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Report on the State of Alternative Energy in the Arctic

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Polar Knowledge Canada

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Executive Summary

This report provides a contemporary snapshot of domestic energy usage in Canada's Arctic (spanning Yukon in the west to Nunatsiavut in the east) with a focus on how Northern jurisdictions meet their electricity and space heating needs. Specifically, the research team investigated the role of alternative energy options, including the governance, policies and financial analysis of these sectors. The team also examined the emerging field of energy conservation and efficiency measures, which have featured prominently in recent years.

In the electricity sector, Arctic jurisdictions each have very different regulatory, resource endowment and operational landscapes. This is especially true in Yukon and Northwest Territories where legacy hydroelectric facilities and extended grid systems have been developed, while Nunavut, Nunavik and Nunatsiavut rely almost exclusively upon fossil fuels to power isolated community-scale generation facilities. Each jurisdiction is currently grappling with the high costs of reliably supplying electricity services to its citizens in remote communities.

In the case of electricity, a number of policies including net metering and support for distributed generation exist at the territorial / regional level to support alternative energy options, conservation and demand management. Concurrently, increasing usage of renewable sources of electricity in the form of solar photovoltaic technologies, wind turbine installations and biomass generators, among others, is found throughout Canada's Arctic. Successful development and deployment of initial renewable energy technologies has often relied upon a few key individual proponents or energy NGOs, coupled with supportive policy levers, which have helped to overcome inertia to change established ways of generating electricity.

The efficient use of electricity and space heating resources has become a critical policy component in Arctic jurisdictions. Retirement and rebate programs targeting energy efficient appliances, space heating equipment, and building envelope upgrades are common across the Arctic. Governments are also leading by example by undertaking ambitious efficiency upgrades in commercial and residential properties that are publicly-owned. Fuel switching policies have featured prominently, ranging from the promotion of biomass substitution in institutional and government-owned buildings, to developing residual heat

applications that utilize the waste heat produced during electricity generation. Additionally, passive solar thermal designs for new buildings and solar water heating technologies have been deployed in a number of buildings and communities across the Arctic.

Municipal governments have proven to be crucial actors in supporting alternative energy and energy efficiency initiatives as they developed by-laws that mandate new buildings to achieve stricter energy efficiency standards, assisted in the development of long-term community energy strategies. However, the high prevalence of people renting (whether through public housing or through private proprietors) in many jurisdictions in Canada's Arctic has presented the problem of split-incentives whereby tenants may not see the value in conserving energy in buildings they do not own.

Arctic territorial/provincial governments make decisions on energy supply and demand management based on a number of criteria that can be divided into five broad categories: (1) Reliability of supply and quality of service, (2) Affordability in the short and long run, (3) Jurisdictional energy security, (4) Environmental impact reduction, and (5) Local economic benefits. Typically, reliability of supply is perceived as a minimal requirement to be attained. Affordability or cost minimization is a criterion favoured by most participants in public consultations in the Arctic as being a top priority. The techniques used in energy project financial analysis align with the governance framework built around the energy sector. This framework has, over time, culminated in a number of government subsidies or cross-subsidies between energy users, which prevent some Arctic energy users from paying the true cost of energy. Policies need to be crafted in an integrated manner, which includes improvement in rate design, power sector regulation, supply chains, and priorities delineated through public consultations.

There are three broad categories of methodological approaches used in financial analysis of electricity supply-side projects: levelized cost of energy (LCOE), cost-benefit analysis, and resource portfolio analysis. Each approach has its benefits, its drawbacks, and its specific uses. There is wide variation in methods used for financial analyses in Arctic jurisdictions. These discrepancies are due to the resources and timeframes available to perform the analysis, the availability of data and the level of qualification and/or availability of qualified personnel to perform the analysis. A full harmonization of methods is probably impractical as different circumstances call for different methods used in energy financial analyses. However, increased pan-Arctic communication, collaboration and a common core set of tools

might be useful in strengthening financial analysis practices and its transparency. Demand-side energy options (energy conservation, load curtailment and embedded generation) are often more cost-efficient solutions than supply-side options. Studying the financial performance of demand-side options and comparing these to supply-side options would improve decision-making.

Heating projects (such as biomass boilers, furnace efficiency upgrades, insulation and weatherization, dual-energy houses, cold-climate heat pumps and waste heat recovery) are of critical importance due to the magnitude of their potential beneficial impact on the environment, community well-being and on energy costs in the Arctic. Notwithstanding, we found that fewer financial analyses were performed for heating projects. The analyses that were conducted are not as easily comparable because a wider variety of indicators were used for these studies. Indicators include: simple payback period, savings per year or per month (disregarding the capital expenditures), levelized cost of energy and greenhouse gas reduction. Generally, analyses are conducted from the perspective of the participant only; and not from the perspective of the program administrator or from the perspective of the society.

From the financial and qualitative analyses consulted for this research, the following technologies and solutions looked promising: hydro and wind-diesel where the circumstances are favourable, photovoltaic-diesel in Thermal Communities (communities which rely on isolated fossil fuel-fired gensets and isolated distribution systems for power), liquefied natural gas as a potential short to medium-term replacement for diesel, grid optimization solutions such as electric thermal storage, biomass-fired single-dwelling heating and district heating (either imported, or locally-harvested from living forest biomass or burnt forests), building envelope performance improvements through energy codes, standards and labels, and cold climate heat pumps.

The report examines eight case studies from across Canada's Arctic regions, which represent a cross-section of northern alternative energy and energy efficiency technologies, including both public and privately-driven projects. Each case study includes a project description, objectives and drivers, the role of policy, and a description of barriers, outcomes, success factors and lessons learned. The case studies are divided into five operational case studies, describing projects already constructed and producing renewable heat or power, or reducing demand-side energy loss, and three forward-looking case studies, representing projects still under active development.

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1. Introduction

The geographic size and diversity of the Arctic jurisdictions, including isolated communities and population concentrations in central municipalities, the demographic makeup of residents, and a historical reliance upon fossil fuels play pivotal roles in energy supply and demand in Canada's Northern areas. For years, fossil fuels (mainly diesel) - and subsequently formalized supply chains and infrastructure supporting these energy sources - have been a primary fuel source for electric power generation and space heating needs at the residential, commercial/institutional and community levels. While subsidized, energy costs in these communities are substantial, which has a large impact on the affordability of living in these communities. Also, utilities in the North have had long-standing experiences operating both community-scale energy options for remote communities (mainly based upon diesel generators), as well as large-scale systems (e.g. grid-based electricity schemes through large scale hydro).

However, various pressures are forcing an appraisal of the state of energy production and usage in the Arctic. For instance, there is increased recognition of the problems tied to the dependency on fossil fuels (e.g. fluctuating prices, high costs involved in its use in the North, dependency on subsidies from other sources, carbon emissions, air quality issues, risks of spills in situ or in transit, etc.), along with a concurrent appetite to assess the feasibility of alternative energy sources. In addition, residents in the North are contending with climate change impacts with profound implications. Some suggest that cyclical weather patterns are being exacerbated with climate change, causing major stress points. For instance in 2014 NWT provided \$20 million to subside electricity costs as they contended with low water levels in one of their large-scale hydro systems, in a context with competing demands on public finances such as fighting forest fires (costing about \$55 million) (Semeniuk, 2014; Flannigan, Cantin, de Groot, Wotton, Newbery, & Gowman, 2013). Thus, Arctic jurisdictions are currently undergoing a period of renaissance in regards to how they produce, consume and conserve energy. Opportunities for engagement within energy policy planning processes has opened avenues for stakeholders to understand and provide valuable input into territory wide policy decisions, such as through Northwest Territories' recent Energy Charrette¹

¹ An energy charrette is "a collaborative planning process where communities, governments, non-government organizations, industry, and energy experts come together to develop an energy strategy and plan for the future".

in November 2014. It is within this context that the Canadian High Arctic Research Station (CHARS), now known as Polar Knowledge Canada (PKC), commissioned our research team to undertake a study examining domestic energy provision within Canada's Arctic jurisdictions.

Before turning to the report specifics however, it is important to understand attributes found in this region with respect to energy supply and demand. Regarding power system planning, other key aspects differentiate the Arctic from southern jurisdictions given their smaller size and more independent nature. Firstly, there are limited resources available to perform the planning due to the relatively small size of the power system and small number of ratepayers, and therefore limited capacity of the Northern ratepayers to pay for supply-planning overhead. Secondly, the implications of individual decisions regarding supply and demand are exacerbated due to the small scale of the system. In the South, the electricity supply mix is composed of a multitude of primary energy sources and a large number of power plants interconnected in the continental grid. As a consequence, any incremental decision has only a marginal impact on the financial performance of the utilities integrated in the continental grid. The supply mix in the Arctic however entails one or two power plants in remote communities, or at most a dozen power plants in larger urban areas such as Whitehorse, Hay River and Yellowknife. Each decision made regarding power supply (e.g. building a new dam, or at a community level, replacing a diesel genset or investing in an alternative technology) is large compared to the size of the system and thereby can have a profound effect on power supply cost going forward. In addition, none of the Arctic grids encompassed in our study have interties with Southern jurisdictions, thus the impact of any misjudgment during supply planning cannot be mitigated through inter-jurisdictional arbitrage (namely benefiting from electricity trading by storing electricity when prices are low and discharging electricity when prices are high) (Byrne & Silva-Monroy, 2012).

Alternative and renewable energy is one of the research priorities under CHARS' inaugural five-year science and technology (S&T) plan. In order to help define the scope of this priority, CHARS engaged the Carleton University School of Public Policy and Administration (SPPA) and Carleton Sustainable Energy

See <http://lgant.com/news/public-dialogue-energy-2014-energy-charrette>. One characteristic of a charrette is that various parties (e.g. Aboriginal groups, community members) are involved and engaged in the planning process at the outset, rather than after decisions have been made. See: <http://www.iti.gov.nt.ca/energy/charrette>

Research Centre (CSERC) to produce a ‘snapshot’ of domestic energy provision in the north. This report will provide a background on current efforts in sustainable and renewable energy in Canada’s Arctic, aims to guide PKC’s internal research and calls for proposals, and inform policy discussions.

The report seeks to inform practitioners, key policy makers, academics, Non-Governmental Organizations (NGOs), industry leaders, and Northern residents. Stakeholders will be comprised of representatives of these groups, and will provide input throughout the project process, communicate the review’s findings, and validate and refine them. We hope that these audiences will be able to use the project report to either directly improve government policies or provide a foundation for further discussions and research. The approach taken aims at generating novel ideas for ways to address old and new policy problems.

The report is intended as a guide to policy debate, economic analysis, and project planning, both for in-house PKC programming and as a resource for northern partners. The work aligns with PKC cross-cutting activities, in particular technology development and transfer, and capacity building and training (with a focus on Aboriginal youth). In order to realize the study objectives, the report is structured as follows. The first part of the report (Sections 2-6) provides contextual information regarding electricity and heating supply and demand throughout the various jurisdictions in Canada’s Arctic. These sections also focus in on key public policy levers (e.g. federal, territorial / provincial, Aboriginal, community / municipal) and actors that were identified as playing a role regarding sustainable energy options within these jurisdictions. The next part (Section 7) provides background on financial analysis for energy within the Arctic given the importance of economic aspects in energy planning, decision making and use. This analysis consists of cost estimates for different technologies and energy sources used for electricity and heat generation in the Canadian Arctic. The analysis examines financial and economic cost benefit dimensions, along with various energy evaluation tests used in the industry. It contrasts various approaches and energy supply planning processes that are applied in the different Arctic regions. From there the report turns to a number of case studies which are representative of various aspects of energy in Canada’s Arctic including energy supply and demand, heating and electricity (industry (mining) and community-based), and different energy types (e.g. biomass and solar) (Section 8). The analysis examines drivers or rationale for the evaluated projects, their objectives, project performance, and the role

of policy, implementation barriers and lessons learned. The final section (Section 9) examines potential policy implications overall and research recommendations. However, before turning to these aspects, we will first introduce the scope of the report and the methodology used.

1.1. Study Methods and Scope

The methods chosen for the information / data collection and analysis relied on on secondary sources such as published reports and literature on Arctic energy sources relevant to heat and electricity supply, demand management or conservation, which were augmented with primary sources such as focus groups and interviews. In addition the report hones in on specific selective case studies to illustrate barriers and opportunities for alternative energy implementation.

Discussions with Northerners were sought to ground the analysis through real world experiences of policy makers, practitioners and other key players involved in energy issues in Canada's Arctic. These insights allowed the study team to assess various suggestions and assumptions regarding energy and policy issues regarding the Arctic region, and to examine the extent to which they reflect the reality faced by Northern residents working on these issues. With this in mind, the research team sought input and feedback from northern partners through various means, including focus group sessions and interviews/discussions, in order to tailor the work to the needs and objectives of northerners.

The study team acquired ethics clearance from Carleton University's ethics board. In addition, we applied for and obtained a research license as required by Northwest Territories' Aurora Research Institute (ARI) and discussed our study with relevant representatives from other regions in the Canadian Arctic.

The first step of the study was a virtual meeting with Northern partners in September 2014 to determine the study scope. Here, participants determined that the focus of the report would be on electricity and heating in order to narrow the study focus, while recognizing that transportation also plays an important role in energy supply and demand in the North. In addition, it is important to recognize the interlinkages between the use of various resources and electricity and heating demand such as the links between water systems and the required energy requirements. Furthermore, in an effort to get a sense of the energy landscape of the region as a whole, participants decided to focus on energy supply and

demand, conservation, grid-connected and non-grid connected communities, as well as energy for industrial and community purposes. Research includes an examination of both projects and programs. Furthermore, emphasis is placed on economics and project finance given their integral role in energy system analysis, with a distinction made between isolated-grid communities and central-grid communities that have access to hydroelectricity.

All of our researchers attended the Northwest Territories' Energy Charrette on the 3rd and 4th of November 2014. A day after the Energy Charrette we organized a special workshop with representatives from all Arctic regions except for Nunatsiavut (an invited representative was not able to attend). During the workshop we introduced and discussed the proposed structure of the report and conducted breakout sessions to identify current debates and issues in the energy sector in each region. We furthermore discussed the effectiveness of current policies and programs, lessons learned, steps forward and research gaps to guide future research directions. Face-to-face and phone interviews were also conducted with Northerners in December 2014 and January 2015. Interviewees and focus group participants were asked questions about energy supply and demand options within their jurisdiction (macro and micro level e.g. territory / region-wide and community level), as well as barriers and opportunities for sustainable energy options, with a particular focus on the role of public policy in assisting (or hindering) the uptake of sustainable energy options (see Appendix 3 for interview and focus group questions).

1.2. Supply-Side Planning Criteria

Given the report's focus on the state of energy provision in Canada's North, it is important to examine how these jurisdictions plan for their energy systems in the short and long-term. Territorial/provincial governments use a series of criteria in order to make decisions on future supply investment and on other energy policies and decisions. Table 1 shows the criteria that are used by the various jurisdictions in the Arctic. For the purpose of comparison and analysis, we divided the aforementioned criteria in five categories in Table 1.

Table 1 Electricity Supply-Planning Criteria

	Yukon	NWT	Nunavut	Nunavik, QC
Reduce Impact on Environment	-- Environmental impact mitigation, consideration of socio-economic impacts & reduction of GHG emissions	-- Environmental performance -- Social benefits (water use, and waterway impact)	-- Environmental Responsibility	-- Sustainable Development / Environmental Protection
Increase Jurisdictional Energy Security	-- Energy security	-- Social benefits (self-sufficiency) -- Economic impact (reduce import imbalance)	-- Energy Security	
Ensure Reliability of Supply and Quality of Service	-- Reliable winter peak capacity & reliable development (Timing)	-- Technical viability -- Social benefits (reliability)		-- Reliability as an implicit criterion in the off-grid community supply plan.
Minimize Energy Cost in the Short and Long run	-- Reliable development (cost) -- Affordability -- Flexibility (ratepayer cost risk re: mine load reduction)	-- Economic impact (compared with diesel) -- Cost of energy -- Installation cost (Initial Cost)	-- Affordability	-- Development of alternative energy -- Prudent procurement of new generation capacity in the context of steep load growth as an implicit criterion in the off-grid community supply plan.
Generate Local Economic Benefits	-- Economic benefits	-- Social benefits (economic growth)	-- Business and Job Opportunities	-- Economic Growth: small businesses, mining, forestry, tourism, large hydro development where applicable

Sources: (Yukon Energy Corporation, 2011), (Government of Yukon, 2009), (NT Energy, 2013), (Hydro-Québec Distribution, 2013), (Ministère des Ressources Naturelles et de la Faune du Québec, 2006), (Government of Québec, 2012), (Makivik Corporation, 2010)

NOTE at the time of writing (Fall 2014 / Winter 2015), Nunatsiavut was in the process of developing their Energy Strategy; furthermore, electricity planning falls under the purview of the utilities operating in Newfoundland and Labrador (discussed in detail in Section 6).

“Flexibility” refers to the ability of the supply resource to be scaled up quickly and by small capital increments to adapt to future demand, and/or scaled down with minimal sunk costs or stranded assets, or those assets which unexpectedly lose their value for various reasons (e.g. adoption of new technologies, public policies such as a carbon price) (Rozenberg, Vogt-Schilb, & Hellegatte, 2014), (Caldecott, 2014).

Furthermore, the stated objectives do not indicate the weights placed on each criterion. Firstly, government, regulators and utilities typically treat “reliability” more as a “minimal requirement” than as a criterion per se as all agree that the lights must remain on in communities. Blackouts do happen, and this causes major concerns to Arctic Utilities and electricity end-users given the extremes (e.g. weather, isolated communities) found in these settings. While the Nunavut and Nunavik policy documents did not mention “reliability of supply” directly we would conclude that importance of reliability may have simply been taken for granted.

Secondly, minimizing energy cost typically has a greater weight than that of other categories of considerations. Electricity rates are extremely tangible, visible, and on top of mind for residents. Moreover, regulators are in place in all of the territories, as well as Nunavik and Nunatsiavut to review electricity rates. This aligns with what we witnessed during the NWT 2014 Energy Charrette as most stakeholder workgroups reported “Affordability” to be the most important criteria, which was also confirmed in the Charrette report (Government of the Northwest Territories, 2014, p. ii).

2. Yukon Territory Energy Overview

2.1. Electricity: System and Current Trends

The electricity sector in Yukon can be delineated between hydro based and thermal based generation technologies. Four hydro generating stations owned and operated by Yukon Energy Corporation (YEC) generate the majority of electricity in the territory. The Yukon Energy Corporation (YEC) is owned publically but the Yukon Development Corporation is the sole shareholder. YEC operates at arm’s length from the Government of Yukon, and is responsible for the vast majority of electricity generation and transmission in Yukon. An overview of energy governance for each Arctic jurisdiction in this report can be found in **Appendix 1**. The Mayo facility (15.1MW total capacity) is located near the municipality of

Mayo in the north-central area of the territory. The Aishihik facility (37MW capacity) and the Whitehorse facility (40MW capacity) are located near Whitehorse in the south central area of the territory. All of these facilities, with the exception of the Mayo B generator, are legacy hydro facilities built throughout the 1950s-1980s to meet growing demand in the territory and, in the case of the Mayo A and Aishihik facilities, specifically to meet the load demand of nearby mining operations (Yukon Energy Corporation, 2011). Until 2011 YEC operated the Mayo A facility and the Aishihik/Whitehorse facilities on two separate transmission grids. With the completion of Mayo B and the Carmacks – Stewart interconnection line in the summer of 2011 YEC has effectively developed a territory wide interconnected grid system, which has helped to increase reliability and balance generating assets more effectively. The increases in reliability have been especially important given large seasonal variations in water flows for the Whitehorse generating station. Between the summer and winter the peak capacity of the Whitehorse hydro system fluctuates between a peak of 40 MW in the summer and, reaching a low of 24 MW in the winter months.

In 2013 hydro facilities on the interconnected grid generated 424.7 GWh or 95% of all the electricity consumed in Yukon (Yukon Bureau of Statistics, 2014). The grid itself does not extend to every community in Yukon. A number of communities (Beaver Creek, Destruction Bay / Burwash Landing², Swift River³, Old Crow, and Watson Lake) are served by standalone diesel generation systems owned and operated by ATCO Electric Yukon. Additionally, backup and seasonal peaking thermal generation for grid-connected communities is met primarily with diesel, though Whitehorse is currently planning to decommission diesel facilities to replace them with Liquefied Natural Gas (LNG) units. In 2013 thermal generation units in ATCO Electric Yukon communities produced 21.3 GWh of electricity, while YEC grid connected units produced 1.9 GWh, which together is 5.2% of (Yukon Energy Corporation, 2014) all electricity produced in Yukon (Yukon Bureau of Statistics, 2014). Figure 1 below shows Yukon's electrical system.

² Burwash Landing and Destruction Bay share a diesel generator but the bulk of the population lives in Burwash Landing

³ A few communities in and around British Columbia (Upper Liard, Lower Post) are subsidized by Yukon and served by the local grid (Swift River).

Figure 1 Yukon Electrical System

Source: (Yukon Energy Corporation, 2014)

Over the last decade electrical demand in Yukon has been on an upward trend. However, most recently there has been a reduction in annual consumption, from 426 GWh per year in 2012 to 407 GWh per year in 2014⁴. Of the 397 GWh sold in Yukon in 2013, 40.9% was purchased by residential customers and 59.1% was sold to non-residential (commercial, institutional and industrial) customers (Yukon Bureau of Statistics, 2014). Demand by residential customers has remained relatively flat on a per capita basis with each customer increasing their electricity consumption from 9,300 kWh in 2004 to just over 10,200 kWh in 2013 (Yukon Bureau of Statistics, 2014).

In March 2011 YEC organized an Energy Charrette (see Appendix 1 for further details), where stakeholders and experts discussed Yukon's energy system planning, and the public was invited to

⁴ Personal Communication, *Government of Yukon Representative*, 2015

evening sessions to help also contribute to these discussions⁵. YEC also released their *20 Year Resource Plan* where electricity demand is expected to remain relatively flat for non-industrial loads, but the impact of new industrial customers (mainly new mining operations) could significantly increase the load profile of the grid system. YEC estimates that the potential connection of two mines (Eagle Gold by Victoria Gold Corp. and Carmacks by Copper North Mining Corp.) to the grid could increase load demand by 178 GWh (an increase of nearly 40%) per year (Yukon Energy Corporation, 2011). Furthermore, potential load growth in off-grid mining operations (such as the Wolverine and Selwyn zinc mines) may end up dwarfing the current Yukon electrical system, increasing the load from 448 GWh in 2013 to over 1,300 GWh by 2025 (Yukon Energy Corporation, 2011). It is important to note that the vast majority of this potential load growth attributed to future mining operations will be dependent upon a number of factors such as high global prices for metals and minerals. This high level of uncertainty has led YEC to caution readers of its resource plans that any forecasts beyond the five year time period between updates are inherently uncertain and should be used to assess (rather than definitively predict) forecasted challenges and opportunities (Yukon Energy Corporation, 2011).

Recent Policy Developments

Hydro Grid Expansion: Since 2000 many of the largest policy developments have involved upgrades and reconfigurations to Yukon's electrical grid. The majority of these upgrades are from the YEC's *20-Year Resource Plan* released in 2006 but were driven by industrial factors at the end of the 1990s.⁶ The closure of the grid-connected Faro mine near the municipality of Faro in 1998 dramatically reduced the overall load (>200 GWh/year) on the Whitehorse grid system and offset a large amount of peaking thermal generation needed to meet the mine's demand. The early 2000s saw the YEC focus its efforts on utilizing the available hydro to offset diesel generation in Yukon (Yukon Energy Corporation, 2011). As a result, a successive build-out of transmission infrastructure occurred between 2001 and 2011.

⁵ <https://www.yukonenergy.ca/energy-in-yukon/public-engagement/2011-energy-charrette/>

⁶ The Public Utilities Board requires the Yukon Energy Corporation to complete a 20-Year Resource Forecast every five years. This update was made during the development of the 2006 20-Year Resource Plan when the authors noted that the previous system planning report and its methods from 1992 were extremely dated. More frequent planning exercises were thought to be a benefit to the YEC and the Yukon Utilities Board for coping with the inherent uncertainty with long-term demand forecasting (Yukon Energy Corporation, 2013)

The first project connected Dawson City, which previously generated all of its power with fossil fuels, to the Mayo grid in 2003. Shortly thereafter in 2006, YECs first 20-Year Resource Plan broached the idea of an interconnection between the Whitehorse and Mayo grid systems. Utilizing funding available from the federal government's *Green Infrastructure Fund*⁷ and leveraging funds made available by the GY, YEC proceeded to upgrade its transmission and hydro generation systems from 2006 to 2011. As a result of these upgrades YEC began operating a newly interconnected and expanded (see Figure 1 above) power system at the end of 2011.

In 2012 YEC also applied for a retail rate increase with the YUB, its first such application since 1999 (Yukon Energy Corporation, 2014). The increase was deemed necessary by the YEC to cover costs within the system, general maintenance, system planning and to cover inflation costs (Yukon Energy Corporation, 2014). YEC applied for a rate increase of 12.09% over two years and was granted an increase of 11.01%.

Renewable and Distributed Generation: The release of the *Yukon Energy Strategy* in 2009 provided a number of priority areas for further policy development. Measures related to energy efficiency, conservation and demand side management took on a prominent role with the government's pledge to increase energy efficiency by 20% by 2020, which will be discussed in detail later in this report. However, a number of measures were also directed towards increasing renewable energy generation by 20% by 2020, which included the support and demonstration of new renewable technologies (particularly in isolated diesel communities) to confirm their technological and economic feasibility (Government of Yukon, 2009). Similarly, the GY also committed to developing a policy framework for independent power production from non-utility sources, as well as the creation of a net-metering program for micro-generation (Government of Yukon, 2009).

⁷ The Green Infrastructure Fund was an Infrastructure Canada program run between 2009-2014. The stated goals of the program were to fund "projects that will improve the quality of the environment and lead to a more sustainable economy over the long term." Details about projects funded through the Green Infrastructure Fund can be viewed at: <http://www.infrastructure.gc.ca/prog/gif-fiv-eng.html>

The net-metering program (known as the *Micro-Generation Policy*) was finalized and released in October 2013.⁸ The policy allows for the connection of renewable units with a capacity under 25 kW to the system and systems up to 50 kW considered on a cases-by-case. Additionally, any electricity that is sent back into the grid receives 21.0 c./kWh for interconnected grid customers and 30.0 c./kWh for customers in isolated communities (Yukon: Energy, Mines and Resources, 2013). Another policy, the Independent Power Production (IPP) Policy is for larger scale projects up to a maximum 300 kW for producers in isolated communities and 2MW for grid connected is currently in the draft stages and was set for release by mid-2015 (Yukon: Energy, Mines and Resources, 2014). The larger second-tier projects under the IPP policy will be power purchase agreement between the IPP and Yukon Energy or ATCO, and these agreements must be approved by the YUB to ensure they can be included in Yukon's rate structure. Building on these framework policies the GY has also undertaken and encouraged feasibility and demonstration projects for a number of different technologies.

In addition to policies at a more macro level, the GY (e.g. the Energy Branch, Department of Energy, Mines and Resources), and the YEC have undertaken a number of renewable electricity projects over the last several years focusing mainly on wind and solar technologies. With respect to wind as a potential power source, wind resource measurements have been the subject of a three-year feasibility project north of Stewart Crossing known as Tehcho (Yukon Energy Corporation, 2014). Resource measurement studies were carried out in preparation for the potential development of a 21 MW wind farm at this site. Additionally, resource measurement studies will commence in 2015 on Mt. Sumanik (Yukon Energy Corporation, 2015). Despite these favourable developments, wind energy faces a number of barriers to further development in Yukon as identified by YEC in its 20 Year Resource Plan, including a lack of reliability for meeting demand peaks, its non-dispatchable nature and that the resource does not provide a reliable backup for seasonal fluctuations in hydro generation (Yukon Energy Corporation, 2011). Wind power, however, is most productive when hydro flows are low in the winter because the winter is when wind energy is at its greatest potential on Yukon's mountain-top sites.

⁸ For more information the Yukon Governments *Micro-Generation Policy* please see:
<http://www.energy.gov.yk.ca/microgeneration.html>

In early 2014 the ESC released a report summarizing the performance of three grid connected solar photovoltaic (PV) arrays, two of which are in Whitehorse and the third in Watson Lake. The report notes that despite seasonal fluctuations in electricity production solar technologies have operated very successfully (in one case above modeling predictions (see case study on Lutselk'e, Northwest Territories and NorthWestTel)) with little operation and maintenance costs for a number of years (Energy Solutions Centre, 2014). But despite positive performance and considerable decreases in installation costs since 2008, payback periods for PV systems are in the range of 20 years for residential sized developments (Energy Solutions Centre, 2014). Interestingly, depending upon the price of different fossil fuels, larger grid connected PV systems could be competitive with current generation costs (in the case of diesel offsets) in the near future, and are only slightly less competitive than LNG generation (Energy Solutions Centre, 2014). The economic case for PV systems is strengthened in the fly-in communities such as Old Crow in northern Yukon, which relies on imported diesel fuel for nearly 100% of its electrical generation. For example, a recent prefeasibility study completed for the Vuntut Gwitchen First Nation, of whom the majority of Old Crow residents belong, shows that a medium sized (330 kW) solar PV array could offset nearly 98,000 litres of diesel each year and that the system would pay for itself in 11 years (Bigham, 2013) That being said, subsequent design work in Old Crow has already noted significant interconnection issues and problems with oversizing.

Alternative Generation

Despite the progress being made on a number of fronts with renewable technologies there are still short-term pressures influencing recent decisions within the YEC. The prospects of new mining loads have led the YEC to focus heavily on being able to meet this predicted demand increase while keeping GHG emissions as low as possible. Historically, short-term load growth has been met by utilizing existing thermal capacity; however, volatile resource prices, aging infrastructure (diesel units nearing their end of life span) and a high emissions profile has led both the GY and YEC to examine alternative generation options.

YEC's 2011 *20 Year Resource Plan* undertook a detailed analysis of liquefied natural gas (LNG), as a cleaner and cheaper fossil fuel option for thermal generation. Additionally, the study noted that LNG use

for off grid loads would be the ideal transition fuel in the near term (until 2020) as further studies, planning and permitting is conducted for new hydro and other renewable energy technologies (Yukon Energy Corporation, 2011). As a result of these reports and expected short-term load growth, YEC proceeded to apply for and received permission to replace two diesel generator units in Whitehorse in the summer of 2014, although at the time of writing these two generators were still in operation. While many Yukoners were critical of YEC's choice to develop fossil fuel projects after voicing their support for renewable technologies at the 2011 YEC Energy Charrette,⁹ and arguing that continued use of another fossil fuel helps to 'lock in' the territory into high carbon sources for their energy system, the LNG facilities went ahead and are expected to be in operation by the spring of 2015 (YEC, 2015).

2.2. Space Heating: Fuels and Trends

Heating demand in Yukon is highest in the winter months with the majority of Yukon residents relying upon heating oil for their needs (Yukon Bureau of Statistics, 2014). This being said a number of divergent trends are present in Yukon that are not prevalent in other northern jurisdictions. According to household surveys, fuel expenditures for heating comprise a much lower annual amount of overall household operational expenses compared to other territories and is between \$1,100 and \$2,100 less than in the Northwest Territories and Nunavut respectively (Yukon Bureau of Statistics, 2014). Secondly, there has been a marked upturn in the number of households that have reported using electricity as their heat source with nearly 18% of Yukon household utilizing this source up from around 10% in 2003 (Yukon Bureau of Statistics, 2014). Modeling studies completed for GY also note that a large percentage of new home construction are using electric heating as their primary space heating resource and expect the total consumption for residential space heating needs to nearly double from 33.2 GWh in 2010 to over 63.9 GWh in 2030 (ICF Marbek, 2012). This trend is also replicated in the commercial/institutional building sector where space heating is the second largest subsector for electricity use in buildings behind general lighting, consuming 21.5 GWh of electricity in 2010 (ICF Marbek, 2012). Similar to residential trends electricity space heating within commercial buildings is expected to grow through 2030, albeit at a much

⁹ Anonymous, *Focus Group Interviews*, November 2014

faster rate, nearly tripling overall consumption of electricity to 60 GWh per year by 2030 (ICF Marbek, 2012). Biomass mainly in the form of locally sourced cord wood and imported wood pellets comprises roughly 17% of total home heating fuel, and a much smaller percentage of commercial and institutional heating needs.¹⁰

Recent Policy Developments

Most recent policy developments affecting space-heating needs are indirectly the result of energy efficiency measures and the relatively low cost of electricity when compared to fossil fuels. By-laws passed in the City of Whitehorse in 2009 (then made territory-wide in 2012) have mandated new building construction to meet the equivalent of EnerGuide 80 ratings (Government of Yukon: Energy, Mines and Resources, 2011)). More recently, the City of Whitehorse Energy Conservation Bylaw Amendment has increased the minimum EnerGuide rating required from 80 to 82. Additionally the relatively low cost of hydroelectricity has instigated a push for electric heating conversions usually in conjunction with a wood-stove backup (City of Whitehorse, 2013).

Similarly, new standards implemented for new and replacement oil and wood based boilers, furnaces and stoves systems have also aimed to increase the efficiency of space heating options for Yukoners. Additionally, through its *Good Energy Rebate* program the ESC provides Yukoners with cash rebates for the purchase of high efficiency heating appliances. Since the programs launch in 2007 an average of 187 rebates have been issued each year with furnaces, boilers and woodstoves being the most common choice of appliance upgrades (Energy Solutions Centre, 2014). Furthermore, the ESC estimates that nearly 28,000 tonnes of greenhouse gases have been displaced as a result of heating appliance upgrades (Energy Solutions Centre, 2014).

In the case of institutional operations a number of buildings have chosen to convert their heating systems from fossil fuels to biomass based systems. The Whitehorse Correctional Centre installed a wood-pellet boiler in 2011 and Dawson City also installed a biomass boiler to heat its wastewater treatment plant in 2012 (Government of Yukon: Energy, Mines and Resources, 2013). Further, commercial and institutional applications of biomass heating are being sought at this time with two

¹⁰ Personal Communication, *Government of Yukon Energy Branch*, July 2015

projects (the Elijah Smith and Hidden Valley Schools) currently undergoing feasibility analysis (Government of Yukon: Energy, Mines and Resources, 2013). Most recently, the GY released a draft biomass strategy for public comments in April 2015 to help facilitate a biomass energy sector. The YG Energy Branch is currently incorporating these comments into the final strategy to be released in the near future.¹¹

In addition the City of Whitehorse has completed two studies examining the potential of district heating in the community of Whistle Bend. A 2009 study funded in part by the Federation of Canadian Municipalities looked at collecting waste heat and utilizing ground source heat pump technology to help offset the heating load in the new community.¹² A follow up pre-feasibility study done in cooperation with YEC and Natural Resources Canada in 2012 looked at utilizing solar borehole thermal energy storage as a district heating option.¹³

2.3. Energy Conservation and Efficiency

As mentioned in previous sections, energy efficiency and conservation efforts are the cornerstone of the GY's short-term energy policy. Reasons for the focus are possibly the result of a number of unique characteristics of Yukon's overall energy system. First, although more buildings are using electricity as a source for their heat, the majority of Yukoners rely upon fossil fuels for their space heating needs. Efficiency and conservation efforts that can improve the usage of these fuels while also encouraging fuel switching will help reduce overall emissions for this subsector. With this in mind the GY, largely through the Energy Branch, Department of Energy, Mines and Resources, has decided to focus on the built environment for efficiency and conservation programs. The GY's Energy Branch offers a rebate for "energy assessments" (similar to energy audits) and delivers the *Good Energy Rebate* program. Both

¹¹ For more information on the GY's biomass strategy please see:
<http://www.energy.gov.yk.ca/Biomass-Energy-Strategy.html>

¹² For more information on the Whistle Bend district heating study please see:
<http://www.city.whitehorse.yk.ca/index.aspx?page=265>

¹³ For more information on the Whistle Bend district heating pre-feasibility study utilizing solar borehole thermal technology please see:
<http://www.whitehorse.ca/index.aspx?page=462>

programs aim to help consumers understand and lower household energy consumption.¹⁴ The recently announced *Good Energy Residential Incentives Program* also provides purchase incentives (\$10,000) for new homes that achieve an EnerGuide 85 rating and offers rebates for building retrofits that improve the airtightness and insulation of existing homes (Energy Solutions Centre, 2014). The Energy Branch also offers commercial incentive through the Good Energy Program.

Additionally, the Yukon Housing Corporation has developed an innovative building standard for homes in Yukon: the SuperGreen label. SuperGreen is not a standard per se. It is an endorsement that a certain residential building achieves a certain level of energy conservation performance. It provides an indication to home buyers interested in purchasing a high-performance house (i.e. over and above a minimum performance standard). A house can get the SuperGreen label when it is built according to strict construction and insulation standards (Government of Yukon, 2008). According to the Yukon Housing Corporation, a house that gets the SuperGreen label must have Energuide Home Rating of 85, which is exceptionally high and above the minimum standard of 82 in Whitehorse (also relatively high compared to other Canadian jurisdictions). However, there is no official support from the territorial government for the SuperGreen label and, according to the Energy Branch, no homes have received the label in recent years¹⁵.

When discussing the electricity sector it is important to note that the population of the Yukon is highly concentrated along the interconnected grid system with some 95% of the population living within communities that are connected (Yukon Bureau of Statistics, 2014). Combined with the dominance of hydro generation on the grid system the Yukon's overall electricity profile is markedly different from other northern jurisdictions such as Nunavut and Nunatsiavut in northern Labrador, that exclusively rely on fossil fuels for electricity generation in a number of isolated communities. Additionally, long-term planning for the interconnected system relies upon developing new hydro resources, and is evidenced by the GOY's 2013 *Yukon Hydroelectric Planning Directive*, which tasks the Yukon Development Corporation with planning hydro projects to meet long-term (20-50 years) needs (Government of Yukon, 2013). Due to YEC's hydro infrastructure, policy measures intending to decrease GHG emissions in the

¹⁴ Personal Communication, *Government of Yukon Energy Branch*, May 2015

¹⁵ Personal Communication, *Government of Yukon Energy Branch*, May 2015

electricity sector can be targeted towards mitigating the need for thermal generation. As a result, efficiency and conservation programs known in the utilities industry as Demand Side Management (DSM) were given prominent positions in a number of key electricity policy documents after the Yukon Utilities Board instructed the YEC and ATCO Electric Yukon to develop a territory wide conservation and efficiency policy paper in 2009 (ATCO Electric Yukon, 2014). YEC and ATCO Electric Yukon implemented a planning exercise that was more than expected by the Yukon Utilities Board and presented a full-on DSM plan: i.e. the 2013 Yukon Five Year Demand Side Management Plan (ATCO Electric Yukon, 2014).

A number of recent public and stakeholder engagement initiatives took place in Yukon in which policy makers, utilities, experts and individuals alike were able to voice their opinion including the GY's Energy Strategy, the 2011 Energy Charrette and the YEC's 20-Resource Plan.

In addition to these, in 2011, the two utility companies and the GY formed a steering committee and working group and commissioned a Conservation Potential Review (ICF Marbek, 2012), the results of which informed (among other policies and initiatives) the development of the aforementioned 2013 Yukon Five Year Demand Side Management Plan. According to this plan, the Utilities proposed to launch a DSM portfolio divided into two programs: residential (consisting of four program elements) and commercial (consisting of five program elements). According to that plan, the residential program were to include a mixture of rebate offerings (LED technologies and automotive heater timers), low-cost energy efficient product promotion (free energy efficient products such as low-flow showerheads and point-of-purchase information materials), as well as pilot projects such as cold climate and ground source heat pumps) and public engagement, feedback and education (ATCO Electric Yukon, 2014). The commercial program was to include building retrofit incentives (lighting re-design, refrigeration retrofits, electronic equipment efficiency upgrades) as well as construction incentives for new energy efficient builds and engagement, technical training for HVAC upgrades and operation and communication (ATCO Electric Yukon, 2014). These programs were to complement existing and new programs administered by two government agencies (the GY Energy Branch and Yukon Housing Corporation), such as those already mentioned in this document. The government programs, however, are funded through government budget while the Utilities' programs are funded by ratepayers and thereby are subject to approval of the Yukon

Utilities Board. The ratepayer funding for DSM, while common in Canadian Southern jurisdictions and was used in Nunavik and Nunatsiavut was new to Yukon.

The “novel” sources of funding for DSM in Yukon experienced an interesting setback. Only two program elements of the Utilities’ DSM plan (the LED rebate and the block-heater rebate) were granted funding by the Yukon Utilities Board (ATCO Electric Yukon, 2014), which looks over rate levels and how ratepayer funding is being used. All other program elements laid out in the plan were temporarily held back. Moreover, the Yukon Utilities Board only allowed one year worth of ratepayer funding for the two program elements. Rate-payer monies for the second year and onward, as well as additional funding for future DSM program elements may be approved by the Yukon Utilities Board at future utility general rate applications.¹⁶ Since availability of rate-payer funding for DSM is uncertain, the Energy Branch is considering funding conservation incentives targetting the same market segments through regular government funding and including them in the Good Energy Program.¹⁷

City of Whitehorse

Due in part to its title as capital of Yukon, as well as a very large share of Yukon residents calling the city home Whitehorse has played a unique role in driving the development of integrated energy planning and management. In 2008 Whitehorse developed a strategic sustainability plan with the aim of incorporating sustainability principles into all of its municipal operations and decision-making. A detailed energy management plan was developed in 2012, which sought to translate the strategy into implementable actions and ideas.¹⁸ A recently completed municipal building (the Emergency Management Building) is evidence of the strategies’ implementation and a second building is currently in the planning stages.¹⁹

¹⁶ See Section 7.1 for an explanation on what a general rate application is

¹⁷ Personal Communication, *Government of Yukon Energy Branch*, May 2015

¹⁸ For more information about the City of Whitehorse Energy Management plan please see:

<http://www.city.whitehorse.yk.ca/modules/showdocument.aspx?documentid=2939>

¹⁹ Personal Communication, *Government of Yukon Energy Branch*, May 2015

3. Northwest Territories Energy Overview

3.1. Electricity: System and Current Trends

The NWT electricity system, divided into a **Thermal Zone** and a **Hydro Zone**, can be thought of as two separate hydro systems and many different thermal systems. Most of these isolated, or ‘islanded’ (meaning that the energy is generated close to where the energy is being used) communities rely on diesel as a fuel source, although two communities use natural gas. Furthermore, a growing number of communities are turning to renewable energy options to reduce their dependency on conventional energy sources. These communities have different operational characteristics, load profiles and generation capacity. **Figure 2** below illustrates the multiple system concept showing the grid infrastructure dominated by hydro capacity in the North and South Slave regions (9 communities), and 23 individual thermal systems based on diesel elsewhere. Two communities, Inuvik and Norman Wells, are electrified via natural gas.

Figure 2 Northwest Territories Electrical System

Source: (NT Energy, 2013)

The North Slave system is primarily based upon hydro electricity provided by the Snare and Bluefish Hydro facilities (37 MW total capacity) and is transmitted via the Snare Grid to four communities (Yellowknife, Behchoko, Dettah and N'Dilo). Peak matching capacity for the Snare system is provided by thermal diesel generation (29 MW of installed capacity) to meet annual peak demand in the winter months when water flows are lowest (NT Energy, 2013). Like other Arctic jurisdictions, demand varies greatly throughout the year with peaks occurring in winter and lower demand throughout the summer months. Each year nearly 25% of available hydro capacity is discarded over spillways during the summer months (NT Energy, 2013). The North Slave region's annual peak is around 39 MW and annual demand is roughly 190 GWh (NT Energy, 2013).

The South Slave system is nearly 100% hydro based with power provided by the Talston Dam (18 MW capacity) with installed diesel generators (6.7 MW capacity) providing emergency backup to the communities of Hay River, Hay River Reserve, Fort Resolution, Fort Smith and Enterprise. The dam is oversized for the demand load (peak demand of 12.8 MW reached in 2012) of the Talston grid and, as a result, Northwest Territories Energy Corporation (NTEC) estimates that nearly 50% of the water available is spilled instead of being utilized for power production. Peak demand is reached in winter around 13MW and annual consumption is around 54 GWh (NT Energy, 2013).

There are 23 communities that comprise the majority of the Thermal Zone systems who rely upon local stand-alone diesel generators for the vast majority of their power supply. These individual systems have a diverse range of installed capacity (from 230 kW in Jean Marie River to 10.1 MW in Inuvik) but operate only within the local community and relying almost exclusively upon imported diesel as their fuel source. Each community scales its installed capacity to meet 100% redundancy, meaning that the installed facilities are twice the size of historical peak demands. This is done in order to ensure that a breakdown of a single generating unit does not result in a loss of electricity service to the entire community.

Finally, there are two communities, Norman Wells and Inuvik, who use natural gas in place of diesel fuel for electricity generation. In the case of Norman Wells, natural gas was used as a heating fuel for homes and buildings and also to generate the town's electrical power, which was purchased from the nearby oil field processing facilities owned by Imperial Oil (Campbell, 2014). Access to the resource for heating needs was recently ended as Imperial Oil began to re-organize its operations and use the natural gas to increase oil production in its depleting wells, though negotiations to extend access to electricity from the processing facility for a further five years are currently ongoing (Campbell, 2014).

The Mackenzie Delta region is home to very large natural gas resources estimated at roughly 5.7 trillion cubic feet by the National Energy Board (National Energy Board, 2014). However, because of the low continental prices of natural gas, exploration and drilling activities in high cost Arctic areas near Inuvik have been put on hold. Recently, Inuvik's two producing natural gas wells exhausted their reserves and Northwest Territories Power Corporation (NTPC) was forced in 2012 and 2013 to turn to diesel fuel to meet electrical needs (Northwest Territories Power Corporation, 2014). In 2013 NTPC began to

construct liquefied natural gas (LNG) storage facilities and today Inuvik's electricity supply is reliant upon LNG (Northwest Territories Power Corporation, 2014)

Solar PV has been developed in a number of communities in the NWT. As of March 2015, two large-high penetration solar PV projects are currently in operation in the communities of Colville Lake and Fort Simpson. The Fort Simpson system is 104 kW and was developed in two phases, first becoming operational in the spring of 2012 and expanding in the spring of 2013 (Northwest Territories Power Corporation, 2015). The Colville Lake system is 54 kW and has been in operation since October 2014 (Northwest Territories Power Corporation, 2015).²⁰ The Colville Lake array has incorporated battery energy storage into its design (Wohlberg, 2014). In addition to these community-scale projects, there have also been a number of household and individual building scale solar developments in the communities of Yellowknife, Sachs Harbour and Behchoko (Department of Environment and Natural Resources, 2011).

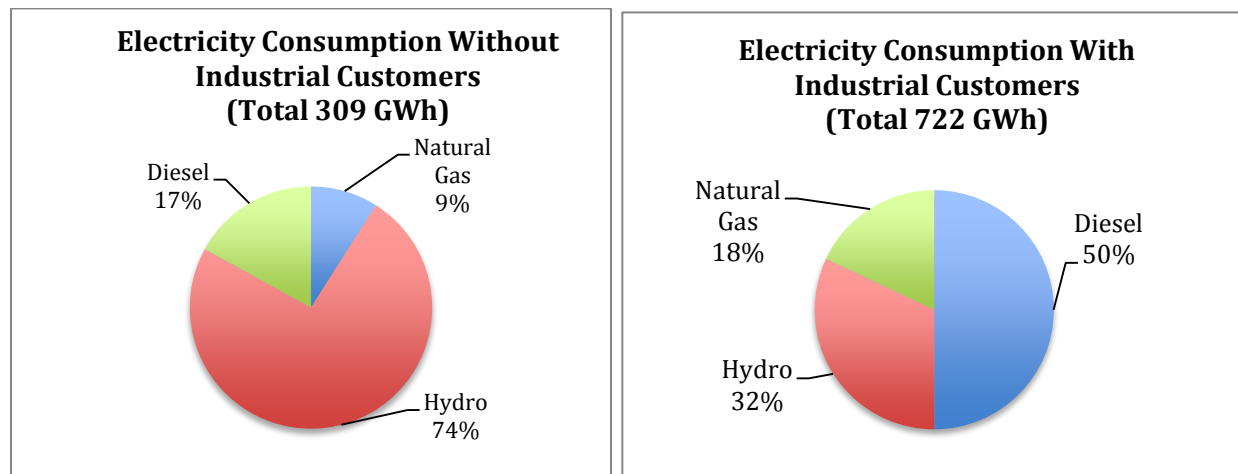
Depending upon the location of the community, the base rate charged by NTPC for electricity consumption fluctuates but is harmonized by the Government of the Northwest Territories (GNWT) through the Territorial Power Subsidy Program (TPSP). The TPSP subsidizes electricity rates for residential customers (up to 1000 kWh per month in winter and 700 kWh in summer) to align with prevailing prices in Yellowknife. The subsidy therefore equalizes rates between the thermal systems and the North Slave system, where the 2014 rate was 29 cents/kWh (Arctic Energy Alliance, 2014). After the allowable consumption level is exceeded rates increase dramatically between hydro and thermal systems. According to the Arctic Energy Alliance, rates for thermal zone communities more than double to 58.0 cents/kWh, while rates in the North Slave and South Slave systems remain relatively stable around 33.0 cents/kWh and 21.0 cents/kWh respectively (Arctic Energy Alliance, 2014). For commercial customers prices more accurately reflect the cost of generation within the community. In Thermal Zone communities, prices are capped at 50.0 cents/kWh. For customers in the North Slave system prices fluctuate between 21.0-30.0 cent/kWh with Yellowknife having the lowest rates, while customers in the

²⁰ It is important to note that while these two examples are relatively large they are still small when compared to the diesel systems serving each community. For instance the diesel system in Fort Simpson is roughly 3,200 kW, nearly 30 times larger than the installed PV system (NT Energy, 2013)

South Slave system pay between 17-26 cents/kWh, with Hay River having the lowest rates (Arctic Energy Alliance, 2014)

An important distinction to make with electricity trends in NWT is the effect that industrial consumers have on overall energy consumption. Within NWT, community-level electricity needs usually include residential, commercial, government and small industry consumers. Large industrial operations (mainly mining and oil and gas projects) consume significant amounts of electricity in their operations. In 2010 electrical demand doubled from 309 GWh to 722 GWh, when industrial loads are included (Government of the Northwest Territories, 2013). Figure 3 below is adapted from data in the GNWT's *Energy Action Plan* and shows the fuel mixture for electricity generation with and without industrial customers (Government of the Northwest Territories, 2013). It shows that diesel supply is not as essential for residential consumers as it is for industrial consumers with every mine in the NWT currently being served by diesel generators.

Figure 3 Electricity Consumption in the NWT in 2010



Source: (Government of the Northwest Territories, 2013, p. 10)

Industrial loads are often in isolated and remote areas and are usually supplied by generators set up by individual companies and are not included in general consumption figures published by the GNWT. While it is beyond the scope of this report to comment upon industrial electricity fuel choice it is worth noting that many of these operations have the same cost pressures faced by the GNWT when supplying isolated communities with diesel fuel to meet their electrical demands. These cost pressures have led some companies, such as RioTinto, to explore alternative electricity generation as a replacement for

diesel. For example Rio Tinto's Diavik diamond mine recently installed over 9MW of wind generation, providing a supply on average of 10% of the mine's total energy needs, to offset the costs of importing diesel fuel to its remote mine northeast of Yellowknife (Canadian Wind Energy Association, 2013).²¹

Recent Policy Developments

Policy Targeting Grid Systems: The most recent policy actions in the electricity sector are the result of a 2009 report entitled *A Discussion with Northerners About the Electricity System*. This document gathered a large number of viewpoints from across the NWT in order to inform a public debate about the future of the electricity system. Issues that attracted widespread attention included the high cost of electricity for consumers, moving away from diesel generation towards renewable and alternative fuel sources (though not at any price), encouraging conservation and increasing system reliability (Government of the Northwest Territories, 2009). Since the release of this foundational document large-scale planning initiatives by NTEC have focused on maximizing the benefits of the NTPC's legacy hydro infrastructure, as well as looking for new opportunities to expand hydro development.

In November 2012, the GNWT held their first Energy Charrette, which helped to inform the NWT 2013 Energy Plan and the NWT Power System Plan by NTEC. The 2012 Power System Plan report produced by NTEC examined the possibility of interconnecting the Snare and Talston grids, as well as intertying²² with southern grid systems in Alberta, Saskatchewan and possibly Manitoba (NT Energy, 2013). After initial studies in 2013 the high capital costs for new hydro plants and associated transmission infrastructure that would be needed for interties was seen as unviable in the short to medium term. The interconnection of the Talston and Snare system was initially seen as a way to provide dual resilience to each system without having to resort to diesel;²³ however, once technical feasibility studies were completed it was determined that the costs of transmission expansion would be uneconomic without outside sources of funding or major new load commitments by industrial customers. These large capital

²¹ For more detailed information please see: <http://friendsofwind.ca/building-a-wind-farm-in-arctic-conditions-rio-tintos-diavik-mine/>

²² Intertie: is the physical connection of separate electrical grids allowing for the exchange of power between the two systems.

²³ (Miltenberger, 2014)

and transmission costs as well as events outside of government and utility control have caused policy priorities to shift.

For instance, 2014 was a challenging year for government and electrical companies of Northwest Territories. A dry spring and summer led to a record year for forest fires in the NWT, pushing government spending eight times above its allocated budget to fight the blazes; with some suggesting that while these forest fires occur cyclically, climate change is exacerbating their magnitude (CBC News, 2014) (Flannigan, Cantin, de Groot, Wotton, Newbery, & Gowman, 2013). Additionally, low water flows for the Snare hydro system that same year led the NTPC to request a general rate increase of 13% to help cover additional diesel costs required to meet power needs (R. Marshall and Associates , 2014). The GNWT provided a \$20 million subsidy in September 2014 to prevent this rate increase due to opposition from residents and municipalities. Some residents feel this subsidy represented a ‘lost opportunity’ to support other forms of power, such as renewable energy (Wohlberg, 2014).

Overall, these most recent pressures brought the costs of electricity services to the forefront of GNWT policy making, and resulted in a second Energy Charrette in November 2014 with the goal of identifying immediate and short-term potential actions to help consumers cope with higher energy costs (Government of the Northwest Territories, 2014).²⁴ Key outcomes from the 2014 Energy Charrette include focusing on affordability when making energy planning decisions, being more aggressive promoting energy efficiency and conservation programs in thermal communities, finding ways to use excess hydroelectricity from the Talston grid, continuing to consider community and regional scale energy supply projects where economically feasible and are under discussion with territory residents as the government prepares its response (R. Marshall and Associates , 2014). These near-term cost pressures as well as initiatives undertaken since the release of the GNWT’s greenhouse gas strategy in 2011 have brought a number of renewable and alternative energy technologies into focus.

²⁴ The Energy Charrette planning process has now been used twice in Northwest Territories as a way to collaboratively discuss and develop energy policy priorities. For more information about the Charrette process and energy policy governance in the Arctic more broadly please see Appendix 1

Renewable Electricity Policy

The *Greenhouse Gas Strategy for the Northwest Territories 2011-2015* outlined the overall approach that the GNWT is taking to combat climate change and introduced steps for increasing renewable electricity generation through hydro, wind, solar, geothermal and biomass power (Department of Environment and Natural Resources, 2011). These initial priority areas provided a foundation for further policy developments, which includes strategic directives to develop the market for solar energy technologies, programs to measure and map wind resources, examining the use of biomass as a fuel option, as well as a proposal for geothermal in Ft. Liard.²⁵ Additionally, a requirement for NWT communities to craft community energy plans (in order to access funds from the federal gas tax) also had the effect of bringing local energy consumption, policies and planning to the fore of local political concerns.²⁶ The non-governmental organization Arctic Energy Alliance (AEA) has played an important role in assisting NWT communities in determining their energy profiles, identifying energy savings opportunities, etc. through various activities including developing community energy profiles and plans, conducting energy audits and yardstick audits, etc.; AEA also plays an important role in energy policies and programming in the NWT overall. AEA was established as a not-for-profit organization in 2000, and “helps communities, consumers, producers, regulators and policymakers to reduce the costs and environmental impacts of utility services in the Northwest Territories” and is funded primarily by the GNWT (Arctic Energy Alliance, 2015)²⁷.

The *Northwest Territories Solar Energy Strategy* released in 2011, aims to increase the usage of PV arrays in NWT communities to offset diesel generation. Related to this strategy was the development of two community-scale PV projects (discussed in the previous section) in Fort Simpson and Colville Lake, as well as further developments such as the recent solar independent project in Lutselk’e (see Section 8.1.3). However, interest in solar technologies has not been limited to large, community scale projects. Individual solar projects have been under development in the NWT since the early 2000s with small-scale

²⁵ For further information please see the *Northwest Territories Solar Energy Strategy 2012-2017* and the *Northwest Territories Biomass Strategy 2012-2015*

http://www.nwtclimatechange.ca/sites/default/files/Solar_Energy_Strategy_2012-2017_0.pdf
http://www.nwtclimatechange.ca/sites/default/files/Biomass_Energy_Strategy_2012-2015_1.pdf

²⁶ Outlet, *Focus Group Interview*, November 2014

²⁷ For more information about the Arctic Energy Alliance and its activities please see Appendix 1.

arrays being deployed on residences and community owned buildings in many different locations across the territory. While early projects often relied upon the work and expertise of individual technology proponents (both inside and outside the government) for their development, more recent projects are self-initiated and often have diverse rationales.²⁸ For instance, some individuals and outdoor adventure lodges that are not connected to the two hydro grid systems have mentioned the desire to cut down on costly diesel generation as well as enhancing their own electrical reliability as reasons to install solar arrays (Vela, 2012). Similarly, institutional and commercial customers installing PV systems have noted the high cost of electrical power as a reason for their decision to move towards self-generation.

With respect to wind power, strategies for monitoring and measuring wind resources in diesel generation communities commenced in the early 2000s in conjunction with the Aurora Research Institute (ARI) and the Ministry of Environment and Natural Resources. Strong wind resources were found in the Beaufort Delta region with the communities of Sachs Harbour, Ulukhaktok and Paulatuk being of particular interest (Pinard, 2007).²⁹ A wind pilot project for the community of Tuktoyaktuk was proposed in 2007 but construction has not yet gone ahead.³⁰ In addition, a feasibility study prepared for the ARI, for the community of Fort Providence also looked at wind generation to help decrease the town's reliance upon diesel generation. This study determined that the town's wind resources were poor and recommended against further development (Pinard, Maissan, & Trimble, 2014). A significant barrier to any wind development project in the NWT (and northern jurisdictions more broadly) is due to scale. Many remote communities that would be interested in developing wind resources have very small load profiles, and, therefore cannot benefit from economies of scale that exist when developing larger wind installations.³¹ Additionally, capital costs and repairs to turbines in the North are much more costly than in the rest of Canada (due to design requirements in permafrost, shipping and lack of available equipment

²⁸ (Carpenter, Focus Group Interview, 2014)

²⁹ Pre-feasibility studies for wind resources in these communities can be viewed at <http://www.nwtclimatechange.ca/content/wind>

³⁰ A conference discussing wind energy in remote Arctic communities was also held in Tuktoyaktuk in 2007. The conference proceedings summary report can be viewed at <http://www.nwtclimatechange.ca/sites/default/files/Wind-Energy-Conference-Proceedings-Report-March-2008.pdf>

³¹ Sparling, *Focus Group Interview*, 2014

locally—including cranes for bigger turbines).^{32,33} For instance, the GNWT drew from this \$20 million fund to fix a turbine from their Snare hydro system, costing over \$1.6 million³⁴. Training on how to maintain and operate wind turbines in the North is a need that has also been identified.³⁵ That being said, Section 8 examines the use of smaller scale reused wind turbines that are more mobile, easier to install and that work at smaller scales of production in Yukon, which could be worth exploring further, as it tends to be better suited to northern climates and communities (e.g. operate at smaller scales; less reliant on large scale equipment for installation).

Resource studies carried out by the GNWT show that the NWT is home to substantial potential geothermal resources. The communities of Fort Liard, Fort Providence, Fort Simpson and Hay River were noted to have especially strong resource potential and it was recommended that further studies should concentrate on these areas if geothermal development was to be pursued in the NWT (EBA Engineering Consultants Ltd., 2010). In 2008 a project was initiated by a private developer in the community of Fort Liard whom proposed to build a 700-1000 kW combined heat and power plant (Thompson & Dunn, No Date). In cooperation with the Acho Dene Koe First Nation, and backed with funding from the Federal Government's Clean Energy Fund housed within Natural Resources Canada (NRCan)³⁶, Borealis initiated discussions with the GNWT and NTPC to secure a power purchase arrangement, along with additional funding, to develop the project but could not overcome a number of technical and financial barriers (Holroyd & Dagg, 2011). Specifically, the overall costs of drilling geothermal wells (estimated to be about \$8 million per well drilled) and the inherent risks (e.g. the well missing the target resource) provided too much uncertainty and the project was discontinued in 2013.³⁷

Other than the GNWT, project funding comes from a number of different sources. For example, the federal government (Aboriginal Affairs and Northern Development Canada) offers funding through the ecoENERGY for Aboriginal and Northern Communities Program (EANCP). EANCP has provided over \$1.8 million in funding to renewable energy projects in NWT since 2007 (to present), supporting such

³² Anonymous, *Focus Group Interview*, 2014

³³ Sparling, *Focus Group Interview*, 2014

³⁴ <http://www.cbc.ca/news/canada/north/broken-turbine-repaired-at-n-w-t-snare-lake-hydro-plant-1.3000016>

³⁵ Sparling, *Focus Group Interview*, 2014

³⁶ <http://www.nrcan.gc.ca/energy/funding/current-funding-programs/cef/12410>

³⁷ Anonymous., *Personal Interview*, December 2014

projects as the solar project at Colville Lake, a wind installation in Tuktoyaktuk (that has so far not gone ahead), and a rooftop solar array on the local arena in Fort Providence (Aboriginal Affairs and Northern Development Canada, 2015).³⁸ Additionally, the Federation of Canadian Municipalities (FCM)'s Green Municipal Fund has provided \$252,000 in funding to community sustainability projects to communities in NWT since 2005 (Federation of Canadian Municipalities, 2015). The Federation of Canadian Municipalities has also contributed funding to the City of Yellowknife's community energy plan, as well as a geothermal district heating feasibility study for the city (Federation of Canadian Municipalities, 2015). While these programs have been important for cost sharing of renewable energy projects the GNWT has provided funding for the largest number of renewable energy projects.

The GNWT's central policy platform for smaller scale renewable projects is the *Alternative Energy Technology Program* (AETP) funded by the GNWT but administered largely through the Arctic Energy Alliance. The AETP is a three-pronged approach to developing alternative energy technologies for residential, commercial and community scales. Individuals or organizations applying under the residential or commercial designation are eligible for funding to cover up to one third of the cost of deploying wind, solar or in-stream/micro-hydro technologies (Arctic Energy Alliance, 2014). The community level program is funded by the GNWT through the *Community Renewable Energy Program* and is administered through the ENR. Electricity generating technologies qualifying for this program include PV and wind systems as well as wind monitoring and measuring programs and are eligible for up to one half (maximum \$50,000/year) of funding (Department of Environment and Natural Resources, 2014).

Finally, renewable electricity projects in the NWT may be eligible for net-metering administered by NTPC. Net-metering allows individuals, businesses and communities to receive credit for the electricity they produce that is sold into the electricity grid. The credit is then subtracted from future electricity consumption charges, (Northwest Territories Power Corporation, 2014). Notwithstanding the success of these territorial programs there have been difficulties and challenges along the way. The overall cost of GNWT incentive programs has been a continual challenge since their inception. The cost of renewable

³⁸For a complete list of funded projects throughout Canada please see the ecoEnergy for Aboriginal and Northern Communities Program website at <https://www.aadnc-aandc.gc.ca/eng/1334855478224/1334856305920#yr2> and <https://www.aadnc-aandc.gc.ca/eng/1314215496845/1314215722851>

energy projects in the NWT differs significantly depending on whether the project is located within a thermal zone or hydro zone community.

Alternative Electricity Policy

The final alternative option for electricity production that has been considered is to convert existing diesel generators to operate on LNG. LNG has the benefit of having lower overall GHG emissions than diesel fuel and the overall economic costs are an improvement upon diesel refurbishment (NT Energy, 2013). Additionally, newer diesel generators are adaptable and can burn a mixture of LNG and diesel (NT Energy, 2013). The recent conversion of Inuvik's diesel facilities to LNG, show that the technology has interest from utilities in the NWT.

3.2. Space Heating: Fuels and Trends

Space heating needs in the NWT follow similar seasonal fluctuations as electricity demand. The number of heating days varies, however, across the NWT with some far north communities having nearly 25% higher demand than southern communities (NTEC, 2012). Space heating fuels are uniform across the NWT, and are mostly comprised of different petroleum products with heating oil being the most common fuel source. In Inuvik a mixture of propane and air known as synthetic natural gas (SNG) is being used to meet heating needs while local utility Inuvik Gas is keeping the option open of using LNG in the future (Inuvik Gas, 2014). Similar to diesel for electricity generation almost all of the petroleum products used for heating are sourced outside of the NWT and need to be imported to communities in bulk shipments. Subsequently, the cost of heating oil rises with the level of isolation from major municipal hubs. For instance residential customers in Yellowknife pay \$1.28/litre for heating oil while residents in Wekweeti, 200km northeast of Yellowknife, pay \$1.90/litre (Arctic Energy Alliance, 2014). In addition to petroleum, biomass in the form of cord wood and wood pellets are also important fuel sources for space heating needs, comprising roughly 14% of the total demand (Department of Environment and Natural Resource, 2011).

Recent Policy Developments

Due to the high cost of heating oil, space heating has been a major policy focus in recent years. The GNWT advanced a number of policies promoting fuel switching for heating appliances, and in partnership with municipalities has developed systems using residual heat from electricity generation and looked into the application of district area heating systems in municipalities. Community energy plans that incorporate district and residual heating have become a focal point for the GNWT. In 2005 the GNWT signed a nine-year agreement with the federal government to transfer federal Gas Tax Revenues for community funding (Department of Municipal and Community Affairs, 2009, p. 5). As a prerequisite to accessing these funds communities were given the task of developing energy plans that would allow for targeted infrastructure funding that is environmentally responsible, supports the local economy and improves quality of life (Department of Municipal and Community Affairs, 2009). In some cases communities developed their plans independently, but in others the AEA and the GNWT formed partnerships with communities and assisted them in the planning process.³⁹ As of 2010 all 33 communities in the NWT had completed energy plans, which allowed them all to access the community funding.

Fuel switching has been promoted since the release of the GNWT's *Greenhouse Gas Strategy* with biomass (wood pellets and waste wood) being identified as the preferable fuel source for displacing fossil fuel usage (Department of Environment and Natural Resources, 2011). The 2012 *Northwest Territories Biomass Energy Strategy* further promoted biomass and identified a number of different priority areas for expanding biomass usage in the NWT. One such initiative was the expansion of biomass usage in GNWT-owned buildings in the hope of stimulating demand in the residential and commercial building sectors. Private and public sector actors have since supported these policy initiatives in a number of different ways. Officials from the GNWT noted that many of the initiatives were pursued with the goal of building a local biomass market in the NWT.⁴⁰ The AEA has become a key actor in biomass uptake in the NWT. Not only does the AEA administer the Alternative Energies Technology Program (AETP), which

³⁹Partnerships were developed mainly due to a lack of dedicated personnel in many isolated communities. Anonymous, *Personal Interview*, December 2014

⁴⁰ (Miltenberger, 2014)

offer rebates for biomass fuelled boilers, the organization has also undertaken a number of studies that have examined supply chain options for wood pellets, district heating for community-level projects, and produced information guides for residential customers contemplating switching to biomass fuels. Individual proponents have also been instrumental in introducing and championing biomass technologies in NWT communities. One such proponent has spent nearly seven years developing a completely NWT-sourced wood pellet-processing mill near the village of Enterprise. Once in operation (circa 2015) the mill is expected to provide an annual output between 40-60 tonnes of wood pellets for consumption in the NWT⁴¹ and another 150-170 tonnes exported outside of the territory (Church, 2014). Similarly, early fuel switching projects in City of Yellowknife buildings involved proponents guaranteeing heating cost reductions with biomass boilers and offering to assume the financial risk if the projects would cost more than fossil fuel based options.⁴² Despite these successes, there have still been challenges to the adoption of biomass in other areas of the NWT.

To date much of the biomass consumed in the NWT is sourced from B.C and Alberta, which has presented constraints for reaching isolated communities in more remote areas of the territory outside of the South Slave region. Additionally, some early adopters have noted that the extra maintenance needed for pellet boilers when compared with fuel oil boilers has been a barrier.⁴³ However, officials with the City of Yellowknife have noted that increased educational campaigns and a greater diffusion of biomass technologies throughout the community are helping to overcome these initial challenges.⁴⁴ Project demonstration, financial de-risking by project proponents and information dissemination have all helped to grow the biomass market in the NWT.

In addition to biomass, solar heating technologies are supported through GNWT policy initiatives. Solar thermal heating for hot water has been deployed on community owned buildings in a number of communities and is being promoted on newly-designed buildings (Department of Environment and Natural Resources, 2011). Similarly, solar air heating systems have been deployed on six buildings around the NWT. Solar air systems pre-heat outdoor air before it enters a building's heating and

⁴¹ (Miltenerberger, 2014)

⁴² Anonymous, *Personal Interview*, January 2015

⁴³ Anonymous, *Personal Interview*, January 2015

⁴⁴ Anonymous, *Personal Interview*, January 2015

ventilation system, helping to lower overall heating costs. A 2011 report for the AEA in collaboration with *NSERC Smart Net-Zero Energy Buildings Strategic Research Network* noted the promise of solar air heating systems for reducing space heating costs in the NWT. Unfortunately, the report also showed that current solar air heating applications in the NWT suffer from a number of problems including improper orientation and a general lack of maintenance and monitoring that has so far prevented the measurement of the performance of these projects (Chen, 2013). The report recommends that future applications of the technology include robust monitoring systems to confirm the future suitability of the technology for deployment in the NWT.

In addition to individual technological applications, community scale systems have also been developed for meeting space heating needs. As was discussed earlier, the use of residual heat is an option for many communities. Residual heat from diesel electricity generation is used as a space-heating source in a number of communities including Fort Simpson, Fort Liard and Whati, in partnership with NTPC (ITI, 2014). Additionally, Fort McPherson has developed a district heating system using a biomass boiler as its heat source and will be discussed in detail in Section 8.3 of this report.

3.3. Energy Conservation and Efficiency

Similar to Yukon, energy efficiency and conservation has been a priority in the NWT for a number of years due in part to the high cost of electricity and heating. Commitments to energy efficiency can be traced back to the GNWT's initial *Greenhouse Gas Strategy* released in 2001 (Department of Environment and Natural Resources, 2011). Renewed commitments were made under the 2011 *Greenhouse Gas Strategy*, the 2013 NWT Energy Action Plan and were highlighted as an immediate priority that should be aggressively pursued during the 2014 Energy Charrette (R. Marshall and Associates, 2014). The discussions at the Energy Charrette noted that expanded delivery of energy efficiency programs and enhanced support should be top priorities for thermal zone communities. Responsibility for delivering energy efficiency programs falls largely to the AEA for residential and commercial projects, as well as to the ENR through a jointly administered program for community scale projects. The Department of Public Works and Services is the lead agency for incorporating efficiency measures in government-owned projects. The NWT Housing Corporation also operates energy efficiency

rebate programs for private and public housing retrofits. Programs under both departments are mainly for existing building upgrades as well as product replacement.

Residential and Commercial Programs

The AEA administers a number of energy efficiency programs including the Energy Efficiency Incentive Program (EEIP), which is designed to offer rebates for the purchase of energy efficient products such as: LED light bulbs, building envelope products such as insulation and air sealing services, refrigerators, freezers, heat water recovery systems, and heating appliances (Arctic Energy Alliance, 2014).⁴⁵ While the program scope is broad, energy sector professionals noted that energy efficient product uptake has been a continual problem for the rebate programs.⁴⁶ A suggestion was put forth during the 2014 Energy Charrette discussions that a more aggressive concentration on thermal communities should be a priority as the energy savings would result in offsetting costly imported diesel fuel.

Similar to the EEIP, the Commercial Energy Efficiency and Conservation Program targets businesses in the NWT. A “*Yardstick Audit*” service is provided by the AEA to clients who are then eligible for rebates up to a maximum of \$15,000, one third of the eligible cost, or five times the estimated annual money saved (Arctic Energy Alliance, 2014) to carry out recommended measures. In addition to the funding programs, the AEA also administers energy audit programs for commercial and residential buildings and conducts educational campaigns about energy services and the efficient use of energy.

The final financial program administered by the Department of Environment and Natural Resources is the Energy Conservation Program, designed for institutional projects owned or leased by community/Aboriginal governments, agencies/boards and non-profit groups. These projects must reduce the use of electricity, heat energy, and water or be a study/activity that leads to future conservation projects and provides funding up to a maximum of \$50,000 (Department of Environment and Natural Resources, 2009).

⁴⁵ For more information and a complete list of the products covered under the **Energy Efficiency Incentive Program** please see <http://aea.nt.ca/programs/energy-efficiency-incentive-program>

⁴⁶ Anonymous, *Personal Communication*, November, 2014

Institutional Programs

The Department of Public Works and Services (PWS) is responsible for increasing the energy efficiency of GNWT owned buildings and spaces. The PWS has engaged in a number of projects targeting efficiency upgrades in everything from lighting and ventilation to building envelope and heating control installations (Department of Public Works and Services, 2014). Additionally, some of the largest projects undertaken by PWS in recent years have involved the replacement of heat generators in publicly owned buildings.⁴⁷ PWS has also carried out a number of residual heat projects in schools in Fort Liard, Whiti and Fort McPherson (Department of Public Works and Services, 2014). Similarly, the PWS has been instrumental in deploying biomass-based heating systems in a number of institutional settings including the North Slave Correctional Facility and the Legislative Assembly Building in Yellowknife (Department of Public Works and Services, 2014). Finally, in the 2011 Greenhouse Gas Strategy, the NWT Housing Corporation committed to carry out energy efficiency retrofits for public housing units in the territory (Department of Environment and Natural Resources, 2011).

Energy Efficiency Building Codes

The NWT Housing Corporation and the City of Yellowknife have undertaken a number of efforts in advancing energy efficiency requirements for newly constructed buildings. In 2012 the City of Yellowknife passed a by-law that mandated all new residential homes and multi-family units reach a minimum score of EnerGuide 80, and commercial, institutional and industrial buildings reach a minimum energy efficiency target that is 25% greater than National Model Energy Code of Canada for Buildings for 1997 (City of Yellowknife, 2012). This same standard was adopted by the NWT Housing Corporation as well as the GNWT for its own new buildings.

⁴⁷ For a complete list of projects completed by the Department of Public Works and Services as well as plans for future projects please see http://www.pws.gov.nt.ca/pdf/publications/2014%20PWS_ECP%20ANNUAL%20REPORT%20WEB.pdf

4. Nunavut Energy Overview

4.1. Electricity: System and Current Trends

Nunavut is the largest geographical jurisdiction in Canada, totaling two million square kilometers (1.9 million of land) with a population of 36,687 people, the vast majority (81%) of whom are Inuit (Nunavut Bureau of Statistics, 2014). Residents of Nunavut live in 25 communities spread across the territory. Communities are not connected via ground transportation and as a result air and marine travel is relied upon exclusively to transport goods and materials into each municipality. Additionally, all 25 communities in Nunavut lie above the Arctic tree line, where the primary geographical features are limited to Canadian Shield and Arctic tundra. Nunavut's energy system is completely dependent upon imported fossil fuels to meet the territory's energy needs, costing the Government of Nunavut and its related parties upwards of \$300 million in 2012/2013 (Government of Nunavut Energy Secretariat, 2014). Both electricity generation and space heating needs are met exclusively with fossil fuels while transportation fuels account for roughly 36% of the total amount of fossil fuels consumed in Nunavut (Government of Nunavut Energy Secretariat, 2014).

Unlike Yukon and NWT no centralized grid system exists in Nunavut. The vast distance between communities made interconnections unfeasible, and as a result Qulliq Energy Corporation (QEC) operates 26 stand-alone power systems sized to meet the demands of each municipality. Each of these systems is reliant upon imported diesel fuel for generation, with fuel purchases accounting for over half of QEC's revenue requirements throughout the year. Diesel fuel for electricity generation is purchased from the Government of Nunavut's Petroleum Products Division (PPD) at different times throughout the year. Roughly half of the fuel is purchased and stored by QEC in their own facilities upon delivery by barge from southern Canada and allows QEC to pay "off the boat" prices reflective of overall global oil supply and demand (Qulliq Energy Corporation, 2011). The other half is purchased from the PPD who stores the fuel in their storage facilities throughout the year on an as needed basis. In the 2012/2013 fiscal year 48.018 million litres of diesel fuel was estimated to be consumed in electricity generation according to the

1014/15 GRA, which the Energy Secretariat estimates cost QEC approximately \$49.5 million (Qulliq Energy Corporation, 2013). (Qulliq Energy Corporation, 2013)⁴⁸

Electricity rates in Nunavut are some of the highest rates in North America and largely reflect the cost of thermal generation in isolated communities. In charging customers for their consumption, QEC has developed four rate classes, dividing the typical residential and commercial classes into government and non-government. Rates for non-government residential customers range from a low of 60.29 cents/kWh in Iqaluit to a high of \$1.14/kWh in Kugaaruk before subsidies are accounted for. (Qulliq Energy Corporation, 2014). For commercial customers rates are generally lower on average, but vary significantly between communities from a low of 50.86 cents/kWh in Iqaluit to a high of \$1.11/kWh in Whale Cove (Qulliq Energy Corporation, 2014). The GN operates a number of subsidy programs that help to bring down the high cost of electrical power for Nunavut residents.

The Nunavut Electricity Subsidy Program was implemented in 2005 and provides a rate subsidy to residential and commercial customers capped at specified consumption amount prevalent upon the time of year (Government of Nunavut, 2005).⁴⁹ The subsidy is calculated at 50% of the residential rate in Iqaluit. In 2014/2015 the base rate in Iqaluit was 60.29 cents/kWh, which corresponds to a 30 cents/kWh subsidy to all customer classes in communities outside the capital. In addition to this territory-wide subsidy, Nunavut residents who live in public housing and those who access the Income Support Program (provided by the GN to low-income individuals and families to help cover basic needs) also receive subsidies to their electrical consumption. Similarly, electrical rates for public housing residents are capped at 6.0 cents/kWh regardless of consumption through the Public Housing Power Support Program paid for by the NHC (Qulliq Energy Corporation, 2014). This dramatically subsidized rate is onerous for the government of Nunavut when one considers that 52% of all housing in Nunavut are public housing units. Similarly, the number of Nunavummiut that access income support programs is around 14,000 with

⁴⁸ (Pye, Personal Correspondence, 2015)

⁴⁹ For residential class customers the rates are differentiated based on the time of year. During the April – September billing cycle the first 700 kWh per month is subsidized, while during the October-March billing cycle the first 1000 kWh is subsidized. For commercial enterprises with less than \$2 million in sales the first 1000 kWh per month (regardless of time of year) is subsidized. If customers consume beyond these allowances they pay the prevailing community rates set by the Utility Rate Review (Government of Nunavut, 2005).

these programs containing indirect subsidies to electricity usage (CBC News, 2014); (Government of Nunavut Energy Secretariat, 2014)

Power demand per capita has been relatively stable in recent years. However, over the same time Nunavut has seen rapid population growth with the number of residents increasing from just over 30,800 in 2006 to 36,585 estimated residents in 2014 (Nunavut Bureau of Statistics, 2014). In its 2011-2016 Corporate Plan, QEC identified rapid load growth as one of the most significant pressures on its operations (Qulliq Energy Corporation, 2011). QEC also estimates that load growth in Nunavut will be around 2.0-2.5% per year with the Iqaluit region growing closer to 4-5% (Qulliq Energy Corporation, 2011). Preparing for new load growth and managing its fleet of aging power plants will be a major challenge for QEC over the next decade (Qulliq Energy Corporation, 2013).

Recent Policy Developments

Despite establishing the goal in *Ikummatiit*, The Government of Nunavut's Energy Strategy, to reduce fossil fuel use, little progress has been made in operationalizing this goal. Feasibility studies were completed for a hydroelectric development for Iqaluit at Jayne's Inlet southwest of Iqaluit along Frobisher Bay. However, the small load profile of Iqaluit and the high capital cost of the project (estimated at \$200 million including transmission infrastructure) would have exceeded the GNs federally imposed debt cap and the project was postponed indefinitely in 2013.⁵⁰ Recent capital budget plans developed by QEC focus heavily on refurbishment and expansion of existing diesel generators and in some cases replacing older generators with newer versions (Qulliq Energy Corporation, 2011).

The reasons behind the continued reliance on diesel power generation systems in Nunavut are multi-faceted. Participants in focus group discussions noted that the GN and QEC are reluctant to look beyond familiar and reliable generating technologies. QEC for its part sees "keeping the lights on" as its primary mandate,⁵¹ a mandate that diesel generation (despite its financial and environmental costs) is suited for as

⁵⁰ Anonymous, *Focus Group Interview*, 2014

The federal debt cap limit is to protect the federal government in case of a default as the Government of Nunavut, which is technically a legal entity of the federal government. Similarly, the federal government views Qulliq Energy Corporation as a legal entity of the Government of Nunavut so its corporate debt structure is indistinguishable from the Government of Nunavut (McDonald & Pearson, 2012)

⁵¹ Anonymous, *Focus Group Interviews*, 2014

evidenced by QEC's power reliability rating of 99.84% in 2012/2013 (Qulliq Energy Corporation, 2013). Similarly, the GN is pressured on a number of competing policy fronts. Spending on energy technologies must compete with other acutely important policy areas such as housing, health and education. The financial commitments needed to demonstrate, test and then deploy new renewable technologies were recognized as a large barrier in Nunavut.⁵² Past experiences with technologies also impacts how current initiatives are initially perceived especially in the case of Nunavut where previous negative experiences (such as an abandoned wind turbine still seen in Cambridge Bay) with renewable technologies may have darkened the public's perception of these types of projects in general. Because of this, it is important to foster a group of 'project champions', providing them with a sense of 'ownership' and responsibility towards these projects to ensure that projects are not dependent on a single individual for success.

Additionally, Nunavut currently does not have a net-metering program for individuals to receive credit for the power they produce, which was seen as a barrier to renewable energy deployment. An official from the GN noted that a net-metering policy and interconnection guidelines are currently under development and is expected to be unveiled in 2015.⁵³ Additionally, the recent rollout of a smart-meter program in Iqaluit has the potential to streamline the technical deployment of renewables when combined with the new net-metering policy.

Despite these obstacles, a few small solar projects have been developed and have received funding from the federal government. Examples include the construction of solar PV arrays on the Nunavut Arctic College in Iqaluit in 1995, which has operated successfully producing roughly 2,600 kWh of electricity per year (Poissant, Thevenard, & Turcotte, 2004). This project was financed in part through a Natural Resources Canada study looking at PV technology performance in high Arctic conditions. The Federal Government's ecoEnergy for Aboriginal and Northern Communities Program has also provided funding for a PV project on the Arviat community centre, and for a small PV project for a community freezer in Kugaaruk (Aboriginal Affairs and Northern Development Canada, 2015). The GN has seen some success with solar hot water and solar thermal projects in its buildings (Appendix 2).

⁵² Anonymous, *Focus Group Interview*, 2014

⁵³ Anonymous, *Focus Group Interview*, 2014

4.2. Space Heating: Recent Trends

Space-heating needs in Nunavut are met exclusively from imported fossil fuels; primarily heating oil and diesel fuel. In 2012/2013 households, businesses and government-owned consumers used over 66 million litres of fossil fuels for heating, at a cost of roughly \$73million.⁵⁴ These figures represent a drastic increase from 2008/2009 figures, when nearly 60 million litres of fuel were consumed at a cost of over \$67 million.⁵⁵ Overall, space heating fuels comprise 38% of the total amount of fossil fuels used in Nunavut, roughly the same as the amount used in transportation (Government of Nunavut Energy Secretariat , 2014). Heating fuel demand has been driven primarily by population growth, which has resulted in an overall increase in the number of buildings constructed and occupied, with the largest growth occurring in Iqaluit.

Recent Policy Developments

All Nunavut communities are located north of the tree line and the option of using biomass products, such as wood pellets or even cord-wood, is prohibitively expensive for Nunavummiut. While Nunavut has an estimated 9.5 trillion cubic feet of conventional natural gas, exploration and development of these resources are still in the pre-feasibility phases.⁵⁶ Because of these circumstances many recent policy options have focused on a few select technologies and programs. Conservation and efficiency policies will be discussed in detail below but the usage of solar thermal technologies (both passive and active) have recently been deployed to reduce space-heating needs.

The inclusion of heat recovery ventilators (HVRs) in roofing designs have become more common in recent years, as have improvements to overall building envelope design and the usage of EnergyStar rated windows and doors. Additionally passive solar design has been incorporated into model housing projects completed between the Nunavut Housing Corporation (NHC) and the Canadian Mortgage and Housing Corporation. A recent large-scale implementation of many of these changes can be found in the Plateau Subdivision of Iqaluit.

⁵⁴ Pye, A., *Personal Communication*, 2015

⁵⁵ Pye, A., *Personal Communication*, 2015

⁵⁶ Pye, A., *Personal Communication*, 2015

New design parameters for energy efficiency were adopted in 2010 with the unveiling of the Facility Energy Efficiency Review (FEER) program which is applicable to all new Government of Nunavut owned buildings constructed in Nunavut. The FEER program subjects each new building design to a detailed review to ensure that cost effective measures are being taken to reduce energy usage and costs (Department of Community and Government Services, 2010).

In addition to more energy efficient projects for Nunavut buildings and homes underway, residual heat from power plant operations has also been a focus area in Nunavut. Residual heat usage has a long history in Nunavut, and has been used to heat GN owned buildings in several communities (Cambridge Bay, Pelly Bay, Sanikiluaq and Rankin Inlet) since the early 1990s (Nunavut Power Corporation, 2002), although some are no longer in operation. More recent examples of completed projects, which were partially funded through the Federal EcoEnergy for Aboriginal and Northern Communities program, have been completed in Baker Lake, Arviat, Iqaluit and Rankin Inlet while two other projects in Hall Beach and Taloyoak received funding in 2014 (Aboriginal Affairs and Northern Development Canada, 2015).

4.3. Energy Conservation and Efficiency

Energy efficiency and conservation measures have been at the forefront of energy policy in Nunavut for quite some time and an array of different programs and funding measures exist to help the GN, homeowners and businesses improve their energy usage. The overarching policy for EE measures is the Nunavut Energy Management Program, which is comprised of three individual policies: the Nunavut Energy Retrofit Program, the Save 10 initiative and the Facility Energy Efficiency Review.

The Nunavut Energy Retrofit Program (NERP) (see Section 8.1.4.) was modeled after the Government of Canada's Federal Buildings Initiative (FBI) and allows the GN to enter into long-term contracts with energy management firms that will finance, develop and implement energy retrofit projects (Department of Community and Government Services, 2010) through the energy savings generated from the project. To date the majority of work under the NERP has been under the Iqaluit Pilot Project, which renovated 37 GN owned buildings from 2007-2014. Buildings in the Kivalliq Region of Nunavut, mostly

in the community of Rankin Inlet have recently been chosen for the second round of retrofits under the FEER program.⁵⁷

The second program is the Save 10 education initiative, which is a two-pronged approach to educate GN employees and other building occupants of newly renovated facilities to reduce their energy and water consumption while at work or school. It also trains facility managers how to efficiently operate the new buildings (Department of Community and Government Services, 2010). The third program is the FEER initiative for new building design. Together these three initiatives have been estimated to have cumulatively saved the GN \$1.2 million in energy cost between 2006 - 2013 (Department of Community and Government Services, 2013).

In addition to programs designed for GN owned buildings, the NHC offers a subsidy program, called the Home Renovation Program, for renovations and repairs undertaken by private homeowners. This program provides a forgivable loan to homeowners in order to undertake necessary renovations, home repairs and upgrades.

Despite early successes with energy efficiency retrofits, barriers and challenges remain. Members of a focus group noted that while policies for new buildings are excellent in their initial design phase, a lack of continued monitoring and maintenance often leads to diminishing returns over time.⁵⁸ Because of Nunavut's housing shortage GN budgets are heavily skewed towards construction of new builds while operations and maintenance outlays are significantly less. This budgeting situation led one participant to lament that in Nunavut "we are good at building BMWs [meaning the expensive German-made automobile] (referencing new builds, such as new homes built under LEED⁵⁹ specifications) but we're not good at maintaining them."⁶⁰ Additionally, participants also noted that renovation and efficiency incentives were targeted at wealthier homeowners who had the ability to pay for renovations on their own, while middle and lower income groups were largely unable to access energy efficiency programs. Additionally, individuals in public housing units have little incentive to efficiently use energy as the costs

⁵⁷ Anonymous, *Focus Group Interviews*, 2014

⁵⁸ Anonymous, *Focus Group Interview*, 2014

⁵⁹ Leadership in Energy and Environmental Design (LEED), a certification scheme for sustainable buildings started by architects in the United States, and used by various building councils worldwide

⁶⁰ Anonymous, *Focus Group Interview*, 2014

are largely borne by the GN. Focus group participants noted that in some cases tenants would go so far as to open windows to cool rooms that were too warm rather than turn down the thermostat. This is a common challenge noted in other energy efficiency studies, and is termed *split incentives* to highlight the tension that exists between building owners (not interested in investing in retrofits that will benefit tenants versus themselves) and those who are renting space within these buildings (for examples see (Brown, 2001); (Worrell, 2011)).

5. Nunavik Energy Overview

5.1. Electricity: System Layout and Recent Trends

Nunavik's electricity system is similar to that found in Nunavut with each of the regions fourteen communities being powered by independent diesel systems. Installed capacity in 2012 was 15.5 MW which allowed Hydro Quebec to generate 82.4GWh of electricity (Hydro Quebec Distribution, 2013) (Hydro Quebec Distribution, 2013). The electricity system in each community is owned and operated by Hydro Quebec Distribution who is also responsible for collecting revenues from customers. Electricity rates in Nunavik are staggered based upon consumption and allow for lighting and small appliance use only. Households are charged 5.57 cents/kWh for basic service for the first 30 kWh of daily consumption (Kativik Regional Government, 2014). If demand exceeds 30 kWh in a single day the rate jumps to 33.64 cents/kWh. Businesses and government buildings are charged 9.38 cents/kWh for basic service for the first 30 kWh with rates increasing to 74.14 cents/kWh afterwards (Kativik Regional Government, 2014). Due to the cost of generation in Nunavik's isolated communities Hydro Quebec prohibits the use of electricity for space and hot water heating if the electricity is being generated by non-renewable sources, as a result Nunavik residents consume roughly 9,260 kWh of electricity per year which is less than one third of the annual consumption of southern Quebec residents who consume nearly 30,000 kWh/year (Kativik Regional Government, 2014).⁶¹

⁶¹ (Henderson, Personal Interview, 2014)

Recent Policy Developments

In 2002 the Kativik Regional Government, the Makivik Corporation and government of Quebec entered into the Sanarrutik Agreement on Economic and Community Development in Nunavik. One part of this agreement called for a study by Hydro Quebec that would explore the possibility of connecting Nunavik communities and Xstrata's Raglan mine to Quebec's provincial grid system. The study confirmed that while technically feasible the cost of the transmission line was roughly \$1.6 billion if no new hydro developments were undertaken in Nunavik and \$890 million if a new hydro development were to go ahead (Kativik Regional Government and Makivik Corporation, 2012). Due to the small number of rate-payers in the region the project was deemed far too costly at this time for Hydro Quebec to undertake (Kativik Regional Government and Makivik Corporation, 2012). Plan Nunavik, released in 2012 called upon Hydro Quebec to investigate the possibility of developing a small hydro project near Inukjuak (discussed further in Section 8.7), conduct feasibility studies for wind-diesel hybrid systems and to look at the potential for hydro-kinetic (submersible run of river turbine systems) development in several communities (Kativik Regional Government and Makivik Corporation, 2012). As of 2013, for both technical and financial reasons, Hydro Quebec has not yet moved forward on developing any of these systems, opting instead to replace and maintain diesel generation systems in the short term while more work was done to assess the potential for renewable projects individually (Hydro Quebec Distribution, 2013). One project that has moved ahead in the Nunavik area is the development of a wind-diesel hybrid system for the Raglan Mine. The initial pilot project will see Glencore install a 3MW turbine combined with three different storage systems (flywheel, batteries and a hydrogen fuel cell), which will help to moderate the variability of the turbine (Friends of Wind, 2014). This project is discussed in detail in Section 8.5.

5.2. Space Heating: Recent Trends

Space heating needs in Nunavik are met primarily with heating oil which is also used to heat water. It is important to note that nearly 99% of housing units in Nunavik are government owned social housing or corporate owned housing, and there are only 120 privately owned homes in Nunavik (Kativik Regional Government, 2014). In 2009 a typical household in Nunavik consumed roughly 3,200 litres of heating oil

(Kativik Regional Government and Makivik Corporation, 2012). In 2009 a total of 28 million litres of heating oil was consumed in the region. To help offset the cost of heating oil Hydro Quebec and the Makivik Corporation operate a subsidy program for Nunavik residents (Makivik Corporation, 2014). Through the program Hydro Quebec directly augments the rate charged to Nunavik households who successfully enroll in the program, with the customer only being charged the difference between the cost of the oil and the subsidy rate (Makivik Corporation, 2014). A report completed in 2010 that examined programs designed to reduce the cost of living in Nunavik estimated that the heating oil subsidy program saves Nunavik residents over \$2.2 million annually (The Working Group on the Reduction of the Cost of Living in Nunavik, 2010)

Recent Policy Developments

The usage of residual heat from power generation has been investigated as an option for offsetting some space heating needs in larger community owned buildings in Kuujjuaq, Kangiqsualujjuaq and Akulivik. However, feasibility studies completed by Hydro Quebec noted that the high cost of installing and operating these types of systems in Nunavik were prohibitive and in 2013 Hydro Quebec decided against completing any further studies on this type of technology (Hydro Quebec Distribution, 2013).

5.3. Energy Efficiency and Conservation

Energy efficiency and conservation efforts in Nunavik have been carried out mainly by Hydro Quebec who is responsible for both electricity generation and the maintenance of space heating equipment. As mentioned earlier Hydro Quebec has been diligent in discouraging the usage of electricity for space heating needs. This has led Hydro Quebec Distribution to develop the electricity rate regime outlined in Section 5.2 wherein the higher price of electricity after 30kWh is consumed in a day is intended to discourage the use of electricity for this purpose (Hydro Quebec Distribution, 2013). Despite this pricing program Hydro Quebec has argued that the usage of backup electric space heating is a problem in Nunavik communities and is actively working with the appropriate Nunavik agencies to look at the specific causes of over consumption and to find solutions acceptable to all parties (Hydro Quebec Distribution, 2013). Additionally, Hydro Quebec is also operating two programs that target energy

efficiency for lighting in both residential and public buildings and is promoting the usage of LEDs to replace conventional lighting fixtures (Hydro Quebec Distribution, 2013). Finally, Hydro Quebec is also undertaking educational campaigns in Nunavik schools to help increase energy literacy and target behavioural aspects of energy usage (Hydro Quebec Distribution, 2013).

Outside of these programs operated by Hydro Quebec it does not appear that there are any current renovation programs directly targeting energy efficiency or fuel switching technologies in Nunavik. However, the stock of social housing units has drawn concern in recent years leading to an increase in renovation funding by the Quebec government. A 2006 study undertaken by the Société d'habitation du Québec examined over 95% of social housing units in Nunavik and found significant deterioration of the housing stock (Société d'habitation du Québec, 2014). The report estimated that the total cost of renovating these housing units could exceed \$400 million which prompted the government of Quebec to drastically increase its funding for home renovation programs. Between 2008 and 2013, \$257 million has been invested in housing renovations in Nunavik (Société d'habitation du Québec, 2014).

6. Nunatsiavut Energy Overview

6.1. Electricity: System Layout and Recent Trends

Nunatsiavut's electricity system is owned and operated by NL Hydro and consists of isolated grid systems developed around diesel generation within each community. NL Hydro is responsible for the operation, maintenance and refueling of these systems as well as for applying for rate collection. Rates are based on a block system, which differentiates prices based on seasonal needs, allowing for higher consumption at a lower price during the winter months and reversing it in the summer. The allowable consumption in the first block set for the winter months is 1000kWh (for December-February) and is reduced to 700 kWh in the summer (for July-September) (Newfoundland and Labrador Hydro, 2014). Rates in 2014 for domestic customers are adapted from NL Hydro's 2014 interim rate application and are shown below in Table 2.

Table 2 Electric Power Rates for Residential Customers

Consumption	Rates
First Block	11.178 c./kWh
Second Block	12.608 c. /kWh
>1000 kWh	17.095 c./kWh

Source: (Newfoundland and Labrador Hydro, 2014)

However, these rates do not reflect a Government of Newfoundland subsidy that is included in the Northern Strategic Plan. The subsidy aims to bring the basic electrical needs of residential consumers in isolated communities in line with the residential rates of Happy Valley-Goose Bay (GNL Department of Natural Resources, 2014). When the subsidy is factored in, the rate for the first block of electricity consumption (either 1000 kWh or 700 kWh depending upon the season) in Nunatsiavut communities decreases to 3.28 cents/kWh, reverting to the rates in Table 2 thereafter (Newfoundland and Labrador Hydro, 2014).

Rates for general service customers (e.g. local businesses) are higher overall and based upon the overall current demand of the customer. Similarly, government customers (e.g public housing units and government offices) are also charged a higher rate overall than domestic and general service customers, additionally they do not qualify for the block consumption system and do not receive subsidies. Rates are adapted from NL Hydro's 2014 interim rate application and are shown below in Table 3.

Table 3 Electric Power Rate For Non-Residential Customers

Maximum Demand	General Service	Government
Domestic	Non-Applicable	78.10 c./kWh
<10 kW	17.073c. /kWh	69.701 c./kWh
> 10 kW	16.616 c./kWh	49.554 c./kWh

Source: (Newfoundland and Labrador Hydro, 2014)

Overall, due to high population growth levels, electricity demand has been increasing in recent years. As far back as 2012 NL Hydro studies estimated that the current diesel facilities in Nain and Hopedale would no longer meet peak demand (Nain Research Centre, 2015). Simultaneously, the existing diesel and electrical distribution infrastructure is relatively old and nearing its end of life. These twin pressures have led to an increasing number of power outages during peak demand times. The community of Nain, for example, had five outages in one year.⁶² In response, drastic measures have been taken to encourage Nunatsiavut residents to decrease their consumption during the winter months. This included a letter-writing campaign and encouraging residents to turn off their holiday lights when cooking dinner in the community of Rigolet.⁶³ Electricity shortages are also affecting the overall economic development of communities. For instance the community of Makkovik has two fish processing plants; however both cannot operate at the same time due to their power demand.⁶⁴

Recent Policy Developments

The development of an Energy Strategy has been the focus of the Nunatsiavut government most recently, largely in response to some of the power problems being faced in the region. Similarly, a lack of dialogue between NL Hydro, the Nunatsiavut Regional Government (NRG) and Nunatsiavut residents has

⁶² Anonymous, *Personal Interview*, December 2014

⁶³ Anonymous, *Focus Group Interviews*, November 2014

⁶⁴ Anonymous, *Personal Interview*, November 2014

strained relations between the parties.⁶⁵ To voice the concerns about the effects of these price increases on Nunatsiavut proposed in NL Hydro's November 2014 general rate application, the NRG was granted intervener status during the Public Utility Board Hearings to take place in 2015.⁶⁶ Subsequently, the government of Newfoundland passed an Order in Council in late December 2014 requiring NL Hydro to apply an equal rate increase for isolated diesel customers as that proposed for Newfoundland's interconnected customers, which due to falling global oil prices will result in a 6.3% decrease in rates for Nunatsiavut residents beginning in March of 2015 (Newfoundland and Labrador Hydro, 2015). The increasing frequency of power outages and current strained relations with NL Hydro have prompted the NRG through the Sustainable Communities Initiative, to make energy a priority area of activity. In 2014 the NRG began working with an external consultant to develop an energy strategy. A draft of this strategy is expected in early 2015. The government of Newfoundland and Labrador is also contemplating the development of a net-metering policy.

6.2. Space Heating: Recent Trends

Space heating needs are primarily met with fuel oil and biomass (mainly wood) resources. Fossil fuel-based products are delivered via marine transport, while biomass resources are harvested from nearby forests. A recent door-to-door housing assessment survey conducted by the NRG found that 55% of Nunatsiavut residents heated their homes with wood, 35% used fuel oil with the remaining 10% of homes using unidentified materials. In a small number of homes in Nain electric baseboard heaters were used for heating (Nunatsiavut Regional Government, 2014). While useful for delineating space heating options the survey also uncovered a number of problems in Nunatsiavut homes. The survey showed a chronic situation of heating poverty in many residential dwellings. 44% of the survey respondents mentioned that they have had recent problems keeping their dwellings warm throughout the year (Nunatsiavut Regional Government, 2014). Residents in Nain and Hopedale were the most severely afflicted by heating poverty and expressed concern about the high cost of heating oil/electricity, the poor condition of their dwelling, and problems collecting firewood as the primary reasons for inadequate heating. Similar trends were

⁶⁵ Anonymous, *Personal Communication*, 2014

⁶⁶ Anonymous, *Personal Communication*, 2014

identified in the remaining three communities with dwelling conditions, access to and procurement of firewood, and the high cost of fossil fuels as the primary drivers of home heating poverty.

Recent Policy Developments

In response to the housing survey results the NRG, Torngat Regional Housing Authority, Newfoundland Housing Corporation and the Nunatsiavut Group of Companies (NGC) have introduced a number of different programs to help alleviate several of the problems faced by Nunatsiavut residents.

Since 2010 the NGC has been conducting a yearly “Wood to the Coast” program that assists coastal communities and their residents experiencing firewood shortages during the winter (Nunatsiavut Group of Companies, 2014). The program is operated by Nunatsiavut Marine, which prepares and packages the wood, and by the provincial government that delivers the wood to communities. All the wood is provided free of charge and municipal governments are tasked with dispersing the wood as they see fit. In addition to delivering firewood to communities, the Government of Newfoundland and Labrador also operates a home heating rebate program for low-income households earning less than \$40,000 each year. Residents of Nunatsiavut are eligible to apply for a maximum one-time rebate of \$500 regardless of the heating source (Department of Finance, 2014).

6.3. Energy Efficiency and Conservation

Energy efficiency and conservation programs in Nunatsiavut are primarily directed towards addressing the severe problems in housing, with renovation and retrofit programs being operationalized by both the NRG and the Torngat Regional Housing Authority. In August 2014 the NRG and the Newfoundland Housing Corporation established a home renovations program totaling \$700,000 (with funding shared 50-50 between the two governments) to conduct renovations on residential houses in Nain and Hopedale (Nunatsiavut Regional Government, 2014). The program will focus on energy efficiency improvements and is targeting attic repair, alternative and enhanced insulation levels and increasing the air tightness of houses. Nunatsiavut residents apply to this program through the NRG in Hopedale and Nain. If successful, homeowners then receive a consultation and assessment from the independent energy management firm hired by the NRG, and then repairs are completed. In addition to this program the

Torngat Regional Housing Association, who is funded by the NRG, also operates a renovation and repair program.

The programs discussed thus far are only for existing buildings and residences, but as part of the Sustainable Community Initiative, the Nain Research Centre has also been developing a housing strategy for Nunatsiavut called the Healthy Homes Program.⁶⁷ The primary aim of the Healthy Homes Program is to learn from the existing housing problems in Nunatsiavut and to adapt housing to changing climate realities. This program is being developed over four phases and began in 2011. The Healthy Homes Program will be discussed in detail in Section 8.2.3.

⁶⁷ The *Sustainable Communities Initiative* is a inter-governmental, inter-departmental multi-disciplinary project jointly funded by the GNR, Newfoundland Office of Climate Change and Energy Efficiency, AANDC and Health Canada and includes academic partnerships with Memorial Univeristy, Trent University and the University of Guelph for more information please see <http://nainresearchcentre.com/research-projects/the-sustainable-communities-initiative/>

7. Economic and Financial Analysis

Section 7 consists of a detailed overview of how financial analysis is currently carried out for alternative energy projects in the Arctic, with a focus on electricity supply, heating and demand-side management. We will mainly focus on the economic and financial dimension given that affordability was identified as a priority in most Territories' energy strategies and visions.

7.1. Cost of Capital

Understanding the financial aspects of the power system are of critical importance because electricity supply is generally more capital intensive⁶⁸ than heating, and therefore requires more in depth analysis regarding primary energy source choice, generation, transmission and distribution infrastructure investments. A large portion of the average cost of supplying electricity to a house or a building comes from building the infrastructure that has to be put in place to generate, transport (transmit) and distribute that electricity to this house or building. In comparison, the average infrastructure cost required to deliver heating oil is lower.

Electricity rates in the Arctic typically are proposed by the utilities, then accepted/rejected and validated by a regulator (also known as a public utilities board). Typically, rates are accepted but with a number of modifications such as change in the return on equity being used, change in the allocation of cost between rate classes being proposed, or change in the capital expenditure plan that is typically filed along with the General Rate Application (GRA). The set of regulatory proceedings that lead to setting the rate is called a GRA. Regulators typically accept rates that represent the average cost of producing, transmitting and distributing electricity for each category or consumer (or rate class). This average cost, usually referred to as “cost of service”, comprises the utility's operational expenditures, fuel cost (if any), depreciation of past investments (capital expenditures), and an industry-average return on equity (or regulated return on equity) on past investments. To put simply, rates are set by dividing a forecast of the operational and capital expenditures required to provide the service as well as amortization and interest

⁶⁸ That is: a large portion of the average cost of supplying electricity to a house or a building comes from building the infrastructure that has to be put in place to generate, transport (transmit) and distribute that electricity to this house or building. By opposition, the average infrastructure cost required to deliver heating oil is less costly.

due to past investments, by a forecast of the electricity demand. The numerator of that rate-setting formula is often referred to as the “rate base”⁶⁹. Regulators can be seen as the protectors of the “rate base” because every new expense included in the rate base will have an impact on rates. It is in the interest of the ratepayers for the regulator to not approve proposed projects that would unreasonably burden the rate base by increasing prices. The regulator is often left as the sole judge to define “unreasonable burden”.

Table 4 presents a high-level synthesis of the electricity rate-setting framework.

Table 4 Electricity Rate Setting Framework

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
General Approach to Rate-Setting	Cost of service regulation w/cross-subsidies ⁷⁰ to lower electricity rate in off-communities ratepayers and of non-government ratepayers and government subsidy for all residential rates	Cost of service regulation w/government subsidy for all residential rates <i>in off-grid communities</i>	Cost of service regulation w/government subsidy for all residential rates <i>in most communities outside of Iqaluit.</i>	Cost of service regulation w/cross-subsidy from Québec continental grid ratepayers to lower electricity rate	Cost of Service Residential and commercial/institutional rates are pegged to that of Newfoundland Power and thereby are cross-subsidized. Governments’ rates match cost of service.
Schedule for the GRA	When required for YEC, every 3 years, approximately, for ATCO Electric Yukon	When required for NTPC. There was a GRA for NTPC in 2012, the one before was in 2007, and they currently are in the process of updating it. Northland Utilities filed a first phase of their GRA in 2013, and then a second phase in 2014. Northland Utilities needs more frequent GRAs; i.e. every second year approximately.	There was a GRA in 2010/2011 and then another one GRA in 2014/2015. Thereby, every four years approximately.	Yearly province-wide GRA. (Occurring November to February)	There was a GRA in 2013, which was amended in 2014. Previous GRA was in 2006. Capital expenditures get approved on an annual basis.
Hydro-Grid Generation & Transmission	Yukon Energy Corporation (YEC) Regulated ROE: 8.25% Debt Ratio: 60% L-T Interest Rate: (Forward looking) 3.69%	NT Power Corporation (Publicly-owned) Regulated ROE: 8.5% Debt Ratio: 70% L-T Interest Rate: 5.77%	N/A	N/A	N/A

⁶⁹ Definition of “Rate Base”: The rate base is the value of the total asset owned by the utility used to deliver electricity services and on which the utility is entitled by the regulator to earn a return on equity. In this paper, as it commonly done in the electricity sector, we refer to the “rate base” in the broader sense of “all utility costs that are to be recovered through rates”, thereby encompassing both asset depreciation and operational expenditures.

⁷⁰ The concept of cross-subsidy will be defined and discussed in Section 7.4.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Hydro-Grid Distribution	ATCO Electric Yukon (Privately-owned): Regulated ROE: (Proposed) 9.21% Debt Ratio: 60% L-T Interest Rate: 5.08%	Northland Utilities (NWT) (Privately-owned, mostly by ATCO): Regulated ROE: 9.3% Debt Ratio: 56% L-T Interest Rate: 5.92%	N/A	N/A	N/A
Off-Grid Generation & Distribution	ATCO Electric Yukon (Privately-owned) Regulated ROE: (Proposed) 9.21% Debt Ratio: 60% L-T Interest Rate: 5.08% (Same as for hydro-grid distribution)	NT Power Corporation (Publicly-owned) Regulated ROE: 0% plus a “reserve margin” of 1.5% Debt Ratio: 57% L-T Interest Rate: 8.66% Northland Utilities (NWT) (Privately-owned, mostly by ATCO) Regulated ROE: 9.3% Debt Ratio: 56% L-T Interest Rate: 5.92% (Same as for hydro-grid distribution)	Qulliq Energy Corporation (Publicly-owned) Regulated ROE: (Actual) 6.79% (Proposed) 9.30% Debt Ratio: 60% L-T Interest Rate: 5.20%	Hydro-Québec Distribution (Publicly-Owned) ROE: (Actual) 8.2% Debt Ratio: 70% L-T Interest Rate: (Cumulative) 5.44% <i>for 2013, and for the entire HQD province-wide network.</i>	Newfoundland and Labrador Hydro (Publicly-Owned) Regulated ROE: 8.8% Debt Ratio: 72.5% L-T Interest Rate: 6.67% (2014)

ROE = regulated return on equity⁷¹, L-T Interest Rate = Long-Term Interest Rate⁷²; GRA = General Rate Application. All data provided are based on the latest GRA of the corresponding jurisdiction for the next test year being proposed.

Sources: (Yukon Energy Corporation, 2013), (ATCO Electric Yukon, 2013), (ATCO Electric Yukon, 2014), (Northwest Territories Power Corporation, 2014), (Northwest Territories Power Corporation, 2012), (Northland Utilities (NWT) Limited, 2013), (Northland Utilities (NWT) Limited, 2014), (Qulliq Energy Corporation, 2013), (Hydro-Québec, 2014), (Régie de l'énergie, 2014), (Newfoundland and Labrador Hydro, 2014)

Return on equity, debt ratio and long-term interest rates are often used to determine the rent that utilities expect from capital investment – or “cost of capital”. The blended cost of capital (or weighted average cost of capital (WACC)) may be calculated using the following equation⁷³:

$$\text{WACC} = (100\% - \text{Debt Ratio}) * \text{Return on Equity} + \text{Debt Ratio} * \text{Long-Term Interest Rate}$$

The utilities’ WACC was used in a large number of financial analyses of energy alternatives in the Arctic as the discount rate to reflect the time value of money. The WACC of utilities are typically lower than that for private developers because private developers require a higher return on equity (i.e. they

⁷¹ Annual rent achieved by the owner of the utility as a percentage of the equity portion of the value of the utility’s assets. The current value of the utility’s assets typically is the original investment net of cumulative depreciation.

⁷² Long-term interest rates are the interest rate on debt with a debt term (or maturity) longer than one year. Long-term interest rates of a utility represents the blend of the interest rates of all of these loans.

⁷³ This WACC equation is a simplified equation. The WACC is the weighted average of all sources of capital. Utilities or private project developers may be using other sources of capital that are not captured in this equation.

expect a higher profit because they inherently incur more risk), and their sources of debt financing are typically more expensive because their credit rating is typically lower than that of government-backed utilities. In other words, private capital is more expensive than that of government and government-owned utilities. Regulation can play a role in affecting the cost of capital as well because regulation reduces the business risks by ensuring that costs are being recovered, including the regulated rate of return or profit, through matching electricity rate to cost of service (on average).

The industry-average comparison (or “benchmark”) return on equity currently used by utilities for comparison is 8.75%, set by the Alberta Utilities Commission on December 8, 2011, and by British Columbia Utilities Commission on May 10, 2013 (Qulliq Energy Corporation, 2013)⁷⁴. Most utility rates of return presented in Table 4 fall around this value, with the rate of return of privately-owned utilities typically being slightly higher. Some outliers exist however, such as NT Power Corporation’s (NTPC) rate of return at 0% in off-grid communities. Typically, a portion of returns are re-invested in the form of equity contributions to fund infrastructure projects. A rate of return of 0% requires that NTPC either use the return from hydro communities to fund infrastructure projects in off-grid communities, or else be dependent on the Government of the Northwest Territories to provide equity financing.

7.2. Fundamental Approaches Typically Used in Supply-Side Financial Planning

There are three methods for assessing power supply-side options discussed in this report: the levelized cost of energy (LCOE), cost-benefit analysis, and the resource portfolio analysis. Table 5 presents these three approaches to financial analysis. There is a fourth method in the table, Standard DSM Cost-Effectiveness Testing, which is discussed in Section 7.6.

⁷⁴ Note that benchmark studies of regulated rates of return are not necessarily performed every year and in a consistent basis.

Table 5 Fundamental Metrics of Electricity Sector Supply-Side Planning

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
LCOE	Yes. Yukon also uses “Forecasted LCOE”	Yes.	Yes.	Yes.	Yes. “Levelized Unitary Energy Cost” (LUEC)
Cost-Benefit Analysis	No.	Yes, as part of the 2013 Supply Planning report, the benefit being avoided “diesel” generation. Wherever cost outweighed benefits, the resource was deemed “needing government subsidy to be viable”. (NT Energy, 2013) In addition, a number of financial analyses of wind-diesel system have been performed in thermal communities of the NWT through collaboration between the Aurora Institute, John F. Maissan, Jean-Paul Pinard, and Tim Weiss. ⁷⁵ (Aurora Research Institute, 2015)	Yes. The Government of Nunavut funded a study carried out by a consulting firm based in Inavik, IMG-Golder Corporation, which carried out a number of cost-benefit analysis using RETScreen for Iqaluit, Arviat and Cambridge Bay. (IMG-Golder Corporation, 2011)	Yes. Research Institute in Electricity of Québec (IREQ), a division of Hydro-Québec, conducted a cost-benefit analysis of wind-diesel project for a large number of Nunavik communities. (Institut de Recherche en Électricité du Québec, 2008)	No.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Resource Portfolio Analysis	Yes, as part of the 2012 20-Year Resource Plan that has to be filed every five years.	No.	No.	No. Hydro-Québec Distribution did produce an extensive supply plan for off-grid communities, including Nunavik, but did not publish systematic financial analysis of alternative to diesel generation (outside of wind-diesel) because the resource is site-specific. (Hydro-Québec Distribution, 2013)	Yes. Newfoundland and Labrador Hydro conducted a Resource Portfolio Analysis on a community-by-community basis using the software HOMER. (Newfoundland and Labrador Hydro, 2009)
Standard DSM Cost-Effectiveness Testing (To be discussed in Section 7.6)	Yes, YEC's and ATCO Electric Yukon's 2013 5-Year Demand-Side Management Portfolio, using an approach presented in Section 7.6. (ATCO Electric Yukon, 2014)	No.	No.	Yes. ⁷⁶ (Hydro-Québec Distribution, the Régie de l'Énergie, and the Office of Energy Efficiency and Innovation are proficient with standard DSM Cost-Effectiveness Testing)	Yes, NL Hydro and Newfoundland Power's 2007 5-Year Demand-Side Management Portfolio (Isolated Systems programs) using an approach presented in Section 7.6. (Newfoundland and Labrador Hydro and Newfoundland Power, 2007)

Levelized Cost of Energy

The LCOE is a measure of the real total (including capital and operating cost) life-cycle cost per MWh of supplied energy. It measures the cost of generating energy for a particular system. A net present value calculation is performed and solved in such a way that for the value of the LCOE chosen, the project's net present value becomes zero. This means that the LCOE is the minimum price at which energy must be sold for an energy project to break even. The LCOE is, therefore, quite sensitive to the chosen discount rate, which depends on the cost of capital, including the balance between debt-financing and equity-financing, and an assessment of the financial risk. The LCOE does not take into account the reliability of energy supply, the time at which power is generated (during the day or in the winter or summer) and the required grid balancing cost. The LCOE is, however, a well-established and practical indicator for simple

⁷⁶ No thermal community-specific DSM financial analysis was found for Nunavik despite Hydro-Québec Distribution's program portfolio being delivered in Nunavik, although amount and nature of information found on energy conservation in off-grid communities allows the researcher to speculate that such an analysis had indeed been carried out.

comparison between the costs of a wide array of supply and demand-side energy resources. The LCOE was used in most of the reviewed literature including Yukon Energy's 2012 Resource Plan and NT Energy's 2013 Power System Plan. This metric was referenced extensively at the NWT 2014 Energy Charrette. Table 6 summarizes published LCOE across the five Arctic jurisdictions. The table also indicates if and where a financial analysis other than LCOE was performed.

Table 6 Assumed LCOE across Jurisdictions for a Number of Power Supply Options

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Marginal Cost⁷⁷ of Diesel Generation (See average total cost in Table 7)	\$280/MWh for marginal fuel and operational expenditure <i>only</i> (Weighted average)	\$320 to \$350/MWh for marginal fuel cost <i>only</i> (Weighted average)	Not found. Average total cost of electricity service in Iqaluit is \$500/MWh , (See Table 7) which does not exclusively include diesel fuel cost.	\$390/MWh for marginal fuel cost <i>only</i> .	\$368/MWh for diesel fuel cost <i>only</i> ⁷⁸
Wind Power	Hydro-grid connected: 21-MW farm at \$148/MWh and 10.5-MW at \$155/MWh (note: including the necessary cost of diesel rotary uninterruptible power supply ⁷⁹ .)	\$360 to \$770/MWh The Diavik Mine project had a positive net present value at marginal cost of diesel generation of \$310/MWh .	The Government of Nunavut hired IMG-Golder Corporation to perform cost-benefit analyses of wind, PV, hydro resources, ocean, solar thermal and nuclear power. Results were not provided as LCOEs. According to this study, the cost of wind energy is lower than the current electricity rates in both Arviat, and Cambridge Bay. It is above the current electricity rate in Iqaluit.	IREQ, a division of Hydro-Québec, performed a number of wind-diesel system cost-benefit analysis for a large number of off-grid communities in Nunavik. No LCOE were computed, but results for many communities showed positive NPV, which indicates that the LCOE is lower than the marginal cost of diesel generation.	Wind was considered in a Resource Portfolio Analysis carried out by Newfoundland and Labrador Hydro in 2009. The study showed that in many communities, wind-diesel and hydro-diesel systems would reduce power cost against a diesel-only scenario in the long run.
Solar Photovoltaic (PV)	YEC: \$200 to \$600/MWh and requires storage. Yukon Energy Branch: \$300 to \$400/MWh YEC/ESC/ICF Marbek: \$550 to \$1,110/MWh for small residential installation (approx. 3 kW) \$460 to \$920/MWh for large commercial installation (approx. 20 kW)	\$590 to \$830/MWh	Cost-benefit analyses were performed by IMG-Golder Corporation. According to this study, the cost of PV is higher than the current electricity rates in both Iqaluit, Arviat, and Cambridge Bay.	Hydro-Québec Distribution published final results of a conservation potential review in all thermal communities in the province, including Nunavik. The LCOE for the measures being considered, however, were not published. Embedded residential PV was included as a potential measure, but was not selected as an economically feasible measure.	PV was considered in a Resource Portfolio Analysis carried out by Newfoundland and Labrador Hydro in 2009 but offered financial performances that were inferior to small hydro and wind energy.
Hydropower Enhancements	\$57 to \$85/MWh	Not assessed as part of Northwest Territories Energy supply planning.	No financial analysis found.	No financial analysis found.	No financial analysis found.

⁷⁷ Cost avoided by offsetting the first one unit of production – in this case, kWh. The marginal cost of diesel generation represents the variable portion of the average diesel generation cost. The full average diesel generation, which includes fixed cost, is described as average total cost.

⁷⁸ \$15,565,900 forecasted diesel expenses for test year 2015 in Newfoundland and Labrador Hydro's 2013 GRA divided by forecasted total sale of 42,314 MWh. (cost of service tables, for "Labrador Isolated" communities)

⁷⁹ Special diesel genset unit that includes a large flywheel.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
New Hydropower	Medium and large hydro: sites were identified between \$100 and 150/MWh Small hydro (smaller than 10 MW): \$200 to 230/MWh	Small hydro (1-MW scale): \$375 to \$625/MWh Medium (10-MW scale): \$85 to \$135/MWh Large (100-MW scale), on the Great Bear River: about \$50/MWh , excluding transmission interconnection	Two best sites near Iqaluit: 10-MW Jaynes Inlet from \$230 to \$310/MWh and 6-MW Armstrong South \$370 to \$420/MWh In addition, cost-benefit analyses were performed by IMG-Golder Corporation. According to this study, the cost of hydro is lower than the current electricity rates in both Iqaluit, Arviat, and Cambridge Bay.	The community of Inukjuak (Pituvik Landholding Corporation) is working on a 7.5-MW Innuvik hydro electric project. We were not able to find public data on the financial performance of the project.	Small hydro: 44 potential hydro sites between \$80/MWh and \$4,430/MWh (\$2009), accounting for maximum amount of energy the diesel system could consume from the hydro plant. 25 sites of the 44 sites have a LCOE lower than \$370/MWh .
Very-Low Head Hydro⁸⁰ (Kinetic)	Not assessed as part of YEC supply planning.	We were not able to find any LCOE for the Fort Simpson Hydrokinetic Turbine Pilot Project that was installed in the Mackenzie River in 2010-2011.	No financial analysis found.	Hydro-Québec is studying possible sites for “hydroliennes” on the Koksoak river near Kuujuaq. Technical and environmental feasibility are uncertain.	No financial analysis found.
Biomass Power	Hydro-grid connected: 25-MW Whitehorse: \$166/MWh w/o Combined Heating and Power (CHP) ⁸¹ \$158/MWh w/CHP 10- and 15-MW Minto: \$158 , and \$175/MWh	Not assessed as part of NT Energy supply planning. It was a conclusion of the 2014 Energy Charrette that biomass is a solution worth studying.	Qualitative analysis by IMG-Golder Corp. based on extensive literature review and interviewing rejected biomass as an option for Nunavut although it did not include a financial analysis.	Hydro-Québec Distribution conservation potential review for thermal communities rejected biomass-powered as irrelevant for Nunavik.	No financial analysis found.

⁸⁰ Very-low head hydro is innovative hydropower technology which requires little to no height difference. “Hydrolienne”, a French word, is one type of kinetic hydropower. A hydrolienne is an open turbine standing at the bottom of the sea or of a river, which captures the kinetic energy of the water flow.

⁸¹ Combined heating and power is power generation units with heat recovery, which allows the heat to be used for space heating, domestic hot water and/or industrial processes. The generation unit can run on any combustible such as fossil fuel, hydrogen or biomass. CHP systems have higher system efficiency because the heat is used rather than being exhausted in the atmosphere.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Municipal Solid Waste or Waste-to-Energy (WTE)	Hydro-grid connected: \$135/MWh including revenues from “avoided tipping fees” and from district heating	Not assessed as part of Northwest Territories Energy supply planning.	Qualitative analysis by IMG-Golder Corp. based on extensive literature review and interviewing recommended WTE as an option for Nunavut, did not include a financial analysis, but pointed out that larger WTE plants deliver electricity at a lower cost. The small size of Nunavut communities and absence of a territorial grid would suggest higher cost per kWh than those experienced in Europe.	No financial analysis found.	No financial analysis found.
Geothermal Power (Deep geothermal, i.e. excluding ground-source heat pump or geoexchange)	Not assessed as part of YEC supply planning.	Reports of the feasibility studies for geothermal CHP conducted at Ft. Liard and published on NT Energy website did not contain costing and financial analysis.	Qualitative analysis by IMG-Golder Corp. based on extensive literature review and interviewing rejected geothermal as an option for Nunavut. No LCOE or any other form of financial analysis was conducted.	No financial analysis found.	No financial analysis found.
Intertie w/ Continental Grid	Not assessed as part of YEC supply planning.	\$120/MWh for electricity purchased on the SK or AB markets. Does not include capital cost.	No financial analysis found.	Proposed by the Makivik Corporation in “Plan Nunavik”, at an estimated cost of \$1.6 billion.	No financial analysis found.
Liquefied Natural Gas	Hydro-grid connected: \$120/MWh for a combined cycle, and LNG supplied from Kitimat. \$145/MWh for a simple cycle system and LNG supplied from Fort Nelson.	\$300/MWh for bi-fuel generation capacity. (Lower in Inuvik because gas generation capacity already exists.)	No financial analysis found.	Proposed by a number of mining companies and project developers, and accepted as a final recommendation by the Québec 2013 Public Commission on Energy Issues.	No financial analysis found.
Nuclear	Not assessed as part of YEC supply planning.	No financial analysis found.	Cost-benefit analysis of nuclear in Cambridge Bay conducted by IMG-Golder Corporation. According to this study, the cost of nuclear energy is lower than the current electricity rate in Cambridge Bay. Nuclear was recommended as a long-term resource.	No financial analysis found.	No financial analysis found.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Demand-Side Management programs (LCOE under the program administrator cost test or the total resource cost test as presented and defined in Section 7.6.)	\$90/MWh as per the 5-Year DSM Plan (blended, for the entire program portfolio)	LCOE was not assessed by NT Energy or by Arctic Energy Alliance.	No financial analysis found.	Hydro-Québec Distribution published final results of a conservation potential review in all thermal communities in the province, including Nunavik. The LCOE for the measures being considered, however, were not published. Only the measures that were economically feasible (i.e. they are cheaper than diesel generation) were retained and listed in the report.	Cost-effectiveness test results for Nunatsiavut (i.e. Labrador isolated communities) were presented as benefit/cost ratio rather than LCOE. The benefit/cost ratios published indicated that the benefits of the DSM program portfolio suggested outweighed the costs.
Supply-Side Transmission and Distribution Upgrades	Supply side enhancement (SSE) estimated to be \$75/MWh once blended with DSM.	LCOE was not assessed by NT Energy.	No financial analysis found.	No financial analysis found.	No financial analysis found.
Tidal/Ocean Power	No financial analysis found.	No financial analysis found.	A cost-benefit analysis of tidal power was conducted by IMG-Golder Corporation. According to this study, the cost of tidal is higher than the current electricity rate in Iqaluit.	The “hydroliennes” projects being investigated by Hydro-Québec are located in an estuary (i.e. at the cusp of land river and ocean). No financial analysis was published to date.	No financial analysis found.

Sources: (Yukon Energy Corporation, 2011), (Yukon Energy Solutions Centre, 2014), (ATCO Electric Yukon, 2014), (ICF Marbek, 2012), (Government of the Northwest Territories, 2014), (NT Energy, 2013), (Northwest Territories Energy, 2012), (van Wyk, 2014), (Sinclair-Knight-Merz, 2012), (Kerr, Cook, & Bernhardt, 2012), (IMG-Golder Corporation, 2011), (Saulnier, 2011, p. 35), (Pituvik Landholding Corporation), (Hydro-Québec Distribution, 2013), (Makivik Corporation, 2010), (Hydro-Québec Distribution, 2013), (Newfoundland and Labrador Hydro, 2014), (Newfoundland and Labrador Hydro, 2009)

LCOE results presented in Table 6 should be interpreted with care, considering that:

- The LCOE can vary drastically depending on the size of the power generation project,
- The LCOE assumes that all energy generated can be valued (i.e. time of generation is coincident with the profile of demand),
- The LCOE can be computed in different ways, and assumptions on factors such as the cost of capital and discount rate can significantly impact the result.

Cost-Benefit Analysis

The advantage of a cost-benefit analysis over the LCOE is the possibility to attribute a differentiated monetary value to kWh output depending on when that electricity gets produced and the possibility to attribute a monetary value to firm peak power in kW delivered on demand, thereby accounting for the reliability of the source of electricity. For example, a diesel genset can be relied on to deliver power on demand and thus is said to be “dispatchable” or to be a “firm” resource (Frank, 2014). Diesel in particular has quick ramp up and ramp down periods⁸², which is critical because of the volatility of a remote Arctic community’s load. In comparison, a wind turbine should be attributed a relatively small value for its capacity rating usually having a capacity factor of around 30 % (Frank, 2014). The availability of wind power is, however, highly variable and usually less abundant during peak periods than during off-peak periods in most Southern jurisdictions where peak periods are during the day and in the summer months (as for example in Ontario). This is different in Northern areas where more power is needed in winter months when more wind is available. Despite the demonstrated statistical coincidence between winter peak and wind energy output (simply because the wind tends to blow faster and more often in the winter), it is nevertheless impossible to guarantee that the wind power will be available during peak time (Lefebvre, Moreau, & Théorêt, 2010). For this reason, wind is described as an “intermittent” resource. Solar PV is in the same category, yet with different availability and reliability properties.

Whenever the resource is intermittent, any new capacity added cannot replace diesel (or gas) genset capacity. The genset capacity has to stay in the community as a backup. This is the reason why the wind technology for thermal communities is often referred to as wind-diesel or wind-LNG. Because the genset capacity has to stay in the community, there is an important fixed cost that cannot be displaced by intermittent alternative energy resources. Instead of relying on LCOE that does not take into account the effective ability of new power sources to replace existing ones, it is more accurate to calculate the net benefits of a new power source investment through a cost benefit analysis. In the NWT, a number of pre-feasibility studies, that included cost-benefit analysis, were conducted for a number of thermal communities through collaboration between the Aurora Institute and John F. Maissan, Jean-Paul Pinard,

⁸² Ramping up is the transitional stage during which the load decreases and the genset needs to follow the load decline. Ramp up is the other way round.

and Tim Weiss. The Government of Nunavut funded a comprehensive inventory and a number of desk prefeasibility studies on a wide array of technologies including (but not limited to) wind, solar photovoltaic, small hydro, solar thermal, ocean tidal and nuclear energy. A consulting firm was contracted to carry out the work and used Natural Resources Canada's RETScreen to carry out cost-benefit analysis for projects in Iqaluit, Arviat and Cambridge Bay (IMG-Golder Corporation, 2011). However, the interpretation of the results of this study is challenging because IMG-Golder Corporation compared the cost of alternative energy with the current electricity rates rather than with the displaced cost of diesel production.

For Nunavik (QC), Institut de Recherche en Électricité du Québec (IREQ) developed a model called SIMJED to assess the operational and financial performance of wind-diesel systems in Nunavik, optimize the design and present results in the form of cost-benefit analysis and account properly for the marginal and fixed cost of diesel generation (Institut de Recherche en Électricité du Québec, 2008). The SIMJED is the only model of its kind that the research team found, and could be leveraged to perform similar analysis in other remote coastal communities in the Arctic.

Resource Portfolio Analysis

The resource portfolio analysis is an exhaustive and integrated analysis of all possible options. The resource portfolio analysis is based on the creation of a number of scenarios, each of which is a mix of supply and demand-side resource options that comply with a minimum level of output to fulfill the demand and with a minimum reliability requirement⁸³. The analysis uses cost data inputs such as actual yearly cashflows, LCOE, or actual cost information (i.e. initial investment). Next, the present value of all costs incurred as part of each scenario gets calculated. Then, an assessment is carried out, which consists of comparing the present value of the different scenarios; the scenario with the lowest present value will yield the lowest electricity rates in the long term. The present value can also be converted into a blended LCOE for each scenario, if required.

⁸³ The minimum reliability requirement is ability of the utility to provide electricity to all connected consumers at will during periods when the instantaneous demand (i.e. the load) is the highest (i.e. the peak demand) even if the largest source of power generation of the grid (i.e. hydro grid or thermal community power system) was to stop working at the very moment of the peak. (e.g. if it breaks down, if preventive maintenance is urgently needed, or if the transmission line or power transformation substation fails.)

As an example, a resource portfolio analysis was used by YEC in its 2012 Resource Plan for Yukon's hydro grid. YEC produced a thorough forecast of electricity demand on the isolated hydro grid over a 20-year time span, including potential for new mine connections, as well as a schedule of when existing electricity generation capacity is due to be decommissioned or refurbished. For each scenario, new capacity requirements were to fulfill the forecasted demand and guarantee the service during the winter peak time.

In 2009, Newfoundland and Labrador Hydro conducted the second example of resource portfolio analysis that we found in the Arctic. Newfoundland and Labrador Hydro used the software HOMER to test a number of technological options for the thermal communities of Nunatsiavut on a community-by-community basis. HOMER stands for "Hybrid Optimization of Multiple Energy Resources" (HOMER Energy LLC, 2015). HOMER was designed to carry out automatic resource portfolio analysis for microgrids⁸⁴. The technological scenarios that were tested by Newfoundland and Labrador Hydro included a diesel-only status-quo scenario as well as various scenarios (i.e. permutations) including one or many of the following options: wind turbines, the best small hydro site near each community, and PV. All scenarios included diesel generators as backup. The Newfoundland and Labrador Hydro study is an excellent example on how to carry out a quick comprehensive resource portfolio analysis as a preliminary assessment for multiple communities in a rigorous and cost-effective manner (Newfoundland and Labrador Hydro, 2009). The study concluded that wind and small hydro were the most attractive energy options for most of the Nunatsiavut communities.

The resource portfolio analysis is the most comprehensive approach of the three methods discussed. It provides a more thorough assessment of all options because it looks at energy options in combination. Firstly, the analysis must create a portfolio of supply options that meet basic reliability and energy security requirements. The analysis must consider the interactions and synergies between sources that are intermittent (such as wind and solar) and sources that are dispatchable (such as diesel, LNG and hydro

⁸⁴ HOMER is a software that the research team has encountered multiple times when carrying out a literature review of alternative energy in the Arctic.

with reservoir, and to a lesser extent biomass and geothermal). For instance, the PV from a scenario that mixes both intermittent and dispatchable sources inherently factors in the effect of the potentially lower average total cost of production of the intermittent sources against the diesel baseline, and the balancing cost from the dispatchable capacity needed as a backstop.

Secondly, the analysis must also consider flexibility. Flexibility was defined in the Yukon Resource plan as a combination of development time and how large of an increment the investment(s) comes in. For example, new hydro projects might be attractive from a LCOE perspective, but development time is in the magnitude of 10 to 20 years, and the investment comes only in large increments. Forecasting whether the demand will justify a large new capacity addition 15 years into the future is risky. In other words, large hydro is said to be inflexible because if a developer builds a hydropower facility and does not find customers to sell all the electricity to (i.e. there is a surplus), then it will run into financial problems. No developer would accept this risk (private or public) and thus most if not all potential developers would request a minimal level of cost recovery to be guaranteed before moving ahead with the project (i.e. at least a recovery of amortization and interest). If the costs were to be recovered based on a lower level of sales (in kWh) then the average cost per kWh would increase and this would result in an upward impact on the electricity rates.

Despite the advantages, a drawback of resource portfolio analysis is that it requires a considerable amount of resources and time to be put at the disposal of the utility to carry out the analysis. For this reason, simple LCOE and Cost-Benefit Analysis may be the methods of choice at least for short-term circumstances.

7.3. Supply Planning in an Arctic Hydro-Grid Context

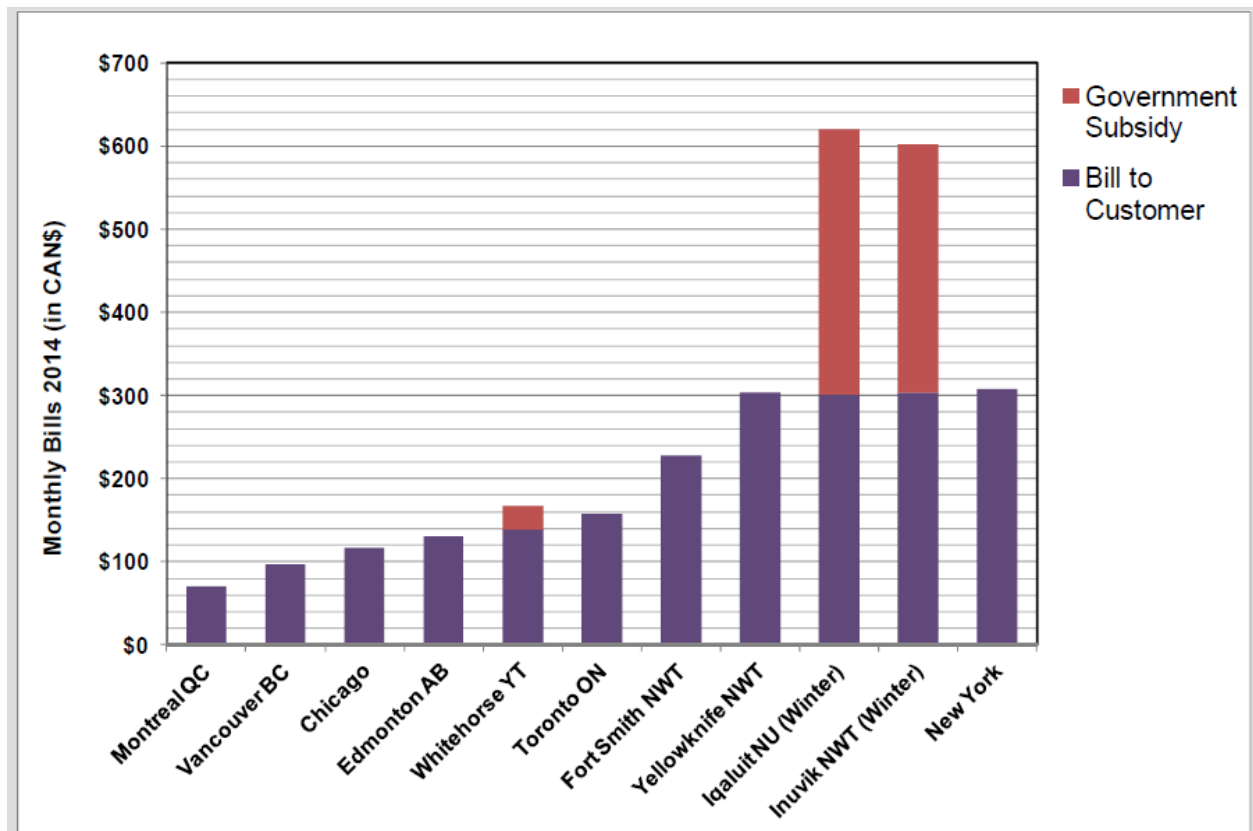
The three transmission grids (one in Yukon and two in NWT) share common characteristics:

- Reliance on hydropower plants for electricity generation;
- Surplus of hydro electricity during the spring, summer and fall, which cannot be stored or sold because of insufficient reservoir capacity and no interties with neighbouring jurisdictions;

- Shortage of hydro capacity during relatively short periods of time in the winter, requiring diesel ‘peaking’ gensets, thereby relying on diesel for a small amount of electricity generation (typically less than 5%); and
- Cost of delivering the electricity service that is considerably less expensive than in remote diesel communities by a factor of four or five (McLaren, 2014).

Figure 4 illustrates the difference in cost of service between Southern jurisdictions, Arctic hydro grids and off-grid thermal communities based on average consumer bills.

Figure 4 Residential (Non-Government) Electricity Bill Comparison



Note: Based on consumption of 1000 kWh/month (with riders, before taxes)

Source: (McLaren, 2014, p. 7)

Whitehorse, Yellowknife, and Fort Smith are representative of the three Arctic hydro grids mentioned above. Iqaluit and Inuvik are representative of off-grid communities.

The average monthly payment by consumers for all off-grid communities in Nunavik will be close to that for Montréal because the Act respecting the Régie de l'Énergie of 2001 compels the provincial utility, Hydro-Québec, to deliver electricity at the same rate for all customers regardless of where they are

located in Québec (Éditeur officiel du Québec, 2011). The interpretation of the Act has been relaxed since then, and consumption above 30 kWh/day (900 kWh/month) is now priced at a significantly higher rate. Monthly payments will nevertheless be relatively close in Nunavik to that in Montréal because most consumers do not use up to the 900 kWh/month, particularly since electric space and domestic water heating is banned in Nunavik (Hydro-Québec Distribution, 2013). Nevertheless, Nunavik's rates are lower than the actual cost of electricity service in Nunavik, which means that these costs are recovered by the utility from hydro-grid Southern ratepayers's contributions. This is referred to as a cross-subsidy.

The characteristics of hydro grids have two major implications for financial analysis. First, the short-term marginal value of any new electricity generator is nil unless it is generated during peak time or there is a reduced water flow. Consequently, intermittent generation sources such as solar and wind energy are of lower value to Arctic hydro grid-connected communities from a financial standpoint unless we experience large reductions in precipitation as was experienced in the summer of 2014 in the NWT.⁸⁵ A net-metering policy⁸⁶, for example, would put upward pressure on rates by reducing the volume of sales (on which the rate base is spread) and by avoiding hydro electricity generation, which comes at a near-zero marginal cost. Similarly, a classical feed-in tariff policy⁸⁷ (with a flat rate, regardless of when generation occurs) would also put upward pressure on rates because it would reduce sales and would, therefore, displace hydro electricity.

Yukon is in a different situation than the two NWT hydro grids because a shortage of hydroelectricity is expected in the winter due to a steep load growth forecast and potential incoming mine connections. That domestic load growth comes from both the effect of a growing population, new dwellings and

⁸⁵ Intermittent sources of energy do generate during peak times, but the peak times are short. Moreover, we are assuming that there is no storage. Firstly, there is some capacity of storage in the existing hydropower reservoirs, but that capacity of storage is limited and is already fully utilized to capture the energy surplus water flow. New storage technologies are being developed and tested in the South, but they have cost implications. For example, storage capability effect (i.e. ability to shift when electricity is delivered to the grid) and cost were factored in Yukon resource-portfolio analysis for two wind farm proposals and the wind farm options were rejected nevertheless due a financial performance that was less attractive than that of other alternatives.

⁸⁶ Net metering is a policy through which the power utility allows electricity consumers to supply electricity to the grid. When they do so, the utility credits their electricity bills an amount equivalent to the volume supplied multiplied by the electricity rate.

⁸⁷ Feed-in tariff is a policy instrument through which the power utility allows electricity consumers (or renewable energy independent power producers) to supply electricity to the grid. When they do so, the utility pays the electricity consumers (or the independent power producer) an amount equivalent to the volume supplied multiplied by an agreed tariff, which typically is higher than the electricity rate paid by consumers.

buildings and an increasing penetration of electric heating in Yukon's households (ICF Marbek, 2012). YEC forecasted a growing need for diesel generation and consequently, a more complex analysis must be performed than the one laid out above in order to establish whether a net-metering policy will have an upward impact on rates (Yukon Energy Corporation, 2011). The next paragraphs will introduce and explain a key concept that is necessary to perform this analysis: diesel-fuel genset marginal production cost.

The marginal production cost of electricity is the incremental cost incurred to generate one additional unit of electricity in a given location at a given moment. Key components of marginal production cost of diesel-fuel generation include:

- Fuel purchase, transportation and storage;
- Variable maintenance cost (periodical mechanical maintenance, after X hours of runtime);
- and
- Deferral of capital expenditures resulting in lower cost related to amortization & interest in the long run⁸⁸.

In Yukon, the second and the third components of the marginal cost were not accounted for and in the NWT the third component was not accounted for. Nunavut used the electricity rates in each community which means that it included both fixed and variable costs, as well as further biases introduced during rate design (e.g. cross-subsidies as discussed in Section 7.4). In Nunavik and Nunatsiavut it is unclear what components were associated with the marginal cost of production calculations (Government of the Northwest Territories, 2014, p. 8), (Yukon Energy Corporation, 2011), (IMG-Golder Corporation, 2011), (Institut de Recherche en Électricité du Québec, 2008), (Newfoundland and Labrador Hydro, 2009).

One promising approach to create a LCOE of alternative energy that can actually be compared with the marginal production cost of diesel generation in hydro grids is the "Forecast LCOE" approach. The "Forecast LCOE" is a variation of the LCOE used by YEC. The Forecast LCOE was computed as follows. Firstly, YEC made a forecast of the expected diesel genset operating periods in future years

⁸⁸ Example: Genset useful life is limited by a maximum runtime. Considering that alternative energy can allow genset to be switched off, the replacement or overhaul of these gensets might get deferred. Another example: a number of on-site storage tanks could be decommissioned due to the lower diesel requirements.

(mostly in the winter) in its hydro grid. Secondly, YEC calculated the LCOE but using only the kWh that actually gets generated during diesel operating periods. Finally, YEC made adjustments to the LCOE to account for its ability to store energy in its hydropower reservoir. Consequently, the Forecast LCOE formula accounts for only the portion of the output of the project that actually can be utilized to displace diesel, and disregards the portion of the output that is redundant. This property of the Forecast LCOE makes it a more appropriate measure to compare any technology with a diesel baseline. The marginal cost of diesel generation was estimated to be 28 cents/kWh in Whitehorse by YEC (Yukon Energy Corporation, 2011). The LCOE of a biomass power plant was estimated at 16.6 cents/kWh if all output was utilized but would have a Forecast LCOE of 92.5 cents/kWh when considering idle capacity. A wind farm with a regular LCOE of 15.5 cents/kWh would have a Forecast LCOE of 34.7 cents/kWh. Even with a Forecast LCOE, wind looks quite competitive with diesel given that it has other social and environmental benefits. It did not, however, look as attractive as the LNG Forecast LCOE at 18.4 cents/kWh (if shipped from Kitimat to Skagway and then trucked from Skagway to Whitehorse).

Although the Forecast LCOE provides a more accurate figure than the regular LCOE, it still does not fully account for the cost of firm backup diesel (or LNG) capacity to balance an intermittent resource like wind. Only a full portfolio analysis or an integrated hybrid-system cost-benefit analysis for off-grid communities, such as the wind-diesel analysis conducted by IREQ with SIMJED (Institut de Recherche en Électricité du Québec, 2008) allows analysts to appreciate the complete picture.

Furthermore, northern hydro grid communities would benefit from exploring more ways to value the surplus hydro electricity in the summer, while at the same time curtailing the winter peaks. This would, in effect, reduce rates because it would spread the rate base over a larger volume of sales at a minimal marginal cost of generation and avoid fossil-fuel generation. What has already been done is to pursue improvement projects on hydro reservoirs to maximize storage capacity, optimize the use of stored hydro electricity, and offer interruptible rates⁸⁹ to the largest customers (Yukon Energy Corporation, 2014).

Thermal communities receive a number of subsidies based on the relatively lower cost of hydro grid electricity. The existence of hydro grids in the North, which provide service to consumers at a relatively

⁸⁹ Interruptible rates are special lower electricity rates offered to customers in exchange for the permission to stop (interrupt) their supply a number of times during the year.

low cost, has led to the creation of a number of cross-subsidies to reduce the gap between the rates in thermal and hydro connected communities. These subsidies will be further discussed in Section 7.4.

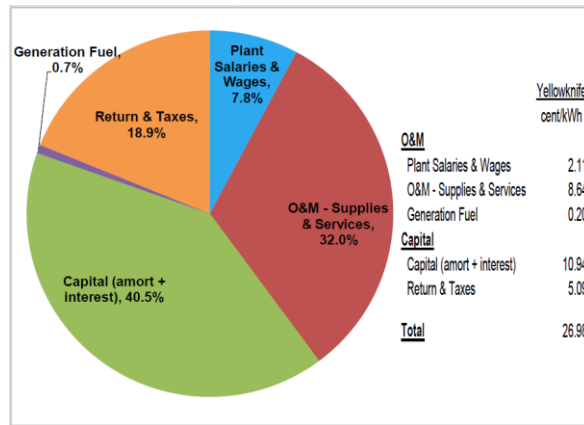
7.4. Supply Planning in an Arctic Thermal Community Context

Diesel generation is the technology supplying electricity to most remote communities in the Arctic (with the noticeable exception of gas in Inuvik, which is depleting faster than anticipated, and Norman Wells). Diesel has been used for several decades and the chain of distribution is well established. Qualified diesel technicians, plant operators and contractors are of no shortage. The technology is robust enough that it requires less involvement from utility headquarters' staff than many alternative energy solutions would (e.g. biomass power, waste-to-energy, wind turbines). It is a firm-capacity resource and it provides reliable dispatchable power. Although diesel system efficiency used to be only about 25 to 30%, the efficiency ratings have improved from 30% for the smaller systems to 42% or even 48% for the larger systems at full load. Diesel gensets also have good part-load efficiencies. (ICF International, 2008)

A Thermal Community diesel system consists of diesel storage tanks, diesel-fired reciprocating engines connected to their respective alternators (gensets), and a small electricity distribution system connecting to community houses and buildings. Diesel power plants usually have more than one genset to modulate the load (i.e. vary the level of production to match demand) and for system redundancy and reliability. The capital expenditure requirements are low relative to most alternative energy sources and operational expenditures (i.e. fuel and maintenance) are relatively high. Diesel genset exhaust or water jacket heat has the potential to be recovered and used for space heating provided that nearby buildings are sufficiently close to make the installation of the heat system economically viable. There are environmental issues related with transportation and storage of fuel, and diesel generation emits greenhouse gas particulates and other contaminants, which contribute to climate change and localized health issues.

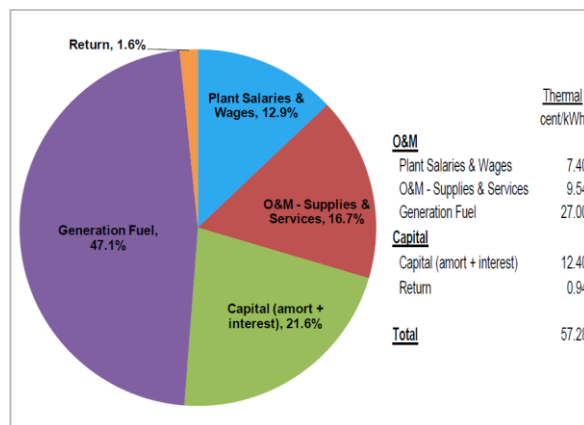
Figure 5 illustrates the cost of generating electricity using diesel in Arctic off-grid communities, in comparison to that in northern hydro grids.

Figure 5 Current NWT Electricity System Costs in NTPC Residential Rate Breakdown



Note: For Rates in place as of November 2014

Source: (McLaren, 2014, p. 2)
NTPC's Hydro Grid



Note: For Rates in place as of November 2014

Source: (McLaren, 2014, p. 4)
NTPC's Thermal Zone (Off-Grid Communities)

Figure 5 presents a breakdown of the total average cost of service for all categories of electricity consumers (i.e. rate classes). The first chart above shows the average cost of service per kWh for the hydro grids, while the second chart shows the cost for NTPC off-grid communities. Amortization and interest of past hydro and transmission capital investments constitute the largest portion of the cost of service (40.5%) in the hydro grid, while fuel costs represent the largest portion in off-grid communities.

The second chart connects with the discussion of the fossil fuel marginal cost of electricity production in Section 7.3. It shows the three components of marginal production cost: fuel, capital expenditures (i.e.

amortization and interest), and operational expenditures (i.e. salaries, wage, supplies and services). Capital expenditures and operational expenditures are often ignored when establishing marginal production cost in off-grid communities.

Table 4 shows the relatively small return on equity (profit) in NWT off-grid communities, which is due to the regulated 0% return on equity in off-grid communities imposed on NTPC (plus a 1.5% reserve margin). NTPC's regulated return on equity for its hydro-grid is 8.5%. Both the return and tax go to the territorial government. Figure 5 shows that the return on equity and taxes, together, amounts for 18.9% of the cost of service. Further, to establish the average cost of service, electricity rate design entails the allocation cost of service to each rate class (i.e. the true cost of electricity). Rate classes in Arctic jurisdictions typically include: non-government residential and non-residential (i.e. general service) rate classes, government residential and government general service rate classes. Cost of service may also be differentiated by hydro versus thermal, and then between thermal communities. After performing cost allocations, utilities and regulators typically establish the final rate for each class by designing "cross-subsidies", which means that rates will not match cost of service allocation. Certain categories of customers will pay more than their "allocated" cost of service and other categories of customers will pay less as long as the total revenues of the utility will match the cost of service. Cross-subsidies (as well as direct government subsidies) are created (or abandoned) on the basis of considerations such as fairness between ratepayers inside a jurisdiction, ability to pay, and economic efficiency.

Table 7 presents the total average cost of electricity generation, also known as “cost of service”, across the five jurisdictions based on available information. The table also includes comments on the components of cost of services, and whether the true cost of service is passed on to residential consumers or if it is somehow subsidized.

Table 7 Cost of Electricity Generation

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Off-Grid Thermal Generation	Weighted Average: \$1.13/kWh Lower Range: \$0.97/kWh Upper Range: \$2.15/kWh (2012)	NTPC: Weighted Average: \$0.58/kWh (2012) Northland Utilities (NWT): Weighted Average: \$0.70/kWh (2015) (Presented as an aggregate in the GRA.)	Weighted Average: \$0.65/kWh Lower Range: \$0.50/kWh Upper Range: \$1.01 /kWh (2012-2013)	Weighted Average: \$0.75/kWh Lower Range: \$0.65/kWh Upper Range: \$1.32/kWh (2013)	Weighted Average (Residential): \$0.86/kWh (forecast test-year 2015)
What Is Included in Cost?	<i>Diesel fuel only.</i> It was not possible to allocate thermal community-specific amortization & interest, O&M expenditures, customer service and administration from the information provided in ATCO’s GRA. Diesel is supplied by a private firm selected through competitive tendering, thereby assumed to be sold at market price to ATCO.	Based on actual revenues divided by sales (kWh), for all the thermal communities; thereby including fuel cost, a portion of amortization and interest, O&M expenditure, customer service and administration.	Based on actual revenues divided by sales (kWh), assuming utility revenues reflect community-specific cost of service; thereby including fuel cost, a portion of amortization and interest (because a number of capital expenditures were funded by the Government of Nunavut), O&M expenditure, customer service and administration.	Including fuel cost, amortization and interest, O&M expenditure, customer service, administration, and DSM program costs.	Including fuel cost, amortization and interest, O&M expenditure, customer service, administration, and DSM program costs. (Complete cost of service.)
Is Final Price Paid by Non-Government Residential Customers Subsidized?	Yes. Cross-subsidy from government toward non-governments customers, and cross-subsidy between hydro-grid and diesel communities (average rate for the Yukon is \$0.15/kWh). The Yukon government subsidize non-governmental <i>residential</i> rates with the Interim Electrical Rebate of \$0.02/kWh.	Yes. Cross-subsidy from government toward non-governments customers (\$5,260,000). Direct government subsidy for residential rate in remote communities to equalize rates with Yellowknife (\$5,214,800 in NTPC communities, and \$518,000 in Northland Utility communities). Fuel price subsidization (\$2,450,000) in sixteen communities where Public Works and Services manages the purchase, transport, and storage of bulk petroleum products. All subsidies were estimated for financial year 2012-2013.	Yes. Cross-subsidy from government toward non-governments customers (being phased out by the regulator), and cross-subsidy between communities to harmonize rates throughout the territory (being progressively phased in by the regulator). While rate harmonization has not been achieved yet, a direct government subsidy is added to pay the differential between Iqaluit rates (approx \$0.50/kWh) and those of other Nunavut communities.	Yes. Cross-subsidy from Southern ratepayers that brings down Nunavik rates to parity with Québec Southern rates (so about \$0.07/kWh) for consumption below 30 kWh per day, which makes electric space heating unattractive.	Yes. Cross-subsidy from other NL Hydro ratepayers that brings down Nunatsiavut rates to those paid by Newfoundland Power customers. Additional direct-government subsidy (i.e. Northern Strategic Plan) to bring the first electricity block price (i.e. the so-called “lifeline” block) further down.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Generation in Hydro Grid (for comparison)	\$0.15/kWh (2012)	NTPC's cost of service (Generation Only): North Slave (Snare): \$0.1726/kWh South Slave (Taltson): \$0.1226/kWh (2012) Northland Utilities (NWT) cost of service (Taltson, including generation): \$0.287/kWh (2015) Northland Utilities (YK): Not available	N/A	N/A	N/A
Notes:	Based on actual total ATCO revenues divided by total sales, assuming utility revenues reflect cost of service; thereby including fuel cost, amortization and interest, O&M expenditure, customer service and administration. Includes diesel generation cost because these were not allocated, but this only represents a small portion of total cost.	Based on actual total utilities' revenues divided by total sales, assuming utility revenues reflect all cost of service; thereby including fuel cost, amortization and interest, O&M expenditure, customer service and administration.			

Sources: (ATCO Electric Yukon, 2013), (McLaren, 2014), (Government of the Northwest Territories, 2013), (Northwest Territories Power Corporation, 2012), (Northland Utilities (NWT) Limited, 2013), (Northland Utilities (NWT) Limited, 2014), (Government of Nunavut, 2005), (Qulliq Energy Corporation, 2013), (Hydro-Québec Distribution, 2011), (Hydro-Québec Distribution, 2013), (Newfoundland and Labrador Hydro, 2014), (Newfoundland and Labrador Hydro, 2014)

As introduced in Table 7, “government” rate classes typically cross-subsidize “non-government” rate classes. In the Yukon and in Nunavik, hydro grid ratepayers cross-subsidize off-grid communities. In Nunavut, Iqaluit ratepayers cross-subsidize ratepayers in other communities.

Further to cross-subsidies, the territorial governments of NWT and Nunavut provide a subsidy to residential thermal community ratepayers to make the final electricity price equal to that of Yellowknife and Iqaluit respectively. The territorial Government of Yukon subsidizes the rate of non-government residential customers in all of the territory.

7.5. Alternatives to Diesel Power Generation

The main technology currently challenging diesel in a number of communities is liquefied natural gas (LNG). The fuel is less expensive, it burns cleaner (less greenhouse gas and other air emissions), and efficiency can be higher with the use of combined cycle plants (Yukon Energy Corporation, 2011).

Existing diesel gensets can be used or else new gensets can be purchased for a relatively modest capital investment, and it is a firm-capacity resource. LNG does not preclude the adoption of intermittent new renewables such as solar photovoltaic and wind, and can serve as a backstop just like diesel. LNG can also be used to supply mining camps to fuel trucks, cars, trains and boats and for space heating (Tugliq Corporation & SECOR-KPMG, 2013).

The main drawbacks of LNG are the missing supply chain, challenges with transportation (it can only be trucked in or shipped by boat or train (where tracks exist), issues with long-term storage because heat slowly penetrates the insulated storage tank and vaporizes the liquid, the volatility of gas prices, and social acceptability. Despite the drawbacks, the economics of diesel to LNG conversion projects are promising enough that the challenges are being addressed by YEC and NT Energy. YEC has an on-going LNG project in Whitehorse, ATCO Electric Yukon has a project in Watson Lake, and NT Energy has one completed project in Inuvik. The Government of Québec also retained LNG as a viable solution for Northern Québec at the culmination of its 2013 public consultation on energy (Lanoue & Mousseau, 2014). Current plans include the possibility of shipping LNG by boat to Nunavik Raglan Mine and coastal communities, and by train to the mines located in the Labrador Trough.

Alternative technologies that are challenging diesel are explored below. Aside from offsetting fuel consumption for power generation in the communities, all of these technologies have the potential to reduce the dependence of communities on imported fuels (energy security) and also offer the benefit of lowering the cost of supply volatility because they are less dependent on the global price of oil or regional fluctuations in the price of LNG.

Wind-Diesel or Wind-LNG Hybrid Systems: Wind is an intermittent resource that can offset diesel consumption. Table 6 showed that the LCOE of wind may, in certain cases, be lower than the marginal cost of fuel for electricity generation. Other benefits include low GHG emissions and lower volatility of production cost than that of diesel generation. The use of electricity storage with a wind system can improve the short-term (diurnal) match between load and generation, which allows wind energy to reach a higher percentage of the total electricity generation for a community (referred to as a “high-penetration” system).

Economy of scale is a critical consideration in assessing wind projects. For instance, larger projects which are connected to Yukon's hydro grid, shown in Table 6, have a much lower LCOE and would be considered attractive if it were not for Yukon's hydro surplus situation during most of the year. Wind also requires qualified mechanics on site to maintain turbines. These reasons may be why large wind turbines have been installed in Arctic mines like the Diavik Diamond mine, NWT, and the Raglan Mine, QC (see case study in Section 8), but have not been widely adopted across the Canadian north. Mines have large predictable loads and many qualified mechanics onsite compared to communities. Wind projects are also relatively quick to implement compared to hydropower, geothermal and biomass power. A number of technical challenges (e.g. frost, foundations, requirement for a crane during construction) related to operating wind turbines in the Arctic have solutions however, the wind resource needs to be sufficiently close to the load, and the turbines have to be proactively maintained.

Solar Photovoltaic (PV): PV shares a number of characteristic with wind energy: it is an intermittent source that requires dispatchable back-up, penetration can be increased if installed along with storage capacity, and it can be cost-competitive with diesel generation in some circumstances.

A key advantage of photovoltaic is its widespread availability in all Arctic off-grid communities; while sufficient wind or hydro resources, by opposition, are not available in all communities. Another advantage is the relative stability and ease of operation and maintenance of the systems (although many grid-integration challenges remain). PV systems are being installed in communities where the marginal cost of fuel is the highest, such as Lutselk'e, NWT where diesel is flown in, or Colville Lake where diesel is trucked in on winter roads. A PV solution is also being studied for Old Crow, where diesel is also flown in. The disadvantages are seasonal and diurnal variations in generation that often are mismatched with demand.

Hydropower: Hydropower may be a firm-capacity resource under certain circumstances but this depends on whether a project is in close proximity of the community. The LCOE of a hydro project may be, in certain cases, lower than the marginal cost of fossil fuel generation over its extensive lifetime (up to 50 or even 100 years). While specific projects have been developed (pre-feasibility only) in Iqaluit, Nunavut, and Inukjuak, QC, specific LCOE for these projects were not available as the projects have been

put on hold⁹⁰. Both project proponents assert that the projects are competitive with the marginal cost of diesel generation. (Pituvik Landholding Corporation) (Kerr, Cook, & Bernhardt, 2012).

As with wind, the feasibility of hydro projects depends on a site being close to a mining site or community and on economies of scale. Projects are more likely to be viable if located near the largest off-grid communities and/or large mines. Large Arctic mines, however, have shown little interest in investing in, or being a partner with a hydro development project despite their high power load. There are two reasons for this. Firstly mines want flexible power generation solutions in terms of development time and capital intensity. They want to be able to start production quickly, and they want to be able to shut down production quickly, if needed, without incurring excessive sunk cost (i.e. without leaving stranded assets behind). Secondly hydro developments are often controversial and trigger public opposition and the permitting process can be lengthy.

Geothermal Power: Geothermal has the potential to be considered a firm-capacity resource. Geothermal is contingent on the availability of the resource near a populated area. There is a large area with excellent geothermal potential in Yukon, East of Whitehorse, and in the NWT, west and northwest of Yellowknife.

In YEC's 2012 Resource Plan, geothermal is considered to be a "long-term" resource depending on successful exploration results. NTPC pursued a number of studies of geothermal power at Fort Liard, but abandoned the project due to perceived risk regarding the quality of the resource, absence of economies of scale (NT Energy, 2013), and technical challenges related to modulation capability required to match the community electricity load (Sinclair-Knight-Merz, 2012). The ability for any electricity production to swiftly respond to demand variation is critical in off-grid communities, more so than it is on the continental grid. A geothermal plant supplying a small community would have to operate at a lower capacity factor, which would have upward impact on the LCOE.

Biomass Power: Biomass power has the potential to become a firm resource capable of fully replacing diesel or LNG. Biomass power was highlighted during the NWT 2014 Energy Charrette because of the abundance of standing burned trees caused by the summer 2014 drought that could be

⁹⁰ Jamie Flaherty, QEC, *Personal Communication*, January 2015

harvested and used as feedstock, and because of the potential of sustainable harvesting of regular trees (see case study on Fort McPherson in section 8.2). NT Energy committed to study the feasibility of using that feedstock to generate power in the communities. The Energy Branch, Department of Energy, Mines and Resources, YTG is also working on solving technological challenges (Preto, 2014). Biomass power in remote communities would face the same challenges as those faced by geothermal power: dependence on the availability of the resource (or on ability to import it in a cost-efficient manner), economies of scale, technical challenges related to the modulation of the output, and availability of qualified mechanics in remote communities⁹¹.

Waste-To-Energy Power: Waste to energy power refers to power generated from burning waste at a high temperature in a boiler, using the heat to turn water into steam, and then generating power using a steam turbine. Alternatively, the waste can be turned into a combustible gas and then used in a generator (reciprocating engine, gas turbine, boiler and steam turbine, or combined cycle). There are a number of ways of doing this. Firstly, waste can be piled up in a landfill, and then the waste fill emits biogas (i.e. gas with high methane content) from the decomposition of organic matters over time. The biogas gets collected, toxic gases are removed, and the clean combustible gases are sent to the generator. Secondly, organic matter can be converted into biogas quicker inside an anaerobic digester. Thirdly, waste can be sorted to remove recyclable and toxic materials, and then the remainder can be fed to an incinerator with heat recovery. Fourthly, the waste can be sorted, and then the remainder can be gasified (through high heat or plasma, for example), then toxic gases get removed, and the remainder of the combustible gases (mostly methane and carbon monoxide) can be supplied to a generator. A benefit of the technology is that it can also help eliminate waste from community landfills. It could become a firm resource in the long run but faces the same challenges as geothermal and biomass.

7.6. Financial Analysis of Demand-Side Resources

Demand-side resources are technological solutions (equipment) installed on the premise of energy end-users. Examples include energy efficiency measures, load curtailment solutions such as dual energy

⁹¹ David Mahon, NT Energy, *Personal Communications*, November 2014

systems, direct load control or three-element domestic hot water tanks, or embedded generation such as building-mounted solar photovoltaic panels or micro-cogeneration. Typical policies that encourage demand-side resources include DSM programs, feed-in tariffs or net metering. This section will explore demand-side resource financial analysis in greater detail. Two examples of demand-side resource financial analysis that were conducted specifically for the Arctic can be found in the 2013 Yukon 5-Year DSM Plan (ATCO Electric Yukon, 2014) and in the 2007 Newfoundland and Labrador 5-Year DSM Plan (Newfoundland and Labrador Hydro and Newfoundland Power, 2007). Hydro-Québec Distribution is both familiar with DSM financial analysis and the delivery of DSM programs in Arctic communities. No demand-side resource financial analyses were found for the NWT or Nunavut.

The financial analysis of all demand-side resources is distinguished from supply-side analysis by two components:

- Two additional stakeholders: “program participants” and “non-participants”,
- New types of cashflow to be considered, including “lost revenues” or “bill savings” and “incentives” or “compensation”.

Demand-side resource financial analysis is typically carried out using the same three methods as presented in section 7.2: LCOE, cost-benefit analysis, and resource portfolio analysis.

DSM programs, load curtailment, or net metering⁹² programs may be led by utilities like InCharge (a joint effort by ATCO Electric Yukon and YEC), takeCHARGE (a joint effort by NL Hydro and Newfoundland Power) and Hydro-Québec Distribution, government agencies such as the Energy Branch, Department of Energy, Mines and Resources, Government of Yukon, or government-funded independent agencies like the Arctic Energy Alliance. These three types of actors are referred to as “Program Administrators”⁹³.

⁹² A policy through which the power utility allows electricity consumers to supply electricity to the grid. When they do so, the utility credits their electricity bills an amount equivalent to the electricity supplied multiplied by the electricity rate.

⁹³ A fourth type of program administrator that is unseen in the Arctic but that is fairly common in North America is the ratepayer-funded independent agency like the Energy Trust of Oregon, or Efficiency Nova Scotia.

In 2012-2013, YEC and ATCO Electric Yukon (the Yukon Utilities, InCharge) jointly designed a portfolio of DSM programs for the residential and commercial/institutional rate classes. InCharge's analysis showed that the benefits (i.e. avoided diesel generation) outweighed costs for society by 40%, for the utilities by 130%, and for program participants by 190%. The results also indicated, however, that 20% of the costs of the program would have to be recouped through a rate increase to compensate, in part, for utilities' lost revenues (ATCO Electric Yukon, 2014). DSM cost-effectiveness testing was also performed by takeCHARGE in Nunatsiavut and other Labrador thermal communities. TakeCHARGE showed that the benefits of thermal community-specific DSM programs outweighed cost from the perspective of society (Newfoundland and Labrador Hydro and Newfoundland Power, 2007).

Conservation programs have benefits beyond financial aspects. For example, "Voters' preference" is a critical factor in favor of energy conservation. When consulted, citizens of the Yukon, NWT and Québec strongly voiced their preference for energy conservation over new supply-side resources (Yukon Energy Corporation, 2011) (Government of the Northwest Territories, 2013) (Lanoue & Mousseau, 2014). It may therefore be justified to conduct DSM programs that do not yield positive benefits under certain circumstances.

Voters' preference for conservation is one more reason to build a strong accountability framework to ensure the continued existence of conservation activity and continuous improvement. Cost-effectiveness testing could be a key component (among others) of that accountability framework. This testing helps program administrators continuously improve their performance by, for example, shedding the least cost-effective programs or conservation measures from their portfolio, wisely selecting which programs to design and implement, better allocating resources, or adapting incentives and levels of effort to changing market conditions.

7.7. Financial Analysis of Space and Domestic Water Heating Projects

Houses and other buildings in the Arctic have traditionally been heated using heating oil, and to a lesser extent propane, wood cords and gas (in Inuvik and Norman Wells, NWT). Domestic water is heated with heating oil, propane or electricity.

Alternative energy projects for heating typically involve boiler or furnace upgrades with or without fuel switching, dual-energy systems (e.g. off-peak electricity as a primary source and heating oil as a backup), district energy systems (possibly supplied by diesel genset waste heat or a biomass boiler), solar water heater, control optimization (e.g. temperature setback), heat recovery, or building envelope improvements.

Cost of Petroleum Products

Table 8 presents the cost of petroleum products in the Arctic. These costs include fuel, transport, storage and retail cost. Externalities such as energy security and oil spill cleanups, despite being important considerations in the Arctic, are not being considered in the table. Table 10 also discusses information on the heating fuel supply chain.

Table 8 Supply Cost of Petroleum Product Used for Space and Water Heating

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Fuel Supply Cost	Price of Heating Oil (Feb 18, 2015): Max: \$1.179/L \$30.70/GJ Min: \$1.062/L \$27.66/GJ Price of Propane: \$0.845/L \$31.87/GJ	Price of Heating Oil (June, 2014): Max: \$1.90/L \$49.48/GJ Min: \$1.27/L \$33.07/GJ Price of Propane: Max: \$1.43/L \$37.24/GJ Min: \$0.72/L \$18.75/GJ Price of Natural Gas: Max: \$35.44/GJ Min: \$18.43/GJ	Price of Heating Oil (2011) Max: \$1.14/L \$28.16/GJ Min: \$1.08/L \$29.69/GJ	Price of Heating Oil (January, 2015): \$1.929/L \$50.22/GJ	Price of Heating Oil (Feb 19, 2015): Maximum Allowable Pricing for Labrador Coastal North \$1.214/L \$31.61/GJ
Types of Suppliers:	Private bulk dealers and commissioned agents (e.g. White Pass, Petro-Canada, and Esso), and then private retailers handles retail sales to residential consumers.	Same as Yukon for most communities. Fuel price subsidization in sixteen communities where Public Works and Services manages the purchase, transport, and storage of bulk petroleum products.	Government-owned and operated supplier: Petroleum Products Division of the Community and Government Services. (Outsourced to privately-owned Uqsuq Corporation in Iqaluit and to Kituna Corp. in Cambridge Bay)	Bulk dealers and commissioned agents owned by the Makivik Corporation. The suppliers handle Hydro-Québec Distribution's subsidy (further discussed below).	No description found.
Price Control	None found.	None found, aside from the subsidies presented below.	Yes. Set by Financial Management Board of the Government of Nunavut for the Petroleum Products Division. The Financial Management Board ensures that all cost gets included in price. The price is stabilized by the Petroleum Products Revolving Fund.	None found, aside from the subsidy presented below.	Yes. There is a Maximum Allowable Pricing set by the Newfoundland and Labrador Board of Commissioners of Public Utilities.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Full Supply Cost Passed to Consumers in Price?:	Yes. Included: upstream costs, transport, storage, and retail.	No. In 16 communities supplied in oil products by Public Works and Services, the price does not contain the amortization and financing of storage facilities. In addition, the Government of the NWT offers a Seniors Home Heating Subsidy and the Housing Corporation The Housing Corporation pays the full cost of heating fuel for its 2,350 housing units.	Yes, as per above. However, Nunavut home owners were eligible for a lump-sum fuel rebate of 500\$ for the 2014/2015 winter season. Also, it should be noted that 52% of all housing in Nunavut are public housing units, with the Government of Nunavut paying for heating oil. Income Support Program includes a heat payment, which also indirectly subsidizes heating oil.	No. Heating oil is subsidized by Hydro-Québec Distribution. 30% of the cost of heating oil for both residential and non-residential ratepayers, representing 40.91 and 46.96 cents per litre respectively (in 2013). Hydro-Québec Distribution also provides maintenance services. The subsidy is a disincentive to using electricity for heating in thermal communities.	Yes, so long that the maximum allowable pricing does not curtail market price, or creates cross subsidies between communities in Newfoundland and Labrador. In addition, residents of Nunatsiavut are eligible to apply for a maximum lump-sum rebate of \$500.

Note: Heating value of heating oil 38.4 MJ/Litre and propane 26.6 MJ/Litre. RETScreen. (Natural Resources Canada, 2015)

Sources: (Government of Yukon, 2015), (Arctic Energy Alliance, 2014), (Siddik Mohammad of the Petroleum Products Division, Personal Communication, 2011), (Petroleum Product Division, 2010) (Government of Nunavut, 2014), (Régie de l'énergie du Québec, 2015), (Hydro-Québec Distribution, 2013), (Newfoundland and Labrador Board of Commissioners of Public Utilities, 2015), (GNL-Department of Finance, 2015)

There are a number of suppliers operating in the Arctic and many are privately-owned. The framework for heating is simpler than that for electricity supply in that there is less regulatory oversight.

There is no general rule that can be drawn from our pan-Arctic research, aside from the fact that the increasing and volatile price of petroleum products is a preoccupation in all Arctic jurisdictions. Prices were found to be the lowest in Yukon, even for the community of Watson Lake, which experiences the highest prices in the territory⁹⁴ (Government of Yukon, 2015). Yukon is the only jurisdiction where no price control strategy or subsidy was found.

The price of heating oil in Nunavik in January 2015 was \$1.929/L, while at the same time the bulk price at the Port of Montreal was \$0.665/L. (Régie de l'énergie du Québec, 2015) Therefore, the cost of transportation by ship, storage, and retail represent approximately \$1.20 per litre in the coastal communities of Nunavik. This is a good illustration of how transport and storage can be a critical component of price.

⁹⁴ The fly-in community of Old Crow, Yukon, was not in the list.

Typical Indicators Used in the Financial Analysis of Heating Projects

The financial analysis of heating options that we found in the North either focused exclusively on the difference between fuel costs (ignoring capital expenditure and O&M) or looked at the simple payback period of heating projects. The simple payback period merely consists of dividing initial project cost by annual avoided cost (or savings). In the Arctic, the perspective used in financial analysis has mainly been that of the technology adopter (i.e. the “participant”), which means that the test that was being used was implicitly the “participant cost test”.

Table 9 presents the identified financial measures for alternative heating projects in the Arctic.

Table 9 Financial Indicators of Alternative Heating Sources

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Imported Biomass	\$50.00/GJ for incremental cost in a new house \$52.78/GJ for full cost in an existing house \$55.56/GJ for a pellet boiler in a building (LCOE)	Percentage representing pellets cost (including transport) compared with oil cost as per May 2009: Max: 65% (Fort McPherson), and 90% in Aklavik (because of winter-road transport costs) Min: 32% (Fort Providence) % compared with gas: Inuvik: 95%, Normand Well: 111% (Pellets trucked from La Crete, AB)	Was not considered in the IMG-Golder Corporation inventory.	No financial analysis found.	No financial analysis found.
District Heating	Cogeneration with imported biomass: 54.76/GJ Cogeneration with LNG: \$54.34/GJ (LCOE with Societal perspective.)	District Heating with Imported Biomass. Simple payback period: 7 years to 31 years, depending on community. Assuming no interest payments and developer’s return on equity, no investment on the customer’s end, and no operational cost other than feedstock cost. Compared with heating oil price on May 2009.	See Wasted Heat from Diesel Plant.	No financial analysis found.	No financial analysis found.
Locally-Sourced Biomass	No financial analysis found.	NWT is currently exploring ways to use standing burned trees from the summer 2014 forest fires. No financial analysis found.	Locally-sourced biomass (including peat) was ruled out by IMG-Golder Corporation, based on extensive literature review and interviewing. The	No financial analysis found.	No financial analysis found.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
			assessment was qualitative only. Biomass was not considered as a priority resource.		
Building-Envelope Energy Conservation	Domestic hot water pipe insulation \$0.64/GJ, Programmable thermostats \$2.89/GJ, Domestic hot water tank insulation \$19.13/GJ, cold-climate air-source heat pump \$47.22/GJ (All LCOE and for existing homes.) Many other LCOEs provided in the ICF Marbek Conservation Potential Review report or CPR.	Commercial Case study: Simple payback period of 7 yr (after applying a \$10,000 incentive funding) for commercial building in Yellowknife. Residential Case Study: Annual Savings \$1,090 for a house in NWT.	No financial analysis found.	Hydro-Québec Distribution conducted a conservation potential review in Nunavik in 2012, which included conservation measures targeting heating oil energy services as well as power peak-load curtailment measures. A number of building envelope measures were investigated. No financial performance indicators were provided by Hydro-Québec, but they did identify a number of measures that were deemed “economically feasible”.	No financial analysis found.
Control or Mechanical System Energy Conservation	Attic insulation \$24.83/GJ, SuperGreen ⁹⁵ Homes for new homes \$26.42/GJ, basement insulation \$28.61, air leakage sealing and insulation \$33.25/GJ. (All LCOE and for existing homes, unless specified.) Many other LCOEs provided in the ICF Marbek CPR.	No financial analysis found.	Qualitative analysis by IMG-Golder Corp. based on extensive literature review and interviewing suggested ground-source heat pump projects (also known as geothermal or geoexchange) may be pursued as demonstration projects. Ground-source heat pump was not considered as a priority resource.	Hydro-Québec Distribution investigated control or mechanical system energy conservation measures in Nunavik as part of their 2012 conservation potential review. No financial performance indicators were provided by Hydro-Québec, but they did identify a number of measures that were deemed “economically feasible”.	No financial analysis found.

⁹⁵ SuperGreen is a house energy performance endorsement label invented and promoted by the Yukon Housing Corporation in the Yukon.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Solar Water Heater	\$83.33 to \$166.67/GJ for small residential installation (2 panels) \$55.56 to \$108.33/GJ for large commercial installation (approx. 50 m ²) (LCOE)	Case study: annual savings \$1,282 against heating oil in 2009.	The Government of Nunavut hired IMG-Golder Corporation to perform cost-benefit analyses of solar thermal. Results were provided as internal rate of return and essentially compared fuel cost with the alternative energy. According to this study, the cost of solar water heating is higher than the current fuel cost in Arviat (i.e. the internal rate of return was negative). ⁹⁶	No financial analysis found.	No financial analysis found.
Wasted Heat from Diesel Plant	No financial analysis found.	No financial analysis found.	Qualitative analysis by IMG-Golder Corp. based on extensive literature review and interviewing suggested that numerous residual heat projects were implemented in Nunavut, many of which with AANDC's ecoEnergy program, and that residual heat projects are an attractive solution in a number of circumstances. In 2011, 19 of such systems were in use. No financial analysis was performed.	Hydro-Québec Distribution rejected residual heat projects in Nunavik and stated that they were not cost effective, based on studies in Kujjuag, Kangiqsualujuaq and Akulivik. The reports for these studies were not found.	No financial analysis found.
Off-Peak Electricity Heating through Electric Thermal Storage (ETS)	Cost of heating with ETS or with electric baseboards in 2013: \$43/GJ. Full cost of ETS in existing housing \$12,730, and incremental cost of ETS in new housing \$8,730. ETS would benefit the society by allowing load curtailment, so the ETS cost would need to be refunded to users by the utility.	No financial analysis found.	No financial analysis found.	No financial analysis found.	No financial analysis found.

⁹⁶ i.e. The internal rate of return was so low that the RETScreen model did not provide an actual result other than indicating that the result was negative. Actual Nunavut project costs based on pilot projects were used.

	Yukon	NWT	Nunavut	Nunavik, QC	Nunatsiavut, NL
Biofuels Made from Fish Processing Wastes	No financial analysis found.	No financial analysis found.	\$0.55 per L of biofuel for the small-scale system (which can only use high grade fish oil and therefore has limited capacity) and \$1.62 per L of biofuel for the automated system which can handle fish oil of any quality and is easier to operate. (Unspecified heat content.) Biofuels were not considered as a priority resource.	No financial analysis found.	No financial analysis found.

Note: All financial indicators presented above are under the perspective of the participant (energy end-user / technology adopter) unless specified otherwise. Wherever the financial indicator is a LCOE, by default it includes: initial investment; interest; return on equity; annual fuel, electricity and/or biomass feedstock cost; and operational expenditures. Conversion factor: 3.6 MWh-thermal in 1 GJ.

Source: (Yukon Energy Corporation, 2013), (ICF Marbek, 2012), (Zanasi, Pinard, Hicklin, & Maissan, Initial Economic Analysis of Electric Thermal Storage in the Yukon, 2014), (Arctic Energy Alliance, 2009), (Arctic Energy Alliance, 2013), (Arctic Energy Alliance, 2013), (Arctic Energy Alliance, 2011), (IMG-Golder Corporation, 2011), (Hydro-Québec Distribution, 2013), (Hydro-Québec Distribution, 2013)

Table 9 illustrates that financial analysis of alternative energy for heating project is:

- Less common in the literature than that for electricity supply-side and demand-side projects.
- Less coherent with regard to the method employed.

The methods that were found encompass: cost per GJ comparison, percentage representing alternative energy cost compared with oil cost, cost-benefit analysis, levelized cost of energy in \$ per GJ or in \$ per MWh-thermal, simple payback period, and internal rate of return. Typically, the perspective employed is that of the energy end-users, thereby ignoring any upstream subsidy or externalities. These inconsistencies make comparison of different methods challenging.

8. Case Studies

Over the past two decades, Canada's North has seen an increasing number of renewable energy and energy efficiency projects move from conception stage into completed projects, providing a rich diversity of northern case studies from which to learn lessons, contemplate common barriers, and share success stories. While many of these projects have experienced challenges along the way, most have succeeded in achieving their objectives such as reduced energy costs, lower greenhouse gas (GHG) emissions, local economic stimulation, and building greater local capacity and self-reliance. Given the growing number of

these projects operating and being planned, and the increasing rate of renewable energy and energy efficient project implementations in the North, it is important to examine the key parameters that have influenced the projects and to share what has been learned along the way, so that others may benefit from this growing body of alternative energy knowledge and expertise in the North.

Eight case studies from across the North are highlighted in this chapter. The cases represent a cross-section of northern regions and alternative energy and energy efficiency technologies, as well as representation from both public and privately-driven projects. The case studies are organized under two main categories: 1) **Operational Case Studies**, describing projects already constructed and producing renewable heat or power, or reducing demand side energy loss, and 2) **Forward-Looking Case Studies**, representing projects still under active development.

Each case study includes a project description, objectives and drivers⁹⁷, the role of policy, and a description of barriers, outcomes, success factors⁹⁸ and lessons learned. To ensure information is relevant and useful, experienced sources close to the case study projects were interviewed, including project managers, government and agency employees, energy professionals, community and band council members, development corporations, utilities, industry representatives and engineers.⁹⁹ Reports, studies, policy documents, academic journals and other documents provided additional data for the case study analyses.

CHARS' northern partners also expressed interest in the compilation of a database of renewable and energy efficient projects currently operational in Canada's North. This database, attached in Appendix 2, lists currently operational projects by region: Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut. The projects are categorized as those that involve heat, electricity, or both, and are further subdivided into technology, community or site, size (capacity), and cost data categories.¹⁰⁰ The database does not include private residential renewable energy installations, but does include all other projects greater than 1 kW. Information for this database was compiled through the same combination of primary

⁹⁷ Definition of "Drivers": Factors which spur the initial development of a project

⁹⁸ Definition of "Success Factors": Elements contributing to the successful development/deployment/operation of a project

⁹⁹ The primary interviewees for each case study are referenced in footnotes on the first page of each case study. Additional interviewees are cited as they arise, in footnotes throughout the studies.

¹⁰⁰ All costs detailed in this chapter are in Canadian dollars.

and secondary sources as described in the preceding paragraph. See Appendix 2 for the complete database of northern Canadian renewable energy and energy efficiency operational projects.

Table 10 below shows the total number of renewable energy projects by region, showing totals for both electricity supply projects and heating supply projects. Of the 140 northern renewable energy projects reported, Yukon has implemented 35, NWT 90, Nunavut 14, and Nunavik 1.

Table 11 displays types of renewable energy projects by region, subdivided again into electricity and heating supply projects. Of the types of operational renewable energy projects in the five northern jurisdictions, solar PV projects are the most numerous (57), followed by biomass (34). The summary tables below do not reflect cost or capacity data; they are included rather to give an overview of the number and types of alternative energy projects underway across the North. Energy efficiency projects, while included in the database in Appendix 2, are not shown in the two summary tables below, since some regions provided amalgams of certain types of efficiency projects which were too numerous to list individually.

Table 10 Total Number of Renewable Energy Projects by Region

	Yukon	NWT	Nunavut	Nunavik (QC)	Nunatsiavut (NL)
Electricity	24	51	1	1	0
Heat	11	39	13	0	0
Total	35	90	14	1	0

Table 11 Types of Renewable Energy Projects by Region

	Electricity			Heat				
	Hydro	Solar PV	Wind	Biomass	Geo- thermal	Heat Recovery	Solar Thermal	Other
Yukon	9	13	2	3	4	3	1	
NWT	7	43	1	31		7		1
Nunavut		1				6	7	
Nunavik (QC)			1					
Nunatsiavut (NL)								
Total	16	57	4	34	4	16	8	1

1) Operational Case Studies

Operational case studies are projects that are already constructed and that are producing renewable heat or power, or reducing demand side energy loss. Five operational case studies will be examined.

8.1. NorthwesTel Remote Station Solar/Diesel Hybrid Project

In 2012, NorthwesTel, the privately-owned telecommunications company serving Canada's North, partnered with the Energy Branch, Department of Energy, Mines and Resources, GY and Yukon College's Cold Climate Innovation to conduct research and complete a feasibility study for a solar photovoltaic project at Engineer Creek (65°N), a remote fly-in mountaintop repeater site in Northern Yukon belonging to NorthwesTel¹⁰¹. The project was of great interest to the company because of the high number of NorthwesTel remote sites that are off-grid and fully reliant upon diesel, and the potential to offset their energy requirements with solar PV. The project's feasibility study predicted a simple payback period of five to six years, which is within the accepted investment timeframe for NorthwesTel. The base cost of installed solar PV for the system is \$0.28/kWh, far lower than the base load cost of \$1.63/kWh for the diesel required to power the station's base operational load of 1.8 kW (Yukon Government Energy Solutions Centre, 2013).

¹⁰¹ Primary source: (Sugden, Personal Interview, 2015)

Figure 6 NorthwesTel Engineer Creek Solar/Diesel Hybrid Project



(Photo Fritz Mueller Photography, www.yukon-news.com)

As a result of its demonstrated feasibility, a 15 kW solar photovoltaic system was installed (for approximately \$10/Watt) at Engineer Creek in 2014, consisting of 60 x 250 Watt panels installed in four sub-arrays, with four controllers. Monitoring equipment was also installed for the purpose of tracking the energy produced, as well as monitoring temperature and site conditions.

Objectives

- i. Demonstrate the viability of a PV array installed at a high altitude and northern latitude.
- ii. Meet 60% to 70% of the operational load of Engineer Creek, with the integration of solar photovoltaic arrays with the existing diesel generating station.
- iii. Reduce the high cost of diesel needed to power remote communication stations.
- iv. Confirm the power output of the solar-diesel system as predicted by the feasibility study, in order to secure further funding for solar-diesel hybrids in other NorthwesTel remote stations.

Drivers

Of NorthwesTel's 156 remote stations, 87 are off-grid, relying completely on diesel fuel to power their operations. These stations have operational loads of between two and 15 kW, requiring substantial ongoing expenditures for diesel fuel. These costs become even higher in the 37 remote sites that are

accessible only by helicopter, where all fuel has to be flown in at a cost of up to \$5 per litre (Sugden, 2014). Prior to the solar PV installation, Engineer Creek used approximately 8,400 ltr/year of diesel to power its operations.

Ongoing maintenance of diesel generators is expensive in remote telecommunications sites, costing NorthwesTel up to \$2.5 million per year, which makes the minimal operating costs of solar PV systems very attractive to the company (Sugden, 2014). Coupled with this is the rapidly declining price of solar PV systems, making their implementation in the North increasingly profitable.

From a business perspective, the increasing competition within the telecommunications industry, coupled with shrinking profit margins for telecommunications companies, drives the need for NorthwesTel to produce power in the most cost-efficient manner available. This further supported the company's decision to implement solar PV at their remote sites.

Another significant driver is the excellent solar resource at the Engineer Creek site, notably in late winter, spring and summer, given its northern latitude. Once installed, 100% of the power for the station was provided by solar energy in March and April, when high snow reflectivity, increasing daylight hours and cold temperatures combined to create optimal conditions for solar PV power production.

Role of Policy

Public policy did not play a significant role in this project. Rather, it was privately initiated by NorthwesTel from a purely business case perspective. However, the Energy Branch, Department of Energy, Mines and Resources, performed the original feasibility study, together with the Cold Climate Innovation

Barriers

Apart from the high up-front cost of installing a solar PV system in the North, the key barriers for the project were mostly technical and logistical in nature. Challenges to the project's implementation included the remoteness of the site, which is accessible only by helicopter, and the rugged mountaintop terrain, which made optimal placement of the arrays a challenge. Furthermore, the low solar resource near the Arctic Circle in December and January make the complete elimination of diesel by a solar PV system impossible.

Outcomes

The Engineer Creek site achieved its target of reducing diesel consumption at the site by 60% over its first full year of operation, and confirmed their predicted cost of solar PV power at the site as \$0.28/kWh, compared to the avoided cost of diesel at \$1.63/kWh.

By confirming the accuracy of both the financial and technical modeling from the feasibility study, and by confirming the energy produced by the installed system throughout the year, NorthwesTel was able to secure further funding to install four more hybrid PV-diesel systems at pre-existing NorthwesTel remote sites, all completed in 2014. These include:

- MacKay Lake, NWT (15 kW)
- Weasel Lake, Yukon (10 kW)
- Courageous Lake, NWT (15 kW)
- McEvoy Lake, Yukon (10 kW)

Four additional NorthwesTel remote sites are scheduled for solar-diesel hybrid systems in 2015, and a further four for 2016. In addition, a new NorthwesTel repeater station is slated for Deline, NWT, with solar PV being built right into the power generating system (Sugden, 2014).

Success Factors

Integral to the success of the NorthwesTel solar-diesel hybrid project was the detailed cost and business analysis performed at the outset of the project's conception, which specifically took into account the northern context of the project, to determine the optimal system size and payback. This enabled the company to fine-tune the system to meet their power requirements, without additional wasted expenditure. Equipment size of system components was kept small to accommodate helicopter transport, and the system was designed in a modular fashion to allow for easy manual assembly onsite.

Data logging equipment, temperature sensors and a camera were installed to monitor system performance, all of which aided to assess system performance and function, and to validate modelling predictions. The monitoring equipment was purchased from a \$35,000 grant from Yukon College's Cold Climate Innovation Centre, in exchange for which NorthwesTel agreed to supply data to the college.

Installation decisions also played a role in the project's success. A local electric contractor specializing in solar PV was engaged for the installation, and equipment operators and construction workers were likewise local, providing economic benefits in the region and lowering costs compared to imported labour. The decision to place the panels vertically helped to reduce icing and snow accumulation, and helped with system efficiency when the sun is low in the sky.

Lessons Learned

- i. The most economically feasible size for a solar PV system meeting a base load of 1.8 kW in this northern region is 10 kW to 20 kW. As the system size increases, economies of scale reduce the cost per kW installed to an optimal point (in this case 10-20 kW), after which the price per kW installed increases again, due to increased transportation costs (by helicopter) of the higher weight and bulk, and the higher labour and material costs (Yukon Government Energy Solutions Centre, 2013).
- ii. Economies of scale for northern solar-diesel hybrid systems without storage are a function of: system demand, technological constraints imposed by the diesel hybrid system, labour and material costs, and the helicopter load capacity.
- iii. Rough terrain and limited space available for mountaintop installations such as this force some compromise to ideal power output of the system, although this can be minimized by carefully considered placement of the arrays.
- iv. Current and voltage limits of charge controllers, which can compromise system power output, may be overcome by the installation of additional controllers.
- v. Despite terrain restrictions, remote site logistical challenges and low winter sun levels, solar/diesel hybrid systems such as Engineer Creek perform very well once installed, significantly reducing diesel costs, and lowering GHG emission levels. PV systems for remote sites with low power requirements are sound financial investments that pay off their investment within five to six years (Sugden, 2014).

8.2. Fort McPherson Biomass District Heating Project

Fort McPherson is a Gwich'in community north of the Arctic Circle (latitude 67°N) located on the Peel River southwest of Inuvik, NWT, with a population of 900.¹⁰² A vision was developed from within the community to harvest the local willow, which grows abundantly along the banks of the Peel River, as a source of wood chip heat for a biomass boiler district heating system. A pilot project approach was taken, and after four years of environmental, feasibility, engineering and forest management studies, a biomass boiler was installed in 2013 to heat the Band Office and community health centre with district heat.

Figure 7 Fort McPherson Biomass Boiler Project; Band Office and Health Centre in background



(Photo Lawrence Keyte)

The boiler is a KOB 85 kW tri-fuel burner, able to burn cordwood, wood pellets and wood chips. Sized to meet 50% of the peak-heating load, it is coupled with the existing oil burners, which continue to provide back-up heat. In its first heating season, the project burned locally sourced cordwood during the day, which was manually loaded, and burned wood pellets fed automatically by auger at night. Wood chips were not used immediately as a fuel source because it takes some time to harvest, chip and stockpile

¹⁰² Primary sources: (Kay, 2015)(Pelkey, 2015)

adequately dried wood chips for burning. Pellets are currently imported from northern Alberta and northern British Columbia.

Meanwhile, the willow harvest and chipping operations are well underway, with a goal of beginning to burn the dried local wood chips instead of pellets in the third heating season of 2015/16. Revenue is currently being generated through heat sales to the community health centre. There are hopes for expansion of the project in the future, and for growth of a local biomass industry, which could provide heat to increasing numbers of community buildings.

The Fort McPherson biomass project was financially supported by the Government of Northwest Territories (GNWT) Department of Environment and Natural Resources (ENR), the Canadian Northern Economic Development Agency (CanNor), the Department of Aboriginal Affairs and Northern Development Canada (AANDC) through the ecoENERGY for Aboriginal and Northern Communities Program (EANCP), the Tetlit Gwich'in Council and Rat River Development Corporation.

Objectives

- i. Develop a pilot project to heat two community buildings, the Band Office and the community health centre, with wood chips from locally harvested willow.
- ii. Create local employment (initially in harvesting jobs), with the eventual target of:
 - One full-time position as General Manager of the overall business, operations and growth.
 - One full-time position as Wood Marshalling Yard Supervisor, responsible for day-to-day operations of the wood marshalling yard.
 - One part-time position as Heat Plant Operator.
 - Several part-time harvesting positions (MNP LLP, 2013)
- iii. Improve the local economy by keeping energy dollars in the community, by means of job creation, the sale of locally-sourced heat, and local spending on goods via the sale of cordwood and potentially the resale of bagged pellets to pellet stove users in the village.
- iv. Improve skills and increase capacity within the community.
- v. Reduce dependence on imported oil and reduce GHG emissions.

- vi. Improve community pride and well-being with a more self-reliant economy.
- vii. Operate the biomass heat project as a business, to test the economic feasibility of a local biomass industry.
- viii. Outperform the price of both imported oil (\$45/GJ) and pellets (\$32/GJ delivered) with local wood chips (\$34-\$56/GJ, depending on haul distance and efficiency) (Associated Engineering, 2013)
- ix. Learn lessons regarding biomass heat and the willow harvest, to streamline efficiency so biomass heat can be successfully expanded in the community.
- x. Establish a local industry built on sustainable energy sources, which incorporates traditional knowledge, resources and values.

Drivers

This project grew from the community's dissatisfaction with its dependence on costly imported oil, and the lack of local capacity, employment and self-reliance associated with using imported oil for heat. The community desired a source of local, cleaner heat energy, one that also provided sustainable local jobs and was compatible with traditional harvesting practices. The idea to harvest, chip and burn the local willow resource arose after project manager Johnny Kay attended a biomass conference in Whitehorse in 2010, and came back to the community with a proposal to heat with local biomass. The Elders, Chief and Council, hamlet government and local youth council all supported the project, which aimed to develop a sustainable local industry while increasing local expertise and autonomy.

Another key driver for this project is the abundant local willow resource, and the community's strong desire to clear the area to the west of Fort McPherson, where willows have grown up over the past 40 years and blocked their traditional access to the Peel River. Willows grow extensively on the shifting sand bars and shores of the Peel River, and along the right-of-way clearing shoulders of the Dempster Highway. They regenerate so rapidly after being cut, that prior community efforts to clear them away have been unsuccessful; the willows grow back at rates of up to 1 meter per year. This rapid regrowth supports the forest management studies completed for the project, which confirm that the willow can be sustainably harvested. An FP Innovations harvest study (2011) states that 1 to 1.2 hectares of willow

harvested per year was able to entirely meet the project's heat requirements over its 20-year life cycle, given the large, rapidly-growing willow resource in the area.

Role of Policy

At the territorial level, the Northwest Territories Energy Action Plan lends policy support to projects such as the Fort McPherson Biomass Project, by calling for a reduction of imported fossil fuels (which currently make up 80% of NWT's fuel supply), a reduction of high energy costs and GHG emissions, and increased utilization of renewable forms of energy (Government of the Northwest Territories, 2013).

The Northwest Territories 2012 – 2015 Biomass Energy Strategy also encourages the development of community biomass heating projects and associated harvesting initiatives. The following are selected priority Actions from the Biomass Strategy that support projects similar to Fort McPherson. A brief elaboration (in parentheses) follows each Action:

- i. Support businesses and communities in implementing larger-scale biomass projects (ENR helps design and evaluate proposed systems, determines payback for biomass heat systems, and helps to develop and implement pilot projects.)
- ii. Support businesses and communities in developing biomass supply and distribution (by providing technical expertise and advice about establishing these supply chains).
- iii. Promote distribution and the use of clean burning biomass technologies (The Energy Efficiency Incentive Program, administered by Arctic Energy Alliance, provides rebates for the purchase of clean wood and wood pellet burning stoves that meet the low emissions standards set by the Canadian Standards Association and U.S. Environmental Protection Agency. The Alternative Energy Technology Program, administered by ENR, provides grants for wood and wood pellet burning boiler systems.)
- iv. Support businesses and communities in developing forest industry opportunities (by offering support for community sawmill operations, sharing technical expertise regarding forest management and harvesting, and helping local development corporations create viable business plans).

- v. Promote wood marshalling yards as a model to support local forest capacity and increased biomass availability (by developing viable business plans, assessing market opportunities and meeting training and capacity needs).
- vi. Work with First Nations and communities to develop Forest Resource Management Agreements (which provide a framework for forest stewardship, sustainable management and long-term forest tenure).
- vii. Work with industry to create a NWT Biomass Industry Association (to support cooperation and partnerships among industry to help promote growth and development of markets, products and services for biomass energy uptake).

The NWT's 2011 Greenhouse Gas strategy also supports biomass initiatives, by seeking to stabilize emissions at 2005 levels by 2015, limit the increase to 66% above 2005 levels by 2020, and return to 2005 levels by 2030 (Government of Northwest Territories, 2011).

In addition to the high-level policy support listed above, the federal (AANDC) ecoENERGY for Aboriginal and Northern Communities Program and CanNor's Targeted Investment Program provided funding in support of the project both through ENR and directly to the Tetlit Gwich'in Council in Fort McPherson. The bulk of the funding came from CanNor (\$819,000 between 2010 and 2015) and the GNWT Department of Environment and Natural Resources Biomass Energy Program (\$238,000), in addition to in-kind support from the community.¹⁰³

Barriers

Some of the barriers encountered over the course of project development were: local capacity challenges for boiler operation, service and maintenance; development of local willow harvesting expertise and forest management practices; challenges with supply, distribution and storage of wood pellets and wood chips; and the high up-front cost of project development and implementation. In addition to the operational challenges, local organizational capacity has been a challenge for the community's ability to manage the business end of the pilot project and establish governance practices (Government of the Northwest Territories Environment and Natural Resources, 2014). These types of

¹⁰³ (Correa, 2015)

costs and the human resources required are high for development state projects and demand financial support until the local industry can be established and expanded.

With only one community champion with a dedicated mandate to manage the pilot project, a large part of the project's responsibilities rest with a single person, which spreads capacity thin when multiple simultaneous difficulties arise. Among these difficulties is a lack of pre-existing supply chains for pellets, making it challenging to obtain pellets in bulk. Troubleshooting boiler issues long-distance over the telephone also presents a challenge, as do the complexities involved in efficiently harvesting the willows and the logistics of wood chip production and supply. Forest management challenges include learning the most effective means of cutting, transporting, chipping, drying, and storing the wood and chips in non-contaminated conditions, and in a manner that streamlines efficiency.

Outcomes

During its first partial heating season (December 2013 to May 2014), the biomass boiler provided a total of 101,130 kWh of heat to the band office and health centre, offsetting approximately 11,000 litres of heating oil.¹⁰⁴ Taken over the five-month period of operation, the boiler was providing approximately 55% of the heating requirements for the two buildings (Associated Engineering, 2013). Heat is currently being sold to the GNWT-owned health centre, with approximately \$40-50,000 of revenue predicted annually (Government of the Northwest Territories Environment and Natural Resources, 2014).

Benefits and wages are staying within the community, and flexible part-time harvesting jobs have been created. Skills and capacity have been enhanced by training workshops and by direct experience with the boiler and harvesting initiatives. Lessons are being learned which will enable the community to work towards provision of heat from a local source that is competitive with the cost of imported fuels.

Success Factors

The opportunity for community members to be involved in the harvest of local willow in Fort McPherson provides a Gwich'in cultural connection to the traditional harvest of wood for heating, cooking, drying meat and fish, and building shelter. The use of a renewable local resource, especially one

¹⁰⁴ (Fink, 2014)

that creates flexible employment and work on the land, aligns strongly with traditional values of self-reliance, autonomy, hard work, community pride and connection to the land. This alignment brings with it a strong sense of ownership and support within the community to incorporate biomass heat into their energy mix. Choosing energy options that align with local values is therefore seen as a significant success factor for long-term public support of community energy projects (Keyte, 2015).

Community project champion Johnny Kay has been a key factor in this project's success. He has shown dedication, determination and perseverance in overcoming challenges as they arose. The project also had governmental staff support throughout its development from staff at ENR's Environment and Forest Management divisions and Public Works and Services (PWS) Technical Services. These include Bryan Pelkey, Alternative Energy Specialist with ENR, and Energy Management Specialist Matt Kennelly at PWS. Support from the Arctic Energy Alliance (AEA), with its ability to put people on the ground in the communities, such as John Carr and Margaret Mahon who helped with this project, is likewise seen as a strong factor in the project's success.

Commercial support for the project, specifically from the boiler provider, Burkhardt Fink, of Fink Machines, has been critical to the ongoing management of technical challenges and provision of expertise and best practices. Additionally engineering, forestry, accounting and business development expertise through consulting relationships with Williams Engineering, AEA, Meyers Norris Penny LLP, and KPMG LLP (now a new auditor) has been helpful in overcoming specific challenge areas with the project.

There was a clear decision to start small with a pilot project, which has proven invaluable in terms of managing the risks associated with a new technology and business model, securing funding to finance the project, and building capacity for potential future expansion. The fuel flexibility of the heat system has also proven to be incredibly valuable by allowing the community flexibility to use fuel sources that were more immediately available (pellets and cordwood) while concurrently developing and expanding the long-term willow chip fuel supply chain. The presence of a community sawmill site also aided greatly, as it provided a base from which a wood marshalling yard could be developed, essential to the processing of cord wood and wood chips, and the storage, drying, distribution and sales of various wood products.

Finally strong, clear policy signals from the territorial government for greenhouse gas reduction and biomass uptake helped to move the project forward.

Lessons Learned

- i. Cordwood, while providing an inexpensive local heating option, requires an employee to periodically feed the boiler; it cannot therefore be a consistent source of heat at night. Cordwood is also sourced from mostly spruce trees, which may put pressure on local firewood supply.
- ii. Pellets provide consistent low-maintenance heat; they are a good fuel for reliable heat during the first two years of a multi-fuel biomass boiler project while wood chip harvesting gets underway. Pellets also provide a useful benchmark against which future wood chip costs can be compared.
- iii. Establish pellet purchasing and delivery contracts (ideally in bulk one-tonne bags) early in the project implementation process. Pellets are difficult to access in bulk in Fort McPherson, so pallets of 40 lb bags had to be transported by truck from Inuvik.
- iv. Assign a dedicated accountant or bookkeeper to keep track of expense and income details.
- v. Develop expertise, through training and/or mentorship programs, to manage the biomass harvest and to establish best practices in chip supply.
- vi. Establish clear business management and ownership and governance structures.
- vii. Chip willow stalks onto a non-contaminated surface, not directly onto the ground.
- viii. Performance-based hiring and pay schedules, as opposed to hourly wages, may encourage greater productivity (Government of the Northwest Territories Environment and Natural Resources, 2014).
- ix. Have a plan in place to educate the general public about project details and successes.
- x. If a northern community is willing to start small with a pilot project that builds expertise and knowledge from the ground up, then a biomass boiler, providing district heat to a few community buildings, is an effective means of reducing dependence on imported heating oil, while creating sustainable jobs and building the local economy.

8.3. Lutselk'e Solar Farm Independent Power Producer

Lutselk'e, Northwest Territories is a remote fly-in community (latitude 62°N) with a population of 350. Prior to this project the community was entirely reliant upon diesel fuel for its power generation, and desired an opportunity to incorporate cleaner renewable energy into the community power mix.¹⁰⁵ A study by the Arctic Energy Alliance, funded by the Government of Northwest Territories (GNWT) Environment and Natural Resources department, determined that rooftop net metering, managed by the utility Northwest Territories Power Corporation (NTPC), would produce a significantly higher revenue, approximately three times the amount per kWh generated, than a community-owned independent power producer (IPP) model of power generation. Nonetheless, the community chose the IPP model, due to a strong desire for the independence of owning part of their power system.

Figure 8 Lutselk'e Solar Farm IPP



(Photo Linda Todd)

The ground-based 35 kW solar farm was constructed on the site of a decommissioned tank farm in the village, and was completed in November, 2014. A power purchase agreement is currently underway between the community and NTPC, with interconnection scheduled to take place early in 2015. The array

¹⁰⁵ Primary source: (Todd, 2014)

will produce power to be sold to NTPC and distributed onto the local grid, which currently serves an average community power requirement of 190 kW (Aurora Research Institute, 2011). The solar farm is fully owned by the Lutselk'e Dene First Nations.

Objectives

- i. Displace diesel fuel with clean, locally-derived solar energy.
- ii. Reduce greenhouse gas emissions.
- iii. Reduce noise and local air pollution from the diesel generators.
- iv. Determine which solar PV system and ownership model was the best fit for the community:
 - Net metering with rooftop solar on four buildings totaling 35 kW; each building would be metered, providing power to NTPC's Lutselk'e grid. Higher installation costs and possible re-engineering of roofs were associated with this option. Under the NTPC net metering plan power is fed into the grid by producers with any power in excess of use credited at a one-to-one ratio. Both the rate of net metering credit, and approval for 10 kW installations (the current residential net metering limit is 5 kW per building) would have had to be negotiated. Or,
 - Independent Power Producer contract, where power is produced from a ground-based 35 kW array. In this case, the community owns the solar system and sells the power to NTPC at the displaced cost of diesel, providing less credit for the power they produce than with the net-metering option.

Drivers

In addition to the strong desire of the community to offset diesel fuel use, it was important to Lutselk'e to choose an energy source that aligned with its desire for some measure of energy autonomy and ownership, rather than a system chosen by purely financial cost-benefit analysis arguments. The community also aspired to try something new, this project being the first community-owned solar IPP in Northwest Territories. The Lutselk'e Solar Farm is a community-led project with strong interest from community champions, among them Senior Administrative Officer Agatha Laboucan, Chief Felix

Lockhart, previous Chief Dora Enzoe, Councillors Ron Fatte, Addie Jonasson, Emily Saunders and previous SAO Ray Griffith.¹⁰⁶

It is notable that a decrease in the power bills of end users in the short term was not a driver behind the project. The community was informed from the outset that, while income from power sales may result in decreased power rates for end users at some time in the future, power rates would remain the same in the near term.¹⁰⁷ The community accepted this. Therefore, rather than rate relief being a driver for the project, it was the ownership of a local, clean, renewable energy system that was the principle priority for Lutselk'e, despite the inherent risk and responsibility that local ownership might entail.

Role of Policy

From a policy perspective the Northwest Territories 2012 Solar Energy Strategy supported the development of this community solar project. It stated as its target: "Working with communities, industry and businesses, [to] install solar systems with the capability to supply up to 20% of the average load in NWT diesel communities."

The community of Lutselk'e provided more than 50% of the project's costs, which they accessed through their gas tax funds. These funds are obtained from the federal Gas Tax Fund (given twice a year to provinces and territories, then sent to municipalities), which provides predictable, long-term funding to help communities meet their local infrastructure needs.

The federal government's AANDC ecoENERGY for Aboriginal and Northern Communities Program provided funding in support of the project, and territorial funding was accessed through the GNWT Environment and Natural Resources Department's Community Renewable Energy Fund. GNWT's Department of Municipal and Community Affairs (MACA) also supported the project, representing the community's interest in meetings about project development. The Arctic Energy Alliance provided expertise and assistance in the form of project manager Linda Todd. In addition to these public policy levers, privately-sourced funding and technical expertise played a role in seeing this project come to fruition (expanded upon in the "Success Factors" section).

¹⁰⁶ (Laboucan, 2015)

¹⁰⁷ (Byrne G., 2015)

Barriers

Funding for a northern energy project with high up-front costs is difficult to access for a small community of 350 people. Until this funding was secured and delivered, there were cash flow challenges during the development of the project. Also, permitting to produce electricity is contingent upon secured funding, so there were delays in having permits approved until funding was confirmed.

There is also debate in NWT on the price an IPP should receive from the power it produces, whether it should be greater, less than or equal to the displaced cost of diesel. For example, a price higher than the displaced cost of diesel might encourage more communities and businesses to develop IPPs due to greater projected income from power sales, but might discourage the utilities (who pay for the IPP's power while needing to ensure reliable delivery to consumers) to invest in such a project.

As with many northern projects, high turnover of human resources can be a challenge. For example, there was an election for Chief and Council part way through the project's planning process. There is also typically a large amount of work placed upon one or two individuals, which can make the project development process more time consuming and more vulnerable to potential disruption.

Outcomes

Installation of the solar PV system was completed in November 2014, with an anticipated connection date of February 2015. Four local community members completed a training course on solar PV basics, and two of them received further training through the hands-on experience of installing the solar PV system.

Success Factors

Since the solar farm has been constructed but is not yet interconnected to the Lutselk'e grid, the success factors discussed below refer to factors behind the successful development and construction of the project, rather than those related to its future operation.

The community of Lutselk'e was involved from the very beginning of the Lutselk'e Solar Farm planning process. The community supported the project, and felt that it aligned with their traditional values, their desire to use the land by harvesting sunlight, and their goal to become more self-reliant.

They also recognized that solar energy technology is a good fit for the North, because it has no moving parts and therefore low maintenance and ongoing operational costs.

Project Manager Linda Todd with the Arctic Energy Alliance spent a good deal of time on the ground in the community to fully understand the needs of the project, and acted as a liaison between the community of Lutselk'e, the government funding agencies and the Northwest Territories Power Corporation (NTPC). The community felt that having a project manager with outside connections, but who also has strong relationships within the community, was a major advantage in the development process. The project also benefitted from a good relationship with NTPC Manager of Energy Services Myra Berrub, who was supportive of the utility buying power from the IPP.

The community of Lutselk'e financed more than 50% of the project from their own gas tax funds, which can be used for energy-related projects. Lutselk'e also contributed in-kind resources, such as loads of gravel, two staff available during installation, a loader, a dump truck and the use of a personal vehicle.

Private funding was provided by Bullfrog Power, a Canadian company that matches their customers' power use to clean renewable sources of energy. Bullfrog's business focus is to support the growth of renewable energy across the country including community-based projects such as Lutselk'e, that show leadership in reducing reliance on diesel and the utility by selling electricity and not just buying it.¹⁰⁸ Sean Magee, Director of the Bullfrog Builds program, visited Lutselk'e for a week to determine how best Bullfrog could help the project, and a funding agreement was signed in 2014. In addition to funding, Bullfrog will provide a platform to help Lutselk'e share its story and advertise milestones, in an effort to encourage other remote communities to start their own renewable projects.¹⁰⁹

To ensure sustainable community benefit from this project, the Canadian Solar Institute was engaged to conduct a week-long course on solar installation. The Band provided a training allowance to support community members who took the course, with four completing the course (and a total of 8 people starting the course). Those who completed the course were invited to install the solar PV system under supervision. In this way the training, employment and increased capacity provided by the course remained

¹⁰⁸ (Magee, 2015)

¹⁰⁹ To date Bullfrog has contributed \$1.5 million to date in support of community renewable energy projects across Canada.

within the community, and new skills were acquired that could assist in future employment opportunities. Presentations about the PV installation project were also made to students at the local school.

A final success factor was the community's ability to adapt to the logistical challenges of construction in early winter conditions, and to work with their own limited equipment to prepare the site, move components and install the arrays. The array fitted into the space available, and was completed just before the winter snows fell.

Lessons Learned

- i. Development of community-owned power projects would benefit from higher IPP price incentives. Clear policy guaranteeing a competitive price per kWh of power produced over time through a long-term contract would encourage industry and communities to develop more of these projects, which would reduce reliance upon imported diesel and bring more local clean energy into the mix. For example, an added incentive for clean energy production, such as a price equal to the displaced cost of diesel plus a small amount per kWh, would help incentivize remote solar IPPs such as this. Similarly, a feed-in tariff would provide long-term incentives to potential power producers. In a feed-in-tariff system, eligible renewable electricity generators are paid a cost-based price for the renewable electricity they supply to the grid. Either case (clean energy incentive or feed in tariff) would likely involve some measure of government funding support, so that locally produced clean power would not result in prohibitive increases to the rate base.
- ii. With 500 kW of solar now installed in NWT, and the territory's first solar IPP in place in Lutselk'e, new technologies are forcing governments to develop new policies. A new regulatory system might be required that adapts to the uptake of green energy technologies. For example, the current central utility model found in the North may have to adapt to the advent of IPPs and work towards a more decentralized model of ownership of energy provision.

8.4. Nunavut Energy Management Program: Iqaluit Pilot Project

The Iqaluit Pilot Project is the first project developed under the Government of Nunavut (GN)'s Nunavut Energy Management Program, which was launched in 2007 by the Department of Community and Government Services¹¹⁰. It consists of energy efficiency retrofits and/or renewable energy (solar hot water or solar air) installations in the 39 GN-owned facilities in the Nunavut capital of Iqaluit (population 7500, latitude 64°N). The Iqaluit Pilot Project is currently saving the Government of Nunavut \$1.7 million annually, from a total private sector investment of \$12.7 million (Government of Nunavut, 2010).

Figure 9 Iqaluit, Nunavut



(Photo-<http://www.energy.gov.nu.ca>)

The energy management and environmental consulting company EnviroVest Energy Ventures Inc. was contracted to develop the program and to advise the Government of Nunavut. MCW Custom Energy Solutions Ltd. (MCW CES) was awarded the contract for engineering, risk management, project management, training, monitoring and verification. MCW CES also negotiated the financing of the project with Manulife Financial. Local contractors were given priority for the retrofits, to keep economic benefit, knowledge and experience in the region.

¹¹⁰ Primary sources: (McKenzie, 2015); (Pisco, 2015); (Pye, Personal Interview, 2015)

Following the proven success of the Iqaluit Pilot Project, expansion into the GN's 89 owned buildings in the Kivalliq region of Nunavut started in January 2015, with construction anticipated to begin in 2016.

Objectives

- i. Have mechanisms and a program in place to retrofit government buildings and increase their energy efficiency by 20%.
- ii. Increase capacity in Nunavut by training local personnel in the maintenance and management of retrofitted systems, and provide employment opportunities for local sub-contractor groups in retrofits and installations of energy efficient and renewable energy systems.
- iii. Use successes and lessons learned to implement similar projects in other Nunavut communities.

Drivers

The Government of Nunavut created the Nunavut Energy Management Plan (NEMP) to help manage and respond to the high cost of energy required to run its public buildings (Department of Community and Government Services, 2010). Nunavut currently relies exclusively on imported fuel for its energy needs. It requires over 200 million litres of fossil fuel per year for space heating, electricity, hot water, and transportation of goods and services, resulting in an annual cost of fossil fuel for the GN's Petroleum Products Division of approximately \$200 million (Government of Nunavut Energy Secretariat , 2014). Approximately 61% of these energy costs are for heating and electricity. In Iqaluit alone, the cost to heat and power the community is about \$48.1 million per year (Government of Nunavut, 2007).

Public buildings, both residential and commercial, are Nunavut's largest consumers of electricity and heating fuel (Government of Nunavut, 2010). A substantial part of the GN's budget is spent on energy for these buildings, which means there is less money available for important services such as health and education in the territory. The potential for substantial long-term savings from more efficient public buildings and select renewable technologies drove the Iqaluit Pilot Project's energy initiatives.

An innovative financing mechanism, the Nunavut Energy Retrofit Policy, was used for this project and was modelled after the Government of Canada's Federal Buildings Initiative. This program allowed the government of Nunavut to use existing energy budgets to engage energy management companies that

finance, develop and implement energy retrofit projects.¹¹¹ Using mostly private third-party financing, which is paid back by guaranteed savings, the government was able to carry out a multi-million dollar project with limited operating funds and one dedicated employee. In 10 years it is expected that 100% of GN buildings will be retrofitted and will be more energy-efficient. Once the guaranteed savings have paid for the investment, after 10 years, the GN will enjoy 20% to 30% savings on their utility expenditures. The savings financing mechanism allows the government to invest in these retrofits and to enjoy the benefits from upgraded buildings as a result.

Role of Policy

Energy policy in Nunavut stems from the 2007 Ikummatiit Energy Strategy, which seeks to create a sustainable energy system that is secure, affordable, environmentally responsible, and optimizes economic benefits for Nunavummiut.

The Government of Nunavut's Community and Government Services (CGS) department has a target of 20% energy efficiency savings in GN-owned buildings through the Nunavut Energy Management Program. The GN has stated its desire to reduce its greenhouse gas emissions, although no specific reduction targets have been set.

The Nunavut Energy Management Program plays a key policy role in energy efficiency by allowing existing budgets to be used for partnerships with private sector firms that will develop, manage and finance energy retrofit projects (Government of Nunavut, 2010). Federally, funding from the ecoENERGY for Aboriginal and Northern Communities program covered a portion of the solar installations in Iqaluit, and contributed to the energy audits for the Kivalliq region.

Barriers

The high turnover of northern staff and engineers was a challenge for the project, as was the intermittent availability of local sub-contractors, and limited capacity to manage the systems once installed. Limited local technical capacity resulted in high prices for the retrofit work, which may increase the payback period for certain projects. Technical support from the south that was required to mitigate

¹¹¹ (Pye, Personal Interview, 2015)

these issues was expensive, but local expertise was enhanced by the fact that locals worked alongside the southern contractors, learning skills as a result.

In addition, some handling challenges occurred in buildings where asbestos insulation was found, resulting in the requirement for special permitting. Shipping costs for materials were also high.

While energy education for building occupants has shown results, there have been some issues with lack of interest and participation. This is possibly because in some public buildings, client groups using the buildings are less motivated to conserve, since they are not owners of the premises and do not pay for utilities; rather, the government owns the buildings and pays for their utilities.¹¹²

Outcomes

The energy efficient and renewable energy technologies implemented in the 39 Iqaluit government buildings have reduced greenhouse gas emissions by 1,270 tonnes per year, an estimated 21% reduction. These technologies include:

- i. Fifth Light Lighting Control Systems which allow control over the internet by an energy manager; savings of 60% have been achieved through this technology, which allows light levels for each space to be adjusted to meet the users' needs, and turns off all lights when buildings are unoccupied. As part of this control system, keypads were installed in school classrooms to allow teachers to dim school lights selectively.
- ii. Lighting retrofits, which include daylight harvesting (where daylight is used to offset the amount of electric light required to light an area), energy-efficient lamps and fixtures, motion-detector activation and highly dimmable lights.
- iii. Exterior Light Emitting Diode (LED) lights in all buildings, interior in some. The overall cost for LEDs was in excess of \$825,000. They provide an estimated total annual savings of \$150,600 per year (\$125,600 energy savings, \$25,000 operational savings), for a simple payback of 5½ years.

¹¹² (Pisco, 2015)

- iv. Solar domestic hot water in three residential buildings. The buildings (Taammativvik Residence, Baffin Correctional Centre and the Young Offenders Facility) were chosen for their high consumption of hot water for showers, laundry, and kitchen use.
- v. Solar air heating (Solar Wall) which pre-heats air used for ventilation, on the Baffin Regional Hospital and Taammativvik Residence. Both solar air and solar hot water have met or exceeded savings expectations, and will be considered in the Kivalliq region.
- vi. Replacement of fan and pump motors with more efficient models.
- vii. Retrofits of air handling units for heat recovery systems.
- viii. Control system upgrades.
- ix. Building envelope upgrades, including insulation and air sealing.
- x. Older appliances replaced with energy efficient models.
- xi. Installation of new low-flow plumbing fixtures. (Government of Nunavut, 2010)

Success Factors

In addition to the third-party financing mechanism, energy education is seen as a success factor in the Iqaluit Pilot Project, despite the challenges with varying levels of interest as mentioned in the “Barriers” section. Building occupants were educated on energy conservation practices, by being given the “No Cost and Low Cost Measures for Saving Energy Guide”, which lists detailed steps for occupants to increase energy efficiency in their residences and at work.

The educational Save 10 program also promotes energy awareness among GN employees, Nunavut students and building managers. This program includes electronic newsletters, a website and seminars which describe how to reduce energy consumption by 10% through minor changes in daily routines (Department of Community and Government Services, 2010).

To further the integral role of education in the NEMP, the Department of Community and Government Services, MCW Custom Energy Solutions and Nunavut Arctic College partnered with Seneca Collage to bring the Seneca College Building Environmental Systems (BES) course to the Nunavut Arctic College Iqaluit campus. Six BES courses were taught (each 2-4 days in length) to 19 building operators and managers, training them in the management of buildings systems and operations,

while providing certification and college credits. Distance learning components are also available. The course will be offered to building managers of the Kivalliq region, where the next stage of retrofits is scheduled to begin in 2015.

By means of the BES course, other local training and mentoring initiatives, and the prioritizing of local contractors, the GN is building capacity in the region, while ensuring economic benefits from the Iqaluit Pilot Program remain within the territory.

Finally, monitoring is seen as a key success factor in the program, with energy savings tracked by MCW Energy Solutions and verified by EnviroVest Energy Ventures. To date there are proven savings of 12% in excess of those forecast at the project's onset.¹¹³ The program is therefore over-performing, leaving little doubt as to its viability and extension to the Kivalliq region.

Lessons Learned

- i. Savings of solar hot air and water (from reduced oil heating) were higher than forecast.
- ii. Solar Walls (heated air systems) performed well. With no moving parts and simple components, they are durable, have met or exceeded energy savings expectations, and are relatively maintenance-free.
- iii. Simpler LED control systems would benefit smaller Hamlets. With the rapid evolution of LED technology, more streamlined LED lighting systems are expected to become the norm for smaller communities.
- iv. LED conversions provide notable savings (exterior LEDs alone are providing savings in excess of 186,000 kWh/year).
- v. The earlier that efficiency retrofits can take place, the more economical the savings. Building costs and energy costs are escalating, and energy consumption is increasing, so the most expensive option is often letting buildings remain in their current state of energy inefficiency.
- vi. Training of operators and managers is beneficial and essential for continued success.
- vii. Occupant behaviour education has been successful, showing reduced energy use in buildings.

¹¹³ (McKenzie, 2015)

8.5. Raglan Mine Wind Project

The Raglan Mine Wind Project is Canada's first industrial-scale wind and energy storage facility¹¹⁴. The project is being carried out by Tugliq Energy Corp., a Quebec-based company dedicated to diversifying energy sources and implementing alternative and renewable energy in northern operations and communities. Raglan Mine is located in Nunavik, northern Quebec (at a latitude of 62°N), 100 km south of the Deception Bay seaport on the Hudson Strait and west of the community of Kangiqsujuaq. The wind project, which includes 600 kW of storage capability, consists of one large 3 MW turbine with blades 40 meter in length, supported by an 80 meter tower. The wind turbine is 7 km from the mine site and has been operational since late August 2014. It is expected to displace 2.3 million litres of fuel annually, providing approximately 5% of the mine's power needs, which varies between 14 MW in the summer and 19 MW in mid-winter (Judd, 2014).

Figure 10 Raglan Mine Wind Project



(Photo Glencore, <http://www.nunatsiaqonline.ca>)

Since the mine's power needs far exceed the output of the turbine, a storage demonstration project is being incorporated to increase the penetration of renewable energy, as they are examining alternative

¹¹⁴ Primary sources: (Dorval, 2015; Julien, 2015)

means of providing power versus diesel. It includes an innovative combination of three storage technologies: batteries, a flywheel, and a hydrogen storage loop using an electrolyzer and fuel cells; the storage component should be operational in 2015. Hydrogen produced onsite may eventually be used for running some of the mine's vehicles. There is also the possibility of adding more turbines in the future, which would increase the total capacity of the project to 9 MW resulting in an overall decrease in the mine's diesel consumption by up to 40% (Judd, 2014).

This is a \$22 million project and funding details are discussed in the "Role of Policy" section below.

Objectives

- i. Create Canada's first industrial wind and energy storage facility.
- ii. Test an innovative combination of three storage technologies (batteries, flywheel and hydrogen storage loop) in a northern climate.
- iii. Achieve high penetration of Raglan Mine's micro-grid within the five year demonstration period for the storage technologies.
- iv. Reduce dependence on fossil fuel and the cost of diesel fuel to the mine.
- v. Reduce greenhouse gas emissions.
- vi. Explore the possibility of exporting power to nearby communities in the future.
- vii. Contribute to the knowledge base of wind energy solutions in Arctic environments, and to open the door to northern renewable energy development in communities and industry.

Drivers

The remote location of the Raglan Mine site, being 1800 km north of Montreal and not connected to hydro or natural gas networks, was a main driver behind the wind and storage project, along with the high cost of diesel. The mine uses approximately 60 million litres of diesel fuel per year, leading to significant cost advantages if this diesel use is partially displaced by clean energy. The large potential reduction in GHG emissions was another driver behind the project, with a lower carbon footprint aiding the company's efforts in environmental stewardship.

The need for power in nearby communities also drove the mine's interest in this project. To work towards any potential future power provision, Raglan Mine has taken on the financial, technological and

operational risks in order to use their site as a trial platform, so that best practices can be tested and risks and challenges understood before replicating this process in interested communities.

Role of Policy

The Government of Quebec's ÉcoPerformance program and Technoclimat program provided \$6.5 million of funding for the project. Both programs are funded within the framework of the Government of Quebec's 2013-2020 Climate Change Action Plan, which includes a greenhouse gas emission reduction target of 20% below 1990 levels for 2020 (Government of Quebec, 2012). The plan focuses on the transportation, industry and building sectors, which are the biggest emitters and the sectors with the highest emissions reduction potential.

The Climate Change Action Plan is a self-financing plan, deriving funds from a GHG emission cap-and-trade system in the Western Climate Initiative (WCI), in which Québec is currently trading with California. This system leads to a price signal linked to carbon in the economy, which encourages the reduction of GHG emissions. The Plan raises money from the sale of emission allowances to targeted businesses¹¹⁵, as well as from a levy on fossil fuels (Government of Quebec, 2012). This policy influenced Raglan Mine which, as a large operation with significant diesel requirements and GHG emissions, is motivated by the cap-and-trade system to reduce their exposure to additional costs associated with carbon pricing.

Barriers

Summer in northern Quebec is extremely short, which places time constraints upon construction and project management. Furthermore, because of the mine's remote location, all equipment and materials must be brought in by ship or by air, which adds cost and increases logistical challenges (Judd, 2014). During project development and construction, permitting approval had to keep pace with the project management timeline, which sometimes presented a challenge. In addition, the mining industry is volatile, which makes financial predictions difficult. The high up-front cost of renewable energy projects in the North made financing the project challenging.

¹¹⁵ Targeted companies of Quebec's cap and trade system are those emitting 25,000 tonnes CO₂/year or more.

Outcomes

The 3 MW wind turbine has been providing power to the mine since its installation in August 2014. Between September 1 and June 30, 2015, the turbine saved the mine approximately 1,734,000 litres of diesel (representing 4,838 tonnes of GHG), even before the addition of storage is scheduled to take place in 2015.

Success Factors

Nearly five years of careful analysis was conducted prior to the final decision to go ahead with the project. This included benchmark studies conducted in several northern countries to learn lessons from wind power projects in other harsh climates. A significant advantage throughout the decision-making process was the excellent wind resource where the mine is located; being situated at an elevation of 600m above sea level, above the tree line and with steady winds, all aided in the project feasibility. The addition of storage will allow the maximum use of this wind asset, by significantly increasing the penetration of the power produced by the turbine.

Another success factor was the expertise that Raglan Mine has developed over the past 17 years of working in a remote northern environment. This includes developing proficiency when it comes to logistics, and refining processes for transporting materials using ship or plane to meet set project timelines. This has resulted in many lessons learned and partnerships formed over the years which has aided in the development of the wind project.

Collaboration and respectful engagement with the project's Inuit stakeholders has greatly aided with local support for the project. For example, concerns raised by Inuit about the potential of blade reflection affecting local fish patterns resulted in the company's decision to move the site to another location.

The financial risk of the project was significantly mitigated by government grants. Federal and provincial governments financed more than half the cost of the project through government incentives for GHG emissions reduction and grants for renewable energy.

Lessons Learned

- i. Respectful consultation with Inuit partners has ensured ongoing local support of the project.

- ii. The partnership with Tugliq Energy Corp. has been essential, including the open sharing of expertise between Tugliq and Raglan Mine, as both have a great deal of experience working and operating in a Northern environment. Tugliq's partnership with German wind manufacturer Enercon was key to the project, as Enercon had the northern experience required to provide a turbine suitable to Nunavik's extreme conditions. Their knowledge and expertise with energy storage was also a key component in the project, creating a platform for modeling the high penetration ultimately targeted for industries and remote communities.
- iii. The scaled approach worked well for this project; the mine is happy with the decision to start small with a single turbine, assess carefully, and then build onto the project when feasible.

2) Forward-Looking Case Studies

Forward-looking case studies represent projects still under active development. Three forward-looking case studies are examined below.

8.6. Kluane Wind Project

The Kluane First Nation (KFN) communities of Burwash Landing (population 100) and Destruction Bay (population 50) lie along the Alaska Highway three hours north of Whitehorse, Yukon, at a latitude of 61°N¹¹⁶. They are powered by a diesel generating plant in Destruction Bay, with 16 km of power line between the two small communities.

¹¹⁶ Primary source: (Pinard, Personal Interview, 2015)

Figure 11 Artist rendition of proposed Kluane Wind Farm



(Photo Jean Paul Pinard)

The Kluane Wind Farm was initiated originally by ATCO Electric Yukon. However, during the course of its development strong interest was expressed by KFN in owning the project and selling power as an IPP. As a result, the ownership model shifted and KFN, through Kluane Corporation, will become the project owner, and sell power as an IPP to ATCO Electric Yukon. Once formalized, the power purchase agreement will be submitted to ATCO Electric Yukon, who generates and sells electricity in the Kluane region.

The proposed wind farm, scheduled to be constructed in 2016, is expected to displace 25% to 30% of the diesel required for the two communities. It will be comprised of three 95kW Windmatic turbines, for a total capacity of 285 kW. The Windmatic turbines, purchased from California where they have been in service for 20 years, will be refurbished and put back into service for the Kluane wind project. Purchasing refurbished turbines is much less expensive than purchasing new turbines, and provides an excellent option for the North. For example, the refurbished Windmatic turbines are light and robust, with standardized parts that are inexpensive to repair or replace.

The choice of the mid-sized refurbished turbines was based on their proven record in Alaska, where dozens of Windmatic turbines are successfully providing power to several remote diesel communities.

Various modifications have been made to the Kluane turbines, including a 50-meter tilt-up tower, which does not require a crane like conventional towers, has a lower foundation cost, and is less expensive overall. As crane-erected wind towers have proven to be prohibitively expensive or logistically

impossible in many northern locations, these tilt-up towers have considerable potential for other remote northern wind sites where the need for cranes might otherwise constrain the project. Longer blades are also being designed for the refurbished turbines, which allow them to capture more energy than their original southern design. Both blades and tower will be shipped to the site by truck from Prince Edward Island.

Funding for the Kluane Wind Project has been provided by the federal (AANDC) ecoENERGY for Aboriginal and Northern Communities Program (EANCP), from Yukon Research Centre/Cold Climate Innovation, CHARS, Bullfrog Power, and Teck Resources. The Yukon Government will provide further funding support for the project.¹¹⁷

Objectives

- i. Bring economic opportunities to a small northern community through ownership of a renewable energy project that utilizes the local wind resource.
- ii. Create local jobs and expertise. This will include part-time jobs in management, surveying, tree-clearing, road re-building, installation and monitoring, and an eventual full-time management position.
- iii. Generate income for the community through the sale of power.
- iv. Create a 100% Indigenous-owned project. A KFN-owned company will be created for the sole purpose of managing the wind project. This ownership structure is modelled after the successful First-Nations owned Atlin Hydropower Project in northern British Columbia.
- v. Reduce imported fossil fuel consumption.
- vi. Reduce greenhouse gas emissions.
- vii. Build upon the wind project once it is operational:
 - a. Expand on the wind farm and explore storage options.
 - b. Integrate smart grid technology into the community; find ways to make the community energy system more efficient.

¹¹⁷ (Pinard, Personal Interview, 2015)

Drivers

The Kluane Wind Project has been driven largely by the desire of the project leader, JP Pinard, to see a successful wind project built and to provide power to one of the Yukon's remote communities. Kluane was chosen for its accessibility based on its close proximity to Whitehorse, its favourable wind resource of greater than 6 m/s at a height of 30 meters, and because of the KFN's interest to have the project developed. Another driver was the fact that the wind developer, Carl Brothers, who had built a successful wind-diesel-hydrogen project at Ramea Island, Newfoundland, saw Kluane as a natural fit for a subsequent project.

Role of Policy

Since the Kluane Wind Project has been developed, the Yukon Government has created an Independent Power Production (IPP) Policy as part of its Energy Strategy for Yukon. The goal of the policy is to support IPPs in supplying power to customers, while respecting the integrity of the existing electrical system (Government of Yukon Energy, Mines and Resources, 2014). However, while this policy sets out prices that are based on the avoided cost of diesel for certain areas, IPPs in Yukon's four isolated diesel communities (Old Crow, Beaver Creek, Destruction Bay/Burwash Landing and Swift River) are to be assessed on a case-by-case basis, requiring approval from the Yukon Utilities Board. A standard pricing mechanism, where IPP proponents are guaranteed a known price over time for the power they sell, would encourage greater IPP uptake in these smaller communities. The Kluane Wind Project aims to negotiate a price that is tied to the avoided cost of diesel in Kluane, but with a minimum guaranteed rate of 30 cents per kWh of power produced, to ensure the investment in the project is covered.

Barriers

Many past wind projects in the North have faced significant hurdles and challenges, often failing to meet objectives regarding multi-year power production. This has resulted in considerable community and business caution regarding new wind development. The high cost of project development in the North, the lack of economies of scale for small community projects, a lack of adequate training, and high staff turnover experienced in the North have all created challenges. Furthermore, while funding has been

provided to install these past projects, little funding has been made available to ensure successful ongoing operations of the turbines, which has contributed to the limited success thus far in Canada's community wind projects.

There is a lack of renewable energy incentive programs at both the territorial and federal levels. Given the special needs and high costs of renewable energy implementation in the North, additional incentives are required to attract investment in these remote northern projects.

Project champions for northern renewable energy projects are often under-supported, both financially and logistically. Having funding available to aid project champions in their efforts to develop a project would help ensure more committed and sustainable support for the development of northern renewable energy projects.

Success Factors

A key success factor in the development of the Kluane Wind Project was the team involved, including the project champion and two staff from Kluane who were hired to help move the project forward. Lawyer Dave Austin, who helped overcome legal hurdles in the development of the Indigenous-owned hydro project in Atlin, BC, was engaged to help with legal aspects of the Kluane project. Wind developer Carl Brothers, experienced in remote wind-diesel applications, was involved from the beginning. The Kluane First Nation Chief also showed ongoing support of the project, and the community was motivated to see the project succeed.

Lessons Learned

- i. Expect staff turnover to occur and plan for it.
- ii. Allow for more time to develop a project of this nature in the North. For example, the Atlin hydro-electric project took over a decade when the project champions were expecting it might take only a few years.
- iii. Building an effective and dedicated team is a crucial part of a successful project.
- iv. Ongoing community engagement, and dissemination of project information in general assemblies and other public meetings, is crucial to assure the support of a community and its Elders.

8.7. Innavik Hydro Electric Project

Inukjuak is a small Inuit off-grid community on the northeast shores of Hudson Bay (latitude 58°N) with a population of 1,600¹¹⁸. The project under development is a small 7.5 MW run-of-river hydro project on the Inukjuak River, approximately 10 km upriver of the village of Inukjuak. The hydro project is sized to meet all of the community's electricity needs, and all heating needs over the next 30-40 years at a 95+% reliability level. There may be short periods where emergency diesel backup is required.

Figure 12 Future site of Innavik Hydro Project



(Photo www.innavik.com)

The hydro system does not require a control structure and will include a small (3-4 day) water-storage reservoir. It is designed not to alter the river's flow below the control structure, and will not alter levels downstream. There will be a small increase of water levels upstream of the intake.

The project is being developed for the village of Inukjuak by the Inuit-owned Pituvik Landholding Corporation, with the aid of development partners Groupe RSW Inc. and clean energy expert Chris Henderson of Lumos Energy. It is anticipated that once the project is operational, project earnings will be

¹¹⁸ Primary source: (Henderson, Personal Interview, 2014)

re-invested to support community needs, education, and local economic development. Greenhouse gas emission reductions of 8000 tonnes are expected from the first year of operation.

Objectives

- i. Replace diesel fuel with clean energy from hydro-electricity.
- ii. Reduce the carbon footprint for the village of Inukjuak.
- iii. Create jobs and enhance local capacity.
- iv. 100% ownership of the hydro project by the Inuit Pituvik Landholding Corporation. (This initial objective is in the process of being modified to a more conventional General Partnership structure, with Pituvik as a substantial minority Limited Partner.)
- v. Promote economic development through the use of reliable, high-quality 3-phase hydropower for both space heat and electricity. Some examples of potential economic development associated with the hydro power produced are:
 - a. Location of natural resource exploration offices and technical staff, where reliable power and baseboard heating are considered an asset.
 - b. Location of public facilities, such as educational facilities, correctional facilities, government services.
 - c. Internet-based services, which require reliable power.
 - d. Other services such as integrated power services, information technology, phone and fibre services.

Drivers

A desire for local economic development, capacity building and job creation were among the principle drivers for the Innavik hydro project. Inukjuak is the community with the highest unemployment rate in Nunavik, so any jobs created by the development, construction, operation or management of the project would be a significant boost to the local economy.

Financial drivers include the high cost of the village's current energy provision by diesel generators, and the desire to offset some of this ongoing operational cost with clean energy production.

Role of Policy

One recently modified policy that used to prohibit renewable power baseboard heating in Nunavik will now allow the hydro project to provide electric heat for Inukjuak. Policy *hurdles* have provided significant challenges. These are outlined below in the “Barriers” section.

Barriers

According to project developers, one of the barriers faced in the development of the Innavik hydro project was the lack of a transparent power purchase pricing mechanism needed to for negotiations between the utility and project developer (in partnership with the local community). The developers felt that such a mechanism would encourage developers and communities to take the financial risks required to develop projects such as these.

To illustrate this point, Hydro-Québec, the utility in this case, offered to buy power from the project for a price equivalent to an avoided cost of generation that represented only 40% of the total cost of service and was insufficient to make the Innavik hydro project viable. Hydro-Québec claimed to have valued the avoided maintenance cost and the deferred capital investment in calculating its marginal cost of diesel generation. All of the details of the calculations, however, were not disclosed thus raising doubt amongst developers and the community as to whether Hydro-Québec had undervalued the avoided cost of diesel generation. In contrast, for the Atlin Hydro Project in Atlin, British Columbia, BC Hydro signed a contract offering the Taku Land Corporation a price that was higher in terms of percentage of the cost of service of diesel generation. This agreement allowed the Atlin project to move forward, guaranteeing revenue that was sufficient to make the alternative energy project viable.

No common formula currently exists to calculate this avoided cost of diesel generation that is consistent across the North. Such a formula, if based upon all the cost reductions and external expenses and effects (such as carbon emission and local air pollution) that are removed when a renewable energy project replaces diesel electricity, would be beneficial when utilities and clean energy developers are negotiating power pricing contracts. Having dependable contracting mechanisms in place with utilities would allow small, remote community IPP projects to benefit from power purchase agreements.

A barrier particular to small hydro projects such as Innalik is the high cost of development compared to other renewable technologies. Only limited government funding is available for renewable energy projects, and in the case of the millions of dollars required to develop small hydro projects, this funding is often insufficient.

One means of securing federal funds for infrastructure projects such as Innalik is through the Government of Canada's Public Private Partnership (P3 Canada) Fund, where the private sector is engaged to develop a project, and the government pays for the asset once it is operational. However, eligibility requirements for the P3 fund apply more to larger urban settings than small remote Indigenous communities, and as such the Innalik project did not qualify for the fund.

A final challenge to the project is that communities, utilities, regulators and government, having different priorities regarding energy, do not typically work collectively to resolve policy hurdles. Greater communication between these agencies could help to bring multiple viewpoints together, to address the complexity of policy challenges in Canada's northern energy systems.

Success Factors

Community engagement has been a key to the project's successes to date. This has included extensive community dialogue, as well as presentations by Pitulvik to the community and local schools. There was a local call-in show in the evenings on the community radio station, which allowed listeners to express their views about the project. A pivotal community referendum about the project was held in March 2010, which required 75% of residents to be in favour of the project in order for it to go ahead. This benchmark was surpassed, with 83% voting to support the project (CNW, 2010).

A further example of active engagement occurred when the engineering firm Groupe RSW Inc., hearing the community's concern over water quality, adjusted their construction plans accordingly through the inclusion of additional monitoring, protection and emergency response planning.

The potential creation of jobs through this project also led to local community support. About 20-30 jobs are anticipated for local Inuit during the construction phase, and several long-term jobs related to ongoing operation of the hydro plant.¹¹⁹

Lessons Learned

- i. Cohesive legislation is required (e.g. a Quebec or national counterpart to Ontario's Green Energy Act) which brings together regulatory, utility, and government mandates to encourage and support development of green energy projects in the North.
- ii. A P3 business model did not work due to inadequate adjustment of P3 requirements for northern remote communities; therefore the project had to move to a general partnership.¹²⁰
- iii. Funding is challenging to access for small hydro projects in remote communities.
- iv. If lower interest loans were available for northern renewable energy projects, this would help encourage the investment required to develop these projects. This could be achieved through government or utility backed bonds.

8.8. SakKijânginnatuk Nunalik: Healthy Homes in Thriving Nunatsiavut Communities Program

Nunatsiavut is an Inuit-governed autonomous region in northern Labrador, which includes the five Inuit communities of Nain, Hopedale, Makkovik, Postville and Rigolet.¹²¹ In Nunatsiavut, issues of energy and housing are very closely intertwined. Poor housing conditions, including issues of insufficient heating, mould, overcrowding and homelessness are directly related to energy insecurity.

¹¹⁹ (Henderson, Personal Interview, 2014)

¹²⁰ General partnership: A partnership in which partners share equally in both responsibility and liability

¹²¹ Primary source: (Goldhar, 2015)

Figure 13 Hopedale, Nunatsiavut



(Photo Peter Jennings <http://benlo.com/arctic/hopedale.html>)

A housing needs assessment was conducted in 2012 by the Nunatsiavut Government to complete a detailed survey of all dwellings and the needs of residents in the region. In addition, a housing risk assessment was performed in 2014 in the three largest communities of Nain, Makkovik and Hopedale, two of which (Nain and Hopedale) had been identified in the 2012 Housing Needs Assessment as being in particular need of improved housing (Nunatsiavut Government, 2014). The risk assessment included blower door tests, structural assessment, and thermographic scanning. Results of the risk assessment and survey are highlighted in the “Drivers” section below.

The housing needs assessment informed the creation of the program known as SakKijânginnatuk Nunalik: Healthy Homes in Thriving Nunatsiavut Communities, which aimed to incorporate local knowledge and expert advice with the housing assessment, in order to build healthy sustainable homes adapted to Inuit cultural preferences and the sub-Arctic environment. The Healthy Homes Program won the 2013 Arctic Inspiration Prize¹²², which provided funding of \$350,000. The program included the following housing research and housing action plans for Nunatsiavut:

- i. Housing design charrette (2014).
- ii. Housing risk assessment (2014).
- iii. Sustainable Multi-Unit Dwelling Pilot Project (ongoing).
- iv. Home Repair Program (ongoing).

Two of these initiatives will be examined for the purposes of this case study: the housing design charrette and the sustainable dwelling initiative.

1. Housing Design Charrette

FGMDA Architects from Montreal were engaged to conduct a charrette to gather input from Nunatsiavummiut¹²³ on their ideas for housing designs that are appropriate to their culture preferences and the environmental context. Residents were invited to provide feedback regarding their ideal design feature preferences for the sustainable multi-unit dwelling. The following provide a sample from among the many findings of the charrette.

- i. A seniors' complex and affordable public house rentals were among the top housing priorities.
- ii. Open concept design is preferred for living room/dining room/kitchen.
- iii. Within Elders units, a second bedroom is important to provide space for caregivers to stay, for visiting family members, and for taking in grandchildren and raising foster kids.
- iv. Large pantries for storage of bulk food are desired, and a "cold room" for storage of meat and fish.

¹²² Arctic Inspiration Prize: a prize awarded yearly to multidisciplinary teams who have committed to implement their knowledge into real world application for the benefit of the Canadian Arctic and its people.

¹²³ Nunatsiavummiut: Residents of Nunatsiavut

- v. Cold porches or “Arctic entrances” are important, to buffer the living space from outside cold.
- vi. Intake vents for ventilation should be placed where they are not compromised by drifting snow or chimney smoke.

2. Sustainable Multi-Unit Dwelling Initiative

Based upon the local cultural and environmental needs identified by the design charrette, FGMDA Architects are designing a pilot sustainable multi-unit dwelling to be constructed in Nain in 2015. The building will be a six-plex, with two ground-floor units for Elders, and four units for young singles or couples. The design team will draw upon concepts and lessons learned from the Passive House standard, R-2000 program, CMHC Northern Sustainable House projects, Yukon Super Green Program, and the Cold Climate Housing Research Center Northern Sustainable Shelter projects. While the design is only in the draft stage currently, the EnerGuide Rating System (ERS) was proposed to evaluate energy performance of the multiplex, with ERS 86 identified as a possible energy efficiency design standard. This rating meets the new Natural Resources Canada (NRCan) R2000 energy efficiency performance standard, including a high-performance building envelope, high performance thermal windows and ventilation, efficient building shape, a design that maximizes solar gains, solar PV-ready roofs, and energy-efficient appliances and lights.

Objectives

- i. To slow the deterioration of housing in the region, to reduce overcrowding and mould, and to positively contribute to the mental and physical health and well-being of residents.
- ii. To adapt local housing design principles to local cultural needs and preferences.
- iii. To build a sustainable multi-unit dwelling in Nain that is affordable, replicable, energy efficient and adapted to the warming sub-Arctic climate.
- iv. To monitor the energy efficiency and design features of the pilot dwelling, with the aim of replicating the model in other Nunatsiavut communities.

Drivers

Source: (Nunatsiavut Regional Government, 2014)

Overcrowding

The overcrowding rate in Nain (15%) and Hopedale (14%) far exceeds the national rate of 3%. Based on the National Occupancy Standard (NOS), 16% of homes in Nunatsiavut are “not suitable” and overcrowded, which is nearly three times the national NOS “not suitable” average of 6%.

There are 196 families in Nunatsiavut who live with other families because they can’t afford their own home, or due to a lack of home availability; 38% of homes in Nunatsiavut are occupied by multi-family units, mostly in Nain and Hopedale.

Homelessness

The housing survey lists 50 “temporary residents” who are homeless (mostly in Nain and Hopedale) and staying with family or friends, often on couches, while attempting to secure more permanent homes.

Cold and Deteriorating Housing

Three quarters (74%) of Nunatsiavut’s homes are in need of major or minor repair, with 57% of residents unable to afford the required repairs. More than half the residents in Nain (57%) and Hopedale (64%) have problems keeping their dwellings warm enough. The most common heating source is wood stoves (55%), followed by oil. Long distances are involved for some communities to source wood, such as in Hopedale, where residents travel over 70 km for firewood, often over dangerous shifting sea ice.

Of those homes not sufficiently heated, most residents (79%) attribute this to the poor condition of the home, including foundation problems, faulty construction, and insufficient insulation. Half (52%) also attribute their cold homes to difficulties finding firewood, and half (50%) to the cost of electricity or oil, with average winter heating costs of \$619/month.

Mould

Nearly half (44%) of Nunatsiavut homes suffer from mould, higher than any other Inuit region. Mould is found mostly in homes with inadequate heating (colder homes have more mould) and homes that are in need of major repairs. A slightly weaker relationship exists between mould and homes that heat with wood, homes without a properly functioning air exchanger, and homes with burst water pipes.

Power Deficits

The utility, Newfoundland and Labrador Hydro, is currently unable to meet energy demand for the region. This is a major driver behind the need for more energy-efficient, sustainable buildings in Nunatsiavut. For example, one community has two fish plants, but cannot operate both at the same time due to power constraints. The power deficit forecast for 2014 was 26 kW for Hopedale and 60 kW for Nain (Goldhar & Sheldon, 2014).

Role of Policy

The Government of Nunatsiavut hopes that an outcome of the Healthy Homes Program will be the identification of Nunatsiavut-specific building codes and standards, which are currently the same throughout the province, and not suitable for the region's sub-Arctic environment. Such building standards would help ensure the construction of warmer, more durable mould-free homes.

The Home Repair Program is playing a useful role by facilitating housing upgrades in Nunatsiavut. It provides energy efficient retrofits and repairs for homes where the family unit earns under \$50,000, and is funded through a shared 50%-50% agreement between the Nunatsiavut Government and the Government of Newfoundland and Labrador.

The Nunatsiavut Government, in its 2013-14 budget, assigned \$2.7 million to help develop a sustainable housing strategy. It provides \$2.3 million per year for the repair and/or construction of new homes in each community (Nunatsiavut Assembly, 2013). The Nunatsiavut Government is also currently developing an Energy Security Strategy with the aid of Lumos Energy of Ottawa, a consulting company that develops and manages clean energy projects throughout Canada and the North.

One policy hurdle is that Nunatsiavut does not qualify for many federal funding programs, since it is not north of 60°N latitude and not on reserve, factors that qualify many other northern or indigenous communities. The region therefore misses funding opportunities that would greatly help the region's sustainable development goals. The fact that they lie within the discontinuous permafrost zone, in a sub-Arctic environment that is home to an Inuit population, should qualify Nunatsiavut for similar funding pools available to other northern and Indigenous populations.

Barriers

In addition to overcrowding, homelessness, mould, aging infrastructure and power deficits mentioned in the “Drivers” section, issues of remoteness, rugged and shifting terrain, funding challenges and inconsistent communication from the provincial utility all play a role in the challenges faced in providing sustainable energy-efficient housing for Nunatsiavummiut.

Success Factors

A principle factor in the success of the Healthy Homes Program is the public interest and engagement in the program. Residents have been very keen to improve housing stock, have better heating options for their homes, and inform political leaders of their priorities. An example of this is the remarkable 93% participation rate in the housing needs survey. Interest in healthy homes has occurred from the ground up, rather than being mandated by government. There is direction and guidance for the project through all levels of government, which provides the advantage of a unified team working to fulfill common objectives.

The existence of the Nunatsiavut Government (as opposed to the more distant southern provincial government of Newfoundland and Labrador) has largely enabled the success of this program. The Healthy Homes Program has been conceived, guided, managed and adapted to the region’s needs by the Nunatsiavut Government, which leads to considerably more relevant and streamlined results than reliance upon a more distant provincial government.

Nonetheless, there has been significant external support, which has helped the program to succeed, including university and other expert partners, provincial support for the Home Repair Program, and the Arctic Inspiration Prize for the sustainable dwelling pilot.

8.9. Summary

The case studies examined above represent only a fraction of the sustainable energy projects currently operational or under development in the North. It is evident, however, from the above selection that great diversity exists among northern sustainable energy projects, spread across all five of Canada's northern jurisdictions, covering widely different geographical, social, political and regulatory constraints, representing both public and private interests, and covering a broad range of renewable energy technologies and energy efficiency initiatives.

Of particular interest in examining the case studies is the observation that, while there are many commonalities in the drivers and policies behind the projects, the challenges faced and the factors contributing to their success, there are many more influencing factors that are unique to each project, technology, location or jurisdiction. It is therefore very important, when moving forward with priorities for research and policy/program creation and implementation, that decision-makers be highly flexible and aware of the complexities that apply to each individual case in order to successfully blend overarching policy with the intricacies and diversity that characterize northern energy projects and their needs. Key messages from the case studies above that apply to future research and policy creation, along with those from the preceding chapters, are included below in Section 9 Policy Recommendations and Section 10 Research Recommendations.

9. Policy Recommendations

As indicated in the previous sections, this report seeks to provide an overview of energy (electricity and heating) supply and demand in Canada's Arctic, relevant policies and programs regarding renewable energy, conservation and demand side management, and financial analyses regarding electricity system planning and heating. It also highlighted eight case studies in the North to gain a better understanding of drivers, challenges and effectiveness at meeting project goals, and lessons learned. As a result of this research, a series of policy recommendations and suggestions for future research were developed, and are presented below. Policy recommendations are categorized according to the following themes: energy system planning; financial analyses; and education, engagement and collaboration.

9.1. Energy System Planning Recommendations

i) Align regulation with policy

Any new government policy that seeks to promote renewable energy and energy conservation and demand side management: (1) needs to be built on a deep understanding of energy regulation; (2) needs to be coherent with regulation goals and principles; and, (3) if necessary should entail alterations to the regulatory framework to ensure better alignment of regulatory decisions with the objective of the policy. For instance, the regulator could be provided with specific guidelines on how to determine when an alternative-energy solution maximizes benefits for the society and should thereby be granted funding.

ii) A long-term vision is useful for short and medium term planning

The Yukon 20-Year Plan is a good example of systematic and detailed financial analysis. It includes sensitivity analysis, numerous scenarios and relevant information about technologies of interest. These analyses may benefit ratepayers from decisions that are based on substantial supply planning. The Yukon 20-Year Plan analysis helps to minimize electricity costs and environmental impacts while maximizing societal benefits which are key purposes of regulation. The approach used in Yukon could be applicable, for example, to NWT hydro grids.

The approach used in Nunavik to assess the economic potential of wind-diesel systems in a systematic manner (i.e. using the SIMJEB model developed by IREQ) could be applied to remote

communities across all jurisdictions for decentralized resources such as wind, solar, hydro, biomass and geothermal. The community-by-community resource portfolio analysis approach used by NL Hydro in Nunatsiavut using the software HOMER is also promising. Funding for these studies could be scaled up or down based on the size of the systems being considered.

iii) Seasonal utilization of hydro

Hydro grid communities would benefit from exploring more ways to utilize the surplus hydro electricity in the summer while at the same time curtailing the winter peaks. This could, in effect, reduce rates because it would spread the rate base over a larger volume of sales at a minimal marginal cost of generation and avoid fossil-fuel generation. Since the cold season in the north spans from September to June, summer hydro surplus might be useful for space heating in small-commercial and residential buildings.

iv) A unified approach to policy is key

High-level political commitments coupled with a coordinated, overarching policy approach, where regionally-appropriate renewable energy, conservation and energy efficiency strategies are incorporated into overall energy plans, allows for greater coordination between community, governmental and industry efforts to implement sustainable energy projects.

Strong, clear policy signals spur interest and concrete actions towards sustainable energy projects. An example of a coordinated approach to sustainable energy policy can be found in the Northwest Territories where the NWT Energy Action Plan, the NWT Greenhouse Gas Strategy, the NWT Power Systems Plan, the NWT Solar Energy Strategy and the NWT Biomass Energy Strategy all combined to signal interest by the government, which has in turn sparked development of the renewable energy and energy efficiency sectors, while reducing greenhouse gas emissions as mandated by the NWT Greenhouse Gas Strategy. This systematic approach is being pursued, for instance, in NWT's Biomass Energy Strategy that aims to build upon supply chains in this sector. In addition to these high-level commitments regarding policy development, a concurrent effort is needed to support sustainable energy actions 'on the ground' (e.g. support for community leaders and NGOs).

v) Examine potential for locally sourced biomass

The economics of shipping local biomass for commercial or residential biomass boilers, furnaces and district heating systems needs to be assessed and considered as an alternative to wood pellet imports from other provinces. In doing so it will be important to work with communities (e.g. on land claims and forestry management dimensions). Local economic development and the creation of local, seasonally flexible jobs should also be considered when determining the best fuel for biomass boilers. Locally sourced wood chips can provide harvesting and processing (chipping, transporting, storing) jobs in communities where jobs are scarce. Sources of wood chips vary with local context and may include local trees (including fast-growing willow trees where available) harvested specifically for wood chips, waste wood from mills, burned forests or pine-beetle kill.

vi) Adapt and replicate effective energy efficiency standards in the North

Standards involving high-efficiency building envelopes, such as those included in Whitehorse and Yellowknife's city by-laws for new buildings, could be converted into mandatory building codes by the respective territorial governments. The further development of energy efficiency endorsement labels such as the SuperGreen home performance label (similar to the Natural Resources Canada's R2000 or EnergyStar), or Leadership in Energy and Environmental Design (LEED) (or LEED-North equivalent) created by Northerners for Northerners is recommended.

9.2. Financial Policy Recommendations

The main challenges in the implementation of financial policy recommendations consist of gaining utility and public acceptance, obtaining regulatory approval and designing a policy that would redistribute the benefits of sustainable energy implementation in a fair manner.

i) Consider consistent and transparent methods for financial analysis

A critical challenge to the development of renewable energy projects in Arctic remote communities is the lack of a consistent and transparent definition and measurement of the marginal cost of diesel generation that can be curtailed by supplying the communities with renewable electricity. A more comprehensive calculation of all the saved costs (including GHG emission reductions) tied to diesel displacement needs to be derived for different local contexts.

ii) Analyze demand-side vs. supply-side options

Demand-side resource cost-effectiveness analysis is a useful tool to use in the Arctic, helping Arctic energy conservation program administrators (or other administrators delivering net-metering programs) to optimize their portfolio of programs. It needs to be further examined when DSM is the cheaper alternative to new supply options. Some conservation programs prove to be more expensive than supply-side resources, particularly programs that are labour intensive and require significant human resources. In addition residents' preferences should be considered as well as financial considerations. For example, some citizens of the Yukon, NWT and northern Québec voiced their preference for energy conservation over new supply-side resources when consulted (Yukon Energy Corporation, 2011) (Government of the Northwest Territories, 2013) (Lanoue & Mousseau, 2014). In some cases it may therefore be justified to carry out DSM programs even without supporting financial arguments.

iii) Starting small can help manage risks

Pilot projects afford opportunities for communities, government and industry to learn, adjust, and overcome challenges, and to bring learning experiences to future projects, making them more likely to succeed. These pilots however often involve a high up-front cost and they may considerably stretch local resources and capacity. Funding for pilot projects should take into consideration not simply the development and capital costs of the project but the additional funding required to support the project initially with outside expertise if necessary until local capacity accrues. Funding should also include careful monitoring and evaluation of performance, which would help to identify benefits and challenges, and aid in justifying further project expenditures or eventual expansion.

iv) Ensure representation of all northern jurisdictions for federal funding criteria

Nunatsiavut does not qualify for several federal funding sources due to failing to meet requirements of being either north of 60° latitude or being a reserve. The fact that Nunatsiavut lies within the discontinuous permafrost zone, in a sub-Arctic environment that is home to an Inuit population, should qualify Nunatsiavut for similar "Arctic" funding pools available to other northern and Indigenous populations.

v) Examine potential for alternative financing models to support renewable energy and energy efficiency and conservation:

A significant challenge to alternative energy integration in the North is the high upfront costs involved in project development and implementation. One suggestion is therefore to examine the feasibility of alternative financing models.

Similar to the activities of Energy Service Companies (ESCOs), who identify and provide guarantees for projected energy savings, one suggestion for communities, institutions (e.g. schools, hospitals), individuals, governments, etc. is to consider the possibility of leasing a technology from a Northern partner, such as a Northern-based ESCO or utility, or an indigenous-owned organization such as Nunavut Tunngavik Inc. in Nunavut and Makivik Corporation in Nunavik. These organizations may have more resources to devote to capacity building and investment, rather than individual communities or organizations taking on these responsibilities.

Policies that allow these innovative funding mechanisms, such as the Nunavut Energy Retrofit Policy (modelled after the Government of Canada's Federal Buildings Initiative), enables cash-strapped governments to access otherwise unavailable third-party private funding, paid back by guaranteed savings. Such a policy could be considered by other jurisdictions to enable cost-saving energy efficiency retrofits and building upgrades with third-party funds (see the Iqaluit Pilot Project in the Case Studies chapter for details).

vi) Incorporate less-conventional drivers, beyond financial considerations, in decision-making

When evaluating a project's feasibility some weight should be given to subjective values such as independence, autonomy, traditional values, connection to the land and well-being, especially in projects which involve Indigenous communities, such as indicated in the Lutselk'e and Fort McPherson case studies. Choosing an energy source that resonates with local culture or traditional practices and values may increase long-term community buy-in and support for a project as well as enhancing a community sense of pride and well-being.

9.3. Education, Engagement and Collaboration Recommendations

i) A decentralized presence within communities can galvanize support

Having a non-governmental agency dedicated to sustainable energy such as the Arctic Energy Alliance (AEA), has allowed a single point of contact for the Northwest Territories public regarding clean energy and energy efficiency initiatives and public education. With agency offices throughout the territory, rather than a centralized approach with one office, the AEA has been able to engage in continuous relationship-building with local communities, which has helped to streamline the development and advancement of projects in the Northwest Territories. This model of an arms-length agency funded by the territorial government but operating outside the structures of government could be considered for replication in other jurisdictions.

ii) Devote energy efficiency education to those involved with building maintenance and building occupant behaviour

Space heating and the retention of heat in buildings are of critical importance in Arctic jurisdictions. Policy makers have done well in developing innovative policies that encourage fuel switching and incentivizing retrofits to increase energy efficiency but equal weighting has not been given to maintaining these buildings once construction or retrofitting has been completed. A policy program designed to educate citizens and building tenants about essential maintenance and energy behaviour is important for maximizing the long-term returns from investing in energy efficiency measures.

iii) Focus on building capacity through training and education

In some cases alternative energy initiatives have been abandoned due to the departure of the sole project champions. Education and skills training for energy projects should therefore be provided to groups rather than single individuals and should accompany all new sustainable energy projects. This can help to build capacity in the community (or organization), which is vital in order to successfully maintain and manage the project over time. Positive examples of this include the Seneca College Building Energy Systems course provided for building managers and operators as part of the Iqaluit Pilot Project.

iv) Support engagement in the energy policy process

It is important to provide opportunities for stakeholders and the public to engage in the energy policy process. The regulatory apparatus governing the electricity sector in Arctic jurisdictions is inherently complex for citizens and policy makers not directly involved in the process. As a result residents are often confused and sometimes upset when decisions are made for certain courses of action or when some power generation technologies are favoured over others. A commitment to transparency and a dialogue between policy makers, utility companies and citizens are incredibly important to illustrate how decisions or a specific courses of action are chosen, and for energy system planners and policy makers to receive input.

v) Develop opportunities to foster information sharing and cooperation

Collaboration across jurisdictions is important. A one-size-fits-all approach to policy development does not take into account the widely differing circumstances faced by jurisdictions. However, the sharing of best practices, success stories and education about different policy options enhances knowledge mobilization across jurisdictions. Communities, policy makers, utilities and crown corporations could all benefit from this pan-regional cooperation and sharing of lessons learned.

vi) Establish a network of project champions

The establishment of a network of project champions, supported by some public funding, would further promote the sharing of knowledge and experience between communities across the Arctic involved in sustainable energy projects. Project champions are often over-stretched due to limited local capacity or support and as a result frequently feel isolated as challenges arise with their projects. A network of champions would not only provide support and mentorship but would enable communities and champions to share success stories and build upon lessons learned throughout the North.

10. Research Recommendations

From this review of current programmes, policies, financial and economic analysis and the selected case studies a number of research gaps and further research directions have been identified. Further research is recommended in the following areas:

- i. **Renewable Energy Technologies:** Conduct further research into the development, testing and deployment of renewable energy technologies in the northern context. This research should address technological challenges particular to northern operations, as well as reducing cost, increasing reliability, and reducing system complexity so projects can be more successfully and sustainably operated in small northern communities with limited capacity.
- ii. **Regulatory Framework Optimization or Reform:** Deepen the research on energy regulation in order to come up with specific recommendations on how to alter regulation to maximize social benefit through a multifaceted approach that would account for considerations such as environmental and health impact minimization, and economic growth.
- iii. **Energy Subsidies:** Quantify all energy subsidies and cross-subsidies to better understand the implications of alternative energy on whomever is funding the subsidies – in many cases taxpayers, certain categories of ratepayers or both (i.e. when government rate classes cross-subsidize other rate classes) – and thereby be able to reform the current subsidy channels, and/or take actions that would create clearer incentive signals for energy conservation and new renewable energy investments.
- iv. **Involvement in Hydro Development:** Provide funding, research, technical assistance or become a stakeholder in ongoing efforts toward northern jurisdictions acquiring greater hydro capacity. Hydropower can be a low impact resource that provides a stable source of power with good potential for integration with other renewable sources.
- v. **Electricity Grid Optimization:** Carry out comprehensive multidisciplinary studies on the feasibility, implementation, and potential social impact of demand-response and Arctic electricity grid optimization (in the absence of advanced metering infrastructure such as smart meters). Some solutions are applicable to hydro grids (e.g. dual-energy systems), and others are more appropriate for remote community grids (e.g. thermal storage). Multiple facets of the solutions need to be addressed including engineering solutions and feasibility, social acceptability, divisions of benefits between adopters, ratepayers, utilities, government and society, policy considerations, as well as business models and implementation methods. Electricity grid optimization has the potential to minimize electricity rates in the long-run, increase reliability, increase the potential for renewable energy penetration and increase the value of intermittent

alternative energy such as wind and solar. In remote communities grid optimization has the potential to ease the adoption of alternative solutions that are challenging to modulate, such as geothermal and biomass power.

- vi. **Locally Sourced Biomass:** Provide funding, research, technical assistance or become a stakeholder in northern jurisdictions' efforts toward building the supply chain for locally sourced biomass for heating and power generation. Explore the link between the harvesting of local biomass for heat and long-term economic development within a community.
- vii. **Storage Solutions:** Develop and refine storage technologies that are affordable and efficient in remote northern settings where storing excess energy from intermittent sources would have considerable benefit.
- viii. **Energy Conservation Performance for Housing:** Study the feasibility, and collaborate with Yukon Housing Corporation (YHC), to use the Green and SuperGreen endorsement labels in other jurisdictions beyond Yukon. YHC has used a comprehensive policy approach including engagement and partnership with municipalities, utilities and governments, training for housing developers and advertisement for homebuyers. The Green and SuperGreen labels are effective residential energy performance labels created in the North for Northerners.
- ix. **Independent Power Production Negotiation:** Study and develop a model to conduct cost-benefit analysis of solar, wind, hydro, geothermal and biomass power projects that are based on the actual marginal production cost of diesel generation in remote communities. Study the option of using private capital and private developers, through Independent Power Producer agreements, to develop alternative energy projects in Arctic communities. Develop tools, best practices and general guidelines for Independent Power Producer agreement negotiations, while recognizing that they will need to be adapted to the regulatory and governance context in each jurisdiction.
- x. **Demand-Side Resource Financial Analysis:** Perform a jurisdictional review across North America of standard demand-side resource economic analysis, and determine applicability in the North. Consult with Northern partners to validate feasibility, interest, and acceptance of these techniques. Deliver training and disseminate information about the use of standard demand-side economic analysis in a Northern context. Develop job aids (tools) for Northerners to carry out standard demand-side cost-effectiveness tests.
- xi. **Social Acceptance of Alternative Energy Technologies:** Study the links between alternative energy technologies and traditional Indigenous values and practices. Endeavour to understand connections between energy supply and community self-reliance, well-being and local project acceptance. Explore the link between cultural connectedness to an energy source and long-term community support and buy-in.

- xii. **Energy Resilience:** Develop a model to assess resilience as it relates to a northern community and its energy system (considering factors such as energy costs, energy supply, diversity of energy sources, energy efficiency of homes, age of infrastructure, community capacity to manage the system, local economic benefit, vulnerability to oil spills, local air pollution, social resilience, etc.). Having the ability to determine the resilience (and conversely vulnerability) of a population based upon energy issues would enable a more focused response and prioritization of solutions specifically designed to improve a community's resilience and quality of life.
- xiii. **Emissions Pricing:** Analyse the effects that having a price on greenhouse gas emissions would have on the different northern jurisdictions. Of the five regions encompassed in this study, only Nunavik is currently affected by such a mechanism, under Quebec's cap and trade system with California. Evaluate the effect this policy has had, and its potential effect in the future, on renewable energy uptake in Nunavik.
- xiv. **Energy Awareness and Education:** Evaluate the effect of different energy awareness education programs in the northern jurisdictions. Determine best practices for engaging individuals and communities in decision-making around alternative energy and for educating project managers, operators and the general public about alternative energy and energy efficiency projects and programs.
- xv. **Energy Needs for Mines and Industry:** Mining and industry have increasing energy demands that are often highly volatile and sometimes temporary for the duration of the mining or industrial project. Increased research attention must be given to the energy infrastructure for these projects, its financing and what to do with the infrastructure once mining or industry projects are no longer viable.
- xvi. **Interface Between Water and Energy:** While this research focused upon northern alternative energy supply and demand, it should be noted that provision of domestic water in the North has large impacts on domestic energy usage including its transportation, delivery, heating and storage. Future research on energy in the Arctic should contemplate the interface between energy and water provision.

11. Conclusion

The report on the state of Arctic energy provision is an overview of what is known to this date of energy programmes, policies, technologies and challenges. Given the scope and timeline of the project it was not practical to provide a more detailed analysis and discussion. It is however felt that it is important and urgent for policy makers, practitioners and scholars to pay more attention to Arctic energy solutions and challenges. Consumers and businesses in the Arctic have to cope with high energy prices whilst dealing with extreme living conditions; there is therefore a need to be even more creative and innovative in the Arctic energy context. Different Arctic regions are at different stages of developing energy systems and energy demand and supply responses and incentives. Lessons can be learned from individual experiences, providing insights for other jurisdictions.

The new approach in public policy and programme evaluation of incremental adaptive decision-making should also apply to Arctic energy decision-making. There is a need to experiment more with new alternative energy policies and technologies while carefully assessing successes, failures and lessons learned. This could be done in a more strategic way with federal support and guidance and clear dissemination of results to all Northern partners. It could also lead to new directions in training, capacity building and economic development, particularly if new ways to market opportunities for other Arctic regions and Northern areas in Canada are developed at the same time (e.g. transportation, infrastructure). Any solutions require local and regional inputs and need to be compatible with traditional practices. This provides an opportunity for additional education in energy literacy, and integration of wage-based and traditional activities and culturally atuned approaches for more effective energy solutions.

Glossary

Biomass Power	Power generated from burning the biomass in a boiler, turning water into steam, and then generating power from using a steam turbine.
Cold-Climate Air-Source Heat Pump	A system that transfers heat from a cooler medium (or “source”) to a hotter medium (i.e. typically a building or hot water tank). The source is typically air, water or the ground. A heat pump uses electricity. The energy performance of heat pumps is approximately two to three times that of electric baseboards on a seasonal basis. However, the performance of a conventional air-source heat pump gets lower as the temperature drops. A conventional air-source heat pump for a house cannot heat the house anymore when the temperature drops below -5 degrees Celcius (approximately), at which point the house needs a back up heat generator. Conventional heat pumps are a mature technology and have been available in North America for the past three decades and supply chain exists in certain areas in the Arctic (e.g. Whitehorse). A cold-climate heat pump is a new technology that can still heat the house at low temperature until it drops to -30 degrees Celsius and heat the house with at a higher performance at any temperature point when compared with a conventional heat pump. It is, however, significantly more expensive, but still less expensive than a ground-source heat pump.
Combined Heating and Power	Power generation units with heat recovery, allowing the heat to be used for space heating, domestic hot water and/or industrial processes. The generation unit can run on any combustible such as fossil fuel, hydrogen or biomass. CHP systems have higher system efficiency because the heat is used rather than being exhausted in the atmosphere.
Cost of Capital	The annual monetary return on investment expressed as a percentage that is needed to secure the capital required to fund investment. The weighted average cost of capital (WACC) simply is the average expected return rate or interest rate of all sources of capital weighted by their respective size in the funding mix of the utility (or the private developer).
Diesel Rotary Uninterruptible Power Supply	Special diesel genset unit that includes a large flywheel to store energy and damper the quick start-ups and shutdowns.
Discount Rate	The principle under which the current value of money is lower in the future. The further away in time the money is spent or earned, the lower its present worth is. The time value of money is usually reflected by an annual discount rate. For example, an amount of money earned one year in the future must be divided by $(100\% + \text{Discount Rate})$, if it is earned two years in the future it must be divided by $(100\% + \text{Discount Rate})^2$, if its three years the divider is $(100\% + \text{Discount Rate})^3$, and so on.
District Heating	Heat generated in a central location and then carried to individual buildings through steam or hot water pipes.

Drivers	Factors which spur the development of a project
Feed-In Tariff	A policy through which the power utility allows electricity consumers (or renewable energy independent power producers) to supply electricity to the grid. When they do so, the utility pays the electricity consumers (or the independent power producer) an amount equivalent to the electricity supplied (typically in kWh) multiplied by an agreed tariff, which typically is superior to the electricity rate.
Geothermal Power	Power generated from heat coming from deep within the earth's crust, typically on the order of kilometers in depth. Boreholes are drilled in order to access heat pockets, which then generate steam for a turbine. The feedwater is reinjected into the earth's crust to avoid a number of toxic or climate change-inducing gases being released in the atmosphere. Geothermal power is often confused with Ground-Source Heat Pumps.
Ground-Source Heat Pump	A heat pump for which the source is the ground. Heat energy typically gets collected through water (or a mix of glycol and water to prevent freezing) either from a closed loop pipe system or open loop (pumped from rivers or aquifer). Since the ground has a more stable temperature than the air, a ground-source heat pump has higher performance than that of a conventional heat pump, and can heat buildings or houses at an excellent level of performance even during extreme cold temperatures.
Incentive	An incentive or compensation can take multiple forms such as rebate at the cash registry of a store, a check sent by mail, credit on energy bill, subsidized interest rate on a loan, special electricity rate (i.e. lower than regular rate), feed-in tariff payments, equipment giveaways and gifts, direct install (i.e. the program administrator pays for the equipment and its install), or performance payments (i.e. recurring payments in exchange for continued participation in program).
Internal Rate of Return	The discount rate at which the benefits are equal to the costs, once both are adjusted for the time value of money. Investors typically seek investment opportunities with high internal rate of returns.
Interruptible Rates	Lower electricity rates offered to customers in exchange for the permission to stop (interrupt) their supply a number of times during the year. Typically, the utility would schedule the interruption, and call in advance to announce the interruption to the customer. Interruptible rates are usually offered to larger customers such as industrial facilities and mines. The customer either has to stop production during the interruptions or use embedded generation such as emergency diesel gensets. The interruption allows the utility both (i) to curtail the load during peak periods and thereby avoid or defer investment in generation capacity; and (ii) to sell more electricity during off-peak period thereby dividing the cost of service by higher sales (in kWh) and in turn lower rates for customers.
Kinetic Hydropower	Hydropower technology that requires little to no height difference but instead draws energy from currents. <i>Hydrolienne</i> is one type of kinetic hydropower. A hydrolienne is an open turbine standing at the bottom of the sea or a river which captures the kinetic energy of the water flow.

Levelized Cost of Energy (LCOE)	A measure of the per-kilowatt hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.
Long-Term Interest Rate	The interest rate on debt with a debt term (or maturity) longer than one year. Typically, long-term interest rates are higher than short-term interest rates (but not always) because the risk taken by the lender is higher, which is factored into the rate. Utilities have a mix of loans cumulated over time with different levels of maturity. Long-term interest rates of a utility represent the blend of the interest rates of all of these loans.
Marginal Cost of Diesel Generation	Cost avoided by offsetting the first one unit of production – in this case, kWh. The marginal cost of diesel generation represents the variable portion of the average diesel generation cost. The full average diesel generation, which includes fixed cost, is described as average total cost.
Micro-Cogeneration	A generator that generates both heat and power from a combustible (often natural gas or propane). Micro-cogeneration is a small cogeneration unit that can fit in a building
Minimum Reliability Requirement	The ability of the utility to provide electricity to all connected consumers during periods when the instantaneous demand (the load) is the highest (peak demand), with the largest source of power generation not producing (for example for maintenance or due to accident or disaster).
Net Metering	A policy through which the power utility allows electricity consumers to supply electricity to the grid. When they do so, the utility credits their electricity bills an amount equivalent to the electricity supplied (in kWh) multiplied by the electricity rate.
Program Participants	Ratepayers implementing energy conservation measures, or installing embedded generation projects inside their premise. Non-participants refer to all other ratepayers. The definition of participant can be stretched to include ratepayers that are indirectly influenced by a program or policy.
Ramp	The transitional stage during which the load decreases (ramp down) or increases (ramp up) where the genset needs to follow the change in load.
Rate Base	The value of the total asset owned by the utility used to deliver electricity services and on which the utility is entitled by the regulator to earn a return on equity. In this paper, as is common practice in the electricity sector, we refer to the “rate base” in the broader sense of “all utility costs that are to be recovered through rates”, thereby encompassing both asset depreciation and operational expenditures.

Return on Equity	Annual rent achieved by the owner of the utility as a percentage of the equity portion of the value of the utility's assets. The current value of the utility's assets typically is the original investment net of cumulative depreciation.
Simple Payback Period	The number of year required to pay back the investment from savings. It is the simplest method of financial analysis and typically is used to assess the financial performance of alternative energy from the perspective of an energy end user. The equation is: Simple Payback Period (in year) = Initial Investment (in \$) / Annual Operational Savings (in \$ per year). The equation for the simple payback period after incentive funding is: Simple Payback Period (in year) = (Initial Investment (in \$) – Funding (in \$)) / Annual Operational Savings (in \$ per year).
Success Factors	Elements contributing to the successful development/deployment/operation of a project.
SuperGreen	A housing energy performance endorsement label developed and promoted by the Yukon Housing Corporation. In addition to specific construction and insulation standards in excess of building code requirements, an Energuide Home Rating of 85 is required. The previous standard, 'GreenHome', required an Energuide rating of 80. This standard was adopted as the minimum requirement in Whitehorse. Energuide Home Rating is a home energy performance label created and managed by the Office of Energy Efficiency of Natural Resources Canada. It rates the energy performance of houses from 0 to 100, with 100 being the perfectly energy-independent house. Energuide Home Rating falls into the category of "information label" (it gives an "information" about the performance of a house) and it is not mandatory to obtain it for houses in Canada.
Supply Chain	Businesses buying a commodity from producers, transporting and dispatching, and then retailing the commodity to end-users. Typically, the supply chain consists of a manufacturer representative or agent selling to a distributor (or wholesaler) who in turn will sell it to a retailer (or contractor), which then sells it to end-users.
Waste-to-Energy Power	Power generated from burning wastes at a high temperature in a boiler to produce steam for a turbine, or waste being turned into a combustible gas and burned in a generator such as a reciprocating engine or turbine.

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Appendix 1: Overview of Governance of Energy Policy in Arctic Jurisdictions

Governance of Energy Policy in Yukon

The Governance of energy policy in Yukon represents a layering of a number of actors, agencies and processes that have been developed over the territory's history. Like most jurisdictions in Canada the primary directing actors in the energy policy space are governmental or publicly owned bodies. Consumers (individuals, commercial and institutional groups) are also important in the energy planning process and have accessed a number of different avenues to state their views and shape policy direction. This section will discuss the different roles played by public agencies, actors and governance processes that Yukon utilizes in governing its energy sector.

Departments and Agencies

The primary actor in developing and setting overall energy policy is the Government of Yukon and its various departments. Specifically, energy resources including electricity policy and fossil fuel procurement activities are under the purview of the **Department of Energy, Mines and Resources**. This department is responsible for high level priority setting in energy policy and is also the main conduit through which a number of specialized agencies involved with Yukon's energy sector are governed. The **Department of Transportation and Public Works** is the ministry in charge of the Yukon government's vehicle fleet as well as the government's stock of publicly owned buildings and facilities. In this role the department has been involved in a number of recent studies and programs aimed at monitoring energy usage and increasing energy efficiency in publicly owned buildings.

Of primary importance in the energy sector is the **Yukon Development Corporation (YDC)**, a crown corporation solely owned by the Government of Yukon and which is responsible to the minister of Energy, Mines and Resources. The primary focus of the YDC is restricted to energy-related activities designed to promote the economic development of Yukon, and to: ensure an adequate supply of energy, alleviate energy shortages and to promote the establishment, development and operation of industries that are by their nature energy dependent through the provision of cost-effective energy or energy related

infrastructure (Yukon Development Corporation, 2015). For meeting electrical needs the YDC accomplishes these objectives through its subsidiary company **Yukon Energy Corporation (YEC)**, the primary electricity generator and transmitter in the territory. YEC is also the primary distributor of financial programs (subsidies and rebates) targeting electricity consumers in Yukon. The distribution of heating and transportation fuels, on the other hand, is largely handled by the private sector through a number of different local and national companies.

Another branch agency of the Ministry of Energy, Mines and Resources that plays a large role in Yukon energy is the Energy Branch, or sometimes referred to as the Energy Solutions Centre (ESC), primarily as a delivery agency of government policies and programs. The mandate of the Energy Branch is to encourage improvements in energy efficiency and the adoption of more forms of renewable energy (Energy Solutions Centre, 2011). In accomplishing these goals the Energy Branch is the lead agency for a host of programs aimed at consumers. The Energy Branch operates several energy efficiency programs (including rebate and appliance switching), energy audit services, providing training programs to increase local technical capacity, public education and outreach programs as well as interacting and cooperating with similar agencies in other jurisdictions. The **Yukon Housing Corporation (YHC)** is the crown corporation tasked with developing and providing affordable housing to Yukon residents and Government of Yukon staff. In fulfilling its mandate the YHC owns and maintains 820 properties throughout the territory and has taken a lead role in developing energy efficient housing (Yukon Housing Corporation, 2014).

Non-Governmental Actors

Apart from territorial government agencies there are a number of state and non-state actors which either help to craft or carry out energy policy in Yukon. The Yukon Utilities Board (YUB) is responsible for regulating electrical rates offered in Yukon, determining the geographic areas that utilities will serve and regulating the expansion or alteration of services offered by utilities through application and adjudication procedures (Government of Yukon, 2002).

The ATCO Electric Yukon (formerly known as Yukon Electrical Company Limited) is a privately owned (by the ATCO group) distribution company serving the vast majority of Yukon residents and

businesses. Similar to YEC the ATCO Electric Yukon is a regulated utility by the YUB and must apply to the Board for rate increases, change of service and expanding its operations.

Finally, at the municipal level, the City of Whitehorse is another important actor in energy policy. Whitehorse is home to nearly 76% of Yukon residents and decisions taken at the municipal level in regards to energy efficiency, residential heating and electrical generation are important drivers for Yukon's overall energy makeup (Yukon Bureau of Statistics, 2014).

Processes

The processes for developing energy projects and crafting and implementing energy policy in the Yukon reflects a layering of the different governmental departments, regulatory bodies and private actors outlined above. At the very highest levels the framework for Yukon's energy policy is crafted by the Government of Yukon, while the specific details of these policies are very often delegated to governmental departments (ESC) and crown corporations (YDC, YEC, YHC), where they are operationalized for Yukon citizens. Throughout this process there are a number of access points for individuals and stakeholders to voice their concerns and share their opinions. Public comment periods, resident surveys, town hall meetings and stakeholder engagement sessions have all been utilized by governmental agencies when developing the Territory's most recent energy and climate change strategy documents. An *Energy Charrette*, organized by YEC in 2011, brought together a number of different stakeholder groups, experts and individuals to discuss updates to the YEC's 20-year resource plan. The Charrette process was noted as an excellent way to open the energy policy planning process to Yukoners and has been lauded as an important step for establishing energy planning priorities. Indeed, the Charrette was instrumental in establishing YEC's four planning principles (reliability, affordability, flexibility and environmental responsibility) for future electricity projects (Yukon Energy Corporation, 2011) (Yukon Energy Corporation, 2011).

Governance of Energy Policy in Northwest Territories

Similar to the case of Yukon, the governance of energy resources in Northwest Territories (NWT) reflects a layering of different institutional factors, government agencies, utility companies, private actors

and policy-making processes. A marked change in governance structure in the NWT has recently occurred following the conclusion of more than twenty years of negotiations between the federal government and the Government of the Northwest Territories (GNWT) over devolution of federal control over land and resource management in the NWT. Signed into law on June 25, 2013, the federal government transferred management of public land, water and resources to the GNWT, giving the territorial government broad control over resource development and land use throughout much of the territory after April 1 2014.

Departments

Broad authority over energy policy frameworks, natural resource development and land use planning within the territory resides with the GNWT. The Ministerial Energy Coordinating and Climate Change Committee of Cabinet (MECC), consisting of the territorial Premier and a number of ministers, has broad authority over energy policy development. The Department of Environment and Natural Resources (ENR) has jurisdiction over environmental protection, climate change programs, water regulation, GNWT scientific pursuits, as well as alternative and emerging energy technologies. The Department of Industry, Tourism and Investment (ITI) plays a role in general energy policy planning, oil and gas development, mining and electricity policy planning. Finally, the Department of Finance oversees electrical subsidy programs, and the Department of Public Works and Services is responsible for petroleum product deliveries and for managing the GNWT's physical assets including buildings and vehicle fleets.

Broad authority for energy policy has recently been scheduled to move to the Department of Public Works and Services in April 2015. The decision to centralize energy policy governance within one department was made because the current approach of having different departments managing different aspects of energy policy was less than optimal.¹²⁴ It is suggested that Public Works and Services has the expertise and project management skillset needed for the diverse energy portfolio.¹²⁵

Outside of government departments three agencies also play crucial roles in delivering energy services to residents of the NWT. **NT Hydro Corporation** is a crown corporation solely owned by the

¹²⁴ Anonymous. *Focus Group Interviews*, 2014

¹²⁵ Anonymous. *Personal Interview*, December 2014

GNWT and is the parent company of **NT Power Corporation (NTPC)**, responsible for generation, transmission and distribution in much of the NWT; and **NT Energy Corporation (NTEC)**, responsible for new energy options and new technology integration into NTPC's operations. These three companies (but specifically NTPC) provide the vast majority of electrical power to North Slave and thermal zone area communities and residents.

The **Arctic Energy Alliance (AEA)** is also a key actor in the NWT. The AEA carries out a number of different programs and educational campaigns that aim to improve energy awareness, but also to help consumers of all types to increase energy efficiency, and to assist in the deployment of new renewable energy technologies. In the past the AEA has carried out a number of studies and reports on energy efficiency and renewable technologies in the NWT, including several on wood pellet logistics and technologies, solar heating implements, as well as market mapping studies for several technologies.¹²⁶

Similar to other jurisdictions in Canada there are several non-governmental actors that also help shape and carry out energy policy in the NWT. **Northland Utilities** is a private company owned by the ATCO Group and is an important actor in a number of respects. In addition to being the distribution company for the Yellowknife area, Northland is also a transmitter and distributor for communities in the South Slave region. While Northland purchases the majority of its power from NTPC's generators around Yellowknife and in the South Slave area, it does own and operate backup diesel generators in many of the region's communities (Northland Utilities, 2015)

Another important organization is the **Aurora Research Institute (ARI)**, headquartered in Inuvik, which is the research division of **Aurora College** (formerly Arctic College) with campuses in various centres in NWT. The ARI engages in scientific research pursuits in the NWT and has been involved with a number of energy projects including studies on wind resources and solar photovoltaic demonstrations.

Processes

Energy policy processes in the NWT follow a number of different trends, reflecting the actors and agencies involved. High-level policy planning and strategic goals are articulated at the ministerial level,

¹²⁶ For more information about the programs and research conducted by the Arctic Energy Alliance please see: <http://aea.nt.ca>

while specific program implementation and overall electrical system planning are carried out at the agency and crown corporation level. In addition, recent strategic initiatives have begun to further engage the public in energy policy and planning processes. Within the NWT the hallmark events of this planning shift have been the introduction and usage of Energy Charrettes as a means to incorporate feedback from various stakeholders with respect to energy planning and prioritization of efforts. First used in 2012, the Energy Charrette format allowed for a diverse range of government actors, stakeholders and individuals to convene around energy and electrical policy issues. This approach was the by-product of individuals within the GNWT looking to expand, engage and converse more broadly when developing energy policy priorities.¹²⁷ The results of the Charrette was also used to inform and develop the 2012 Power System Plan released by NT Energy, as well as the GNWT's Energy Action Plan released in 2013 (Government of the Northwest Territories, 2013). The Charrette process was revisited and utilized again in 2014 when a number of acute issues (low water supply on the hydro systems and multiple forest fires) and the resulting financial cost of utilizing diesel backup generation, strained the NWT's electrical system, forcing the territory to re-examine these short term and long term energy plans and priority areas of focus.¹²⁸

Governance of Energy Policy in Nunavut

Nunavut was established on April 1, 1999 and is Canada's newest territory. Since its creation the governance of energy policy in Nunavut has evolved along with its administrative and managerial capacity. An important factor to note is that Nunavut has not yet completed the devolution process like the NWT and Yukon and therefore does not yet have control over Nunavut's public lands and resources and does not benefit from resource development royalties. Additionally, because of its relative infancy and the developing nature of many of its economic sectors the GN is dependent upon federal transfers for over 90% of its annual funding (Government of Nunavut, 2015).

Departments and Agencies

¹²⁷ Anonymous. *Personal Interview*, November 2014

¹²⁸ Anonymous. *Personal Interview*, November 2014

Ikummatiit: The Government of Nunavut's Energy Strategy was developed by the Energy Secretariat and approved by the GN in 2007, aims to create an energy system that is affordable, sustainable, reliable and environmentally responsible (Government of Nunavut, 2007). The Nunavut Energy Strategy notes the high cost (both financial and environmental) of reliance upon imported fossil fuels, and commits to increasing energy efficiency and conservation, and to exploring alternative and renewable energies, as well as and natural resource development (including oil and gas) in the territory (Government of Nunavut, 2007)

The coordination of energy policy development and delivery of energy programs is the responsibility of **The Energy Secretariat** housed within the Department of Economic Development and Transportation. The Energy Secretariat is tasked with developing, coordinating and delivering Nunavut's energy strategy designed to reduce dependence upon fossil fuels. The Energy Secretariat along with the Department of Community and Government Services (CGS) is responsible for the development of Nunavut's Energy Management Program (NEMP), the GNs central program for energy efficiency and conservation measures in its buildings. Similarly, CGS plays a key role as it oversees several important sub-divisions that deal with the day-to-day implementation of energy policy.

Residing within CGS, the **Petroleum Products Division (PPD)** is responsible for the annual bulk purchase, transportation, storage and distribution of petroleum products in Nunavut. PPD is also the owner of storage and distribution facilities in all Nunavut communities except for Iqaluit and Cambridge Bay where facilities are privately owned. CGS also houses the **Community Services** division which is tasked with assisting communities in infrastructure and capital planning and for developing local capacity for delivering services such as building maintenance and operation, land administration and utility maintenance and operation (Government of Nunavut-Community Services, 2010). Similarly, the **Government Services** division of CGS oversees a number of GN operations including property and asset management, facilities management, architecture and engineering services and an energy services branch which houses the operational arm of the NEMP (Government of Nunavut-Government Services, 2010).

Qulliq Energy Corporation (QEC) is the GN's Crown Corporation tasked with generating, transmitting and distributing electrical power in Nunavut communities. The QEC owns electrical service

assets in all 25 Nunavut communities and is the sole electrical power company in the territory. The organizational structure of the QEC includes an independent board of directors and chairperson as well as a president and chief executive officer who guides QECs operations. Similar to the structures in place in the NWT a Minister Responsible for the Qulliq Energy Corporation is a critical link between the GN and QEC's overall strategic direction and submits rate applications to the **Utility Rates Review Commission** on behalf of the QEC. The **URRC**, is the arm's length regulator responsible for setting electricity rates in Nunavut.

The **Nunavut Housing Corporation (NHC)** is the Crown Corporation responsible for public housing, government staff housing and homeownership (Nunavut Housing Corporation, 2009) in the territory. NHC works with 25 community based **Local Housing Organizations (LHOs)** to provide public housing for Nunavummiut. The LHOs are responsible for day-to-day program delivery and maintenance of public housing, with the NHC overseeing the overall stock of public housing in Nunavut as well as providing financial and professional support resources to LHOs. The NHC also works with local agents and contractors in the construction of new public housing units across Nunavut. The NHC is responsible for the staff-housing program for the GN, which provides subsidized rental housing for GN employees to aid in the recruitment and retention of staff in Nunavut communities. According to the 2010 Nunavut Housing Needs Survey the NHC, through its ownership of public and government employee residences, is responsible for roughly 5,750 (4,400 public and 1,350 GN employee units) of Nunavut's 8,550 occupied dwellings (Nunavut Bureau of Statistics, 2011). The NHC offers financial and technical services for first time Nunavut homeowners as well as homeowners looking to upgrade or retrofit their residences through a number of programs, some of which were discussed in detail in Section 4.3.

Processes

Similar to the cases involving Yukon and the NWT, the GN directed its municipalities to develop individual Integrated Community Sustainability Plans (ICSPs) between 2009-2011 to identify infrastructure priorities and to engage officials and individuals in planning for their long-term future. Currently, each community in Nunavut has a completed ICSP in place.

In 2010 a consulting firm was brought in to advise, design and develop the ICSPs for communities.

The process included meetings and scoping exercises carried out with officials and representatives in each community (Consilium Consulting Group, 2010). Also included were community workshop sessions which when completed required ratification by the Hamlet Council. These plans have been useful in identifying opportunities for energy efficiency and conservation and have helped to increase energy awareness among residents and officials.

Governance of Energy Policy in Nunavik

More so than any of the other jurisdictions examined in this report, Nunavik's energy policy is largely developed outside of the region. Nunavik has completed land claim agreements with the federal government and with the government of Quebec twice in its history in 1975 (*James Bay Northern Quebec Land Claim Agreement*) and in 2007 (*Nunavik Inuit Land Claims Agreement*). While these two agreements gave Nunavik residents control over their land and resource development they did not lead to a further devolution of specific energy related powers. Throughout 2011 Makivik negotiated on behalf of the Nunavik people to gain further authority over the regions governance, with the goal of becoming a self-governing jurisdiction. However, after a draft agreement was reached in 2011 the citizens of Nunavik voted to reject the agreement and for now rejecting the possibility of becoming a fully autonomous region (Directeur général des élections du Québec, 2011).

Agencies, Departments and Actors

The conclusion of the James Bay Agreements in 1975 led to the founding of the Makivik Corporation to administer the settlement funds from the agreement. However, Makivik's mandate ranges from owning and operating large profitable business enterprises and generating jobs; to social economic development, improved housing conditions, to protection of the Inuit language and culture and the natural environment. In fulfilling this role Makivik owns a number of subsidiary businesses, one that is particularly important for this report is Kautaq Construction, a residential construction company who has built the majority of housing units in Nunavik since 2000 and has also carried out the social housing renovation program which began in 2011 (Makivik Corporation, 2015). Additionally, the Kativik Regional Government

(KRG) was created in 1978 pursuant to the James Bay Agreements to deliver public services to Nunavik residents. In the energy field the KRG is responsible for environmental and climate change research and land-use planning for Nunavik communities (Kativik Regional Government, 2015).

In 1994 Hydro Quebec and the Makivik Corporation entered into an electricity supply agreement where **Hydro Quebec Distribution** would be responsible for providing electricity services to Nunavik communities and also for delivering, storing and distributing fossil fuels for space heating and transportation (Hydro Quebec Distribution, 2013) (Makivik Corporation, 2014). As such the decisions for electricity system planning and the setting of rates is largely conducted through Hydro Quebec's regulatory processes with L'regie, Quebec's independent energy regulator. Additionally, Hydro Quebec is also responsible for many of the energy efficiency programs discussed in Section 5.4

Governance of Energy Policy in Nunatsiavut

Similar to Nunavut, Nunatsiavut has a complex, layered governance structure involving several political entities. The Nunatsiavut region was created following the 2005 Labrador Inuit Land Claims Agreement, (LILCA) which concluded nearly three decades of negotiations between Labrador's Inuit populations and the provincial and federal governments. The Agreement provided Labrador's Inuit communities with land claim areas (Nunatsiavut) as well as self-governing provisions within the land claim agreement over health, education, culture, language, justice and community affairs which are managed by the Nunatsiavut Regional Government (NRG) (Nunatsiavut Regional Government, 2015). For other areas of governance including natural resources, off-shore resources and electricity, Nunatsiavut shares jurisdiction with the provincial and federal governments. The relationships and responsibilities between these three levels of government are not always clear. This is especially true in governance areas that fall between the provincial and regional governments such as energy policy.¹²⁹ The regional government, the Nunatsiavut Assembly, is based in Nain (the largest Nunatsiavut community with a population of around 1,200) and is comprised of elected members of Nunatsiavut communities, and includes one AngajukKâk (community leader) from each community. In addition to the regional

¹²⁹ Anonymous, *Personal Interview*, 2014

government, Inuit Community Governments in Nunatsiavut's five communities are responsible for the day-to-day delivery of services to community residents. This blending of jurisdictions and responsibilities has implications for energy governance in Nunatsiavut.

Departments and Agencies

Energy policy is primarily coordinated and developed by the Nunatsiavut Secretariat, a strategic planning and management division providing advice and services to the **Executive Council** (Nunatsiavut Regional Governmentb, 2015). Broad policy objectives and development plans are crafted within the Secretariat and then operationalized through other departments. The Department of Lands and Natural Resources has four divisions responsible for land, renewable resources, non-renewable resources and environment while also having responsibility for policy development in the areas of land use planningⁱ as well as environmental assessment and protection The Department of Nunatsiavut Affairs is broadly responsible for the implementation of the LILCA and is responsible for areas important to energy governance such as housing, community relations and public property.

At the provincial level a number of different agencies and ministries have overlapping jurisdiction with the NRG. For instance, the Newfoundland Government's **Departments of Natural Resources and Environment and Conservation** has many of the same responsibilities and share jurisdiction with the NRG **Department of Lands and Natural Resources**. Additionally, the **Department of Climate Change and Energy Efficiency** oversees provincial programs related to energy conservation and climate change. Finally, housed within the Executive Council of the Newfoundland and Labrador Government is the Labrador and Aboriginal Affairs Office, which is responsible for policy development and monitoring provincial initiatives in Labrador as well as coordinating efforts between the NRG, along with provincial and federal governments in relation to policies affecting Aboriginals (Government of Newfoundland and Labrador, 2014). These responsibilities include the monitoring of the provincial government's *Northern Strategic Plan* as well as fulfilling commitments made under the LILCA.

Outside of formal NRG and provincial government departments several arms length crown corporations are involved in carrying out energy policy development. Created in 2006 by the NRG, the **Labrador Inuit Capital Strategy Trust** is tasked with providing independent oversight of the NRG's

business interests held under the banner of the **Nunatsiavut Group of Companies (NGC)**. The NGC are prominent in the fields of air and marine transport, land leasing, construction and service and logistics in remote areas in Nunatsiavut and Labrador (Nunatsiavut Group of Companies, 2015). The **Nain Research Centre** was established in 2011 and is managed by the **Environment Division of Lands and Natural Resources**. It aims to support the knowledge needs of a healthy and prosperous Nunatsiavut and is currently undertaking the *SakKijânginnatuk Nunalik* (Sustainable Communities) Initiative, investigating issues of housing, community planning, energy security and food security (Nain Research Centre, 2015).ⁱⁱ

At the provincial level the most prominent agencies are crown corporations in the utility and housing sectors. **Nalcor Energy** is the legislated monopoly provider of electric power generation and transmission in Newfoundland and Labrador and through its subsidiary **NL Hydro** is responsible for providing services in Nunatsiavut. Finally, the Board of Commissioners of Public Utilities, headquartered in St. John's is responsible for processing, adjudicating and setting utility rates across the province.

Processes

The NRG is committed to a consensus form of parliamentary democracy and shares the roles and responsibilities of governance between the regional and community level. Broad policy directives and goal setting are the result of deliberations and agreement at the regional level while community leaders are given significant leeway for actually implementing policies. This approach can help produce effective localized results, however community level governance can cause difficulties with policy implementation directives from the NRG. Furthermore the NRG, through the Nain Research Centre has been working with a number of different departments, governments and academics to develop both a housing and energy strategy. While neither project is yet complete the NRG has committed financial resources in its latest budget to complete these initiatives.¹³⁰

¹³⁰ Anonymous, *Personal Interview*, December 2014

Appendix 2: Northern Renewable Energy and Energy Efficiency Project Database

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Northern Renewable Energy and Energy Efficiency Project Database

Territory	Type	Technology	Community/Site	Project	Size	Capital Cost	Service Date
<u>Nunatsiavut</u>							
Nunatsiavut	Heat	Efficiency	Nain and Hopedale	Attic Retrofit, Energy Efficiency and Home Repair Program: Energy efficiency retrofits and home repairs to 24 homes		\$ 700,000	2014-2015
<u>Nunavik</u>							
Nunavik	Electricity	Wind	Raglan Mine	Raglan Mine Wind Project	3 MW turbine + 1.8 MW storage	\$ 22,000,000	2014
<u>Nunavut</u>							
Nunavut	Electricity	Solar PV	Iqaluit	Nunavut Arctic College Solar PV	3.2 kW		Mid-1990's
Nunavut	Heat	Heat Recovery Ventilator	Cambridge Bay	Tri-territorial Heat Recovery Ventilator Pilot Project			
Nunavut	Heat	Solar Air	Iqaluit	Baffin Regional Hospital Solar Wall		\$ 100,000	
Nunavut	Heat	Solar Air	Iqaluit	Inuksuk High School Solar Wall			
Nunavut	Heat	Solar Air	Iqaluit	Iqaluit Airport Solar Wall			
Nunavut	Heat	Solar Air	Kangiqiniq (Rankin Inlet)	Alaittuq School Solar Wall			

Nunavut	Heat	Solar Hot Water	Iqaluit	Baffin Correctional Centre solar water heating	\$	110,000
Nunavut	Heat	Solar Hot Water	Iqaluit	Taammativvik Residence (40 bed) solar water heating	\$	110,000
Nunavut	Heat	Solar Hot Water	Iqaluit	Young Offenders Facility solar water heating	\$	55,000
Nunavut	Heat	Waste Heat Recovery	Kangiqiniq (Rankin Inlet)	Community Residual Heat Distribution Project	1900 kW	
Nunavut	Heat	Waste Heat Recovery + district heating	Arviat	Community District/Residual Heat Distribution Project	750 kW	
Nunavut	Heat	Waste Heat Recovery + District Heating	Hall Beach	Community District/Residual Heat Distribution Project		
Nunavut	Heat	Waste Heat Recovery + district heating	Iqaluit	Community District/Residual Heat Distribution Project	4000 kW	
Nunavut	Heat	Waste Heat Recovery + District Heating	Taloyoak	Community District/Residual Heat Distribution Project		
Nunavut	Heat/ Electricity	Efficiency	Arviat	CMHC/Nunavut Housing Corporation Arviat Northern Sustainable House: high insulation, passive solar, efficient lighting and appliances, solar PV-ready, heat recovery ventilation		

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Nunavut	Heat/ Electricity	Efficiency	Iqaluit	Iqaluit Pilot Project, part of Nunavut Energy Management Plan: Efficiency upgrades to 39 Government of Nunavut buildings		\$ 10,600,000	2007 to Present
<u>Northwest Territories</u>							
NWT	Electricity	Efficiency	Yellowknife	City of Yellowknife buildings (multi-plex, curling club, arena, pool) interior lighting retrofits from metal halide to T5 fluorescents			2013
NWT	Electricity	Efficiency	Yellowknife	City of Yellowknife facilities exterior lighting LED retrofits		\$ 80,000	
NWT	Electricity	Efficiency	Yellowknife	City of Yellowknife LED Streetlights (816 retrofitted as of Oct. 2014)			
NWT	Electricity	Efficiency	Yellowknife	City of Yellowknife traffic lights LED retrofits		\$ 167,750	2013
NWT	Electricity	Hydro	Yellowknife	Bluefish hydro dam	7.5 MW	\$ 37,400,000	2013
NWT	Electricity	Hydro	Snare River	Snare Cascades hydro dam	4.3 MW		
NWT	Electricity	Hydro	Snare River	Snare Falls hydro dam	7.5 MW		
NWT	Electricity	Hydro	Snare River	Snare Forks hydro dam	9.2 MW		
NWT	Electricity	Hydro	Snare River	Snare Cascades hydro dam	8.5 MW		
NWT	Electricity	Hydro	Fort Smith	Taltson hydro dam	18 MW		

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NWT	Electricity	Hydro Kinetic	Fort Simpson	Fort Simpson Hydro Kinetic Turbine Pilot Project, Northwest Territories Power Corp				2011
NWT	Electricity	Solar PV	Aklavik	Northwest Territories Housing Corp: Aklavik Senior Centre (new build) Solar PV	15 kW			2015
NWT	Electricity	Solar PV	Behchoko	Tlicho Construction Shop Solar PV	4.8 kW	\$	57,729	2011
NWT	Electricity	Solar PV	Behchoko	Youth Centre Solar PV	5 kW			
NWT	Electricity	Solar PV	Edzo	Edzo Youth Centre Solar PV	5 kW	\$	64,776	2012
NWT	Electricity	Solar PV	Fort Good Hope	K'asho Got'ine Band Office Solar PV	5 kW			2013
NWT	Electricity	Solar PV	Fort Providence	Community Arena Solar PV	15 kW			2013
NWT	Electricity	Solar PV	Fort Simpson	Northwest Territories Housing Corp Solar PV	5 kW			2013
NWT	Electricity	Solar PV	Fort Simpson	Liflil Hue Band Office Solar PV	5 kW			2013
NWT	Electricity	Solar PV	Fort Simpson	Northwest Territories Power Corp Ground Mount Solar PV near airport	61 kW			
NWT	Electricity	Solar PV	Gameti	Gameti Community Store Solar PV	5 kW	\$	48,557	2012
NWT	Electricity	Solar PV	Gameti	Northwest Territories Housing Corp: Gameti senior Centre (new build) Solar PV	17 kW			2015
NWT	Electricity	Solar PV	Gameti	Health Centre Solar PV				

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NWT	Electricity	Solar PV	Hay River	Northwest Territories Housing Corp Hay River Senior Centre Solar PV	60 kW			2014
NWT	Electricity	Solar PV	Hay River	Northwest Territories Power Corp Headquarters Solar PV	1 kW			Late 1990's
NWT	Electricity	Solar PV	Inuvik	Aurora Research Institute Solar PV	1 kW			2011
NWT	Electricity	Solar PV	Inuvik	Gwich'in Centre Solar PV	1.7 kW			
NWT	Electricity	Solar PV	Inuvik	Northwest Territories Housing Corp Solar PV	10 kW			2013
NWT	Electricity	Solar PV	Inuvik	Inuvik Town Hall Solar PV	5 kW			2009
NWT	Electricity	Solar PV	Inuvik	Midnight Sun Rec Complex Solar PV	7 kW			2009
NWT	Electricity	Solar PV	Inuvik	CMHC/NWT Housing Corporation Northern Sustainable House Solar PV	3.5 kW			2011
NWT	Electricity	Solar PV	Jean Marie River	Band Office Solar PV	1.3 kW			2006
NWT	Electricity	Solar PV	Litselk'e	Ground Mount IPP Solar PV	35 kW			2014
NWT	Electricity	Solar PV	Nahanni Butte	Community School Gymnasium Solar PV	4.8 kW	\$	43,462	2011
NWT	Electricity	Solar PV	Norman Wells	Department of Environment and Natural Resources Office Building Solar PV	2.86 kW			2011
NWT	Electricity	Solar PV	Paulatuk	Angik School Solar PV	1.7 kW			2011
NWT	Electricity	Solar PV	Paulatuk	Paulatuk Youth Centre Solar PV	5 kW			2011
NWT	Electricity	Solar PV	Sachs Harbour	PolarGrizz Inn Solar PV	4.3 kW	\$	56,726	2010

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NWT	Electricity	Solar PV	Tsiigehtchic	Northwest Territories Housing Corp: Tsiigehtchic Senior Centre (new build) Solar PV	18 kW			2015
NWT	Electricity	Solar PV	Tulita	Community Arena Solar PV	10 kW			2013
NWT	Electricity	Solar PV	Wekweeti	Wekweeti Youth Centre Solar PV	4.2 kW	\$	57,189	2010
NWT	Electricity	Solar PV	Whati	Northwest Territories Housing Corp: Whati Senior Centre (new build) Solar PV	16 kW			2015
NWT	Electricity	Solar PV	Whati	Whati Community Store Solar PV	5 kW	\$	74,329	2012
NWT	Electricity	Solar PV	Wrigley	Wrigley Senior Centre (new build) Solar PV	19 kW			2015
NWT	Electricity	Solar PV	Yellowknife	Department of Environment and Natural Resources Air Monitoring Station Solar PV	1.8 kW			2009
NWT	Electricity	Solar PV	Yellowknife	Greenstone Building Solar PV	33.5 kW			2004
NWT	Electricity	Solar PV	Yellowknife	Ollerhead & Associates Ltd. Solar PV	5 kW	\$	41,977	2011
NWT	Electricity	Solar PV	Yellowknife	Renewable Resources Inc. Solar PV	5 kW with battery storage	\$	52,571	2012
NWT	Electricity	Solar PV	Yellowknife	Sir John Franklin High School Solar PV	2 kW			2002
NWT	Electricity	Solar PV	Yellowknife	Yellowknife Bailing Facility Solar PV	3 kW	\$	20,000	2014
NWT	Electricity	Solar-Diesel Hybrid	Colville Lake	Utility Solar/Diesel Hybrid (High Penetration) with 200 kWh battery storage	135 kW			2015

NWT	Electricity	Solar-Diesel Hybrid	Courageous Lake	NorthwesTel Remote Station Solar/Diesel Hybrid Power Generation	15 kW	
NWT	Electricity	Solar-Diesel Hybrid	Fort Simpson	Northwest Territories Power Corp Solar-Diesel Hybrid	104 kW	
NWT	Electricity	Solar-Diesel Hybrid	MacKay Lake	NorthwesTel Remote Station Solar/Diesel Hybrid Power Generation	15 kW	
NWT	Electricity	Wind	Diavik Diamond Mine	Diavik Diamond Mine Wind Farm	9.2 MW	
NWT	Heat	Biomass	Behchoko	Chief Jimmy Bruneau Regional High School Wood Pellet Boiler	750 kW	2009
NWT	Heat	Biomass	Behchoko	Elizabeth Mackenzie School	500 kW	2013
NWT	Heat	Biomass	Fort McPherson	Band Office and Health Centre District Heating Biomass Boiler	85 kW	2013
NWT	Heat	Biomass	Fort Providence	Deh Gah School Biomass Boiler	300 kW	2013
NWT	Heat	Biomass	Fort Resolution	Deninu School Biomass Boiler	160 kW	2015
NWT	Heat	Biomass	Fort Simpson	Central Heating Plant Biomass Boiler	823 kW	2012
NWT	Heat	Biomass	Fort Smith	Health Centre Biomass Boiler	750 kW	2012
NWT	Heat	Biomass	Fort Smith	PWK School & Recreation Complex Biomass Boiler	750 kW	2010

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NWT	Heat	Biomass	Fort Smith	Thebacha College Biomass Boiler	750 kW	2010
NWT	Heat	Biomass	Hay River	Central Heating Plant Biomass Boiler for Harry Camsell School, Princess Alexandra School, Ecole Boreale & Diamond Jenness School & Trades Shop	1 MW	2010
NWT	Heat	Biomass	Hay River	Highways Maintenance Garage Biomass Boiler	260 kW	2010
NWT	Heat	Biomass	Hay River	South Mackenzie Correctional Centre Biomass Boiler	220 kW	2015
NWT	Heat	Biomass	N'Dilo	Kalemi Dene School Biomass Boilers	3 x 23 kW	2009
NWT	Heat	Biomass	Norman Wells	Airport Terminal Building Biomass Boiler	150 kW	2014
NWT	Heat	Biomass	Norman Wells	Combined Services Building Biomass Boiler	220 kW	2014
NWT	Heat	Biomass	Norman Wells	Health and Social Services Centre and Long Term Care Facility (new build) with biomass boiler		
NWT	Heat	Biomass	Norman Wells	Mackenzie Mountain School Biomass Boiler	220 kW	2014
NWT	Heat	Biomass	Yellowknife	Airport Terminal Building Biomass Boiler	400 kW	2015

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NWT	Heat	Biomass	Yellowknife	City of Yellowknife Pool, arena and curling facility wood pellet boiler and district heating system	740 kW	\$	532,000	2008
NWT	Heat	Biomass	Yellowknife	City of Yellowknife Solid Waste Facility Biomass Boiler	340 kW	\$	358,900	2010
NWT	Heat	Biomass	Yellowknife	Combined Services Building Biomass Boiler	500 kW			2012
NWT	Heat	Biomass	Yellowknife	Legislative Assembly Building Biomass Boiler	300 kW			2010
NWT	Heat	Biomass	Yellowknife	New Office Building Biomass Boiler and district heat to two adjacent buildings	800 kW			2014
NWT	Heat	Biomass	Yellowknife	North Slave Correctional Facility Biomass Boilers	2 x 750 kW			2006
NWT	Heat	Biomass	Yellowknife	Northern Property Bison Apartments Biomass Boiler	740 kW			
NWT	Heat	Biomass	Yellowknife	Northern Property Fort Gary/Ridgeview Apartments Biomass Boiler	740 kW			
NWT	Heat	Biomass	Yellowknife	Northern Property Garden Townhomes Biomass Boiler	740 kW			
NWT	Heat	Biomass	Yellowknife	Northern Property Norseman Apartments Biomass Boiler (5 buildings)	740 kW			
NWT	Heat	Biomass	Yellowknife	Northern Property Sandstone Apartments Biomass Boiler (2 buildings)	740 kW			

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NWT	Heat	Biomass	Yellowknife	Northern Property Aurora Heights Apartments Biomass Boiler (3 buildings)	740 kW	
NWT	Heat	Biomass	Yellowknife	Sir John Franklin School Biomass Boiler	750 kW	2008
NWT	Heat	Biomass	Yellowknife	St. Joseph School Biomass Boiler	540 kW	2009
NWT	Heat	Efficiency	Yellowknife	Lift Station 4 and new office building additional insulation		2013
NWT	Heat	Efficiency	Yellowknife	Roof upgrade for City's Public Works garage		2009
NWT	Heat	Electric heat from excess hydro power from Taltson Dam	Fort Smith	Electric boiler installations (from excess Taltson Dam hydro power) for heating Breynat Hall, DOT Garage, JBT Elementary School, Catholic Cathedral		2008-2012
NWT	Heat	Geothermal	Fort Smith	Thebacha Campus Pilot Ground Source Heat Pump		
NWT	Heat	Solar Air	Inuvik	Aurora Research Institute SolarWall	26 m ²	2011
NWT	Heat	Solar Air	Yellowknife	Weledah Catholic School SolarWall	200 m ²	1998
NWT	Heat	Solar Hot Water	Arviat	Public swimming pool solar water heating		
NWT	Heat	Solar Hot Water	Fort Providence	Public swimming pool solar water heating		
NWT	Heat	Solar Hot Water	Fort Resolution	Triplex solar water heating		

NWT	Heat	Solar Hot Water	Hay River	Apartment Building (28 Units) solar water heating
NWT	Heat	Solar Hot Water	Inuvik	CMHC/NWT Housing Corporation Northern Sustainable House solar water heating
NWT	Heat	Solar Hot Water	Norman Wells	Pubic swimming pool solar water heating
NWT	Heat	Solar Hot Water	Tulita	Pubic swimming pool solar water heating
NWT	Heat	Solar Hot Water	Yellowknife	Fred Henne Territorial Park Campground solar water heating
NWT	Heat	Solar Hot Water	Yellowknife	Reid Lake Territorial Park Campground solar water heating
NWT	Heat	Solid Waste Gasification	Old Crow	Old Crow Solid Waste Gasification System
NWT	Heat	Waste Heat Recovery + District Heating	Fort Liard	Residual/District heating for school, garage, offices, fire hall (Northwest Territories Power Corp)
NWT	Heat	Waste Heat Recovery + District Heating	Fort McPherson	Residual/District heating for school, hamlet building and tent and canvas shop (Northwest Territories Power Corp)

NWT	Heat	Waste Heat Recovery	Inuvik	Water Treatment Plant waste heat recovery (Northwest Territories Power Corp)			
NWT	Heat	Waste Heat Recovery	Whati	School waste heat recovery			
NWT	Heat	Waste Heat Recovery	Yellowknife	City of Yellowknife heat recovery from ice plant for Multiplex Rink and monitoring system			2011
NWT	Heat	Waste heat recovery	Yellowknife	City of Yellowknife network server rooms waste heat recovery (and cooling from outdoor air instead of air conditioning)	\$	64,268	2010
NWT	Heat/ Electricity	Efficiency	All	Public Works and Services energy efficiency aggregate for biomass boilers + efficiency: Lighting upgrades, envelope and insulation upgrades, heat recovery systems, electric heat conversions, control systems			

NWT	Heat/ Electricity	Efficiency	Inuvik	CMHC/NWT Housing Corporation Northern Sustainable House: High quality envelope, high insulation, heat recovery ventilator, solar hot water, solar PV, EGH 87		\$ 1,000,000	
NWT	Heat/ Electricity	Waste Heat Recovery from natural gas	Inuvik	Northwest Territories Power Corp Midnight Sun Recreation Centre waste heat recovery			
<u>Yukon</u>							
Yukon	Electricity	Efficiency	Dawson City	Dawson City LED street lights pilot project			
Yukon	Electricity	Efficiency	Whitehorse	Government of Yukon parking space block heater controller upgrades			
Yukon	Electricity	Efficiency	Whitehorse	Mendenhall LED street lights pilot project			
Yukon	Electricity	Hydro	Aishihik	Aishihik Hydro Facility	37 MW		1975
Yukon	Electricity	Hydro	Fish Lake	Fish Lake Hydro Facility	1.3 MW		1950
Yukon	Electricity	Hydro	Mayo	Mayo A Hydro Facility	5 MW		1951
Yukon	Electricity	Hydro	Mayo	Mayo B Hydro Facility	10 MW	\$ 120,000,000	2011
Yukon	Electricity	Hydro	South Klondike Highway	Fraser highway camp and Canada Customs micro-hydro, south Klondike Highway	250 kW	\$ 550,000	1990
Yukon	Electricity	Hydro	Watson Lake	Boulder Creek Dam hydro			
Yukon	Electricity	Hydro	Watson Lake	Canyon Creek micro-hydro			

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Yukon	Electricity	Hydro	Whitehorse	Lucky Love Creek micro-hydro	3 kW			2014
Yukon	Electricity	Hydro	Whitehorse	Whitehorse Rapids Hydro Facility	40 MW			1958
Yukon	Electricity	Solar Diesel Hybrid	Engineer Creek	NorthwesTel: Remote Station Solar/Diesel Hybrid Power Generation	15 kW			2014
Yukon	Electricity	Solar Diesel Hybrid	McEvoy Lake	NorthwesTel: Remote Station Solar/Diesel Hybrid Power Generation	10 kW			2014
Yukon	Electricity	Solar Diesel Hybrid	Weasel Lake	NorthwesTel: Remote Station Solar/Diesel Hybrid Power Generation	10 kW			2014
Yukon	Electricity	Solar PV	Burwash Landing	Burwash Landing Solar PV net metering on Kluane First Nation government garage	4.7 kW	\$	23,000	2012
Yukon	Electricity	Solar PV	Carmacks	Solar PV-powered irrigation system on community farm				2008
Yukon	Electricity	Solar PV	Old Crow	Arctic Research Facility Solar PV	12.1 kW			
Yukon	Electricity	Solar PV	Old Crow	John Tizya Visitor Reception Centre Solar PV	3.6 kW			
Yukon	Electricity	Solar PV	Watson Lake	Government of Yukon Northern Lights Science and Space Centre Solar PV	4.4 kW			2011
Yukon	Electricity	Solar PV	Whitehorse	Government of Yukon Solar PV on main administration building	4.1 kW			2008

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Yukon	Electricity	Solar PV	Whitehorse	Whitehorse Rapids Fishladder Solar PV Demonstration Project (Yukon Energy)	1 kW	
Yukon	Electricity	Solar PV	Whitehorse	Yukon College Renewable Energy Demonstration Site Solar PV	1.5 kW	1992 (off-grid), tied to grid in 2000, upgraded 2009
Yukon	Electricity	Solar PV	Whitehorse	Yukon College Solar PV on research lab	2.5 kW	
Yukon	Electricity	Wind	Haeckel Hill	Haeckel Hill Wind Farm	810 kW (150 kW to be removed in 2015)	1993 and 2000
Yukon	Electricity	Wind	Whitehorse	Yukon College wind turbine	1.8 kW	1992
Yukon	Heat	Biomass	Burwash Landing	Kluane First Nations wood chip boiler; district heat to community hall and three other buildings	590 kW	1998
Yukon	Heat	Biomass	Dawson City	Biomass Boiler Facility	720 kW	2013
Yukon	Heat	Biomass	Whitehorse	Correctional Centre biomass boiler	238-950 kW	2011
Yukon	Heat	Heat Recovery Ventilator	Whitehorse	Tri-territorial Heat Recovery Ventilator		
Yukon	Heat	Waste Heat Recovery	Watson Lake	Watson Lake School waste heat recovery system		
Yukon	Heat	Waste Heat Recovery	Whitehorse	Canada Games Centre waste heat recovery system		

Yukon	Heat	Geothermal	Mayo	Municipal water systems geothermal heat freezing prevention	
Yukon	Heat	Geothermal	Whitehorse	Fish Hatchery geothermal heat	
Yukon	Heat	Geothermal	Whitehorse	Municipal water systems geothermal heat freezing prevention	
Yukon	Heat	Geothermal	Whitehorse	Takhini Hot Springs geoexchange system	
Yukon	Heat/ Electricity	Efficiency	Haines Junction	Champagne and Aishihik First Nation super-green house using vacuum insulated panels	
Yukon	Heat/ Electricity	Efficiency	Various communities	Yukon Housing Corp superinsulation to Energuide 85; multiplexes, homes, seniors' residences	
Yukon	Heat/ Electricity	Efficiency and solar hot water	Dawson City	CMHC/Tr'rondeck Hwech'in Han First Nation Northern Sustainable House E/9 Project (passive solar, high insulation, HRV, solar hot water)	
Yukon	Heat/ Electricity	Efficiency and Solar PV	Whitehorse (Takhini River Subdivision)	Champagne and Aishihik First Nation and Habitat for Humanity super green triplex with 4.5 kW solar PV on each unit	3 x 4.5 kW

Appendix 3: Guiding Questions for Interviews and Focus Group Session

Semi-Structured Interview Questions

Context

Can you please tell me a little about your organization and your role within it?

Our research team is aware that no two communities in the Arctic are identical in their energy use profiles, can you tell us a little about your community and how it meets its energy needs for electricity and heating?

How do you see energy supply and demand changing over the next few years in your community?

Have you noticed geographic differences or trends in energy supply/demand within your region?

What do you see as the key drivers affecting energy policy in Arctic at present? Do you expect these drivers to change in the future?

Who are the key actors/stakeholders involved with energy supply and demand within the Arctic?

Could you please comment on the roles of the different actors that you have named and how their roles may have changed over time?

Can you comment on the role played by central utility companies?

Have you noticed any stresses (technological/political/economic) affecting Arctic energy systems in both the short and long term?

Energy Conservation Policy

What role do you see energy conservation (policies aimed at decreasing or stabilizing energy demand for heating and electrical energy) playing in Arctic communities?

Has your organization promoted energy conservation in your community?

Who do you see as having the most responsibility for developing and promoting energy conservation policies?

Can you comment on some of the specific energy conservation policies that have had high adoption

rates in your community thus far?

In your opinion have overall conservation policies been effective in the past?

Why do you say this?

How can conservation policies be better developed and promoted in the future?

Renewable Energy Technologies/Case Studies/Barriers

What role do you see fossil fuels playing in future of your communities' energy future?

How do fossil fuels affect the development of renewable energy technologies in the Arctic?

Are there any renewable technologies that look especially promising for your community?

Why do you say that?

What do you think will drive the adoption of renewable technologies?

Have you had any experience with renewable energy technologies in your community/employment position?

-Can you please comment a bit more on specific projects?

What do you think are relevant measures to help promote renewable technologies in your community?

Do you see some policy measures as being more appropriate for your community than others? Why do you say that?

Can you comment on the barriers that communities/governments/stakeholders face when developing renewable energy projects first in your community but also in the Arctic generally?

Focus Group Guiding Theme Questions

Session One- Groups will be organized along geographic lines for the opening session

Context - A quick group tour asking participants about their organization/affiliation and its role in formulating and carrying out issues

regarding energy supply and demand in their communities.

Recent Policy – Can you please comment on some of the recent experiences your jurisdiction has had in its energy policy?

Future Demand Drivers – What are the factors that are driving energy demand in Arctic communities? Are there geographic differences in demand and are they expected to heighten or decrease in the future?

Hot Issues – Our research team is very much interested in contemporary debates around energy policy in the Arctic. What are some of these hot debates and how are they affecting your territory and communities?

These “hot issues,” will be synthesized by the research team over lunch to draw out common themes that will guide the afternoon discussion.

Session Two- Groups will be randomized in an effort to get a holistic perspective on common energy issues across the Arctic

Based on preliminary discussions we are hoping to draw four-five common themes from the morning session that will form the basis for the afternoon session.

ⁱ The Department of Lands and Natural Resources completed a draft Land Use Plan for Inuit lands in 2011 and submitted this plan to the Provincial Government. Currently no decision has yet been made about its adoption provincially. <http://www.nunatsiavut.com/departement/land-use-planning/>

ⁱⁱ The *Sustainable Communities Initiative* is a inter-governmental, inter-departmental multi-disciplinary project jointly funded by the GNR, Newfoundland Office of Climate Change and Energy Efficiency, AANDC and Health Canada and includes academic partnerships with Memorial University, Trent University and the University of Guelph for more information please see <http://nainresearchcentre.com/research-projects/the-sustainable-communities-initiative/>