over 340 installations (Waddell, 2020). Nunavut's QEC installed a solar demonstration project at the Iqaluit power plant in 2016, with promising results (Qulliq Energy Corporation N.D.) A 1995 installation at Iqaluit's Arctic College, a 3.2 kW, 60 panel PV array, operated over 20 years (Poissant 2013). In

2021, a new solar array was installed at the college. However, it has not produced electricty yet due to the lack of a power purchase agreement being reached between the proponent and the utility (Bakz, 2022).

Wind Power. As wind energy potential is much more localized and variable from month-to-month and year-to-year than solar, sizeable wind projects require monitoring for at least a year with meteorological towers. (Wills et al. 2021) A combination of wind and solar can give favourable outcomes. Following an analysis of options for Nunavut, World Wildlife Fund (WWF) noted that "… wind is the preferable renewable energy option in Nunavut, though in (certain) communities… the diesel-solar-wind-battery combination was found to be the most cost-effective" (World Wildlife Fund 2016).

Most planned community-scale wind projects in the Canadian North would be only tens to hundreds of kilowatts in capacity. However, the installation at Northwest Territories' Diavik mine was the world's largest wind-diesel hybrid farm when built, with four 2.3 MW Enercon E-70 direct-drive turbines. From 2012 to 2019, the turbines saved $36.37 million in fuel costs and offset 84,194 tonnes of CO_2 (Rio Tinto 2019).

Full substitution of diesel generators withwind or solar photovoltaic energy is not a viable option due to the intermittent quality of wind and solar. It has been said that low or medium penetration systems can be integrated without using a battery storage system (Power Engineering International 2017). Currently, in the three territories, "renewable energy integration limits in remote communities vary… but go no higher than… 20%", a conservative approach to maximize reliability (Pembina Institute, 2021). Arguments are being made that this could be safely increased. For example, the Northwest Territories caps renewables at 20% (Government of the Northwest Territories, N.D.). However, a 2021 microgrid stability analysis performed for five small NT communities noted that "the existing grid(s) could support up to 45% of renewable energy penetration without grid stability concerns" (Government of the Northwest Territories, 2021).

Reliability

Reliable electricity generation and distribution from power plants in cold remote locations is more important than that in non-remote and more temperate locations. New, well-maintained generators with a secure fuel supply can be "extremely reliable" (Standing Senate Committee on Energy, the Environment and Natural Resources 2015). However, many existing community diesel generators are aged, and fuel supply is never 100% secure. Diesel-powered communities and mines rely on local storage tanks, resupplied by winter ice roads, sea lift, or barge. Variable conditions can shorten the transport season, trapping supplies and necessitating costly air delivery.

Reliability also depends upon resiliency and redundancy. Outages and equipment failure can cause serious inconveniences, or worse, during extremely cold weather. Diesel plants may not have 100% redundancy on the entire plant, but should meet peak load with their largest generator out of service (NT Energy 2013). Conventional fixed-speed diesel generators are the norm in Northern and remote power plants; however, a 2018 pilot project in Aklavik, NT, using a variable speed generator and solar array is operating well (Government of the Northwest Territories 2019). Fixed speed generators are most efficient at loads above 30% to 50%; running them at light load risks failure or premature aging. Adding renewable energy to the grid can lower costs and provide resiliency, but the intermittent and seasonal nature of renewables such as solar and wind requires careful integration to maintain grid stability. Because wind speed varies, power plants need to adapt quickly to power input changes. Small diesel plants with fixed speed machines do not have this capability – spinning reserves are needed to keep the grid stable. In small plants with low penetration, this is done by running diesel generators full time at low load. At higher penetrations, specialized controls and energy storage are needed.

FUNDING PROGRAMS

Provincial/Territorial Incentive Programs for Renewables

The following major funding programs available for renewable energy in Canada's northern regions at residential and business/community government levels at the time of writing are summarized below. This is not a comprehensive list.

Territorial Residential. Nunavut offers incentives to homeowners for installing renewables systems as forgivable loans up to $15,000 through the Home Renovation Program (Nunavut Housing Corporation 2015). The Northwest Territories' Alternative Energy Technologies Program provides rebates up to $20,000 (Arctic Energy Alliance 2022). The Yukon provides rebates of $800 per kW to a maximum of $5,000 per system per year (Government of Yukon 2022).

Territorial Business. The NT offers a grant program for up to 25% of project costs business and 40% for non-profits

(Government of the Northwest Territories N.D.). Yukon offers grants to various groups for renewables generation up to $500,000 or 75% of eligible expenses for (Government of Yukon 2022). No such programs currently exist in Nunavut.

Federal Funding Programs. For community-scale projects, there are two core programs. Clean Energy for Rural and Remote Communities (CERRC) delivered by National Resources Canada (NRCan) funds projects supporting use of local renewable energy to replace diesel. Northern Responsible Energy Approach for Community Heat and Electricity (Northern REACHE) delivered by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) funds Northern projects using proven renewables technologies. Both programs encourage Indigenous leadership and partnerships.

The Arctic Energy Fund, introduced in 2018 as part of Infrastructure Canada's Rural and Northern Communities Infrastructure Stream, supports energy security in the North. $400 million over 10 years provides funding for communities to "upgrade existing fossil fuel-based energy systems or to supplement or replace these systems with renewable energy options…" (Government of Canada 2017).

Another program, now closed to applicants, is the Indigenous Off-Diesel Initiative (IODI) supporting remote diesel communities to establish diesel reduction plans, starting with $20,000 with the possibility of more funding at a later time. (Government of Canada 2022)

Other Funding Opportunities. Independent energy companies can partner with Indigenous or community groups, contributing funding towards renewable energy projects. Development companies may also offer planning, design and project management. Well-developed independent power producer (IPP) policies with secure long-term contracts can be attractive to investors.

Price on Carbon Pollution

A carbon tax, initiated by the Canadian government in July 2019 is designed to encourage the use of renewables. All territories participate in this program. The initial cost was set at $20 per tonne, increasing $10 per year to $50 per tonne in 2022. The initial increase on diesel fuel in the North was just over 5 cents per litre and increased to 13.7 cents in July 2022 (Government of the Northwest Territories 2019). Different approaches for rebating are used in different jurisdictions, some rebating all, some rebating half, etc. For a very comprehensive overview of policies in 2019, see Pembina Institute's "Power Shift in Remote Indigenous Communities" (Heerema & Lovekin 2019).

Provincial/Territorial Net Metering and Independent Power Producer Policies

The following is a snapshot of net metering and independent power producer (IPP) policies in remote locations. Generally, net metering allows customers credit at full cost of the power, whereas IPP policy credits larger producers at avoided cost of diesel fuel (not the full cost of the avoided diesel-generated power).

The Northwest Territories' NTPC Net Metering Program allows customers generating up to 15 kW to send surplus energy to the grid and bank excesses. Independent power producers may negotiate their projects with NTPC; the first such project in 2016 was a joint effort between the Lutsel K'e Dene First Nation and Bullfrog Power for a 35 kW solar facility (Lovekin 2019).

Since 2018, Nunavut's QEC permits *residential* customers with generating capacities up to 10 kW to receive credits for the surplus power delivered to the grid. The recently developed commercial and industrial power producer (CIPP) program, now accepting applications, allows existing commercial and institutional customers to sell their generated power to QEC (Qulliq Energy Corporation N.D.). The amount of power which can be sold is limited by capacity of interconnections in the community. The price is based upon the avoided cost of diesel, currently (October 2022) 24.76 cents per kilowatt-hour (Qulliq Energy Corporation N.D.). QEC's IPP policy is currently on pause after a period of public consultation. The IPP would allow producers other than the utility to generate power from renewables and sell back to QEC (Quilliq Energy Corporation 2022). The purchase price is proposed to be a "guaranteed minimum price, i.e., the avoided cost of diesel fuel to enable the proponents to secure financing." (Quilliq Energy Corporation 2022). The Pembina Institute notes that power purchase agreement (PPA) rates for Nunavut IPP and CIPP policies should "increase by at least 50% from the current rate of $0.25 per kWh" to reflect the actual cost of avoided diesel (Pembina Institute, World Wildlife Fund Canada, & Indigenous Clean Energy Social Enterprise 2022).

Yukon Energy Corporation and ATCO Electric Yukon allow net metering for small producers (under 50 kW) and IPP projects for producers above 30 kW. In diesel communities, the price would increase at full Consumer Price Index (CPI); for on-grid projects the price increases at half the CPI. "10 percent of new electrical demand (is) to be met by IPP, and at least 50% of these projects are to have First Nations involvement" (Gignac 2019).

Net metering and IPP policy and experience are recent in the North. Current policies are simple, based upon the avoided cost of diesel fuel, and do not provide much impetus for investment. Some considerations include:

Fair price: Ideally the recompense to producers should be at a price which allows the producer to have a fair and secure price, but does not penalize the utility for reducing its production (and receiving less in subsidies).

Total load on existing plants: Jurisdictions should consider load on existing plants, and at what point of penetration to "cut off". The GNWT is the only jurisdiction which caps net-metered and IPP amounts (Intergroup Consultants 2021).

Type of power (net metered or IPP): No jurisdiction distinguishes the amount of each type of power (solar, wind, etc.) which could best use the "available" renewables portion.

Type of renewable, and season: Another costing refinement would differentiate between types of renewables (Pembina Institute 2016). Solar power produces most in summer, whereas wind is more likely to produce more power in other seasons. Too much solar in a community could negate the chance for wind to provide much needed power in winter when heating and electricity needs are high. Pricing should reflect the season in which power is contributed and reflect its importance; there is no economy in paying producers for power that is unused and must be discarded.

CHALLENGES AND RECOMMENDATIONS

Although there are many successful renewables projects in remote locations, challenges still exist. The following is an overview of policy challenges noted in a literature and news review, and discussions with those involved in current and past projects. There is a lack of information on project performance and lessons learned, which hampers the design and development of new projects. Policy-wise, the independent power producers' policies with under-estimated cost of avoided diesel are arguably the greatest deterrents and delayers of projects.

Use of Avoided Cost of Diesel

As noted earlier, avoided cost of diesel does not represent the true savings of replacing diesel electricity generation with renewable energy. According to the Pembina Institute, "…governments and utilities that only offer PPA prices based on avoided cost of diesel showcase a lagging perception that clean power projects, and inherently the technologies that they incorporate, are not reliable or sufficiently robust in contrast to conventional diesel power plants. This perception impedes positive clean power project economics…," (Lovekin 2016).

Recommendation: More Realistic Pricing. Since a utility is keen to maintain its rate base and avoid increasing prices up for existing consumers, it prefers to keep the pay-out costs low. However, with more efficient and smaller diesel generators in the future, the utility's costs to run the plants may lower, allowing them to consider more appropriate prices for renewables. "The avoided cost of diesel approach to setting clean power prices does not offer adequate financial incentive for private sector and communities to develop clean power projects…. Limited support for diesel alternatives is exacerbated by unacknowledged downstream subsidies for diesel fuel systems and electricity, and lack of understanding of full operational and maintenance costs of diesel power plants, as compared to hybrid or full clean power plants" (Pembina Institute 2016).

Lack of Appropriate IPP Policy and Process

Although it is possible for projects to proceed in the absence of IPP policies by negotiating and agreement specifically for a given project, as has been done for select projects in Yukon, NWT, and Laborador, clear IPP policies and processes would be beneficial to project advancement. All jurisdictions have net-metering and IPP policy, except Nunavut, which has a very new CIPP and a draft IPP policy. For Nunavut residents, organizations, and developers, this is a serious missing piece and has caused projects to stall. It is hoped that the pricing aspect will be finalized and these stalled projects will be resumed and completed to help meet Nunavut's environmental and climate goals, as well as lowering the cost of living. Other delays can occur in approvals, permitting, and inspections, from slow responses from utilites or others, or conflicting information being provided.

Recommendation: Solid, Clear, and Fair IPP Policy and Process: The use of true cost of diesel for IPP producers would encourage investment and reduce risk to community groups or government. Processes, procedures, and timelines should be clear and transparent to reduce undue delays to applications and their associated installation projects.

Funding

There are numerous ever-changing sources of funding, from public to private. Federal, provincial, and territorial sources have different requirements, application dates, and lengths of program. Remote and Northern projects may take longer, and funding may run out before the project is complete, but past government funding aided many projects. The “vast majority of the existing energy infrastructure in the Arctic has been constructed using national or sub-national public funding” (Poelzer 2016). This level of government funding may not be sustainable in the future.

Recommendation: Appropriate and Flexible Funding. Funding programs should allow for the longer project times in North, and the sizeable early project costs. Small communities may have difficulties obtaining the full financing required (for example, bank loans) due to modest cash flow and lack of collateral. WWF has noted that “low-interest financing options are still needed to increase the attractiveness of renewable energy integration” (World Wildlife Fund 2019). Local or private funding should be encouraged, perhaps in the form of public-private (PPP) partnerships, which “can reduce the risk associated with project development, especially cost overruns…” (Poelzer 2016). Private investors want to see regular dividends, so a solid IPP policy with fair pricing is important.

Procurement

Procurement policies are designed to make purchasing fair and equitable. But standard polices with no incentive to include local labour or allow local partnerships can deter innovation and on-the-job training for renewables projects. Restrictions on sole source contracting can make it hard for proponents to specify a particular model of equipment, one that is proven and tested to operate in cold weather conditions. Other procurement challenges include the limited pool of of designers and equipment suppliers. In addition, the project funding timeline may not fit the most efficient procurement. Federal government projects must have funding commitment in place and then work with Public Services and Procurement Canada (PSPC), whose processing times of several months can hold up or delay projects. Procurement delays can often set a remote northern project back a full year due to the narrow shipping season in the Arctic Ocean.

Recommendation: Streamline Procurement. Procurement approaches must encourage the use of local labour so the community can gain expertise and independence. Processes should be streamlined for projects whose timeframe is lengthened by logistics or by unrealistic funding timelines. Government procedures and policies should accelerate procurement, not delay them, including the prioritization of procurement for remote northern communities, due to the significant additional time and effort required to prepare and ship equipment for the north. Smaller renewable energy equipment must receive electrical safety review in southern Canada before being sent to site.

Utility Interconnection Fees

Utility connection fees can be substantial, up to $250,000 per 100 kW turbine (Pinard 2016). This includes insurance, disconnect relays, meter, transformers, and line upgrades.

Recommendation: Utility Interconnection Fees. It is recommended that fair interconnection fees are determined before the project is built.

Utility Monopolies

Most, if not all, remote and Northern utilities are “the only game in town,” meaning the only entity to whom independent producers may sell. While utilities are becoming more open to renewables integration, their basic business practice is to purchase the cheapest power while meeting the legislated requirements of reliability. Renewables add some uncertainty and create additional work. With expected higher penetration rates of renewables in the future, utilities will have to adapt their business structures and pricing.

Recommendation: Utilities Buy-In. Utilities should be mandatedto engage with renewable energy projects. Incentives should be realigned such that utilities see benefit from incorporating renewable energy into their electricity supply. This may include ensuring subsidies to every facet of diesel generation are appropriately redirected to renewable energy generation for the proportions they offset, while considering the non-dispatchability of wind and solar energy. When old infrastructure is being replaced or upgraded, renewables should be considered as an alternative or supplement to fossil fuels.

CONCLUSIONS

While the use of renewables in remote northern communities is growing on a national scale, most of these communities still depend on fossil fuels for nearly all their electricity and space heating needs. Canada aims to reduce its greenhouse gas emissions to a fraction of its 2005 levels by 2030, and by the same time, significantly reduce diesel generated electricity in these locations. Generally, the use of renewables in the far north has been on quite a small scale. There have been successful projects integrating some penetration of renewables into existing diesel systems, and such hybrid systems, with or without storage, are becoming more common. Larger, community scale solar arrays are appearing, and turbines providing sizeable portions of community power are in construction or planning stages.

This paper has reviewed the current state of policies and economics affecting the successful installation and operation of renewable energy projects. The installation and operating and maintenance costs of solar photovoltaic and wind turbine systems in northern and remote communities were presented in contrast to locations in southern Canada and also in contrast to the cost of diesel-generated electricity. An overview of funding programs was presented, along with description of policies enabling or inhibiting the generation of electricity by independent producers. The shortcomings with recommendations were summarized, in hopes of encouraging improvements resulting in reduced carbon emissions and increased resiliency.

ACKNOWLEDGEMENTS

Thanks are extended to the following for input on this subject area: H. Shilton of Nunavut Nukkiksautiit Corporation, R. Cooke of Polar Knowledge Canada, D. Lovekin of The Pembina Institute, M. Lenio of World Wildlife Fund, A. Giroux of Arctic Energy Alliance, J. Vandenberg and D. Mahon of the Government of the Northwest Territories, K. Mann and R. Falconi of Hydro One, I. Flood of the Northwest Territories Power Corporation, and M. Tawashy of Northern Energy Capital.

REFERENCES

Arctic Energy Alliance. 2022. *Home Renewable Energy*. Retrieved from AEA Renewable Energy: https://aea.nt.ca/program/renewable-energy/#:~:text=The%20AEA%20provides%20funding%20for%20renewable%20energy%20sources,communities%2C%20commercial%20businesses%2C%20non-profit%20organizations%20and%20NWT%20residents.

Arriaga, M. et al. 2014. *Database of Electrical Grid Systems in Canada's Remote Communities.* Technical report.

Bakx, K. 2022. *Flipping the Switch*. Retrieved from: https://www.cbc.ca/newsinteractives/features/diesel-solar-wind-electricity-remote-Iqaluit-QEC-NNC

Boggon, C. 2019. *Solar vs Diesel: why solar generators should power rural communities*. Retrieved from EKOenergy: https://www.ekoenergy.org/solar-vs-diesel-why-solar-generators-should-power-rural-communities/

Canada Energy Regulator. 2018. *Market Snapshot: Residential solar is financially viable in some provinces and territories, but not in others.* Retrieved from Canada Energy Regulator Market Snapshot: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-residential-solar-is-financially-viable-in-some-provinces-territories-but-not-in-others.html

Canada Energy Regulator. 2022. *Market Snapshot: The cost to install wind and solar power in Canada is projected to significantly fall over the long term*. Retrieved from Canada Energy Regulator Market Snapshot: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-cost-install-wind-solar-power-in-canada-is-projected-significantly-fall-over-long-term.html

Canada Energy Regulator. 2022. *Provincial and Territorial Energy Profiles – Canada*. Retrieved from Canada Energy Regulator Provincial and Territorial Energy Profiles – Canada: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

CBC News. 2013. *Canadian diamond mine uses wind power in Northwest Territories*. Retrieved from Eye on the Arctic: https://www.rcinet.ca/eye-on-the-arctic/2013/09/16/canadian-diamond-mine-uses-wind-power-in-northwest-territories/

Energy Hub. 2021. *Cost of Solar Power in Canada 2021*. Retrieved from Energy Hub Cost of Solar Power in Canada 2021: https://www.energyhub.org/cost-solar-power-canada/

Energy Hub. 2021. *Electricity Prices*. Retrieved from Energy Hub Electricity Prices: https://www.energyhub.org/electricity-prices/

Gignac, J. 2019. *Independent Renewable Energy Producers can now sell to Yukon Utilities*. Retrieved from Yukon News: https://www.yukon-news.com/news/independent-renewable-energy-producers-can-now-sell-to-yukon-utilities/

Government of Canada. 2017. *Investing in Canada Plan: Integrated Bilateral Agreement Letters – Nunavut*. Retrieved from Infrastructure Canada: https://www.infrastructure.gc.ca/plan/letters-lettres/pt-nu-eng.html

Government of Canada. 2022. *Clean Energy for Rural and Remote Communities Program*. Retrieved from Government of Canada Green Infrastructure Programs: https://www.nrcan.gc.ca/reducingdiesel

Government of Canada. 2022. *Indigenous Off-Diesel Initiave*. Retrieved from Impact Canada: https://impact.canada.ca/en/challenges/off-diesel

Government of Canada. 2022. *New funding partnership adding wind-energy to the grid in the Yukon* Retrieved from: https://www.canada.ca/en/office-infrastructure/news/2022/04/new-funding-partnership-adding-wind-energy-to-the-grid-in-the-yukon.html

Government of Canada. 2022. *Northern REACHE Program*. Retrieved from Government of Canada Climate Change in Indigenous and Northern Communities: https://www.rcaanc-cirnac.gc.ca/eng/1481305379258/1594737453888

Government of the Northwest Territories. 2019. *Energy Initiatives Report 2018-19.* Government of the Northwest Territories.

Government of the Northwest Territories. 2019. *Implementing the NWT Carbon Tax.* Government of the Northwest Territories.

Government of the Northwest Territories. 2021. *Microgrid Stability with Intermittent Renewables*. Government of the Northwest Territories.

Government of the Northwest Territories. N.D. *Renewable Energy Integration Analaysis for Northwest Territories Remote Communities*. Government of the Northwest Territories.

Government of the Northwest Territories. N.D. *GHG Grant Program for Buildings and Industry*. Retrieved from Government of the Northwest Territories Infrastructure: https://www.inf.gov.nt.ca/en/services/energy/ghg-grant-program-buildings-and-industry

Government of Yukon. 2022. *Apply for a Rebate to Install a Reneweable Energy System for Your Home*. Retrieved from Government of Yukon: https://yukon.ca/en/renewable-energy-rebate

Government of Yukon. 2022. *Apply for Funding for Community Renewable Energy Projects*. Retrieved from Government of Yukon Funding and Support for Business: https://yukon.ca/en/innovative-renewable-energy-initiative

Gwich'in Council International. 2017. *Diverging from Diesel Technical Report.* Gwich'in Council International.

Heerema, D. & Lovekin, D. 2019. *Power Shift in Remote Indigenous Communities.* Pembina Instutute.

Intergroup Consultants. 2021. *Net Metering and Community Self-Generation Policy Review Final Report.* ntergroup Consultants.

International Institute for Sustainable Development. 2020. *Canada's Federal Fossil Fuel Subsidies in 2020.* Winnipeg: International Institute for Sustainable Development.

Lee, T. 2020. *Battery prices have fallen 88 percent over the last decade*. Retrieved from Ars Technica: https://arstechnica.com/science/2020/12/battery-prices-have-fallen-88-percent-over-the-last-decade/

Lovekin, D. 2016. *Power Purchase Agreements for Remote Indigenous Communities in Canada.* Pembina Institute.

Morrison, T. L. 2021. *Corporate Knights*. Retrieved from Surging Indigenous renewable projects lead shift to clean energy future: https://www.corporateknights.com/energy/indigenous-communities-leading-clean-energy-future/

Natural Resources Canada. 2012. *Remote Communities Database.* Retrieved from: http://bit.ly/nrcan-remote-database

Northwest Territories Power Corporation. 2021. *Business Electrical Rates*. Retrieved from Northwest Territories Power Corporation Business Electrical Rates: https://ntpc2017.ntpc.com/customer-service/business-service/business-rates

Northwest Territories Power Corporation. 2022. *Residential Electrical Rates*. Retrieved from Northwest Territories Power Corporation Residential Electrical Rates: https://www.ntpc.com/customer-service/residential-service/residential-electrical-rates

NT Energy. 2013. *A Vision for the NWT Power System Plan.* NT Energy.

Nunavut Housing Corporation. 2015. *Home Renovation Program*. Retrieved from Nunavut Housing Corporation Home Renovation Program: http://www.nunavuthousing.ca/hrp

Pembina Institute. 2016. *The True Cost of Fuel in the Arctic.* Pembina Institute.

Pembina Institute, World Wildlife Fund Canada, & Indigenous Clean Energy Social Enterprise. 2022. *Recommendations to Improve the CIPP and the Forthcoming Utility-Scale IPP Policy.*

Pembina Institute. 2021. *How to Boost Renewable Energy Integration in Remote Communities*. Pembina Institute.

Pinard, J. P. 2016. *Potential for Wind Energy in Nunavut Communities.* Whitehorse: Qulliq Energy Corporation.

Poelzer, G. 2016. D*eveloping Renewable Energy in Arctic and Sub-Arctic Regions and Communities.* Saskatoon: University of Saskatchewan.

Poissant, Y. T. 2013. *Performance Monitoring of the Nunavut Arctic Collge PV System: Nine Years of Reliable Electricity Generation.* SESCI.

Power Engineering International. 2017. *Energy Storage in the Arctic*. Retrieved from Power Engineering International: https://www.powerengineeringint.com/renewables/storage-in-the-arctic/

Quilliq Energy Corporation. 2022. *Policy Statement (Draft).* Quilliq Energy Corporation.

Quilliq Energy Corporation. 2022. *News Release: Qulliq Energy Corporation's new territory-wide electricit rates.* Quilliq Energy Corporation.

Qulliq Energy Corporation. 2019. *Customer Rates*. Retrieved from Qulliq Energy Corporation Customer Rates: https://www.qec.nu.ca/customer-care/accounts-and-billing/customer-rates

Qulliq Energy Corporation. N.D. *Commercial and Institutional Power Program*. Retrieved from Qulliq Energy Corporation Generating Power: https://www.qec.nu.ca/customer-care/generating-power/commercial-and-institutional-power-producer-program

Qulliq Energy Corporation. N.D. *Frequently Asked Questions Commercial and Institutional Power Producer Program.* Qulliq Energy Corporation.

Qulliq Energy Corporation. N.D. *Solar*. Retrieved from Qulliq Energy Corporation Solar: https://www.qec.nu.ca/power-nunavut/renewable-energy/solar

Rio Tinto. 2019. *Diavik Sustainability Report 2019.* Rio Tinto.

Standing Senate Committee on Energy, the Environment and Natural Resources. 2015. *Powering Canada's Territories.* Government of Canada.

Statistics Canada. 2022. *Monthly average retail prices for gasoline and fuel oil, by geography*. Retrieved from Statistics Canada Monthly average retail prices for gasoline and fuel oil, by geography1: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000101&pickMembers%5B0%5D=2.7&cubeTimeFrame.startMonth=04&cubeTimeFrame.startYear=2015&cubeTimeFrame.endMonth=10&cubeTimeFrame.endYear=2022&referencePeriods=20150401%2C20221001

The Energy Mix. 2022. *Inuvik Wind Turbine to Cut Diesel Costs $3M by 2023*. Retrieved from The Energy Mix Inuvik Wind Turbine to Cut Diesel Costs $3M by 2023: https://www.theenergymix.com/2022/03/07/inuvik-wind-turbine-expected-to-cut-diesel-costs-by-3m-by-2023/

TWI. N.D. *How Long Do Wind Turbines Last*. Retrieved from TWI Global: https://www.twi-global.com/technical-knowledge/faqs/how-long-do-wind-turbines-last#:~:text=A%20good%20quality%2C%20modern%20wind,increase%20as%20the%20structure%20ages.

Waddell, S. 2020. *Construction of Yukon's largest to date solar project will begin in August*. Retrieved from Yukon News: https://www.yukon-news.com/news/construction-of-yukons-largest-to-date-solar-project-will-begin-in-august/

Wills, A., Banister, C., Pellissier, M., & Berquist, J. 2021. *A multi-year analysis of Canadian Arctic historical weather data in support of solar and wind renewable energy deployment.* Cold Climate HVAC & Energy 2021.

Wood, J. 2019.*India is now producing the world's cheapest solar power*. Retrieved from World Economic Forum: https://www.weforum.org/agenda/2019/06/india-is-now-producing-the-world-s-cheapest-solar-power/

World Wildlife Fund. 2016. *Fuelling Change in the North.* Waterloo: University of Waterloo.

World Wildlife Fund. 2019. *Powering Nunavut's Future with Habitat-Friendly Renewable Energy.* World Wildlife Fund.

Yukon Energy. N.D. *Rate Schedules*. Retrieved from Yukon Energy Rate Schedules: ttps://yukonenergy.ca/customer-service/rates/rate-schedules