Northlands Dënesųłiné First Nation

Community Energy Plan

2017

Options and Issues:

Northlands Dënesųłiné First Nation
Community Energy Plan

Prepared for:

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- Northlands Dënesųłiné First Nation Community Building Energy Assessment Audits
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- Residential energy and water audits
  - prepared by prairieHOUSE Performance Inc.
- Provision of technical and economic studies for a 100% renewable presentation scenario
  - prepared by SoftWhite60
- Development of a wind energy resource assessment strategy
  - prepared by Marc Arbez P Eng.

Executive Summary

The Northlands Dënesųłiné First Nation has partnered with Aki Energy Inc. to develop a Community Energy Plan with financial support from Indigenous and Northern Affairs Canada.

Aki has produced a series of individual technical reports that examine a comprehensive range of options and issues for the supply of energy for Northlands and using energy in the community more efficiently. This report integrates and summarizes these technical reports into a single, easier-to-read document and addresses gaps not covered by the individual reports.

The intent of this report is to advance the discussion about how Northlands can meet its objective of ending its reliance on diesel fuel and heating oil consistent with the Sustainable Development Strategy adopted by the community in March 2016. A summary of energy supply options and recommendations presented in this report can be found in Appendix C.

The scope of this report is focused on an integrated strategy for the sustainable supply and efficient use of energy in existing and future community buildings, facilities and housing in Northlands. Excluded from the project's scope is transportation given there are limited options for the community to reduce transportation-related energy use given its location.

The foundation for energy supply planning in Northlands must be based on a sound forecast of the community's future energy use and peak demand. Current projections by Manitoba Hydro for the next two decades are based on a simple 'business-as-usual' extrapolation of previous rates of growth. There is significant potential to change this trajectory through a comprehensive range of demand-side management efforts outlined in this report. This issue needs to be addressed as soon as possible.

The next step is for the Northlands Dënesųłiné First Nation, using information from this report and support by Aki, is for the Band to identify its preferred long-term energy path for the community and the priorities for implementation. These community decisions can then be used as a basis for discussion by Northlands' leadership with INAC, Manitoba Hydro and other key external stakeholders.

List of Acronyms

BTU	British Thermal Unit
CSA	Canadian Standards Association
CMHC	Canada Mortgage and Housing Corporation
CFL	Compact Fluorescent Light
DSM	Demand-Side Management
ERAAES	Environmental Remediation and Alternative Energy Systems
FSG	Fixed-Speed (Diesel) Generation
GSHP	Ground Source Heat Pump
INAC	Indigenous and Northern Affairs Canada
HAWT	Horizontal Axis Wind Turbine
HOMER	Hybrid Optimization of Multiple Energy Resources
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt Hour
LED	Light-Emitting Diode
LEDP	Lands and Economic Development Services Program
MARRC	Manitoba Association for Resource Recovery Corporation
ORC	Organic Rankine Cycle
PV	Photovoltaics
UL	Underwriters’ Laboratory
ULC	Underwriters’ Laboratory of Canada
VAWT	Vertical Access Wind Turbine
VSG	Variable-Speed (Diesel) Generation

1.0 Introduction

1.1 Project Background, Objectives and Scope

Project Background

The Northlands Dënesųłiné First Nation (‘Northlands’) has partnered with Aki Energy Inc. (‘Aki’) to develop a Community Energy Plan (‘CEP’). Financial support for this initiative has been provided by the Lands and Economic Development Services Program (‘LEDSP’) operated by Indigenous and Northern Affairs Canada (‘INAC’).

Aki is an award-winning, non-profit social enterprise. Aboriginal-owned and based in Winnipeg, Aki works in partnership with First Nations throughout Manitoba to develop strong local economies through sustainable development initiatives. More information about Aki can be found at this link.

For this project, Aki assembled and was supported by a team of energy efficiency and renewable energy experts from several other organizations. A list of Aki’s Project Team and their contact details can be found in Appendix A.

Project Objectives

The objectives of this project are to:

- identify and explore a broad range of energy supply and energy management options for consideration by Northlands that are consistent with the Sustainable Development Strategy adopted by the community in March 2016;
- advance the discussion about how Northlands can meet its objective of ending its reliance on diesel fuel and heating oil; and
- facilitate development of a comprehensive, long-term CEP that is supported by the residents of Northlands that can form the basis of discussion and negotiation with other stakeholders with respect to implementation.

Project Scope

The scope of this project has focused on an integrated strategy for the sustainable supply and efficient use of energy in existing and future community buildings, facilities and housing in Northlands. Excluded from the project’s scope is transportation.

As a small, remote northern community connected to the rest of the province primarily by a winter road system and by air, there are limited options for Northlands to reduce transportation-related energy use. However, there are still some measures that the community can choose to take, especially for the transportation of people and goods within the community. These measures should be considered for future versions of the Northlands Community Energy Plan.

1.2 Purpose and Organization of this Report

Purpose of Report

Aki's Project Team has produced a series of individual technical reports that examine a comprehensive range of options and issues for the supply of energy for Northlands and using energy in the community more efficiently. This Options and Issues Report integrates and summarizes these technical reports into a single, easier-to-read document that also addresses some gaps not covered by the individual reports.

The next step is for the Northlands Dënesųłiné First Nation, with the assistance from this report and support by Aki, is for the Band to identify its preferred long-term energy path for the community and priorities for implementation. Based on the community's decisions, this report will be revised by Aki to serve as an inaugural Community Energy Plan that Northlands can use as a basis for discussion with INAC, Manitoba Hydro and other external stakeholders.

Organization of this Report

The remaining sections of this report are organized as follows:

Section 2.0 Community Energy Profile provides background and context about the supply and use of energy in Northlands including its cost. Special attention is paid in this section to providing information about community's reliance on electricity produced by diesel generators which are approaching the end of their service life. A brief overview is also provided about the 'ERAAES Project' now underway to use renewable energy, biomass and a lake water heat system to reduce the community's dependence on diesel-generated electricity.

Section 3.0 Demand-Side Management: Options and Issues is based on a series of energy and water audits conducted on community buildings and facilities and a representative sample of homes. Recommendations based on these audits are presented in this section for retrofitting existing buildings and houses in Northlands and establishing improved energy efficiency standards for new construction that better reflect the high cost of energy and severe climate.

Section 4.0 Imported Non-Renewable Energy Sources: Options and Issues presents the results of a preliminary feasibility study that examined connecting Northlands to electricity supplied from the SaskPower grid, most of which is generated from non-renewable sources. A brief explanation is provided in this section about why two other potential sources of renewable energy for the community, natural gas and propane, were screened but dropped for further consideration. A brief introduction to the benefits of advanced diesel is provided. Finally, this section also discusses and provides some suggestions for a small project the community is embarking upon to collect and use waste oil for space heating in a public works building.

Section 5.0 Local Clean Renewable Energy: Options and Issues examines several options to use clean renewable energy to significantly reduce and even eventually eliminate the community's reliance on diesel-generated electricity and heating oil. These options hydro-generated electricity (connecting to Manitoba Hydro's provincial electricity grid or building a small-scale hydro generation system using the Cochrane River); using biomass energy for electricity generation and heating; solar and wind generated electricity; and geothermal for heating.

Section 6.0 Integrating the Options analyzes the results from a software program called HOMER that was used to examine several scenarios about integrating select options mentioned above to significantly reduce or eliminate the community's dependence on diesel generated electricity. This section also discusses other energy-related community infrastructure that would be needed or be desirable to integrate and manage multiple sources of energy supply.

Section 7.0 Kick Starting a Northlands Sustainable Social Enterprise discusses how the community can maximize the local economic, employment and social benefits of implementing the energy supply and demand side management options outlined in this report.

Section 8.0 Recommended Next Steps outlines the recommended next steps to finalize the Northlands Community Energy Plan, engage external stakeholders to support the Plan, and begin its implementation.

Except for Sections 7.0 and 8.0, all other sections begin with a summary of 'Major Findings and Recommendations' by Aki's Project Team. These sections conclude with a listing of 'Additional Information' that identify any individual technical reports produced by the Aki Team and, in some cases, other external sources of relevant information.

1.3 Relationship to Other Community Plans

The Community Energy Plan that emerges from this report needs to be consistent with the vision and values of Northlands new Sustainable Development Strategy. More specifically, the Community Energy Plan should be viewed as an expansion and refinement of the Sustainable Development Strategy's focus on diesel transitions strategies, local renewable energy supplies and energy efficiency. Refer to Figure 1 on the next page for the relevant goals and objectives from the Strategy's 'Energy Focus' that have guided the work of Aki's Team.

The development of any additional community plans to support the community's Sustainable Development Strategy (e.g., land use and zoning, construction by-laws, economic development strategy, etc.) should be informed by the Community Energy Plan that emerges from the work described in this Options and Issues Report.

1.4 Limitations of this Report

Caution should be exercised when considering the major findings and recommendations in this report. In some case, there is a comparatively higher degree of confidence in the findings and a lower risk of proceeding with the recommendations. This is true, for example, with the findings and recommendations in Section 3.0 that deal with retrofitting existing buildings, facilities and homes that are based on a series energy audits conducted in the community.

In other cases, findings and recommendations are based on a preliminary analysis or prefeasibility study. For these situations, a more in-depth feasibility analysis would be prudent before taking further action. This is especially true of the findings and recommendations in Sections 5.0 and 6.0.

Readers of this report are also encouraged to refer to the individual studies and reports produced by Aki’s Project Team from which the findings and recommendations of this Options and Issues have been derived.

2.0 Community Energy Profile

2.1 Diesel-Generated Electricity

Major Findings and Recommendations:

- *Manitoba Hydro's diesel generation system for Northlands has proven to be reliable but many of the generator units are nearing the end of their service life.*
- *Unlike other customers who are connected to Manitoba Hydro's main electrical grid, residential customers are limited to a 60-amp service. This limitation is an inconvenience and precludes the option of using electricity as a primary heating source.*
- *The burden of the high cost of electricity in Northlands relative to typical household incomes will likely much become worse over the next five years. Manitoba Hydro is seeking a cumulative rate increase of almost 50% over the next five years.*
- *Based on 'business-as-usual, Manitoba Hydro is forecasting that energy use and peak demand in the community will increase by a total of 20% over the next two decades. However, this load forecast does not consider the impact that an aggressive demand-side program or the ERAAES project now underway can have to reduce or eliminate this growth.*

Discussion

System Description – Northlands is one of only four communities in Manitoba that is not connected to the main Manitoba Hydro electrical grid and relies upon diesel-generated electricity. This exclusive dependency in Northlands on non-renewable fossil fuel for electricity generation will be significantly reduced by the Environmental Remediation and Alternative Energy Systems (ERAAES) Project now underway – see Section 2.4 ERAAES Project for more details.

The Lac Brochet Diesel Generating Station in Northlands was originally designed and built by Manitoba Hydro in the early 1980s. It was later upgraded in the 1990s when the Unit No. 2, 3 and 4 'gensets' (a combination of a diesel engine and an electrical generator) were replaced with larger units and the power distribution and cabling replaced. The Unit No. 1 generator was retained and utilized as the station house generator.

The generating station was subsequently expanded and the Unit No. 5 generator installed. The expansion also allowed space for two more generators to be installed to accommodate future growth in electricity use by the community. However, in 2012 this additional space was utilized to accommodate a new fire protection system.

Service Limitations – Residential customers in Northlands and the other off-grid communities in Manitoba were originally restricted by Manitoba Hydro to a 15-amp service to control the cost of diesel service. In the early 1990s, Hydro's generating and distribution facilities in these communities were upgraded to support 60-amp electrical service. However, the continuing use of a 60-amp service does not permit the residents of Northlands to electricity as a prime source of space heating which requires 200-amp service.

System Efficiency – Only about one-third of the diesel fuel used by a conventional constant speed diesel generator is converted into electricity. The remaining energy is rejected as heat through the diesel engine's exhaust and cooling system. Some of this rejected heat can be recovered and used for other purposes to boost overall system efficiency (e.g., heating water and sewer lines in winter).

Advanced diesel technology that vary generator speed to better match changing electrical loads and use improved combustion techniques and controls can improve efficiency. For a discussion about option of using advanced diesel for Northlands, refer to sub-section 4.3 later in this report.

Manitoba Hydro reports that the diesel generators at the Lac Brochet Generating Station in Northlands produce, on average, about 3.64 kWh of electricity per litre of diesel fuel – see Figure 1 below. A litre of diesel fuel has the energy equivalent of about 10.64 kWh per litre. This means that the diesel generators for Northlands are about 34% efficient at converting diesel fuel into electricity (10.64 / 3.64 x 100 = 34.2%).

Figure 1 – Diesel Generators Fuel Efficiency

Diesel Generating Station	**Fuel Efficiency** (kWh/l)
Brochet	3.14
Lac Brochet	**3.64**
Shamattawa	3.59
Tadoule Lake	3.17
Five-year Average	**3.38**

Reliability and Service Life – A reliable source of electricity is critical in any community, especially for an isolated community in a very cold northern environment such as Northlands.

According to Manitoba Hydro the diesel generators in Northlands, and the other three off-grid Manitoba First Nations (Brochet, Tadoule Lake and Shamattawa), have proven to be very reliable. For example, the report on *Recommendations for Reducing or Eliminating the Use of Diesel Fuel to Supply Power in Off-Grid Communities* completed by Manitoba Hydro in 2009 noted that generator availability was 99.6% in the two previous years.

For planning purposes, a 20-year engine life is assumed for diesel generators. Generally, planned overhauls occur about every 2.5 years at typical cost around $190K. End-of-life projections are based on individual engine operating hours.

The four main diesel generators in the Lac Brochet Diesel Generating Station are rapidly approaching the end of their useful service life based on current levels of usage (see Figure 2 on next page). However, these end-of-life projections can be extended by the introduction of additional renewable energy generation and energy efficiency measures in the community.

In a July 2015 report, Manitoba Hydro expressed concern that the Generating Station will not be capable of reliably meeting the forecast load growth for the community over the next three years.

As back-up, a 1250 kW mobile generator has been placed in the community to provide back-up capacity in the event of prolonged outage.

Figure 2 – Diesel Generator Rating and Remaining Service Life

Generator	Rating	Date Installed	Projected End of Life
Unit 1	175 kW	Dec. 1993	2014
Unit 2	425 kW	Jan. 1996	2021
Unit 3	425 kW	Jan. 1996	2021
Unit 4	425 kW	Jan. 1993	2018
Unit 5	855 kW	May 1998	2018
TOTAL	**2305 kW**		

A July 2015 Capital Project Justification report completed by Manitoba Hydro for a new diesel generating station in Northlands adjacent to the existing station estimated the capital cost to be $53.7-million with $45.8-million (85%) to be contributed by INAC. This also includes replacement of the existing diesel storage tank farm and upgrade of staff accommodations. More recent estimates provided by Manitoba Hydro to INAC indicate a projected capital cost of $84-million.

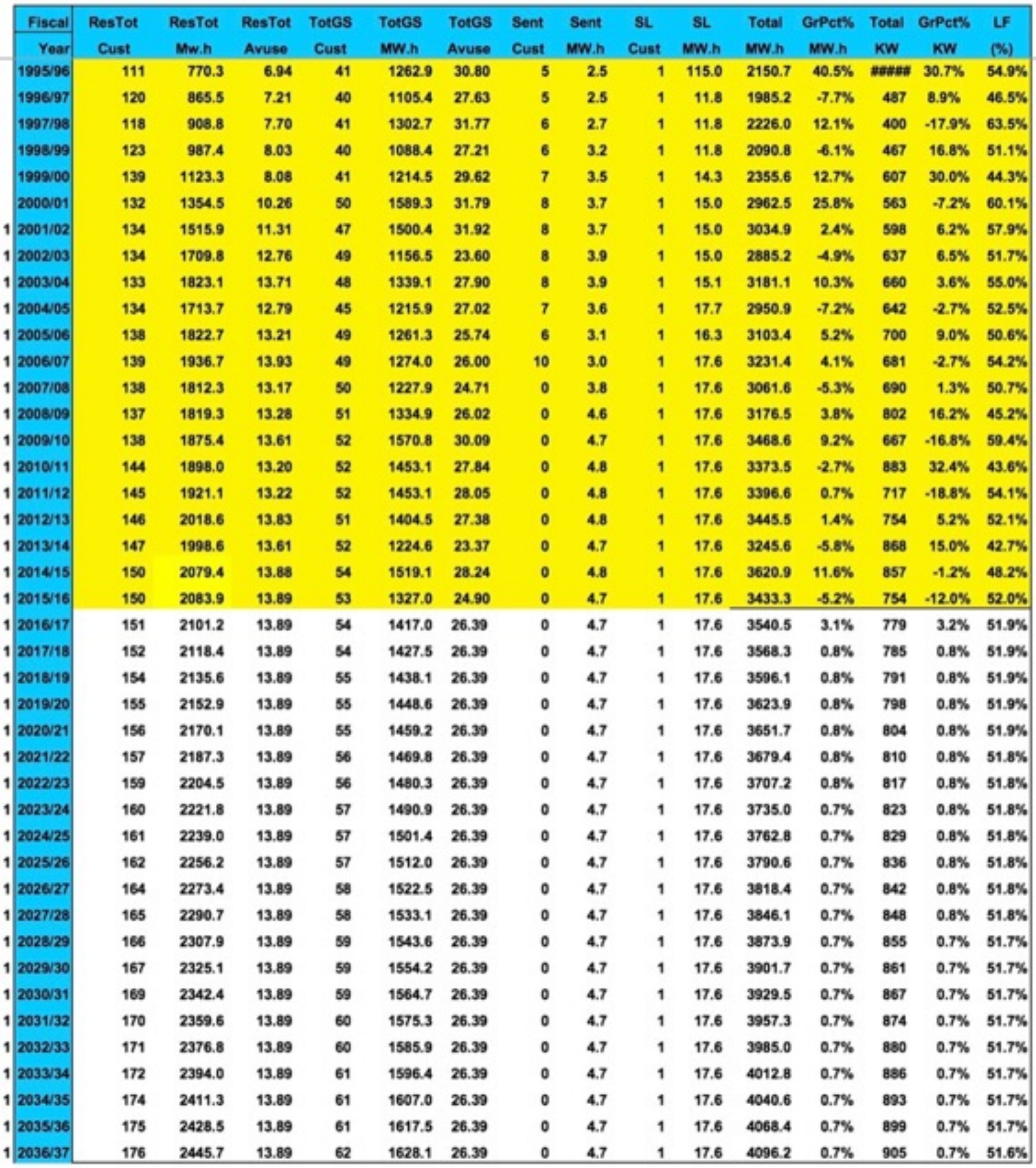
Electricity Use, Peak Demand and Load Forecast – 'Business-as-usual' projections supplied by Manitoba Hydro forecast continued growth in electricity use (MW.h) and demand (kW) over the next two decades in Northlands (see Figure 3 on next page). However, these projections are based on a simple extrapolation of previous rates of growth. They do not consider the remaining potential to reduce electricity use outlined in Section 3.0 of this Options and Issue Report and the impact of the ERAAES Project now underway in the community.

The rate of projected growth from 2016/17 to 2036/37 for Northlands is 19% for electricity use (from 3433.3 to 4,096.2 MW.h) and 20% for peak demand (from 754 kW to 905 kW).

Aki's Project Team was not able to obtain clarifications it sought from Manitoba Hydro to better understand the load history and Hydro's load forecast for the community. For example, there have been some unusually large year-to-year increases and decreases in electricity use and demand.

The above load forecast uncertainties notwithstanding, preliminary results from the energy audits by Aki's Project Team of buildings, facilities and housing in the communities indicate that most, if not all projected load growth in the community over the next two decades can be offset cost-effectively through a comprehensive program demand side management program (refer to Section 3.0 for more details).

Figure 3 – Northlands Electricity Load History and Forecast Growth



	Fiscal	ResTot	ResTot	ResTot	TotGS	TotGS	TotGS	Sent	Sent	SL	SL	Total	GrPct%	Total	GrPct%	LF
	Year	Cust	Mw.h	Avuse	Cust	MW.h	Avuse	Cust	MW.h	Cust	MW.h	MW.h	MW.h	KW	KW	(%)
	1995/96	111	770.3	6.94	41	1262.9	30.80	5	2.5	1	115.0	2150.7	40.5%	#####	30.7%	54.9%
	1996/97	120	865.5	7.21	40	1105.4	27.63	5	2.5	1	11.8	1985.2	-7.7%	487	8.9%	46.5%
	1997/98	118	908.8	7.70	41	1302.7	31.77	6	2.7	1	11.8	2226.0	12.1%	400	-17.9%	63.5%
	1998/99	123	987.4	8.03	40	1088.4	27.21	6	3.2	1	11.8	2090.8	-6.1%	467	16.8%	51.1%
	1999/00	139	1123.3	8.08	41	1214.5	29.62	7	3.5	1	14.3	2355.6	12.7%	607	30.0%	44.3%
	2000/01	132	1354.5	10.26	50	1589.3	31.79	8	3.7	1	15.0	2962.5	25.8%	563	-7.2%	60.1%
1	2001/02	134	1515.9	11.31	47	1500.4	31.92	8	3.7	1	15.0	3034.9	2.4%	598	6.2%	57.9%
1	2002/03	134	1709.8	12.76	49	1156.5	23.60	8	3.9	1	15.0	2885.2	-4.9%	637	6.5%	51.7%
1	2003/04	133	1823.1	13.71	48	1339.1	27.90	8	3.9	1	15.1	3181.1	10.3%	660	3.6%	55.0%
1	2004/05	134	1713.7	12.79	45	1215.9	27.02	7	3.6	1	17.7	2950.9	-7.2%	642	-2.7%	52.5%
1	2005/06	138	1822.7	13.21	49	1261.3	25.74	6	3.1	1	16.3	3103.4	5.2%	700	9.0%	50.6%
1	2006/07	139	1936.7	13.93	49	1274.0	26.00	10	3.0	1	17.6	3231.4	4.1%	681	-2.7%	54.2%
1	2007/08	138	1812.3	13.17	50	1227.9	24.71	0	3.8	1	17.6	3061.6	-5.3%	690	1.3%	50.7%
1	2008/09	137	1819.3	13.28	51	1334.9	26.02	0	4.6	1	17.6	3176.5	3.8%	802	16.2%	45.2%
1	2009/10	138	1875.4	13.61	52	1570.8	30.09	0	4.7	1	17.6	3468.6	9.2%	667	-16.8%	59.4%
1	2010/11	144	1898.0	13.20	52	1453.1	27.84	0	4.8	1	17.6	3373.5	-2.7%	883	32.4%	43.6%
1	2011/12	145	1921.1	13.22	52	1453.1	28.05	0	4.8	1	17.6	3396.6	0.7%	717	-18.8%	54.1%
1	2012/13	146	2018.6	13.83	51	1404.5	27.38	0	4.8	1	17.6	3445.5	1.4%	754	5.2%	52.1%
1	2013/14	147	1998.6	13.61	52	1224.6	23.37	0	4.7	1	17.6	3245.6	-5.8%	868	15.0%	42.7%
1	2014/15	150	2079.4	13.88	54	1519.1	28.24	0	4.8	1	17.6	3620.9	11.6%	857	-1.2%	48.2%
1	2015/16	150	2083.9	13.89	53	1327.0	24.90	0	4.7	1	17.6	3433.3	-5.2%	754	-12.0%	52.0%
1	2016/17	151	2101.2	13.89	54	1417.0	26.39	0	4.7	1	17.6	3540.5	3.1%	779	3.2%	51.9%
1	2017/18	152	2118.4	13.89	54	1427.5	26.39	0	4.7	1	17.6	3568.3	0.8%	785	0.8%	51.9%
1	2018/19	154	2135.6	13.89	55	1438.1	26.39	0	4.7	1	17.6	3596.1	0.8%	791	0.8%	51.9%
1	2019/20	155	2152.9	13.89	55	1448.6	26.39	0	4.7	1	17.6	3623.9	0.8%	798	0.8%	51.9%
1	2020/21	156	2170.1	13.89	55	1459.2	26.39	0	4.7	1	17.6	3651.7	0.8%	804	0.8%	51.9%
1	2021/22	157	2187.3	13.89	56	1469.8	26.39	0	4.7	1	17.6	3679.4	0.8%	810	0.8%	51.8%
1	2022/23	159	2204.5	13.89	56	1480.3	26.39	0	4.7	1	17.6	3707.2	0.8%	817	0.8%	51.8%
1	2023/24	160	2221.8	13.89	57	1490.9	26.39	0	4.7	1	17.6	3735.0	0.7%	823	0.8%	51.8%
1	2024/25	161	2239.0	13.89	57	1501.4	26.39	0	4.7	1	17.6	3762.8	0.7%	829	0.8%	51.8%
1	2025/26	162	2256.2	13.89	57	1512.0	26.39	0	4.7	1	17.6	3790.6	0.7%	836	0.8%	51.8%
1	2026/27	164	2273.4	13.89	58	1522.5	26.39	0	4.7	1	17.6	3818.4	0.7%	842	0.8%	51.8%
1	2027/28	165	2290.7	13.89	58	1533.1	26.39	0	4.7	1	17.6	3846.1	0.7%	848	0.8%	51.8%
1	2028/29	166	2307.9	13.89	59	1543.6	26.39	0	4.7	1	17.6	3873.9	0.7%	855	0.7%	51.7%
1	2029/30	167	2325.1	13.89	59	1554.2	26.39	0	4.7	1	17.6	3901.7	0.7%	861	0.7%	51.7%
1	2030/31	169	2342.4	13.89	59	1564.7	26.39	0	4.7	1	17.6	3929.5	0.7%	867	0.7%	51.7%
1	2031/32	170	2359.6	13.89	60	1575.3	26.39	0	4.7	1	17.6	3957.3	0.7%	874	0.7%	51.7%
1	2032/33	171	2376.8	13.89	60	1585.9	26.39	0	4.7	1	17.6	3985.0	0.7%	880	0.7%	51.7%
1	2033/34	172	2394.0	13.89	61	1596.4	26.39	0	4.7	1	17.6	4012.8	0.7%	886	0.7%	51.7%
1	2034/35	174	2411.3	13.89	61	1607.0	26.39	0	4.7	1	17.6	4040.6	0.7%	893	0.7%	51.7%
1	2035/36	175	2428.5	13.89	61	1617.5	26.39	0	4.7	1	17.6	4068.4	0.7%	899	0.7%	51.7%
1	2036/37	176	2445.7	13.89	62	1628.1	26.39	0	4.7	1	17.6	4096.2	0.7%	905	0.7%	51.6%

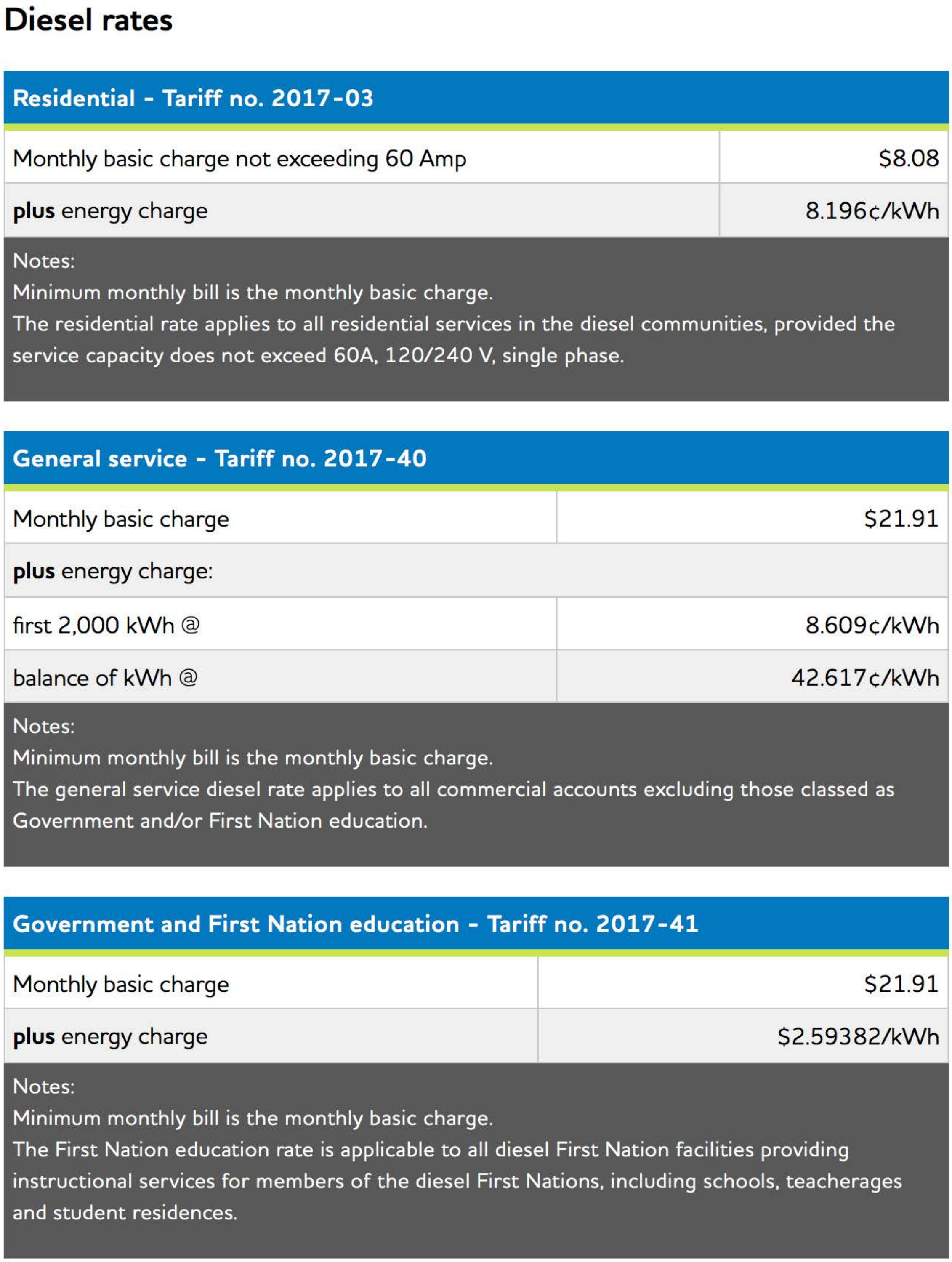
Electricity Rates – There are two issues related to electricity rates that need to be considered in energy planning for Northlands:

1. The burden of the high cost of electricity in Northlands will likely become much worse over the next several years due to rate increases being sought by Manitoba Hydro.
2. The rates that different classes of users pay do not reflect the actual cost of service. This creates a major distortion in who pays and who benefits from efforts to use energy more efficiently in the community.

Manitoba Hydro has three rate classes for electricity in Northlands depending on whether the customer is a Residential, General Service or Government and First Nations account – see Figure 4 on next page. These rates are anticipated to rise significantly. In May 2017, Manitoba Hydro applied to the Public Utility Board (PUB) for a general rate increase. The utility's financial health has deteriorated and its financial plan includes five years of 7.9 per cent rate increases each year starting in 2017. An interim increase of 3.36% effective August 1, 2017 has been granted by the PUB. Public hearings on Hydro's full rate application will begin in December.

Previous rate application filings with the PUB by Manitoba Hydro indicate that the average cost of diesel service for Northlands and the other three off-grid First Nations is the range of about $0.60 per kWh. This excludes any remediation costs for diesel fuel spills.

Figure 4 – Current Diesel Electricity Rates (effective August 1, 2017)



Diesel rates

Residential - Tariff no. 2017-03	
Monthly basic charge not exceeding 60 Amp	$8.08
plus energy charge	8.196¢/kWh

Notes:
Minimum monthly bill is the monthly basic charge.
The residential rate applies to all residential services in the diesel communities, provided the service capacity does not exceed 60A, 120/240 V, single phase.

General service - Tariff no. 2017-40	
Monthly basic charge	$21.91
plus energy charge:	
first 2,000 kWh @	8.609¢/kWh
balance of kWh @	42.617¢/kWh

Notes:
Minimum monthly bill is the monthly basic charge.
The general service diesel rate applies to all commercial accounts excluding those classed as Government and/or First Nation education.

Government and First Nation education - Tariff no. 2017-41	
Monthly basic charge	$21.91
plus energy charge	$2.59382/kWh

Notes:
Minimum monthly bill is the monthly basic charge.
The First Nation education rate is applicable to all diesel First Nation facilities providing instructional services for members of the diesel First Nations, including schools, teacherages and student residences.

Greenhouse Gases and Other Emissions – The diesel-generated electricity and fuel oil used for heating homes and buildings in Northlands results in relatively high per capita greenhouse gas emissions and potentially negative impacts on local air quality.

The most recent data for Manitoba is that each kWh of electricity generated in the province results in the equivalent of about 4 grams of carbon dioxide being emitted. In Northlands, each kWh of diesel-generated electricity results in an average of about 740 grams of carbon dioxide.

Burning diesel fuel and heating oil can also have negative impact on local air quality in Northlands. Besides carbon dioxide, the combustion of diesel fuel and heating oil results in the release of nitrogen oxide (NOx), carbon monoxide, hydrocarbons and particulate matter into the air, all of which have known negative impacts on human health. However, it is unknown whether any air quality measurements have occurred in the community to determine whether provincial and/or federal clean air requirements or guidelines are being met.

Although diesel engines used in vehicles have been regulated for many years, emissions standards for diesel engines used to generate electricity are more recent. For example, limits on emissions for stationary diesel generators by the U.S. Environmental Protection Agency only began on January 1, 2007.

2.2 Heating Oil

Major Findings and Recommendations:

- *Space heating is the largest single end-use of energy for the 27 non-residential buildings in Northlands. Heating oil is the only energy source used for heating in almost all these facilities.*
- *Space heating and domestic water heating are the largest end uses of energy in most of the approximately 140 homes in the community. Heating oil is the dominant form of energy used to meet these needs.*
- *The high cost of heating oil in Northlands relative to typical household incomes already places a major burden on families. The potential for future increases in the price of oil presents a major economic risk to the community.*
- *Heating oil used is a major contributor to Northland's relatively high per capita greenhouse gas emissions and negative impacts on local air quality. This can be reduced by accelerating the replacement of old heating oil equipment with new, more efficient equipment.*
- *The widespread use of heating oil is also contributing to other environmental concerns in the community including indoor air quality concerns and impacts from leaks and spills from storage tanks.*

Discussion

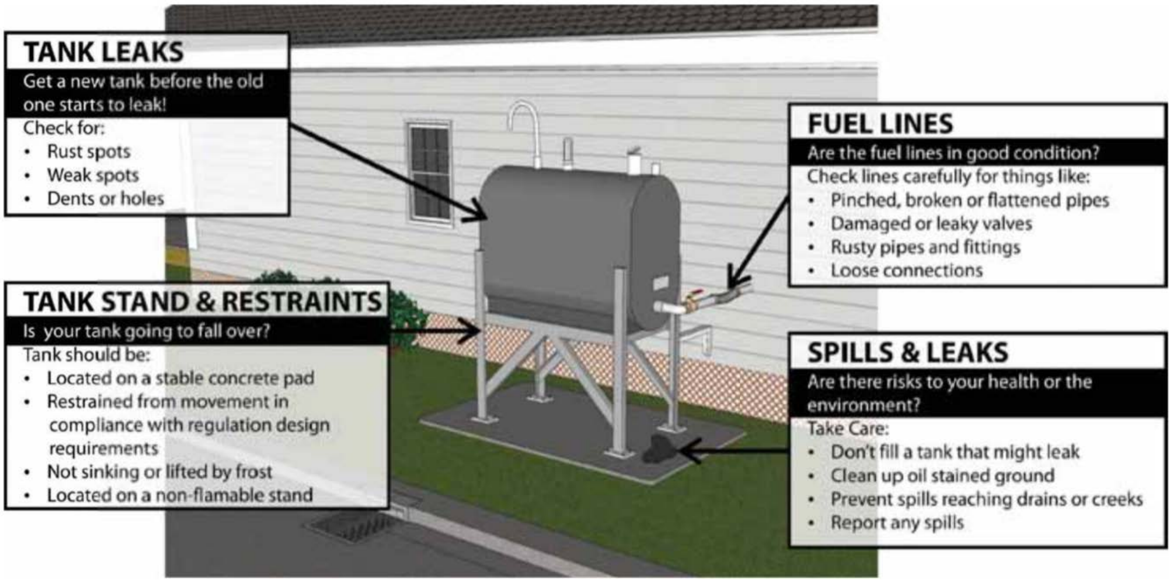
Distribution - Heating oil is brought into Northlands on the winter road system. Distribution is managed by the Band. Storage tanks for individual buildings and homes are filled on as needed basis from the Band holding tanks.

Storage problems – A major issue for the community is leakage and spillage from heating oil storage tanks and the resulting contamination of soil and surrounding environment. Except for the buildings associated with the nursing station, storage tanks throughout the community do not have double walls or double bottoms to contain leaks. These storage tanks generally do not rest on stable foundations and are not attached to the exterior walls of the homes and buildings they serve. As a result, the tanks move independently due to seasonal freeze-thaw cycle which can result on stress and leakage from the connecting piping.

Tracking consumption – Because heating oil is not metered like electricity, it can be challenging to accurately track consumption. Maintaining clear, accurate delivery records will be essential to track the impact of energy efficiency measures discussed in Section 3.0.

Oil price – Heating oil is typically the most expensive energy source in Manitoba for heating. On a historical basis, the current world price of oil is moderate and relatively stable at around $50 U.S. per barrel. However, *Canada's Energy Future 2017* published by the National Energy Board projects the price of crude oil in constant 2016 dollar terms will reach $80 U.S. per barrel by 2027, a 60% increase. If this scenario unfolds as envisioned by the NEB, it will place budgets for heating homes buildings in Northlands under considerable strain.

Figure 5 – Inspection checklist for heating oil storage tanks



Greenhouse gases and other emissions – As noted above in sub-section 2.1, fuel oil used for heating homes and buildings in Northlands along with diesel-generated electricity is resulting in relatively high per capita greenhouse gas emissions and negative impacts on local air quality.

There are no standards in Canada for emissions from oil-fired furnaces, boilers or water heaters. There are, however, minimum energy performance standards for this type of equipment. As older equipment in Northlands reaches the end of its life and is replaced with new, more efficient equipment, the result will be a reduction in emissions.

Additional Information

Aki Team Reports – For more in-depth information about recommendations for reducing the use of heating oil in the houses, community buildings and facilities in Northlands, please refer to these reports produced by the Aki Team:

- *Northlands Dënesųłiné First Nation Building Energy Assessment Audits (April 2017)* by Demand Side Energy Consultants
- *Final Summary Report: Residential Energy and Water Audits in Manitoba's Off-Grid Communities* by prairieHOUSE Performance Inc.
- *ecoENERGY Energy Efficiency Evaluation Reports* for each of the 12 homes that were subject to an energy and water audit by prairieHOUSE Performance Inc.

Further Reading – For more information about the installation, maintenance and standards for heating oil tanks, please refer to these publications:

- *A Guide to Home-heating Oil Tanks* published the Yukon Housing Corporation.
- *CSA-B139 Series-15 "Installation Code for Oil Burning Equipment"* available from the CSA Group.

2.3 Wood Heating

Major Findings and Recommendations:

- *Despite the relatively recent introduction of oil heating in the community, wood heat remains an important source of heating and cooking for many households in Northlands.*
- *Many of the wood stoves being used in Northlands are low-efficiency. This results not only in higher energy use, but also presents health risks to community members.*
- *A long-term, community-based program to identify low-efficiency wood stoves In Northlands and replace them with high-efficiency, U.S. EPA-certified models should an essential element of the community's long-term energy plan.*
- *A Band Council resolution should be considered that mandates that any new installations of wood stoves in the community be high-efficiency, certified models.*

Discussion

Wood is a very important energy source to most indigenous communities, including Northlands. Wood is sought after for heating and cooking because of its cost competitiveness, local availability, cultural preference and home comfort value.

Prior to 2010, most homes in Northlands were heated with wood. Between 2010 and 2012, they were converted to diesel as part of a federal government initiative. However, wood heating remains an important form of supplemental, and is some cases, a primary source of home heating.

Because of the nature of how wood is collected and distributed, it is difficult to make an accurate estimate of how much wood is being used for heating in the community. Extrapolating from other remote Indigenous communities in the Boreal ecosphere, a conservatively estimate is that perhaps 40-45% of thermal heat load for housing in Northlands is being met through wood stoves.

Many of the wood stoves being used in the community are not efficient, lack a fan or other method to distribute heat and tend to have creosote build-up in their chimneys. These stoves also have negative health impacts due to their high emissions of fine particulates. Compared to high-efficiency wood stoves certified by the U.S. Environmental Protection Agency, uncertified wood stoves that are common in Northlands are likely emitting three to four times the amount of fine particulates that can cause or exacerbate chronic and acute respiratory and other diseases.

The poor heat distribution of wood stoves results in two other costly problems in northern indigenous communities: burst water pipes from freezing and mold due to fluctuations in heating and poor air circulations and venting.

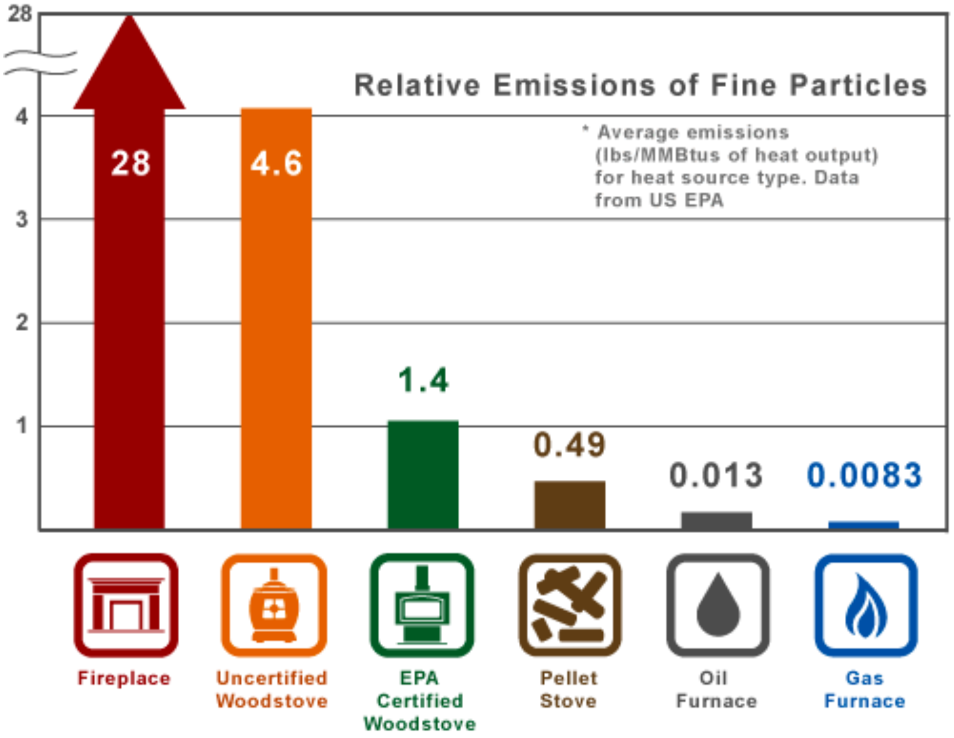
As part of the community's clean energy strategy, there is an opportunity to introduce an Indigenous High-Efficiency Wood Stove Program in Northlands. This would involve:
- gaining support for the initiative through consultation with community elders and members;

- taking an inventory of existing wood stoves in the community to determine their type and likely efficiency;
- demonstrating the use and assessing the performance of the two major types of high-efficiency, U.S.EPA-certified wood stoves (catalytic and non-catalytic) in several homes; and
- based on the demonstration and evaluation ramp-up the long-term replacement of the remaining low-efficiency, uncertified wood stoves in the community.

To reduce cost, either the bulk purchase of new, high-efficiency stoves or establishment of a preferred supplier list and pricing scheme should be explored.

In addition to a replacement program for existing installations of wood stoves, it would also be desirable to pass a Band Council Resolution mandating that any new installations of wood stoves in the community be high-efficiency, certified models.

Figure 6 – Emissions of fine particulates from wood and other energy sources



Additional Information

Aki Team Reports – For more information about wood heating and recommendations for implementing a high-efficiency wood heating program for Northlands, please refer to this report produced by the Aki Team:

- *Northlands Dënesųłiné First Nation Building Energy Assessment Audits (March 2017)* by Lumos Clean Energy Advisors.

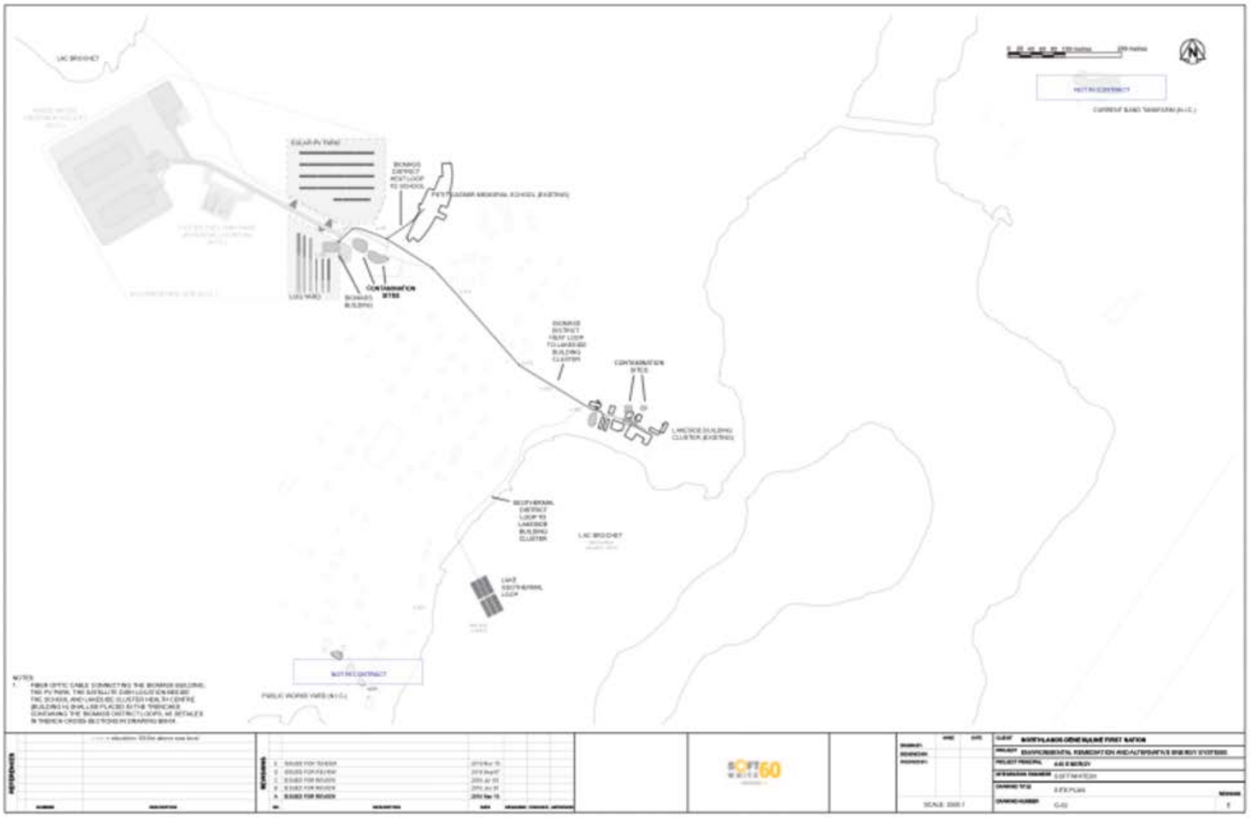
2.4 ERAAES Project

The Environmental Remediation and Alternative Energy Systems (ERAAES) now under construction in Northlands represents a major step in process of ending the community's dependency on trucked-in diesel fuel for generating electricity and heating.

In addition to the environmental remediation of two diesel-contaminated sites in the community, other components of the project include:

- Supply and installation of a 1.4 MW district energy biomass heating system.
- Supply and installation of a 140 kW in-lake geothermal district energy system.
- Supply and installation of a 280 kW solar photovoltaic (PV) array to offset the electricity consumption of the biomass and geothermal systems, as well as a new aerated sewage lagoon in the community.
- Integration between these three new energy systems (biomass, geothermal and PV) and with the community's existing heating and electricity systems.
- Establishment of a biomass harvesting operation from nearby forested areas burnt by fire.

Figure 7 – Map of ERRAES Project



3.0 Demand-Side Management: Issues and Options

3.1 Retrofitting Community Buildings and Facilities

Major Findings and Recommendations:

- *Although some progress has been made in some areas to reduce energy use in the community buildings and facilities in Northlands, overall energy use has risen over the past decade.*
- *Energy audits of eight community buildings have identified many retrofit opportunities with very attractive payback periods.*
- *An overall target of reducing energy use in community buildings and facilities by 20% to 25% appears possible.*

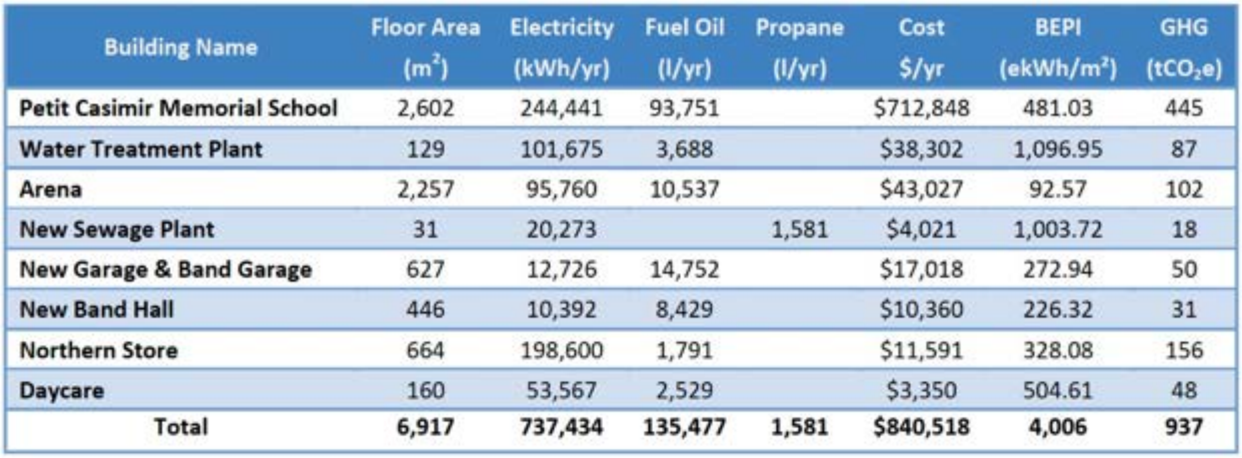
Overview of Option

This option would consist of targeted retrofit measures and capital upgrade projects to improve the energy performance of community buildings and facilities.

Discussion

The Aki Project Team conducted ASHRAE Level 1 Walk-Through Screening Audits on eight community buildings and facilities (see Figure 8 below). Two of these buildings that appeared to have the most promise for retrofitting were selected for more detailed ASHRAE Level 2 Audits.

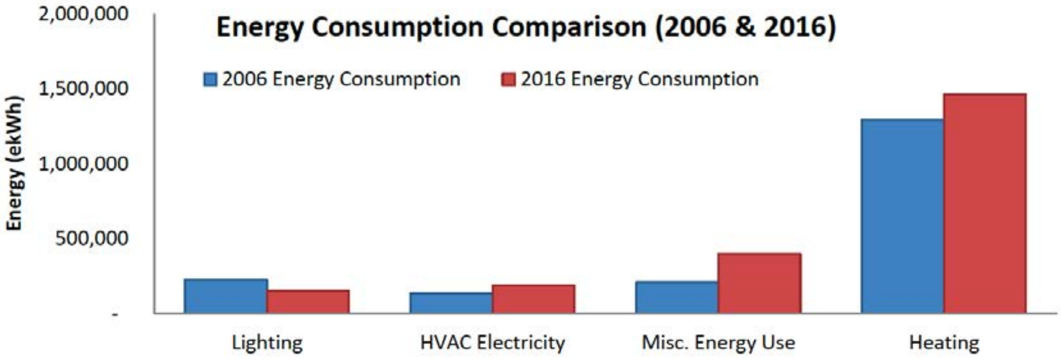
Figure 8 – Community buildings and facilities selected for energy audits



Building Name	Floor Area (m^2)	Electricity (kWh/yr)	Fuel Oil (l/yr)	Propane (l/yr)	Cost $/yr	BEPI (ekWh/m^2)	GHG (tCO_2e)
Petit Casimir Memorial School	2,602	244,441	93,751		$712,848	481.03	445
Water Treatment Plant	129	101,675	3,688		$38,302	1,096.95	87
Arena	2,257	95,760	10,537		$43,027	92.57	102
New Sewage Plant	31	20,273		1,581	$4,021	1,003.72	18
New Garage & Band Garage	627	12,726	14,752		$17,018	272.94	50
New Band Hall	446	10,392	8,429		$10,360	226.32	31
Northern Store	664	198,600	1,791		$11,591	328.08	156
Daycare	160	53,567	2,529		$3,350	504.61	48
Total	**6,917**	**737,434**	**135,477**	**1,581**	**$840,518**	**4,006**	**937**

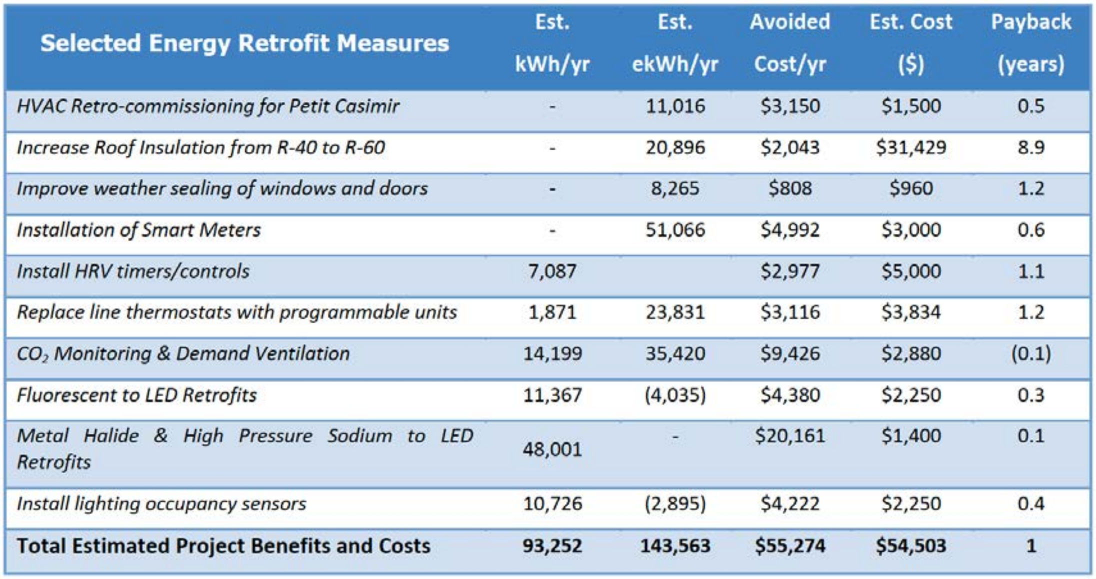
The energy consumption for this group of buildings was compared to an earlier study conducted in 2006. It was found that although progress has been made in reducing energy use for lighting, energy use for all of the other categories (heating, HVAC, miscellaneous loads) has increased over the past ten years (see Figure 9 on next page).

Figure 9 – Energy Consumption Comparison



Based on the Level 1 and Level 2 energy audits, there are many retrofit opportunities for these community buildings and facilities with very attractive paybacks (see Figure 10 below).

Figure 10 – Energy Retrofit Measures



Selected Energy Retrofit Measures	Est. kWh/yr	Est. ekWh/yr	Avoided Cost/yr	Est. Cost ($)	Payback (years)
HVAC Retro-commissioning for Petit Casimir	-	11,016	$3,150	$1,500	0.5
Increase Roof Insulation from R-40 to R-60	-	20,896	$2,043	$31,429	8.9
Improve weather sealing of windows and doors	-	8,265	$808	$960	1.2
Installation of Smart Meters	-	51,066	$4,992	$3,000	0.6
Install HRV timers/controls	7,087		$2,977	$5,000	1.1
Replace line thermostats with programmable units	1,871	23,831	$3,116	$3,834	1.2
CO_2 Monitoring & Demand Ventilation	14,199	35,420	$9,426	$2,880	(0.1)
Fluorescent to LED Retrofits	11,367	(4,035)	$4,380	$2,250	0.3
Metal Halide & High Pressure Sodium to LED Retrofits	48,001	-	$20,161	$1,400	0.1
Install lighting occupancy sensors	10,726	(2,895)	$4,222	$2,250	0.4
Total Estimated Project Benefits and Costs	**93,252**	**143,563**	**$55,274**	**$54,503**	**1**

Overall, it appears feasible to target an overall energy savings of 20% to 25% energy savings for community buildings and facilities through cost-effective retrofits and capital upgrade projects over the next five years (the actual savings potential varies from building to building).

Additional Information

Aki Team Reports – For more in-depth information about the results and recommendations of the energy audits for the community buildings and facilities in Northlands, please refer to this report produced by the Aki Team:

- *Northlands Dënesųłiné First Nation Building Energy Assessment Audits (April 2017)* by Demand Side Energy Consultants

3.2 Energy Standards for New Community Buildings

Major Findings and Recommendations:

- *Because of the high cost of energy in Northlands, new community should exceed the minimum requirements of the National Energy Code for Buildings based on life-cycle costing.*
- *It would be prudent to take advantage of technical support and incentives offered by Manitoba Hydro's New Buildings Program. Maximizing these incentives requires adopting a target of at least a 20% over the NECB.*

Overview of Option

This option would involve adopting a standard for the design and construction of any future community buildings to exceed those of the *National Energy Code of Canada for Buildings 2015* (NECB). This standard would require that life-cycle costing be used for the features of new buildings that impact energy performance to better reflect the harsh climate and high energy costs in Northlands.

Discussion

The energy efficiency requirements of the NECB do not reflect the high cost of energy in remote, off-grid communities such as Northlands. In planning any future community buildings, it would be desirable to instead use life-cycle costing for the energy-related features to balance the construction costs against long-term operating costs for energy.

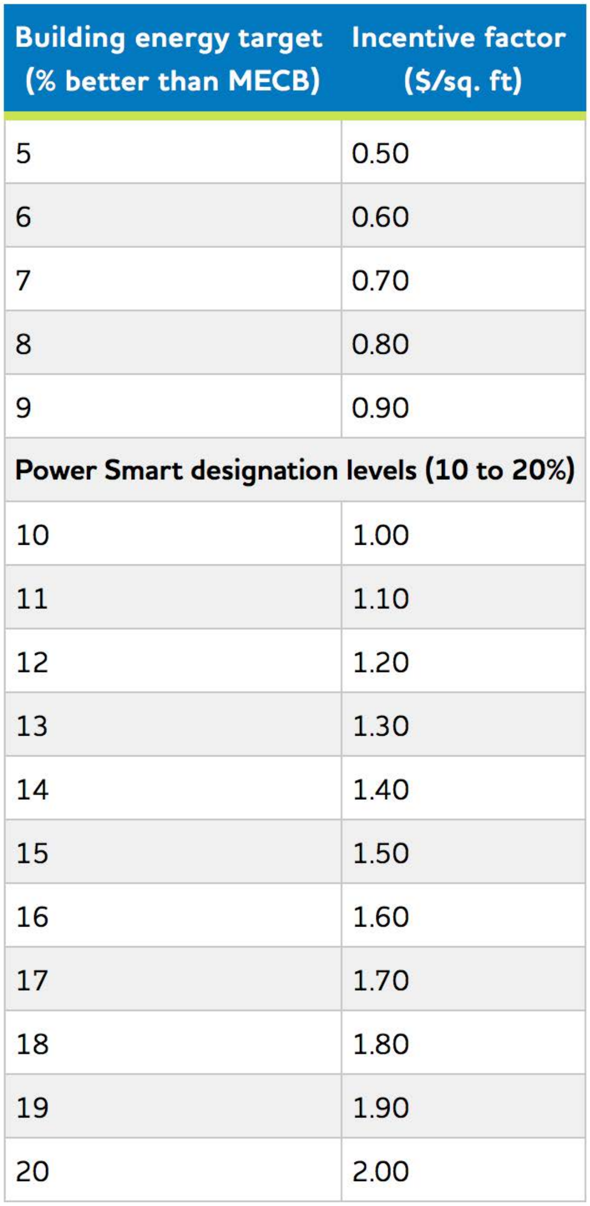
As a minimum, it would make sense to take advantage of the technical support and incentives offered through Manitoba Hydro's New Buildings Program. This program offers an incentive of up to $10,000 for energy modelling which is an important tool to assist with life-cycle costing. Hydro also offers an incentive ranging from $0.50 to $2.00 per sq. ft. of floor area depending on how much the building exceeds the Manitoba Energy Code for Buildings (the MECB is based on the NECB and is virtually identical) – see Figure 11 on next page.

For Northlands, setting a target for new community buildings of at least 20% better than the MECB would be appropriate.

Additional Information

Further Reading – Information about the Manitoba Hydro Power Smart New Buildings Program is available at this link.

Figure 11 – Manitoba Hydro New Buildings incentive levels



Building energy target (% better than MECB)	Incentive factor ($/sq. ft)
5	0.50
6	0.60
7	0.70
8	0.80
9	0.90
Power Smart designation levels (10 to 20%)	
10	1.00
11	1.10
12	1.20
13	1.30
14	1.40
15	1.50
16	1.60
17	1.70
18	1.80
19	1.90
20	2.00

3.3 Retrofitting Existing Housing Stock

Major Findings and Recommendations:

- *Detailed audits on a representative sample of homes in Northlands have revealed that there is a significant potential to cost-effectively reduce energy use for space heating, water heating, major appliances, lighting and vehicle block heaters in most homes in the community.*
- *An aggressive energy retrofit initiative for homes in the community can reduce the size and cost of the energy-supply options discussed elsewhere in this report.*
- *There is also potential to reduce the energy needed to distribute, collect and treat water and wastewater through a comprehensive program to replace toilets, showerheads and faucet aerators in homes throughout the community.*
- *To maximize local benefits, community members should* be trained to conduct audits on the remaining homes and undertake as much of the retrofit work as possible.

Overview of Option

This option would involve conducting streamlined energy and water audits on as many of the homes in the community as possible. These audits would identify and prioritize cost-effective measures for each house to reduce energy use for space heating, water heating, major appliances, lighting and miscellaneous plug loads (e.g., vehicle block heaters, electric heating cables for plumbing lines, etc.). Measures to conserve water (e.g., high efficiency toilets, water-saving showerheads, etc.) would also be identified.

Working with external partners, especially Manitoba Hydro's Power Smart initiative, community members would be trained to conduct these audits and undertake as much of the retrofit work as possible.

Discussion

To inform and support Aki's development of a retrofit strategy for existing homes in Northlands, detailed energy and water audits were conducted on a sample of homes in the community. The following are some key findings and recommendations that emerged from these audits:

Space heating – A potential reduction of 25% to 33% in annual space heating consumption (currently oil) is feasible for a significant portion of homes in Northlands through modest, cost-effective building envelope upgrades (e.g., adding insulation, replacing windows, reducing air leakage, etc.) to Manitoba Hydro's Power Smart standards. In many cases, these retrofits need to be coupled with improvement to ventilation systems to improve indoor air quality and better control excessive moisture to minimize the risk of mold and improve the durability of the homes.

Domestic water heating – Typical savings in the order of about 1,000 kWh per year appear feasible in most homes through a combined strategy of retrofitting water-saving showerheads, aerators for taps, pipe insulation and horizontal drainwater heat recovery devices. Implementation of these measures will need to be monitored carefully to ensure that they don't result in freezing sewer lines.

Major appliances – Additional cost-effective electricity savings are possible through a community-wide program to replace older major appliances such as refrigerators, freezers and clothes washers/dryers with ENERGY STAR models.

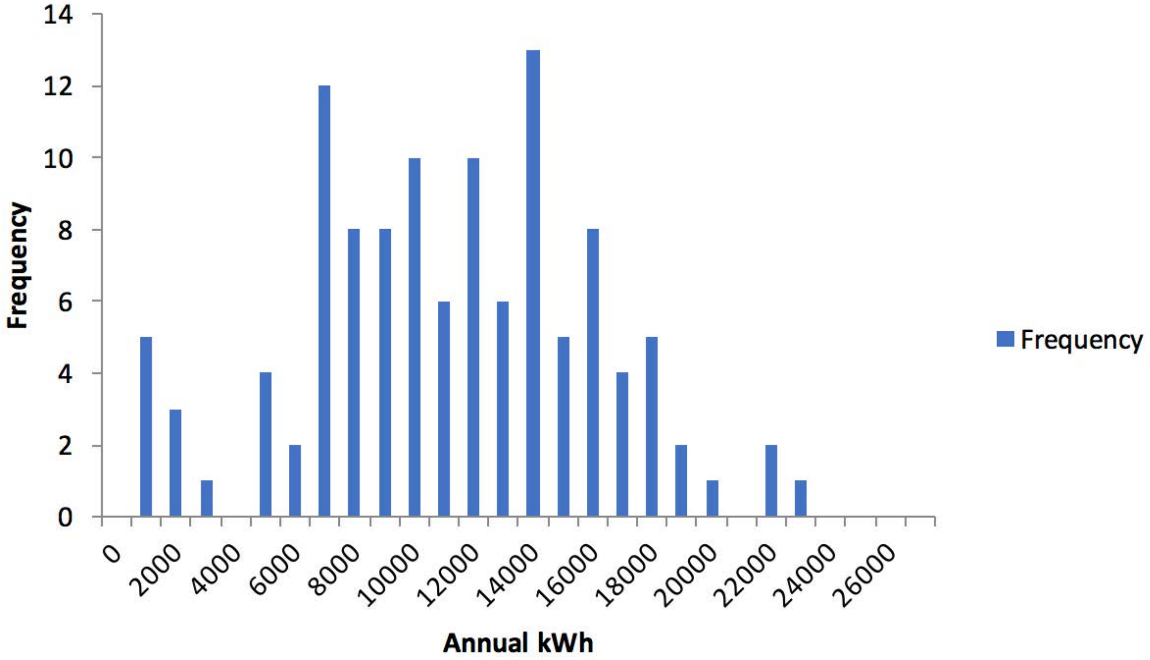
Lighting – The remains significant potential in the community to replace existing incandescent and compact florescent lighting in homes with more efficient LED lighting.

Vehicle block heaters – Installing 'smart power receptacles' to automatically control and reduce electricity use for vehicle block heater plugs should be explored.

Water – The audits have also found that that there is a significant opportunity to replace existing toilets in homes throughout the community with fixtures that use much less water while maintaining proper flush performance to reduce the energy need to distribute, collect and treat water and wastewater.

The energy audits conducted for this project revealed a wide range of electricity use between different homes – see Figure 12 below. In planning a comprehensive retrofit program for the community, priority should be given to auditing and retrofitting those homes with above-average levels of energy use.

Figure 12 – Annual Residential Electricity Consumption



For some of the retrofit measures listed above, it should be noted that the savings will be reduced somewhat by 'interactive effects' (i.e., less waste heat from more efficient appliances and lighting will increase space heating loads during the winter). The impact of these interactive effects will be reduced by the fact that oil-fired furnaces are typically at least twice as efficient as diesel-generated electricity.

Finally, it is important to also recognize that a comprehensive initiative to maximize the energy retrofitting of housing in the community will reduce the size and cost of the energy-supply options discussed elsewhere in this report.

Additional Information

Aki Team Reports – For more in-depth information about options, issues and analysis for retrofitting the existing housing stock in Northlands, please refer to the following reports produced by the Aki Team:

- *Final Summary Report: Residential Energy and Water Audits in Manitoba's Off-Grid Communities* by prairieHOUSE Performance Inc.
- *ecoENERGY Energy Efficiency Evaluation Reports* for each of the 12 homes that were subject to an energy and water audit by prairieHOUSE Performance Inc.

Further Reading – Information about residential savings, rebates and loans offered by Manitoba Hydro through its Power Smart initiative are available through this link.

3.4 Energy Standards for New Housing

Major Findings and Recommendations:

- *There is a reoccurring pattern of homes being built in Northlands using energy-related construction standards that do not adequately reflect the community's harsh climate and high energy costs.*
- *New homes in Northlands should be designed and built to exceed the minimum energy-efficiency requirements of the National Building Code of Canada. It is recommended that the Performance Path of Manitoba Hydro's Power Smart for New Homes Program be used with an energy performance target of 50% better than minimum code requirements.*
- *Adopting this stringent energy performance standard will have several other co-benefits (more comfortable, greater resistance to condensation and mould, improved durability, more resilient, etc.)*

Overview of Option

This option would involve adopting design, construction and quality assurance standards for new homes that significantly exceed those used in the past in the community and the current minimum energy efficiency standards of Section 9.36 of the *2015 National Building Code of Canada.*

These more stringent standards would better reflect the higher occupancy, harsh climate and high energy costs in Northlands. These improved standards would also have co-benefits beyond reducing energy use and the burden of high energy bills – they would also result in new homes that are more comfortable, resilient, durable and healthier for the members of the Northlands First Nation who occupy them.

Discussion

The detailed energy audits of a representative sample of homes in Northlands conducted for this project revealed numerous examples of construction details being used in the community that are resulting in sub-optimal energy performance and significant problems with respect to comfort, durability, moisture control and indoor air quality.

Since April 2014, CMHC has required First Nations to provide a Certificate of Building Code Compliance for new houses built with CMHC funding under Section 95 of the National Housing Act. However, there are problems with this approach.

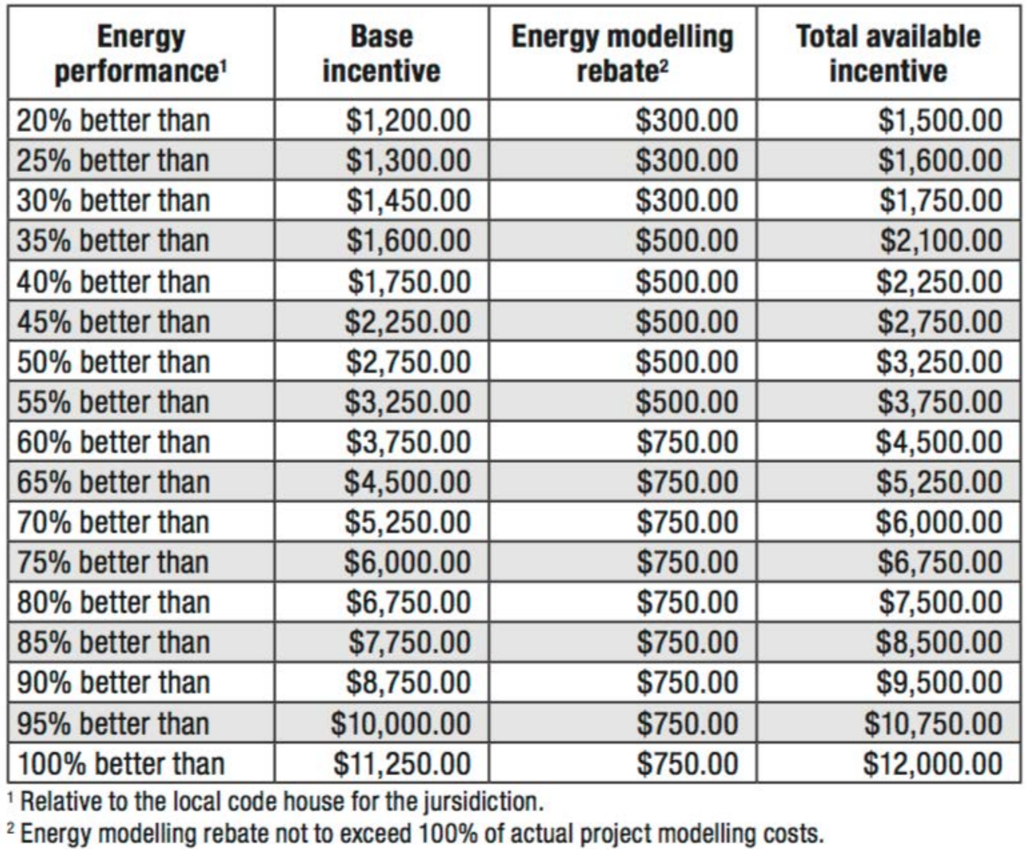
The primary problem is that *National Building Code of Canada* is only a set of minimum requirements. In a remote, northern community with a harsh climate and high energy prices, there is a compelling case to go well beyond minimum code requirements.

This problem has been recognized by Manitoba Hydro and their Power Smart New Home Program. It offers incentives for two options:

Prescriptive Path - Homes must incorporate at 10 prescriptive energy savings measures. These homes will achieve an energy rating equivalent to 20% better than a conventional home built to minimum code requirements.

Performance Path – Homes must be designed with energy modeling and receive a scaled, progressive incentive ranging from $1,500 to $12,000 for increasing levels of performance (see Figure 13 below).

Figure 13 – Manitoba Hydro Energy Performance and Energy Modelling Rebates



Energy performance[1]	Base incentive	Energy modelling rebate[2]	Total available incentive
20% better than	$1,200.00	$300.00	$1,500.00
25% better than	$1,300.00	$300.00	$1,600.00
30% better than	$1,450.00	$300.00	$1,750.00
35% better than	$1,600.00	$500.00	$2,100.00
40% better than	$1,750.00	$500.00	$2,250.00
45% better than	$2,250.00	$500.00	$2,750.00
50% better than	$2,750.00	$500.00	$3,250.00
55% better than	$3,250.00	$500.00	$3,750.00
60% better than	$3,750.00	$750.00	$4,500.00
65% better than	$4,500.00	$750.00	$5,250.00
70% better than	$5,250.00	$750.00	$6,000.00
75% better than	$6,000.00	$750.00	$6,750.00
80% better than	$6,750.00	$750.00	$7,500.00
85% better than	$7,750.00	$750.00	$8,500.00
90% better than	$8,750.00	$750.00	$9,500.00
95% better than	$10,000.00	$750.00	$10,750.00
100% better than	$11,250.00	$750.00	$12,000.00

[1] Relative to the local code house for the jurisdiction.

[2] Energy modelling rebate not to exceed 100% of actual project modelling costs.

Additional Information

Aki Team Reports – For more in-depth information about problems observed with the energy-related performance of the existing housing stock in Northlands, please refer to the following report produced by the Aki Team:

- *Final Summary Report: Residential Energy and Water Audits in Manitoba's Off-Grid Communities* by prairieHOUSE Performance Inc.

Further Reading – Information about the technical requirements for the Manitoba Hydro Power Smart for New Home Program can be found at this link.

4.0 Imported Non-Renewable Energy Sources: Issues and Options

4.1 SaskPower Electrical Grid Connection

Major Findings and Recommendations:

- *Connecting Lac Brochet (Northlands) along with Brochet to SaskPower's electrical grid via Wollaston Lake would be high.*
- *A preliminary high-level assessment of capital cost to service both communities ranges from $189 to $518-million depending on the type of transmission line.*
- *Based on this high-level cost estimate, other renewable energy supply options and aggressive demand-side management would be much less costly.*

Overview of Option

Because Northlands is relatively close to the Manitoba-Saskatchewan provincial boundary, the Aki Project Team conducted a preliminary assessment of the technical and economic feasibility of connecting the community plus Brochet to the Saskatchewan Power grid at Wollaston Lake (see Figure 14 below).

Figure 14 – Potential connection to SaskPower Grid

Discussion

SaskPower – Owned by the Government of Saskatchewan, SaskPower is the principal electric utility in the province. NorthPoint Energy Solutions, a wholly-owned subsidiary of SaskPower, provides access to the utility's transmission system to transport electricity to its wholesale customers or wheel power across the province to other jurisdictions.

SaskPower's electrical grid extends to the unincorporated community of Wollaston Lake and adjoining First Nations community of Wollaston Post, the administrative center for the Hatchet Lake Dënesųłiné Nation in Northeast Saskatchewan.

Technical and Regulatory Issues – Extending and electrical transmission line from Wollaston Lake to Northlands would be a major undertaking that faces several technical and regulatory challenges that include:

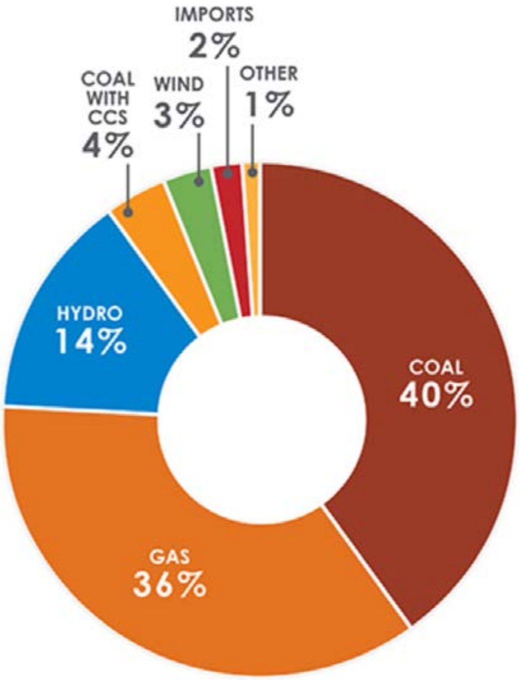
1. Lack of all-season road access
2. Complicated terrain
3. Regulatory approval
4. Environmental assessment process

Preliminary Economic Assessment – A preliminary estimate is that the cost to connect both Lac Brochet (Northlands) and Brochet to the SaskPower grid would be very expensive ranging from $428 to $518-million. The use of a less reliable twin pole design rather than lattice towers would reduce the projected cost to about $189 to $223-million.

Neither of these cost estimates includes any provision for SaskPower transmission upgrades to Wollaston Lake or overhead costs for the transmission construction company.

Greenhouse Gases and Other Emissions – Another factor to consider about this option is that electricity supplied by SaskPower comes mostly from non-renewable fossil fuels (see Figure 15 below).

Figure 15 – SaskPower electricity generation mix



Additional Information

For a more in-depth discussion of this option, see the report *Assessment of Connecting Manitoba Remote Communities to the Saskatchewan Power Grid* produced for Aki by Lumos Clean Energy Advisors.

4.2 Natural Gas Service

Major Findings and Recommendations:

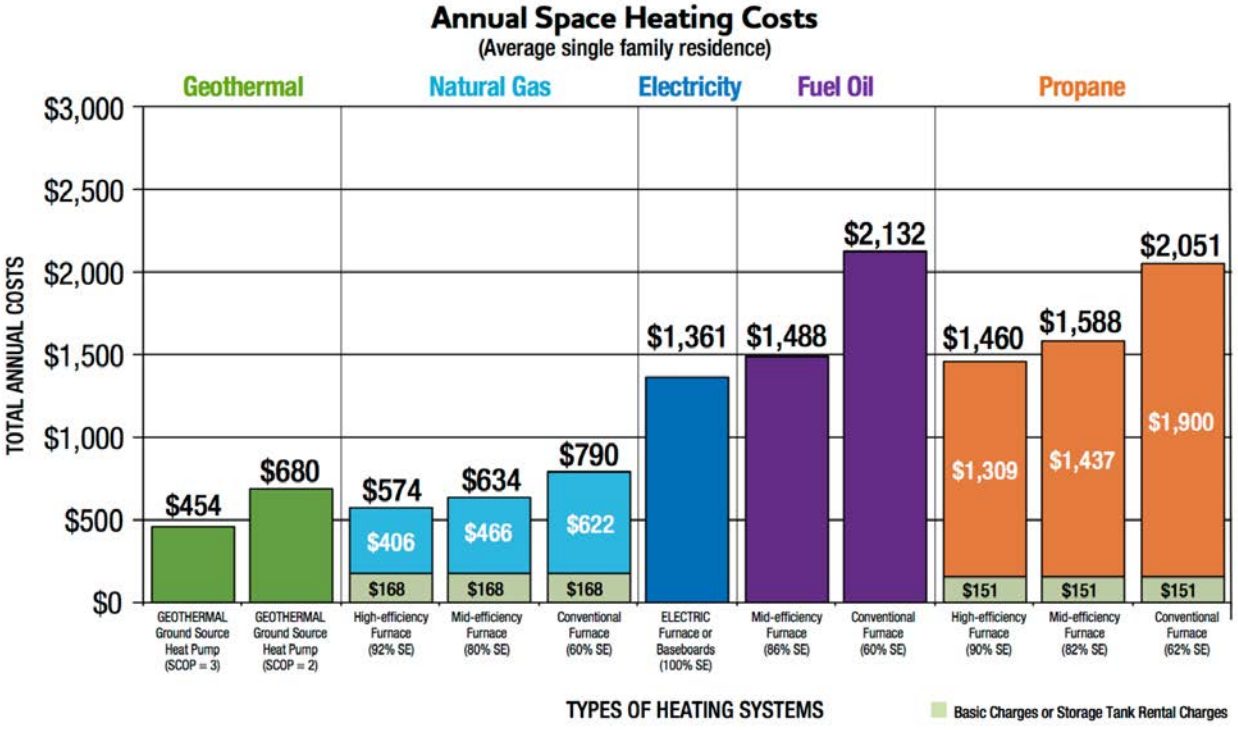
- *Displacing diesel-generated electricity and heating oil in Northlands with natural gas would be attractive due the lower cost for natural gas and the fact that it is a cleaner energy source.*
- *Although it is a more desirable source of energy than diesel fuel or heating oil, extending natural gas pipeline service is impractical due to logistical challenges and the high capital cost driven by the community's long distance to Centra Gas's existing network.*

Overview of Option

This option would involve extending a pipeline from the Centra Gas natural gas network in Southwestern Manitoba to service Northlands (and potentially the other off-grid First Nations in Northern Manitoba). The existing diesel generation station and heating systems for homes and community buildings and facilities would be switched from oil to gas-fired equipment and individual oil storage tanks removed.

Using natural gas rather than diesel fuel and heating oil in the community would have major advantages: it is a significantly less expensive source of energy (see Figure 16 below for Southern Manitoba) and is a cleaner source of energy in terms of greenhouse gases and other emissions. A further advantage is that natural gas would eliminate the risk of soil and water contamination posed by diesel fuel and heating oil.

Figure 16 – Annual Space Cost Comparison for an Average Single Family Residence



Discussion

Although this would be an option, it was deemed to be impractical due to logistical and capital cost barriers.

Extending a natural gas pipeline over several hundred kilometers from Southwestern Manitoba to Northlands over often challenging terrain would be technically possible but prohibitive from a construction cost perspective. There are other communities in Manitoba much closer to the existing Centra Gas network than Northlands where it has been found to be impractical to extend natural gas service.

Additional Information

Aki Team Reports – Because connecting the community to the Centra Gas natural gas network did not pass an initial screening for consideration for the Northlands Community Energy Plan, the Aki Team did not produce a separate report on this option.

4.3 LNG and Propane Service

Major Findings and Recommendations:

- *Displacing diesel-generated electricity and heating oil in Northlands with either LNG (liquefied natural gas) or propane would be attractive because these are cleaner energy sources.*
- *This option has been deemed to be impractical due to logistical challenges of reliably delivering LNG or propane by truck over the short winter road season and safely and economically storing a sufficient quantity of gas as a hedge against supply interruptions.*
- *Propane faces the additional disadvantage that it usually offers little or no price advantage over diesel fuel or home heating oil.*

Overview of Option

This option would involve trucking either LNG or propane to Northlands using the winter road system and storing a sufficient quantity (up to two years) as a buffer against supply interruption. The existing diesel generation station and heating systems for homes and community buildings and facilities would be switched from oil to gas-fired equipment and individual oil storage tanks removed. This would also provide an opportunity to address the excessive oversizing of heating equipment that is common in the community.

Using natural gas rather than diesel fuel and heating oil in the community would have major advantages: it is a significantly less expensive source of energy (see Figure 18 on next page) and is a cleaner source of energy in terms of greenhouse gases and other emissions. A further advantage is that natural gas would eliminate the risk of soil and water contamination posed by diesel fuel and heating oil.

Figure 17 – Example of LNG delivery by truck

Discussion

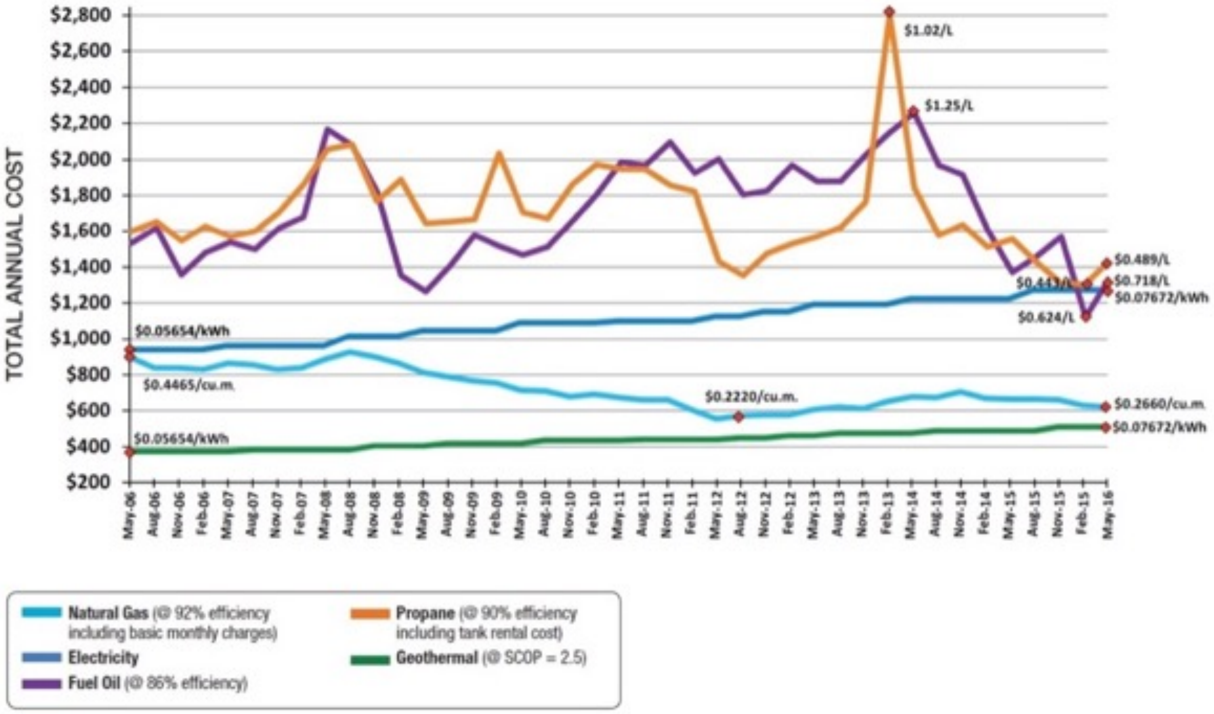
Because it is cleaner burning and offer a cost advantage, there has been some interest in using LNG to displace diesel fuel and heating oil in remote, northern communities and mining projects. However, this approach is still in infancy.

The largest example in Canada of this substitution so far is the Whitehorse Diesel–LNG Conversion Project. Commissioned in 2015, this project involved the installation of two modular LNG-fueled generators to replace Yukon Energy's ageing diesel generation equipment and to provide flexible and reliable back-up power to supplement Yukon's renewable hydroelectric and wind power. More information about this project can be found at this link.

Although cleaner burning, substituting either LNG or propane for diesel fuel and heating oil in Northlands has been deemed impractical. Delivering LNG or propane by truck over the short and often unpredictable winter road season would be difficult. A major barrier would be safely and economically storing a sufficient quantity of gas as a hedge against supply interruptions.

Propane faces the additional disadvantage that it usually offers little or no price advantage over diesel fuel or home heating oil – see Figure 16 below.

Figure 18 – Energy Cost Trends in Manitoba (2006 to 2016)



Additional Information

Aki Team Reports – Because LNG and propane did not pass an initial screening for consideration for the Northlands Community Energy Plan, the Aki Team did not produce a separate report on this option.

4.4 Advanced Diesel

Major Findings and Recommendations:

- *Although reliable, the aging conventional, fixed-speed diesel generators and controls now deployed in Northlands are a barrier to adding a high penetration level of renewable energy sources to the community's electrical grid.*
- *More advanced, variable-speed diesel generators and power management controls would address this issue by linking energy supply closer to energy demand. Because it is more efficient, this technology also has the potential to reduce electricity costs and emissions for the community.*
- *Replacing the existing conventional, fixed-speed diesel generators in Northlands as they reach the end of their service life with advanced, variable-speed diesel generators and controls is a potentially attractive option for option. However, because this is a relatively new technology, a more in-depth analysis is needed. This includes reviewing the operating experience for this technology in other remote, northern communities.*

Overview of Option

This option consists of replacing the existing conventional, fixed-speed diesel generators in Northlands that approach the end of their service life with more advanced, variable-speed diesel generators and power management controls (i.e., 'Advanced Diesel').

Discussion

Fixed-speed, synchronous generators convert the mechanical output of a diesel engine into electrical power for the grid. To maintain electrical frequency, they operate at one-speed. This basic approach has been followed for more than 100 years.

Fixed speed generators have a major limitation when used in a microgrid that integrates significant amounts of renewable energy such solar photovoltaic-generated electricity and wind power. In these cases, fixed-speed generators have difficulty maintaining speed, and therefore frequency, when the renewable energy output changes rapidly due to events such as cloud cover or inconsistent wind conditions (see sub-section 6.4 for an explanation and discussion of microgrids). This causes fixed-speed generators to hunt for frequency which can destabilize the microgrid and therefore often results in a need to curtail renewable energy supplies or increase costs by add energy storage.

A further issue with fixed-speed diesel generators is that they become less fuel-efficient and produce more greenhouse gases and other emissions as their load decreases. Running fixed-diesel engines that power these generators consistently at low to moderate loads can also increase maintenance problems and costs.

In contrast, variable-speed advanced diesel generators operate at higher efficiency at all loads. This is accomplished by decoupling the diesel engine speed from electrical frequency at all loads allowing the generator set to run at the most advantageous speed at any given load. The result is that compared to conventional fixed-speed units, variable-speed advanced diesel generators have better fuel economy, longer engine life, produce fewer emissions and provide lower cost electricity (in the range of 20% to 30%).

Despite their disadvantages, conventional fixed-speed diesel generators have some major advantages compared to advanced variable-speed generators: they are a far more proven and widely available technology with a long track-record of usage in remote, northern communities.

Because advanced, variable-speed generators are a comparatively new technology, a careful assessment of their feasibility for Northlands that includes a review of this technology's performance in other similar communities is needed.

Additional Information

For a more discussion about how 'Advanced Diesel' potentially fits into a high penetration renewable energy strategy for Northlands, please refer to these reports:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (March 2017)* by Soft White 60.
- *Strategic Clean Energy Options Assessment & Implementation Plan: Comparing Alternative Approaches to Meet Long-term Energy Requirements for Off-Grid Manitoba First Nations & Scoping a Plan for Implementation* produced for Aki by Lumos Clean Energy Advisors.

4.5 Waste Oil Heating

Major Findings and Recommendations:

- *The new waste oil handling and heating system to be installed in a public works building in Northlands has the potential to displace a useful amount of heating oil. However, the amount of heating oil displaced will not be known until the system is operational and amount of waste oil collected is tracked.*
- *The new system will also address an existing environmental and community concern of how to properly dispose of used oil and oil products.*
- *The new waste oil system complies with all provincial regulations and is approved by the Canadian Standards Association (CSA), Underwriters' Laboratory (UL) or the Underwriters' Laboratory of Canada (ULC).*
- *Caution should be used to accept used oil and oil products only from trusted sources in the community. Mixing special wastes can be dangerous and void the manufacturer's warranty.*
- *Maintenance of the system will be essential. The equipment should be serviced on a regular basis by a qualified service contractor or local community staff with appropriate training, and in accordance with the manufacturer's recommendations.*

Overview of Option

This option involves installing a waste oil heater in a public works building in Northlands.

Waste oil heaters refer to boilers, furnaces and space heaters that are specifically designed to burn used oil and many other waste oil products (e.g., transmission oil, hydraulic oil, diesel sludge, cooking and vegetable oils, etc.) – see Figure 19 on next page.

When waste oil heaters first became popular, they were often not recommended, because the technology and testing methods were not yet established. However, in recent years, the technology has significantly improved and use of waste oil heaters has increased.

Discussion

MARCC Waste-Oil Furnace Initiative – The Manitoba Association for Resources Recovery Corp. (MARRC) is a non-profit organization formed by manufacturers and marketers to develop, administer and implement a province-wide stewardship program for used oil, used oil filters and used oil containers.

In a remote community like Northlands, shipping used oil and other waste oil products is costly and the fossil fuel used in their transportation to a centralized processing facility in Southern Manitoba outweighs any benefit. MARRC has recognized the use of waste-oil heaters as a safe, environmentally-preferable alternative.

In cooperation with MARRC, funding has been approved under a different program to install and begin operating a waste oil unit in Northlands by approximately March 2018. The unit purchased is a 50kW (175,000 BTU) forced-air furnace which is large enough to provide most (if not all) of the heat requirements of one of the public works buildings in the community.

It is not yet possible to estimate the amount of oil that will be consumed in this unit as the community does not yet have a calculated inventory of waste oil nor is it know how much waste oil is can be recovered. However, given that this unit can consume engine oil, diesel sludge, old diesel and old gasoline, the demand for new heating oil will be offset. The exact amount will be known once the units are operational and oil consumption is tracked.

Figure 19 – Example of used oil handling and forced-air furnace system

Regulations and Standards – It will be important for Northlands to ensure that the waste oil handling and heating system to be installed in the community fully complies with all applicable regulations for health, safety and fire.

Each province and territory in Canada has its own set of rules for the licencing and burning of oil. In Manitoba, the provincial government has enacted the Used Oil, Oil Filters and Containers Stewardship Regulation. Details about this regulation and other requirements for the handling, storage, transportation and burning of waste oil can be obtained through the Hazardous Waste

Program of the Environmental Approvals Branch of Manitoba Sustainable Development – see this link for contact details.

In addition, Manitoba also regulates the safety of oil-fired heating systems through the Manitoba Building Code and Manitoba Fire Code. Information about the installation requirements under these codes can be obtained through the Office of the Fire Commissioner – see this link for contact details.

Operation and Maintenance Issues – It can be dangerous to mix special wastes (e.g., solvents, brake fluid, anti-freeze, etc.) with used oil that is to be burned in a waste oil heater. It may also void the manufacturer’s warranty. It will be important to ensure that Northlands staff who deal with used oil and the waste oil burner are educated about this hazard and only accept used oil and oil products from trusted sources.

It will also be essential that maintenance requirements provided by the manufacturer are closely followed to ensure the safe operation of the waste oil heating system. Maintenance procedures can be very involved. It is therefore recommended that the system be serviced on a regular basis by a qualified service contractor, manufacturer’s representative or local community staff with appropriate training to ensure that the system is in proper operating condition. Annual verification that this has been done should be required.

Additional Information

Aki Team Reports – Because of the small scale of this option, the Aki Team did not produce a separate report on this option.

5.0 Local Clean Renewable Energy: Issues and Options

5.1 Connection to Manitoba Hydro Electrical Grid

Major Findings and Recommendations:

- *Connecting Northlands to Manitoba Hydro's main electrical grid would need to be part of larger project to also connect Brochet (and possibly Tadoule Lake) to Hydro's Laurie River Generating Station via Lynn Lake.*
- *A preliminary high-level assessment of capital cost to service all three communities is approximately $575-million. The costs to upgrade from 60 to 200 amp service within the community is not included in this estimate.*
- *Ignoring costs, connecting Northlands to the grid could be a good option to displace both diesel-generated electricity and use of heating oil.*
- *A detailed feasibility study would provide more accurate costs. However, it appears from the high-level cost estimate produced for this report that other renewable energy supply options and aggressive demand-side management, would be much less costly and require shorter lead times.*

Overview of Option

This option would part of a larger project to extend Manitoba Hydro's main electrical grid to connect Tadoule Lake, Lac Brochet (Northlands) and Brochet with an overhead transmission line to Hydro's Laurie River Generating Station via Lynn Lake (see Figure 20 below).

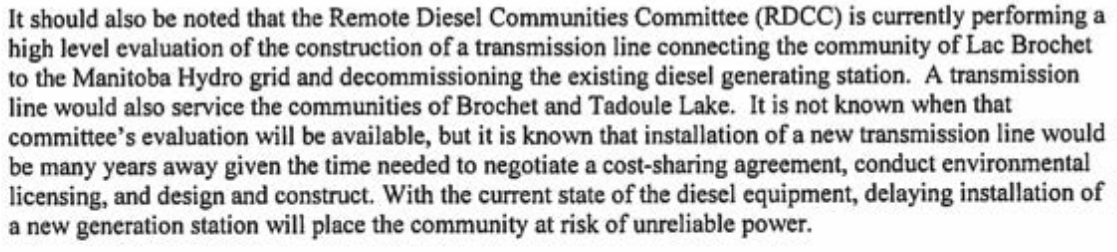
Under this option, the existing diesel generators diesel storage tank farm in Northlands would be decommissioned. The electrical distribution system in the community would be upgraded and homes and community buildings and facilities converted to 200-amp service and electric heating.

Figure 20 –Proposed Transmission Lines to Manitoba's Off-Grid Communities

Discussion

Ignoring the construction cost, connecting Northlands to the grid would be a good option to displace both diesel-generated electricity and use of heating oil. As a result, there have been past efforts to study the option of extending electricity from Manitoba Hydro's main grid to Northlands and the other three off-grid communities in Manitoba (i.e., Brochet, Tadoule Lake and Shamattawa). This includes a November 2008 Generating Resource Screening Study by Manitoba Hydro that conducted a preliminary analysis of three options to reduce or eliminate 60-amp diesel-fired generation in the non-grid communities (the other two options studied were to augment diesel generation with wind power and small hydroelectric generation).

More recently, a July 2015 Capital Project Justification report was completed by Manitoba Hydro for a new diesel generating station in Northlands adjacent to the existing station, plus replacement of the existing diesel storage tank farm and upgrade of staff accommodations. This report by Hydro stated the following:



> It should also be noted that the Remote Diesel Communities Committee (RDCC) is currently performing a high level evaluation of the construction of a transmission line connecting the community of Lac Brochet to the Manitoba Hydro grid and decommissioning the existing diesel generating station. A transmission line would also service the communities of Brochet and Tadoule Lake. It is not known when that committee's evaluation will be available, but it is known that installation of a new transmission line would be many years away given the time needed to negotiate a cost-sharing agreement, conduct environmental licensing, and design and construct. With the current state of the diesel equipment, delaying installation of a new generation station will place the community at risk of unreliable power.

Aki's Team was not able to obtain a copy of the RDCC's evaluation noted above, and therefore conducted its own high level evaluation (see report listed in 'Additional Information' below for details).

Additional Information

For a more in-depth discussion and additional insights about this option, please refer to these reports:

- *Assessment of Connecting Manitoba Remote Communities to the Manitoba Power Grid* produced for Aki by Lumos Clean Energy Advisors.
- *Manitoba Hydro Generating Resource Screening Study: Brochet and Lac Brochet (November 2008)* by Manitoba Hydro.
- *Capital Project Justification – Lac Brochet New Diesel Plant (July 2015)* by Manitoba Hydro.

5.2 Small-Scale Hydro

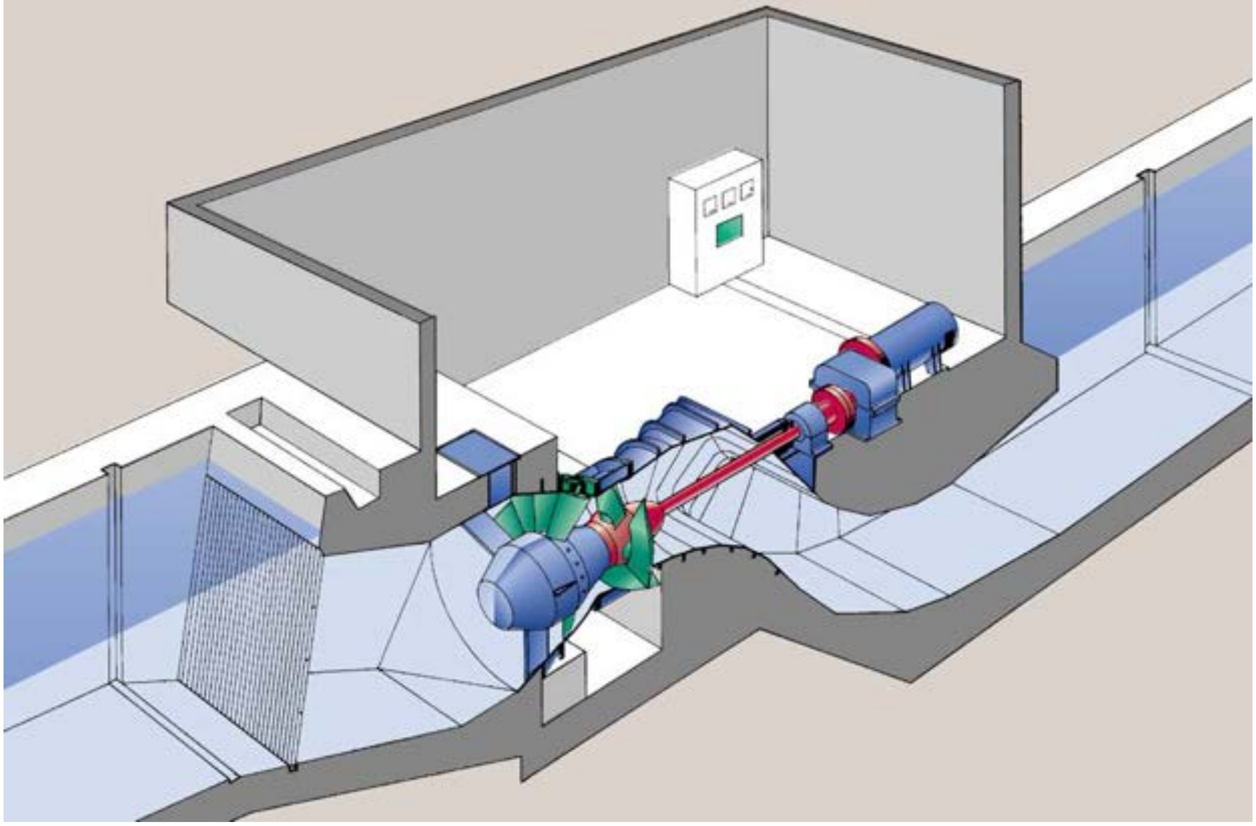
Major Findings and Recommendations:

- *There is the potential to build a small hydro generating station on the Cochrane River to serve the combined electrical needs of Lac Brochet (Northlands) and Brochet or to build a dedicated station for each community.*
- *There have been multiple studies of this option. One of the most recent (2009) found that small-scale hydro would be more expensive than running the existing diesel generation facilities in both communities.*
- *A December 2016 update estimated that the cost of a dedicated hydro generating station for Brochet only would range in cost for $110 to $145-million.*
- *A small hydro generating station would need a long lead time (at least five years and as many as ten years) to complete the necessary studies and design work, secure licencing and construct the facility.*

Overview of Option

This option would consist of building small hydro generation station on the Cochrane River to serve the combined electrical demand for both Lac Brochet (Northlands) and Brochet. Another option would be construct a dedicated hydro station for each community.

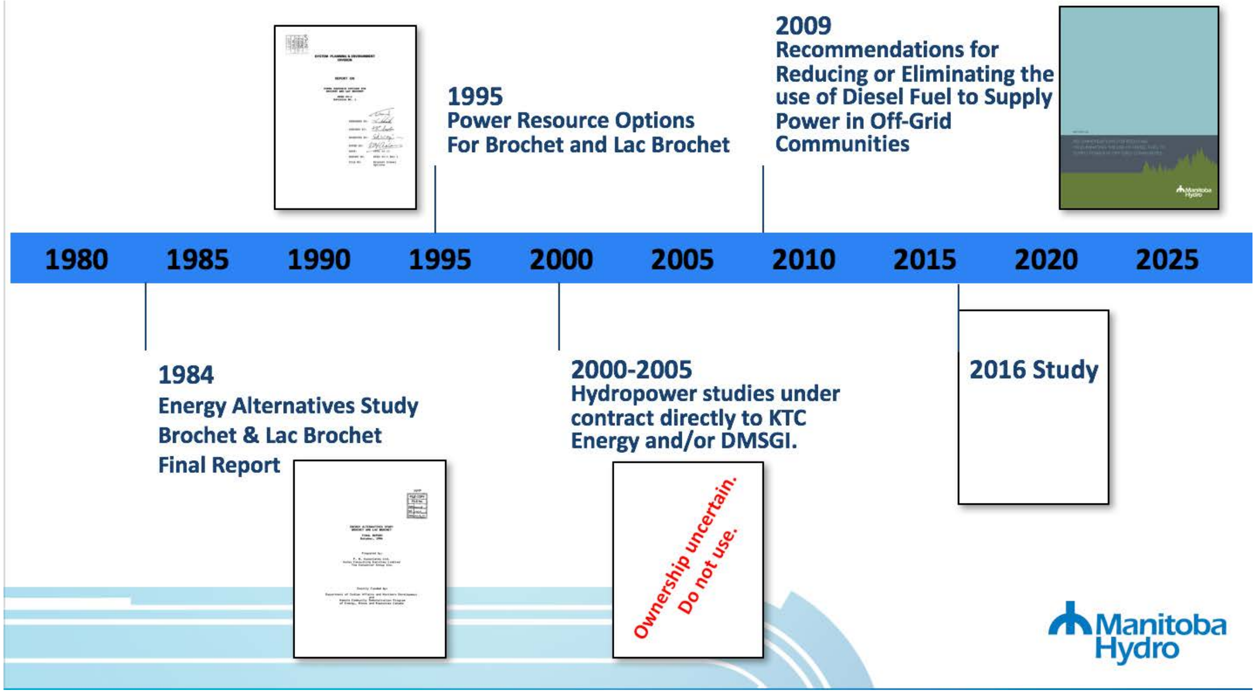
Figure 21 – Cut-away of small scale hydro generation station



Discussion

Since 1984, there have been multiple screening studies and major reports of the technical and economic feasibility of small hydropower options on the Cochrane River to serve Brochet and Lac Brochet (see Figure 22 below).

Figure 22 – Timeline of Hydropower Reports for Brochet and Lac Brochet (Northlands)



The 2009 study by Manitoba Hydro looked at building a small hydro station for both 60-amp and 200-amp service levels. Under average flow conditions, diesel generation was forecast not to be required over the study period (to 2041) with the small hydro station satisfying the combined energy and capacity requirements of both communities.

Under dependable flow conditions, the small hydro plant was forecast to meet the combined energy and capacity requirements for the 60-amp option for Brochet and Lac Brochet until 2027. From 2028 onwards, the existing diesel generation station at Lac Brochet would be needed. These options appear to be based on a 'business-as-usual' scenario with respect to the projected growth in electricity use in the community and therefore do not consider the potential impact of aggressive demand-side management.

For the 200-amp service option, the small hydro station capacity is not adequate to meet peak capacity demand under both dependable and average flow conditions over the study period.

Based on Manitoba Hydro’s now-outdated 2006 fuel price forecast, both options result in higher costs relative to continued operation of the diesel generating stations at Brochet and Lac Brochet.

A December 2016 update from Manitoba Hydro estimated that the capital cost of a dedicated small-hydro generation station for Brochet would cost from $110 to $145-million. The cost to get better information for the next stage of design was estimated at $50 to $100K. Between $10 to $30-million and three to seven years would be required to complete all pre-construction studies and licencing. Construction would take another two or three years.

Additional Information

For a more in-depth discussion and additional recommendations about this option, please refer to these reports:

- *Small Hydro Project Potential (March 2017)* produced for Aki by Lumos Clean Energy Advisors.
- *Recommendations for Reducing or Eliminating the Use of Diesel Fuel to Supply Power in Off-Grid Communities (2009)* by Manitoba Hydro.
- *Brochet Small Hydropower Cost Estimate Update (December 2016)* by Manitoba Hydro.

5.3 Wind Energy

Major Findings and Recommendations:

- *There are many technical challenges to installing, integrating and operating a community-scale wind energy system in a cold, remote community (such as Northlands) that depends on diesel-generated electricity. Targeting a 'low' rather than a 'medium' or 'high level' of penetration of wind energy significantly reduces complexity and these risks.*
- *Cold-climate wind technology continues to mature. Despite many early failures, there are a growing number successful projects across the north that demonstrate that wind-diesel hybrid power systems can be a viable option for remote communities. Based on this experience, the feasibility of wind energy for Northlands should be explored in more depth as part of a comprehensive local renewable energy strategy for the community.*
- *There is a lack of wind data for Northlands. This is a major barrier since the economic merits of a wind energy system will depend heavily on local wind speeds and, to a lesser extent, their distribution throughout the year.*
- *Detailed wind data should be collected for Northlands as soon as possible for a minimum of 12 months and then assessed to determine whether wind-generated electricity should be part of the community's energy mix. A suggested schedule and protocol for this wind monitoring that involves local community resources has been developed by Aki.*
- *An initial cost estimate to purchase a suitable 34-meter tall meteorological wind monitoring tower for Northlands is approximately $16,000. Depending on the number of towers, it would cost about $12,000 to charter a plane to fly the equipment to Northlands. Shipping by truck during the winter road season is another option.*
- *The Prairie Agricultural Machinery Institute (PAMI) has successfully installed and removed several wind monitoring towers in Manitoba and could by contracted to assist Northlands. Aki has requested a preliminary estimate from PAMI for this service.*

Overview of Option

This option would involve collecting detailed wind data for Northlands and, if a sufficient wind resource is confirmed, installing one or two small or medium-scale wind turbines to provide electricity to the community.

Wind is a form of local renewable energy. The terms 'wind energy' or 'wind power' refer to the process of converting wind into mechanical power for a specific task (e.g., pumping water, grinding grain) or, more commonly, to generate electricity.

Aki's analysis of wind energy options for the Northlands CEP has focused on generating electricity with wind turbines. The balance of this *Overview of Technology* sub-section provides several general comments and insights about this technology. This background will enable non-technical readers to better understand the major findings and recommendations about wind-generated electricity for Northlands that has been prepared by the Aki Team.

Wind Resource Assessment – Wind energy is a variable energy resource since its output varies with changes in wind speed. The wind resource available within a reasonable distance to a community is a key factor in determining the economic viability of a wind-diesel project.

The energy content of wind is proportional to the cube of the wind speed. This means that even small changes in the wind speed that a wind turbine is exposed to can have a significant impact on its output of electricity. For example, a small increase in wind speed from 6.0 to 7.0 meters per second (m/s) – 22 to 25 kilometers per hour (km/h) – will increase output by almost 60%.

Local airport wind speed records and data from the Canadian National Wind Atlas can be a preliminary screening tool to rule out communities which obviously do not have an adequate wind resource.

As a rule-of-thumb, communities with an average annual wind speed that exceed 6 m/s (22 km/h) can be screened in and communities with wind speeds less that 5 m/s can be screened out for further consideration. Communities with wind speeds between 5 and 6 m/s could be screened in for consideration if taking advantage of the local topography (e.g., hill or ridge, open area with few or no trees, etc.) might yield a significant increase in wind speed.
Wind speed typically increase significantly with height.

Caution should be used with wind speed data recorded at lower levels above the ground (e.g., at 10 meters) at airports and elsewhere. This can lead to significant underestimation of actual wind speeds at higher levels (i.e., 30 meters and higher) where most wind turbines operate.

Wind Turbines – Wind turbines have blades or rotors which turn in moving air. They spin a shaft, often connected to gearbox, which drives a generator to make electricity.

Wind turbines vary widely in terms of the peak amount of electricity they can generate. They can be classified as follows:

1. *Small wind turbine* – Maximum rated power capacity from 20 watts to 100 kW (1 kW = 1,000 watts).
2. *Medium wind turbine* – Maximum rated power capacity from 100 kW to 1 MW. (1 MW = 1,000 kW or 1,000,0000 watts).
3. *Large wind turbine* – Maximum rated power capacity of more than 1 MW.

For comparison, the annual peak electricity load in Northlands is just under 900 kW (0.9 MW). Most community-scale wind energy systems in remote communities utilize medium capacity wind turbines.

Although there are some novel approaches to modern wind turbines, most fall into two basic groups: horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs) – see Figures X and Y on pages 37 and 38.

Except for a few niche applications, VAWTs are generally inferior and much less common than HAWTs. For this reason, the analysis of wind energy options for the Northlands CEP has been limited to HAWTs.

Wind Turbine Towers – Towers and their foundations to support a wind turbine represent a major portion of the cost of wind energy project. There are three general types of towers: free-standing tubular towers, guyed tubular towers and lattice towers.

Unless erected directly on exposed bedrock, free-standing tubular towers usually require a substantial concrete foundation. Aggregate and concrete in isolated communities (such as Northlands) is expensive and often available only on a seasonal basis.

Some towers are ‘self-erecting’. Most free-standing towers, especially taller ones, require a crane for erection. This presents both logistical and cost challenges in a remote community. Guyed tubular towers or lattice towers have reduced foundation and anchoring requirements and therefore can be less expensive to install.

Lattice towers are less desirable than tubular towers in locations where icing is a problem since they provide more surface area for ice to accumulate.

Tower height is another important factor that requires careful analysis to optimize the performance of wind energy system. Taller towers increase the amount of wind energy that can be captured but cost more and present greater logistical challenges than shorter towers.

Wind Penetration Levels – A critical design factor that impacts the complexity and feasibility of a wind-diesel hybrid power system is how much energy is coming from wind.
Called the ‘wind penetration level’, there are three classifications of systems:

1. *Low penetration* – Less than 50% of peak demand (kW) and 20% of average annual electricity use (kWh) is provided by wind.
2. Medium Penetration – 50 to 100% of peak demand and 20 to 50% of average annual electricity use is provided by wind.
3. *High penetration* – More than 100% of peak demand and at least 50% of average annual electricity use is provided by wind.

Low penetration systems use ‘off the shelf’ technology and are relatively easy to implement. Medium penetration systems are more complex and require a higher level of skill to design, operate and maintain. High penetration systems are very complex and require a sophisticated control system and additional components to store electricity and regulate voltage and frequency. Because high penetration systems are expensive they require a good wind resource to be economical.

There are many different approaches to designing and building a community-scale wind-diesel power system. However, any wind energy system in a remote community can benefit from remote monitoring and access. This allows expert oversight and troubleshooting of system performance to reduce maintenance, improve reliability and minimize downtime.

Advantages and Limitations – Wind energy has both advantages and limitations, some of which are general in nature and others that are specific to a small, remote community in a cold northern environment such as Northlands:

- *Renewable, non-polluting* – Unlike diesel-generated electricity, wind is a free, local renewable energy resource that does not emit greenhouse gases, odours or other air pollutants. A hybrid wind-diesel generating system can reduce diesel consumption does not eliminate the risks associated with transporting and storing diesel fuel.
- *Other environmental impacts* – Although wind energy systems have considerably less environmental impact that diesel-generated electricity, there can be some concern about the noise produced by the blades or rotors of the wind turbine if it is located to close to homes or other buildings.

  Depending on the site, there may also be aesthetic (visual) impacts to consider. Through proper siting of a wind turbine and tower, the risk to birds, bats or other local wildlife can be minimized.

Figure 23 – Examples of horizontal axis wind turbines with a free-standing tubular tower (left) and a lattice tower (right)

Figure 24 – Example of a vertical axis wind turbine

- *Cost effectiveness* – The cost of wind power has declined dramatically during the past decade. However, the technology still requires a higher initial investment than diesel generators. However, when wind energy systems are compared to diesel-generated electricity on a 'life-cycle cost' basis, wind power can be competitive because there is no fuel to purchase, maintenance requirements are less and more local employment is possible.
- *Variability* – Wind turbines are an intermittent source of energy. They normally begin to generate electricity when wind speeds reach at least 3 to 4 m/s (about 11 to 14 km/h and stop operating at about 20 m/s (about 72 km/h) to prevent equipment damage. Unless combined with storage, not all winds can be harnessed to match the timing of demand for electricity.
- *Performance and reliability* – Although wind energy is considered a mature technology, experience with its application in remote, northern communities is still at a relatively early stage. Many early wind-diesel systems installed as pilot or demonstration projects in Alaska and Northern Canada experienced problems and did not perform as expected. However, more recent installations have demonstrated improved performance and reliability

Wind Energy Issues and Options for Northlands

Local Wind Resource – The Aki Team sought local

wind resource data for Northlands from these three sources:

1. *Canadian Wind Energy Atlas (CWEA)* – There are two versions of the CWEA.:
    - One version is a national map with a resolution of 25 x 25 km that expresses wind energy at a height of 50 meters – see Figure 25 on next page.
    - The other version is an online, interactive map of Canada with a resolution of 5 x 5 km that presents wind speeds and wind energy at heights of 30, 50 and 80 meters above ground – see this link.
2. *Manitoba Hydro 80-Meter Wind Map* – In 2006, Manitoba Hydro commissioned a wind map of the province. This map has a resolution of 136 x 136 meters and therefore is much more detailed then the CWEA.

    Manitoba Hydro's map shows estimated wind speeds at a height of 80 meters. Although large wind turbines with hub height of 80 meters are feasible in Southern Manitoba, they cannot be considered an option for remote communities in Northern Manitoba (including Northlands) due to logistical constraints.
3. *Environment Canada 10-Meter Wind Speeds* – Environment Canada has weather stations throughout Manitoba, some of which record wind speeds throughout the year at an industry standard height of 10 meters above ground level (a strong wind regime at 10 meters is often indicative of a good wind resource at greater heights). Unfortunately, Environment Canada does not have a weather station in Northlands.

Based on an analysis of the available wind resource data, Aki Team's has made the following observations and conclusions:

- The CWEA estimates that the average annual wind speed for Northlands at 30 meters above ground is in the range of 6.0 to 7.0 m/s.
- Average wind speed alone does not provide a complete picture of how the wind varies throughout the year at a site of interest. Wind-generated energy production estimates require a site's complete wind speed distribution profile, not just the average wind speed.
- Due to logistical challenges, wind turbines in Northlands will likely be restricted to heights of between 30 to 50 meters above ground.
- Extrapolating the estimated average annual wind speed from Manitoba Hydro's 80-Meter Wind Map to the desired height of 30 to 50 meters creates additional uncertainties.
- A reasonable assessment of the wind energy potential for Northlands will require a rigorous, site-specific monitoring program for a minimum of 12 months.

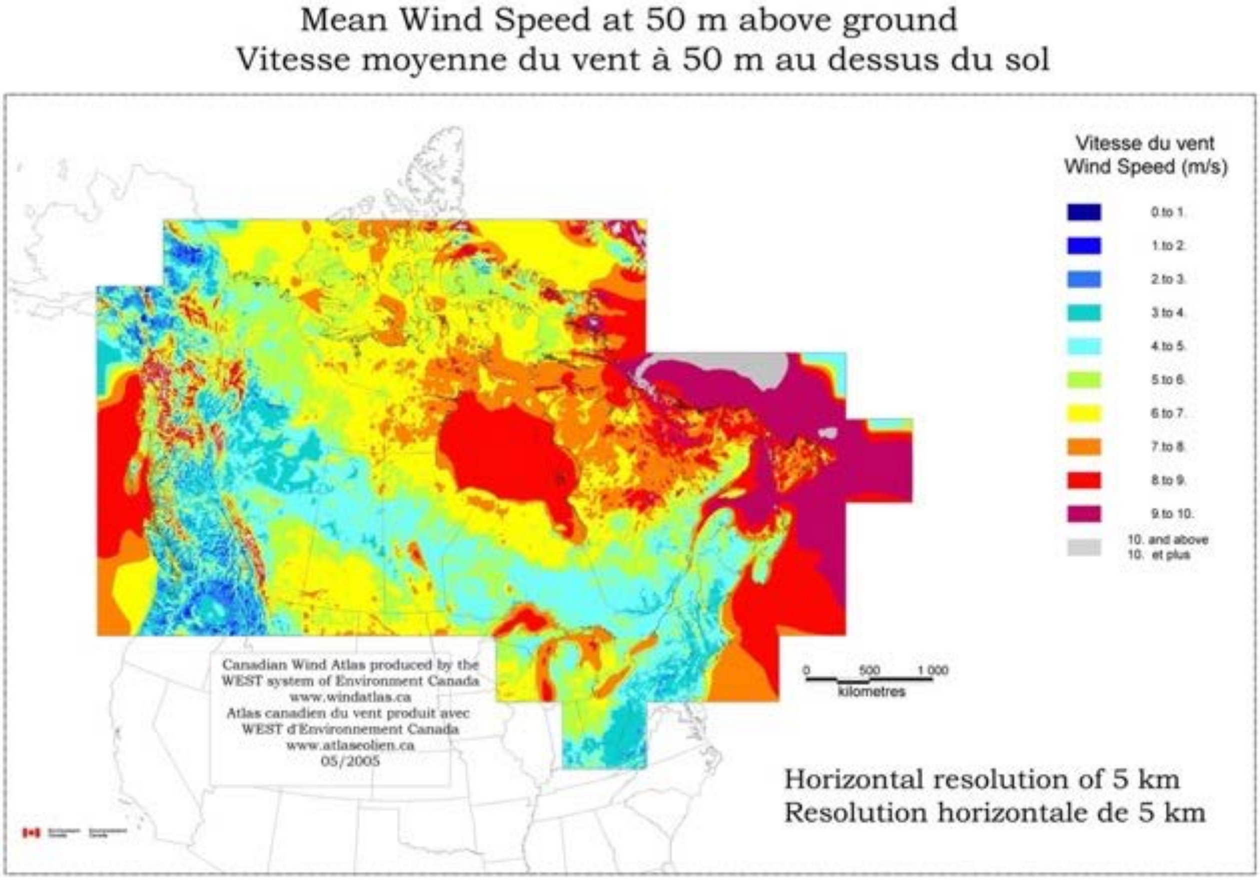


Figure 25 – Canadian Wind Energy Atlas

Wind Monitoring Strategy – The following are key issues and recommendations for the wind monitoring strategy and protocol developed by Aki for Northlands:

1. *Wind monitoring technique* – There are two common approaches to wind monitoring:

- 'LiDAR' (Light Detection and Ranging): This technique uses rapid pulses from a laser light to generate high quality data on wind speed and direction at multiple heights.
- 'Met' (meteorological) towers – This method uses a tall metal pipe supported with several guy wires anchored to the ground. A series of monitoring sensors (e.g., anemometer to measure wind speed, wind vane to record wind direction, etc.) are attached to the tower with horizontal booms – see Figure 26 below.

Aki recommends that multiple met towers rather than LiDAR be used for the wind monitoring in Northlands. Although logistically more challenging to transport and install/remove, met towers offer several other advantages compared to LiDAR (i.e., they are less expensive; they make it more feasible to collect wind data from multiple sites simultaneously; usable data is recorded even if one of the sensors fails or is damaged).

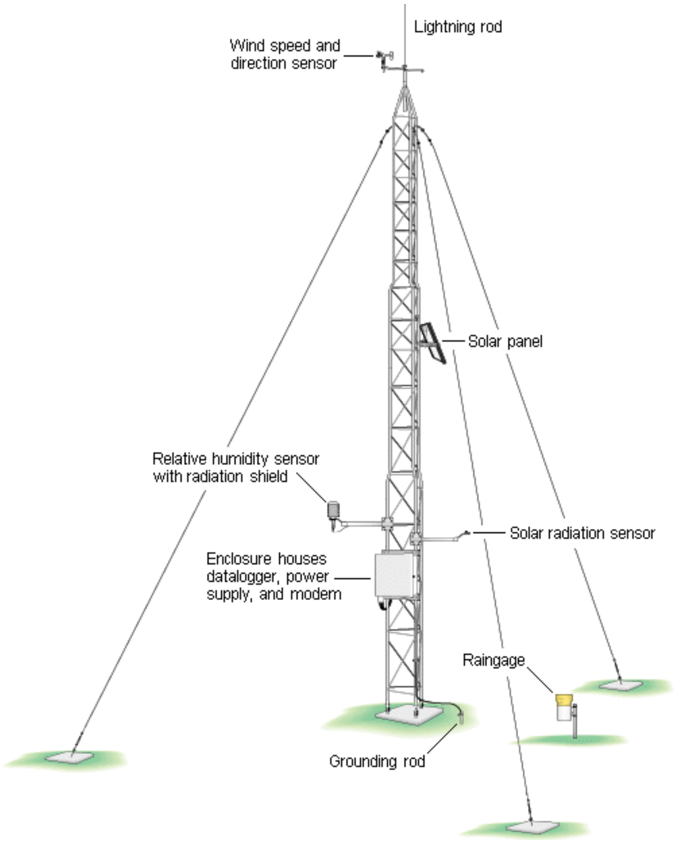


Figure 26 – Meteorological ('met') tower for wind monitoring

2. *Community acceptance* – Acceptance by community members of proposed sites for the met towers should be obtained before they are installed. Met tower installations should be limited to areas that are not sacred sites or ecologically-sensitive areas. Local knowledge will also be useful to determine which areas near the community are likely to have the strongest winds due to geological features (e.g., the 'Big Hill'), road or trail access plus enough open space to assemble and erect the towers.

3. *Use of local community resources* – Experience in other jurisdictions has shown that involvement of community members will enhance the chances of a successful wind monitoring program in Northlands. In addition to providing support for choosing the location of the met towers, one of more community members can assist with the transportation, site preparation, assembly, erection and removal of the met towers. A community member can also be used to periodically monitor the tower and help address any problems (e.g., adjust loose guy wires, replace a failed sensor, etc.).

Wind Turbine Suitability – Wind energy, especially large-scale projects such as the St. Leon and St. Joseph wind farms in Southern Manitoba, is a mature technology experiencing strong growth on a global basis. However, there are several issues that make wind energy more challenging for Northlands and other off-grid First Nations in Northern Manitoba.

The first issue is scale. Large wind turbines are much more effective for generating electricity than medium or small wind turbines. The weight and size restrictions imposed on the winter road system that connects Northlands makes it impractical to transport the large, heavy wind turbines, long blades and massive cranes that were used for the wind farms in Southern Manitoba.

The second issue is extreme cold weather performance. Unlike large wind turbines, there are a relatively small number of suppliers (e.g., Northern Power Systems) that offer 'artic' wind turbines that have a long track record of performance in a climate as cold as Northlands. There are many examples of wind projects across the north that have either failed or fallen short of expectations. However, there are also a growing number of successful projects in Canada's Far North and Alaska that demonstrate that wind is a viable option for remote, off-grid northern communities provided that the project is properly designed, installed and maintained.

The third issue is maintenance. As a remote community, having a wind turbine that is reliable to minimize the need for expensive maintenance or repairs will be an important consideration for Northlands.

Integration with Other Renewables – Consistent with vision and values expressed in the *Northlands Dënesųłiné First Nation Sustainable Development Strategy*, Aki's Team conducted a prefeasibility analysis of several scenarios using different combinations and penetration levels of renewable energy systems (including wind) to completely displace the use of diesel fuel in Northlands.

Wind energy-related highlights from this analysis include the following:

- Three of the scenarios for 100% renewable energy penetration for the community include wind energy with some battery storage.
- The level of wind penetration was determined by a software tool for optimizing micro-grid design (HOMER Pro) to include a single 100 kW wind turbine with a 50-meter hub height for one scenario and two 100 kW wind turbines (also at 50-meter hub heights) for the other two scenarios.

- The lowest cost scenario over a 25-year planning horizon (Case 3) includes two 100 kW wind turbines.
- An additional advantage of incorporating wind turbines (combined with solar photovoltaics and battery storage) is that it will provide more diversity of supply since wind power can be available both day and night, year-round.

For a more complete summary of the 100% renewable energy penetration scenarios and their analysis, please refer to Section '6.0 Integrating the Options'.

Additional Information

Aki Team Reports – For more in-depth information about wind energy issues, options and analysis for Northlands, please refer to the following reports produced by the Aki Team:

- *Development of a Wind-Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations (March 2017)* by Marc Arbez, P. Eng.;
- *Assessing Potential for Wind Power-Diesel Hybrid Option for Manitoba Remote Communities (March 2017)* by Lumos Clean Energy Advisors; and
- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.

Further Reading – For more information about wind energy, including its application in northern, remote communities, here are suggested publications:

- *Alaska Isolated Wind-Diesel Systems: Performance and Economic Analysis* prepared for the Alaska Energy Authority.
- *Wind Energy for the Rest of Us: A Comprehensive Guide to Wind Power and How to Use It* by Paul Gipe.

5.4 Solar Energy

Major Findings and Recommendations:

- *Several active and passive solar energy technologies were considered for Northlands by the Aki Team. Two of these technologies, concentrating solar power and solar water heating were eliminated from further consideration due to concerns that their performance and reliability in a cold, remote community remains unproven.*
- *Two other forms of solar energy, building integrated solar heating and community-scale photovoltaic-generated electricity should form a modest part of a diversified and integrated local renewable energy strategy for Northlands.*
- *Whether more photovoltaic-generated electricity should be added to the community's energy mix beyond the ERAAES project should be part of a full feasibility study.*
- *If more photovoltaic capacity is to be added, fixed PV panels are recommended rather than a single or dual-axis tracking system to reduce maintenance requirements and maximize reliability.*
- *An investment in a battery energy storage system, in combination with other renewables (wind and biomass), will smooth out the daily fluctuations in electricity production from the photovoltaics due to clouds or other shading and the transition from day to night.*

Overview of Options

This option would involve using solar energy to produce heat and/or electricity for Northlands using either passive or active technology.

Solar is a form of local renewable energy. The terms 'solar energy' or 'solar power' refer to harnessing the radiant light and heat from the sun through a range of different technologies.

Solar technologies are broadly classified as either 'passive' or 'active'. An example of passive solar technology is orienting a house so that its south-facing windows maximize heat gain from the sun during the winter. An example of active solar technology is using photovoltaics panels to convert sunlight directly into electricity.

The balance of this *Overview of Technology* sub-section provides general comments and insights about the types of solar energy technology considered by the Aki Team for Northlands. This background will enable non-technical readers to better understand Aki's major findings and recommendations about this technology for the community.

Concentrating Solar Power – Concentrating solar power (CSP) use mirrors or lenses with tracking systems to focus a large area of sunlight onto a small area – see Figure 27 on next page. The resulting heat can then be used directly (e.g., heating buildings, industrial processes, etc.) or indirectly to generate electricity.

A major advantage of CSP systems is that they can be designed to store some of their heat for periods with little or no sun.

Figure 27 – Concentrating solar power research and demonstration project for northern communities at Red River College

Solar Water Heating – Solar water heating systems include solar collectors (most often roof-mounted) and storage tanks to provide hot water. There are two types of solar water heating systems: active systems which have circulating pumps and controls and passive systems that do not – see Figures 28 and 29 on next page.

Passive solar water heaters are simpler, more reliable and less expensive than active systems. However, they aren't appropriate in areas where temperature frequently fall below freezing. In cold climates, active systems circulate a non-freezing heat transfer fluid to avoid freezing problems. This added complexity increases costs and maintenance requirements.

Most solar water heaters are installed as a small, separate system on individual houses and buildings rather than as a larger community-scale system.

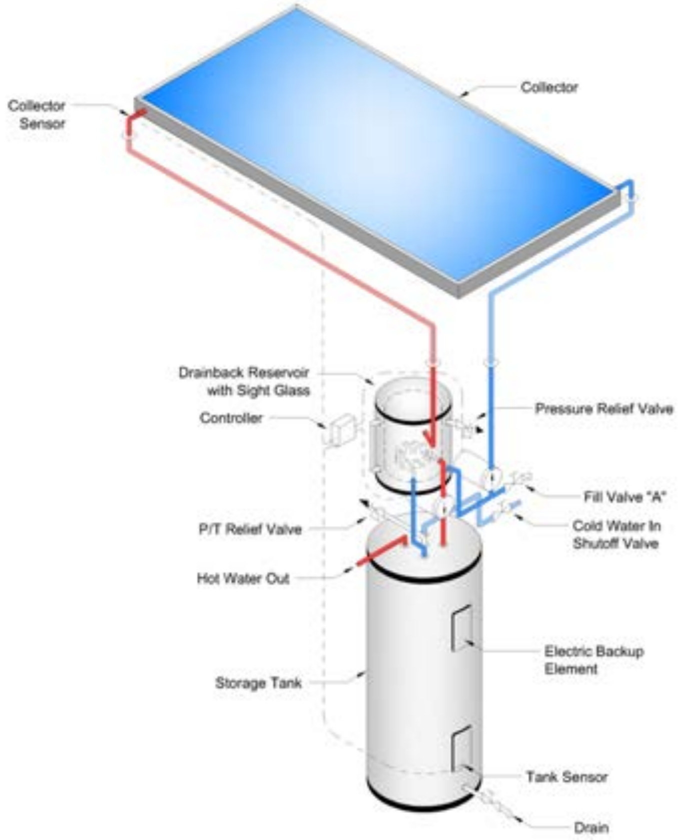


Figure 28 – Active solar water heating systems

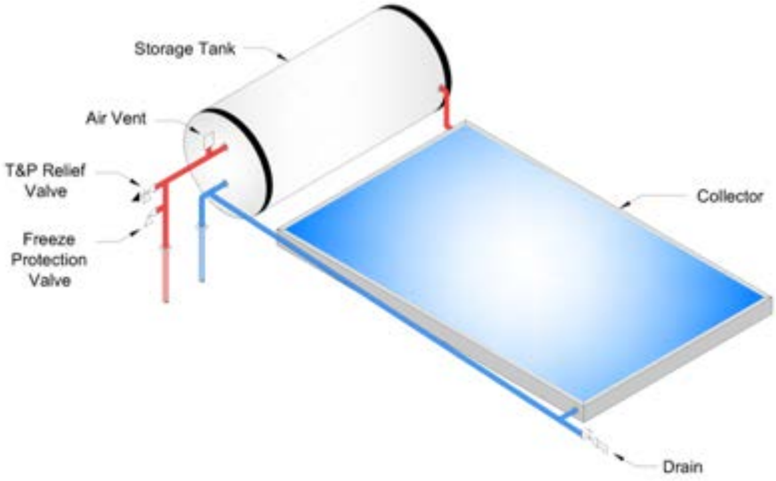


Figure 29 – Passive solar water heating system

Building Integrated Solar Heating – This approach uses dark-coloured, perforated metal panels (sometimes referred to as 'transpired solar collectors') mounted on the sun-facing sides of a building. When exposed to sun, air drawn through the perforations in these panels preheat fresh outdoor air drawn into a building to replace stale air exhausted from the building. This heated air is distributed throughout the building via its ventilation system or dedicated fans and ducting. For summer operation, a bypass is used to avoid heating the building.

The following is a schematic of how building integrated solar heating works:

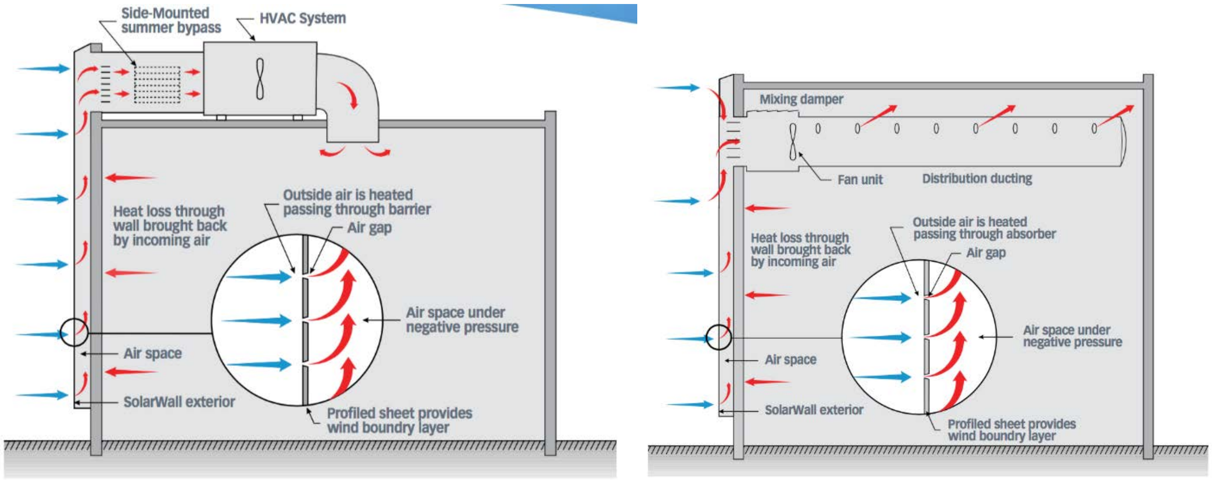


Figure 30 – Building integrated solar heating

Better known by the brand name 'Solarwall', this is a simple, cost-effective and low-risk renewable energy technology. It has also proven to perform well in cold climates with numerous working examples in Manitoba in commercial, institutional, industrial and apartment buildings.

Figure 31 – SolarWall integrated into a credit union building in Winnipeg

Solar Photovoltaic Electricity – A solar photovoltaic (PV) system converts light directly into electricity. A typical solar PV system consists of a solar array that consists of:

- PV panels composed of many PV modules and individual PV cells;
- an inverter, cabling and other electrical controls to convert the electricity from direct current (DC) to alternating current (AC); and
- hardware to support the solar array.

The solar array can be ground-mounted or installed on the roof or wall of a building or house. The array can be fixed or employ a tracking system (single or dual axis) to follow the daily and seasonal movement of the sun to boost the amount of electricity generated.

Most PV systems are connected to the electrical grid and feed surplus power into the grid. Because PV systems only generate power when the sun is shining, the addition of battery storage can be used to supply power at night.

PV-generated electricity is a reliable, mature technology. It has experienced rapid growth in recent years driven largely by changes in public policy, advances in technology and a steep decrease in cost. There are a growing number of successful examples of PV systems that have been installed in remote, northern communities.

Figure 32 – Example of ground-mounted solar PV array (Lutsel K’e Dene First Nation, NWT)

Discussion

Recommended solar technologies – Of the solar technologies described above, solar photovoltaic electricity and building integrated solar heating (‘SolarWall’) have the most potential for Northlands based on their cost-effectiveness and ability to perform reliably in cold climates.

Although very seasonal, Northlands has a reasonably good solar resource potential (see map below – Figure 33). Expanding the use of photovoltaics in the community beyond that already being installed through the ERAAES project now underway (see sub-section 2.4) as part of a broader, integrated renewable energy generation strategy is a viable option (see sub-section 6.1).

From a design perspective, building integrated solar heating is a good fit for northern, remote communities such as Northlands due to the frequent use of metal panel cladding. The feasibility of employing this technology should always be considered in the design process for new community buildings and for existing buildings undergoing a major renovation or recladding.

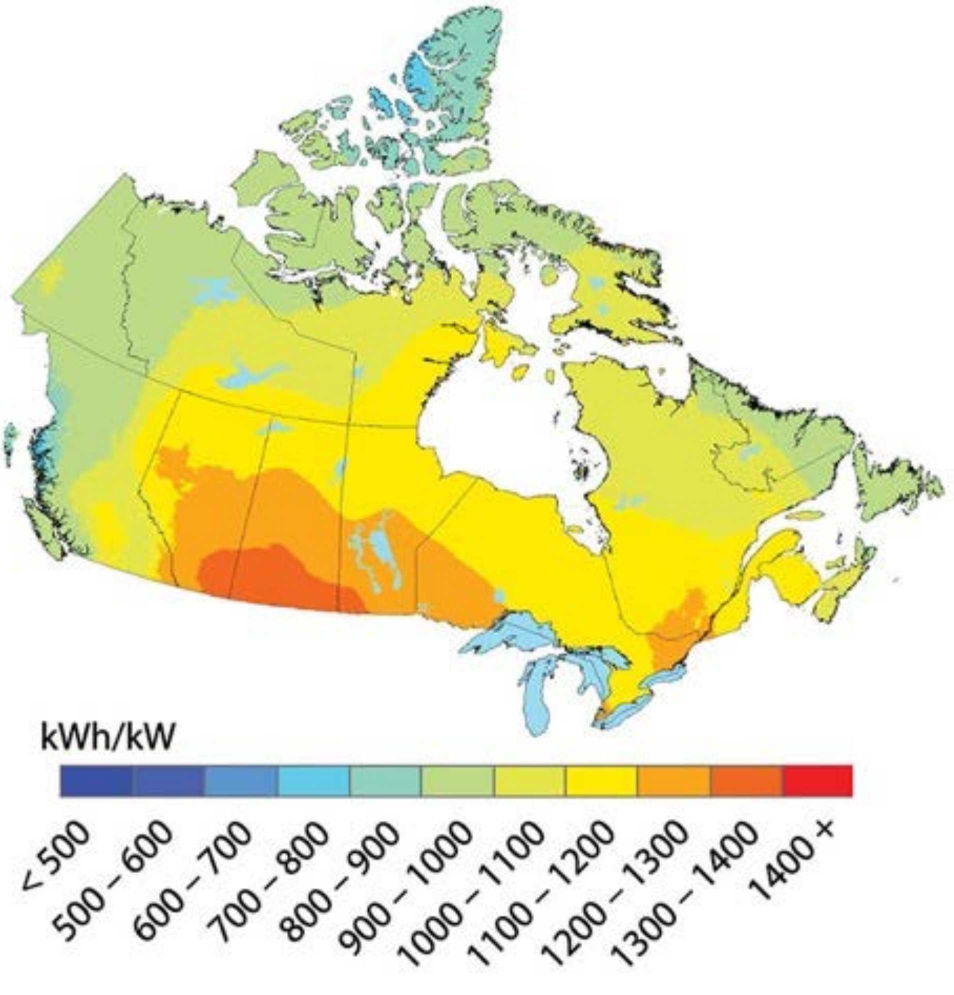


Figure 33 – Photovoltaic potential map for Canada

Technologies Not Recommended – The feasibility of using CSP to provide heat and electricity for remote, northern communities (such as Northlands) has been the subject of a research and demonstration project undertaken by the University of Manitoba in cooperation with Red River College (RRC) and funding from Manitoba Hydro and the Federal Government – see this link for more details.

This CSP project installed at RRC's main Winnipeg campus has encountered weather-related operating problems. Because of these difficulties, CSP has been judged by Aki's Team as a technology that is not yet sufficiently developed for cold climates. As a result, CSP has been eliminated for further consideration as part of a renewable energy strategy for Northlands.

Solar water heating is not recommended for deployment in Northlands due to maintenance, reliability and performance concerns in a harsh northern climate. A simpler, more cost-effective and robust approach to solar water heating for the community would be to install additional photovoltaic capacity coupled with electric water heaters.

Additional Information

Aki Team Reports – For more in-depth information about solar energy issues, options and analysis for Northlands, please refer to the following report produced by the Aki Team:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.

5.5 Geothermal Energy

Major Findings and Recommendations:

- *There is a lack of detailed data about the potential high and medium temperature geothermal resource that could potentially be tapped to generate electricity for Northlands. The limited data that exists for Northern Manitoba suggests a low potential.*
- *Given that there is a lack of working examples of geothermal energy systems in small, remote communities in Canada, this technology was eliminated for further analysis for the Northlands CEP.*
- *Low temperature geothermal heat pumps may be a viable technology for Northlands. Their technical and economic viability should be considered for new community buildings and housing developments in the community.*

Overview of Option

'Geothermal energy' is a renewable source of energy. It consists of two types: the constant flow of heat from the core of the earth to the surface and the energy of the sun that is stored near the surface of the earth on a seasonal basis.

Geothermal resources are broadly categorized into three types:
- High temperature (greater than 150° C)
- Medium temperature (80° C to 150° C)
- Low temperature (less than 80° C)

The temperature of a geothermal resource impacts both the technology needed to develop the resource and its potential use. These uses range from producing electricity to heating buildings, homes and hot water.

High and Medium Temperature Geothermal – The most common application of high and medium temperature geothermal resources is to produce electricity. Because the energy flow is constant, these types of geothermal energy systems can operate at a much higher capacity than solar or wind power which must wait for the sun shine or the wind to blow.

There are many examples of high and medium temperature geothermal power plants in the U.S. and elsewhere in the world. Despite having enormous geothermal energy resources, this technology has not been used in Canada.

Low Temperature Geothermal – Low temperature geothermal energy can either be used directly or in conjunction with a heat pump. In a typical direct application, geothermal water is used with a simple heat exchanger to provide space heating or water heating.

With heat pump systems, a fluid is circulated through a loop embedded either horizontally or vertically in the ground or placed in a body of water. The heat energy added to the circulating fluid is captured by the heat pump and used for space and water heating. The process can be reversed to provide cooling.

Discussion

The high and medium temperature resource in or near Northlands is uncertain. The limited mapping of heat flow measurements from the earth taken in Northern Manitoba indicate that this resource is at the low-end of the scale (see maps below – Figures 34 and 35.

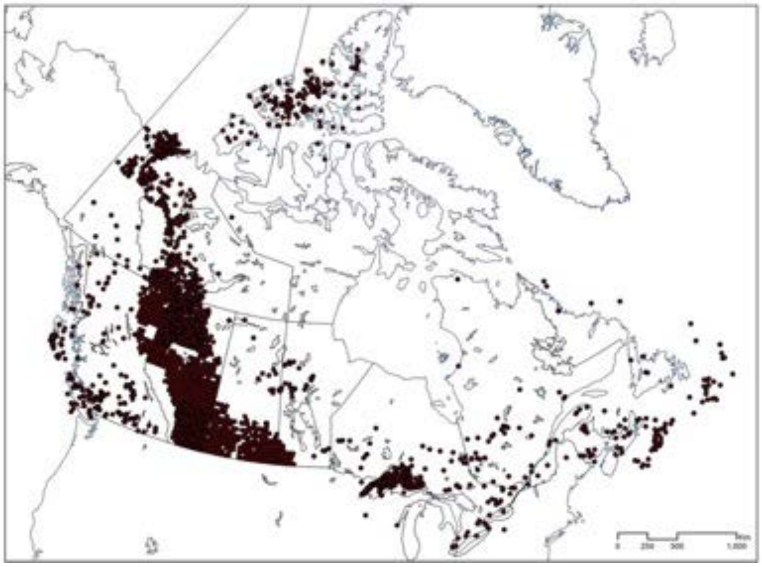


Figure 34 – Map of heat flow measurements across Canada

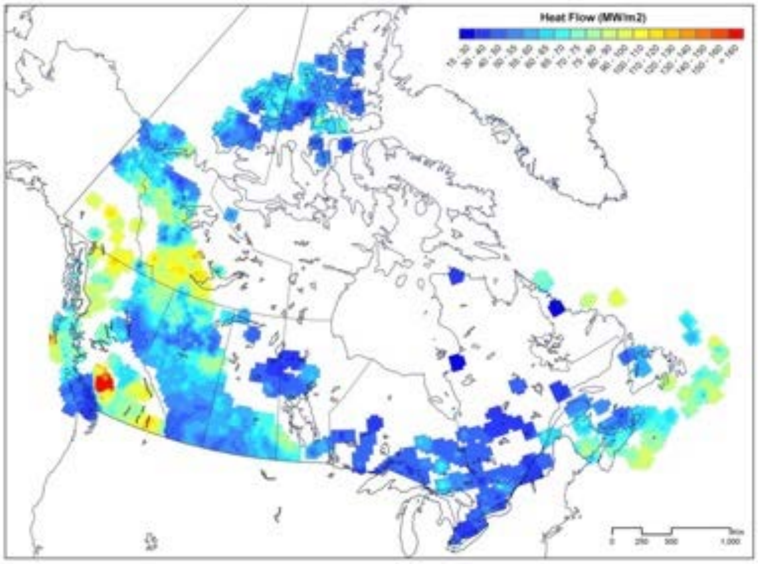


Figure 35 – Heat flow map of Canada

In contrast, low temperature geothermal resources have potential for Northlands using geothermal heat pumps (also called ‘ground source heat pumps’, ‘earth energy systems’ and ‘geoexchange energy systems’). These are a well-proven, mature technology. Aki has worked with several First Nations in Manitoba to develop successful geothermal heat programs for their communities.

Additional Information

Aki Team Reports – High and medium temperature geothermal energy did not pass an initial screening for consideration for the Northlands CEP. As result, the Aki Team did not produce a separate report on this technology.

As noted above, low temperature geothermal energy using heat pumps is a much more viable option for new and existing community buildings and housing in Northlands. See section 3.0 'Demand Side Management: Issues and Options' in this report for comments about this technology.

Further Reading – For more information about solar energy, including its application in northern, remote communities, here are suggested sources:

- *Geothermal Energy Resource Potential of Canada* published by the Geological Survey of Canada provides an in-depth review of geothermal resources in Canada, summary of previous research and priorities for further work to exploit this resource.
- *Ground Source Heat Pumps* by Natural Resources Canada. This online publication introduces how these systems work; their benefits; sizing, design and installation considerations; and provides information on maintenance, operating costs, life expectancy and warranties.

5.6 Biomass Energy

Major Findings and Recommendations:

- *A biomass-fueled Organic Rankine Cycle (ORC) generation system, when combined with photovoltaics, wind and battery-based energy storage, is projected to be the lowest cost scenario for Northlands to achieve 100% renewable energy penetration.*
- *There appear to be sufficient potential long-term supplies of wood for an ORC system in the community. However, this should be verified by a more in-depth analysis.*
- *Although a well-proven technology elsewhere, there is lack of operating experience with ORC systems in Canadian remote, northern communities like Northlands. This risk needs to be addressed.*

Overview of Options

Biomass is another of form of renewable energy. The term 'biomass energy' refers to use of wood or plant-based materials, either directly by burning or indirectly after first converting it to a biofuel, to produce heat, electricity and/or mechanical power.

Aki's analysis of biomass energy options for the Northlands CEP has focused on wood, the most abundant source of biomass readily available to the community. This analysis assumed that the wood is used with a specific technology ('Organic Rankine Cycle' or ORC) to generate both electricity and heat ('combined heat and power' or CHP).

The balance of this *Overview of Technology* sub-section provides a brief introduction to biomass CHP systems that use ORC technology. This background will enable non-technical readers to better understand Aki's major findings and recommendations about these technologies for Northlands.

Combined Heat and Power – CHP, often called 'cogeneration', is the process of generating electricity and useful heat from a power plant at the same time. The main advantage of CHP is efficiency. Some energy is rejected as waste heat in the production of electricity with a conventional power plant. However, with CHP a significant portion of this thermal energy is recovered and used.

Although small-scale biomass CHP systems are relatively rare in Canada, they are increasingly common in Europe where electricity prices are more expensive (see link to ORC World Map under 'Additional Information' below).

Organic Rankine Cycle Power Systems – An ORC power system continuously converts thermal energy (heat) into electricity. Unlike a conventional power plant which uses water (vaporized into steam) as a working fluid, an ORC system operates at low pressure and uses an organic fluid with a low boiling point. This enables it to use low temperature heat from many different sources, such as various forms of renewable energy (i.e., solar, geothermal, biomass) or waste heat from industrial or other processes, to produce electricity. ORC systems may also avoid the need to have an operator constantly in attendance.

Figure 36 – Example of Organic Rankine Cycle (ORC) power plant

Discussion

Wood Supply – There are two potential sources of supply of wood for either an ORC generation system in Northlands or a district heating system:

1. Local fire-killed trees that are still standing in forest burn areas near the community; and
2. Provincial Forestry Management Units (FMUs) located along the winter road system to the community and in the Lyn Lake area.

Based on provincial government and University of Manitoba reports, there appears to be abundant local sources of wood from fire burnt areas. There is also ample truck capacity and winter road duration to supply a full year's supply at a reasonable cost (projected to be $137 per tonne).

At present rates of electricity use and heating demand, it appears that there is a sufficient supply of wood near Northlands and the two other nearby First Nations at Brochet and Tadoule Lake to provide these communities 100% biomass electricity generation and heating for 50 to 200 years. However, a more in-depth analysis should be conducted to confirm whether local fire-burned trees are sufficient or whether additional wood will be required from the FMUs along the winter roads to Northlands and near Lynn Lake.

Reliability – Biomass-fueled ORC generation systems have proven reliable in many applications throughout Europe and North America. However, there isn't experience using these systems in northern off-grid, communities in Canada such as Northlands.

The perception that ORC generation is more complex than conventional diesel generation is partially correct. However, the risk of failure of this technology can be mitigated by a combination of:

- adequate training of local operation and maintenance personnel in Northlands;
- an appropriate maintenance contract with a reputable ORC equipment supplier; and
- leaving the existing Manitoba Hydro diesel generators in place as back-up with enough stored diesel fuel for one year of operation at 100% of the community load.

Integration with Other Renewables – A noted previously, Aki's Team conducted a prefeasibility analysis of several scenarios using different combinations and penetration levels of renewable energy systems (including biomass) to completely displace the use of diesel fuel in Northlands.

Highlights from this analysis related to biomass-fueled ORC generation system utilizing wood include the following:

- Six of the scenarios for 100% renewable energy penetration for the community include biomass-fueled ORC as the backbone for generating electricity for the community.
- The level of biomass-fueled ORC generation in these scenarios was high ranging from 88% to 100% of the community's annual electricity use.
- The lowest cost scenario over a 25-year planning horizon (Case 3) includes biomass-fueled ORC generation combined with photovoltaics, wind and battery storage.

For additional discussion of the 100% renewable energy penetration scenarios and their analysis, please refer to subsection '6.3 Integrating the Options - HOMER Pro Analysis'.

Additional Information

Aki Team Reports – For more in-depth information about solar energy issues, options and analysis for Northlands, please refer to the following report produced by the Aki Team:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.

Further Reading – For more information about solar energy, including its application in northern, remote communities, here are suggested sources:

- *Knowledge Center Organic Rankine Cycle is an information hub dedicated to the promotion of ORC technology.*
- *ORC World Map provides a searchable map of all organic cycle units installed throughout the world.*

6.0 Integrating Options

6.1 Energy Storage

Major Findings and Recommendations:

- *Integrating battery-based energy storage is a viable option to increase the penetration level of solar photovoltaic-generated electricity and wind power for Northlands. There are no technical barriers but the community's remote location will increase costs and make access to on-site technical support more challenging.*
- *Although costs are declining and the technology is improving, the high cost of battery energy storage limits the amount that can economically employed for the community.*
- *Of several renewable energy scenarios examined for Northlands, the analysis found that where intermittent renewable generation is present, a significant battery capacity must also be available, especially for solar.*

Overview of Options

This option would consist of integrating energy storage in the form of batteries to store electricity from renewable energy sources (i.e., solar photovoltaic and wind) to increase the amount of diesel-generated electricity they can displace in Northlands.

Discussion

There are a wide range of energy storage technologies. One of the most rapidly growing forms of energy storage is to use batteries (most often lithium ion) to increase the penetration level and value of renewable energy sources such as photovoltaic-generated electricity and wind power. This is accomplished by storing electricity to smooth out daily variations in production and power quality from renewables due to clouds or changes in wind speeds or to shift daytime energy production to night-time use.

Although costs continue to decline and the technology is improving, storing electricity with batteries, even at a utility-scale, remains a relatively expensive approach. As a result, it is important to take an integrated approach to renewables that minimizes the amount of battery storage that is required.

For Northlands, there are no major technical barriers to the use of battery-based energy storage to boost the penetration of renewable energy sources. The community's remote location will, however, increase the cost of their installation and require additional planning to ensure access to trained personnel for maintenance and troubleshooting.

Several scenarios were examined by the Aki Project Team with respect to the optimal balance of renewable energy supply and battery energy storage for Northlands (see sub-section 6.5). This analysis found that where intermittent renewable generation is present, a significant battery capacity must also be available, especially for solar. During the summer, there is a relatively large amount of solar energy available, but the electricity load is at its lowest and the excess solar energy cannot be stored very long.

Wind power is somewhat less a contributor to this effect because it can charge the battery at any time during the day and across all seasons. This connection between cost per kW of intermittent power and the necessary battery capacity tends to make all intermittent sources more expensive from an initial capital outlay perspective than would be expected in other regions.

Additional Information

Aki Team Reports – For more in-depth discuss about the role of battery energy storage for Northlands, please refer to these reports produced by the Aki Team:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.
- *Solar Storage Integration with Remote Diesel: Displacing Diesel Fuel with Renewable Solar Power (March 2017)* by Lumos Clean Energy Advisors.

6.2 Smart Micro-Grid

Major Findings and Recommendations:

- *Upgrading the conventional electrical grid in Northlands to a 'smart microgrid' is an essential part of a strategy to displace diesel-generated electricity with significant amounts of renewable energy while ensuring reliability and power quality.*
- *An additional benefit of a smart microgrid will be the ability to achieve a higher degree of energy efficiency and peak demand reduction than is possible with the community's existing conventional power grid.*

Overview of Options

This option would consist of converting the conventional electrical power in Northlands to a 'smart microgrid' through the addition of smart grid controller; replacement of conventional fixed-speed diesel generators with advanced variable speed units and power management controls; and smart energy meters for all home, buildings and facilities in the community.

Discussion

A 'smart microgrid' are part a profound change in the way that communities generate and use electrical energy. They are a small community-scale electrical power network that combines a variety of energy supply and advanced operational and control measures that enable the integration of high levels of renewable energy and achieve gains in energy efficiency and reducing peak demand.

This option would not only reduce overall energy use and peak electrical demand in Northlands, it is an essential element to enable the integration of a high degree of renewable energy generation and some battery-based energy storage while ensuring reliability and power quality in the community.

Over time, this smart microgrid would be enhanced as old household appliances and equipment in the community, especially water heaters, reach the end of their service life and are replaced with new, more efficient units that can communicate and potentially react to signals from the grid.

Additional Information

Aki Team Reports – For more in-depth discuss about a smart microgrid for Northlands, please refer to these reports produced by the Aki Team:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.
- *Solar Storage Integration with Remote Diesel: Displacing Diesel Fuel with Renewable Solar Power (March 2017)* by Lumos Clean Energy Advisors.

6.3 HOMER Pro Analysis

Major Findings and Recommendations:

- *Based on an prefeasibility analysis using HOMER Pro software, the most economic case was found to be a combination of using biomass in an Organic Rankine Cycle-generator along with modest amounts of solar photovoltaics, wind power and battery electric storage.*
- *This diverse combination of renewable energy supply options was deemed to likely be a preferred option from a community and environmental perspective.*
- *Given that the HOMER Pro prefeasibility analysis confirm that renewable electricity sources have good potential in Northlands, a full feasibility is recommended.*

Methodology

A prefeasibility analysis was conducted by the Aki Team on both energy supply and demand-side management considerations outlined in this report for Northlands. This analysis utilized HOMER Pro software to produce technically feasible electrical resource scenarios that are optimized for the lowest levelized cost of energy (LCOE) that be realized for the community.

The HOME analysis is based on a 25-year planning horizon. It accounts for hourly wind speeds and solar insolation values, along with 15-minute loads for the community's existing fixed-speed diesel generators plus equipment data to represent battery energy storage, Organic Rankine Cycle (ORC) electricity generation, and advanced variable-speed diesel generators.

The accuracy of the results from the HOMER Pro optimization process is related to the confidence level of the input of technical and cost data. In this analysis, in addition to data from manufacturer's equipment specifications plus data embedded in the HOMER Pro generation data library, a portion of input data had to be estimated to represent specific generation and/or storage devices. The Aki Team's HOMER Pro modellers have extensive experience in this area. We surmise that the LCOE values presented in this report are equivalent to a Class 4 or Class D level, with accuracy estimated to be between -30% to +50%.

Discussion

An overview of the mix of the energy supply options included in each of the nine scenarios examined with HOMER Pro is presented in Figure 37. The results of the projected capital and operating costs from HOMER Pro Analysis are presented in Figure 38.

For a 100% penetration of renewable electrical energy generation, the best economic combination was found to be Case 3 which included biomass (ORC), solar (PV), wind power and battery storage. Case 3 represents a diversity of renewable energy supply options and was deemed to be a preferred option from a community and environmental perspective.

It is important to note that the analysis projects that there is ample waste heat (200%) from the ORC to heat the entire community. The excess waste heat available can be used for additional uses including food security systems such as greenhouses, or additional economic development via a hotel and laundromat. This aspect of implementing a biomass power plant to replace the reliance on diesel fuel should be considered a strong decision point in the final determination of power options.

Overall, the HOMER Pro prefeasibility analysis shows that renewable electricity sources have good potential to be realizable in Northlands. It is therefore recommended that a full feasibility study be pursued for the electrical energy and associated heating options for the community.

Additional Information

Aki Team Reports – For more in-depth discussion about the HOMER Pro analysis results and resulting recommendations for Northlands, please refer to this report produced by the Aki Team:

- *Provision of Technical and Economic Studies for a 100% Renewable Penetration Scenario for Brochet, Lac Brochet and Tadoule Lake (May 30, 2017)* by Soft White 60.

Figure 37 – HOMER Analysis Scenarios

Scenario	Biomass (ORC)	Solar Photovoltaics	Wind	Battery Storage	Advanced Diesel (VSG)	Conventional Diesel (FSG)
100% Renewable Energy						
Case 1	●	●		●		
Case 2	●				●	
Case 3	●	●	●	●		
Case 4		●	●	●	●	
Case 5	●		●	●		
Case 6	●	●		●	●	
Case 7	●					

Diesel-Only						
Case 8					●	
Case 9						●

ORC – Organic Rankine Cycle
VSG – Variable-speed generators
FSG – Fixed-speed generators

Figure 38 – Projected Capital and Operating Costs from HOMER Analysis

Scenario	Capital Cost (millions)	Operating Cost (millions/year)	Life-Cycle Cost of Energy (¢/kWh)[1.]	Average Operating Cost (¢/kWh)[2.]
100% Renewable Energy				
Case 1 Biomass (ORC), Solar (PV), Batteries	$18.0	**$1.4**	58.9	29.6
Case 2 Biomass (ORC), Advanced Diesel	$14.0	$1.6	55.4	32.7
Case 3 Biomass (ORC), Solar (PV), Wind, Batteries	**$18.4**	**$1.4**	59.2	29.3
Case 4 Solar (PV), Wind, Batteries, Advanced Diesel	$12.1	$2.8	77.8	58.2
Case 5 Biomass (ORC), Wind, Batteries	$17.6	**$1.4**	57.4	**28.8**
Case 6 Biomass (ORC), Solar (PV), Batteries, Advanced Diesel	$14.7	$1.5	**55.2**	31.2
Case 7 Biomass (ORC)	$17.8	$1.5	60.4	31.5
Diesel Only				
Case 8 Advanced Diesel	$10.2	$3.4	87.9	71.4
Case 9 Conventional Diesel	**$8.8**	**$4.7**	**113.3**	**99.0**

Red bold text – highest cost
Green bold text – lowest cost
kWh – kilowatt hour

Notes:
1. Includes capital and operating costs.
2. Includes only operating costs.

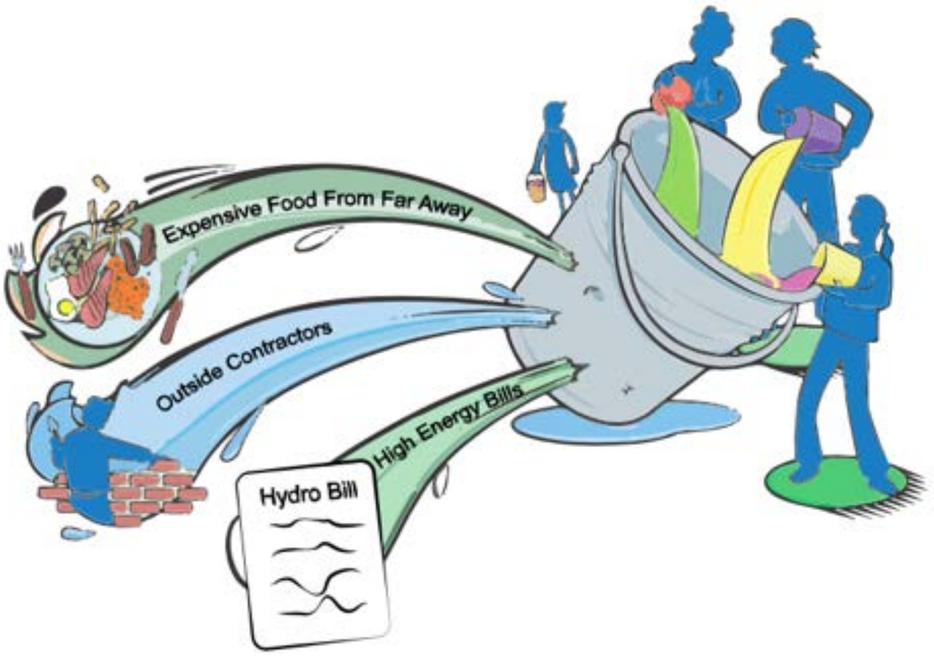
7.0 Kick Start a Northlands Sustainable Social Enterprise

7.1 Fixing the 'Leaky Bucket Economy'

Unemployment rates on First Nations, including Northlands, are much higher than in other Canadian communities. One of the main reasons is because most goods and services are brought into the community from outside, delivered by outside companies.

The concept of the 'leaky bucket economy' is a helpful guide (see Figure 39 below). Financial resources are being poured into this bucket from several sources (e.g., federally funded infrastructure projects, social assistance dollars, earned income, etc.).

Figure 39 – The 'Leaky Bucket Economy'



In most First Nations, the vast majority of this money flows right back out of the community, being used to hire outside consultants, contractors, to cover the cost of expensive diesel and food flown in from the south. The bucket leaks. Most of the financial resources that enters the community doesn't stay for long. Most of it flows south, chiefly benefitting people who are not Indigenous.

An example of this reality is the considerable strain that the high cost of energy places on the budget of the Northlands Dënesųłiné First Nation. The Band typically expends more than $3-million each year for non-renewable imported into the community (see Figure 40 below). This about $3,300 per capita (based on an on-reserve population of 929 persons reported by INAC as of July 2017).

Figure 40 – Utility Expenses for Northlands Dënesųłiné First Nation (Fiscal 2015-16)

Budget Area	Utility Expense
Governance and Administration	$1,027
Social Assistance	$557,132
Health	$306,983
Education	$1,705,042
Operations and Maintenance	$494,956
Other Programs	$6,054
TOTAL	**$3,071,194**

Source: Northlands Dënesųłiné First Nation Consolidated Financial Statements
March 31,2016

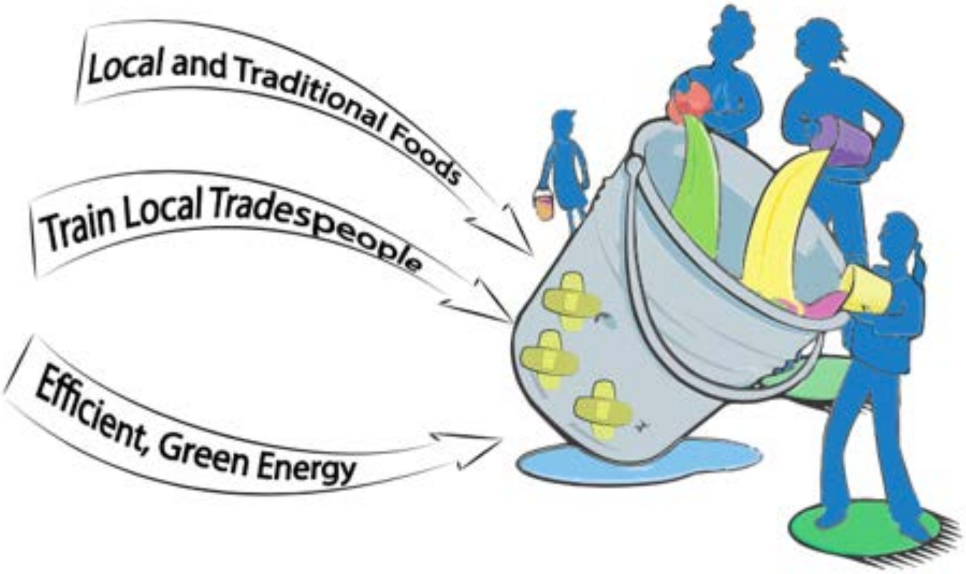
While these number reflects the high costs, they are understated because:

1. Manitoba Hydro is seeking to increase electricity rates by almost 50 per cent over the next five years. While diesel is used for electricity in Northlands, legislation requires that residential rates must be the same across the province.
2. Also, while it is not known what will happen with the cost of diesel in the immediate future, it is general knowledge that for every dollar spent on diesel for space heating, another dollar eventually spent on its cleanup.
3. Because practically all energy used in Northlands is imported. People who might otherwise be working using local options to meet the community's energy needs, are unemployed. This increases social assistance rates and other poverty-related costs.

Plugging the Leaks – To create prosperous communities, it is essential to begin to plug some of the holes in the bucket. This happens when communities take steps to replace outside consultants, contractors, and goods and services with local resources. When this happens, money is kept circulating in the local economy, building local wealth and prosperity.

Investments in energy efficiency and renewable energy in First Nations have the potential to create significant long term local employment and local economic development.

Figure 41 – Plugging leaks in the Northlands local economy



The first step to achieving this is to ensure that First Nation members have the training to install and then maintain local energy systems recommended in this report such as insulation, wind power, biomass, geothermal and solar.

Aki Energy and its First Nation partners have already installed over $7-million of geothermal energy at 350 homes on five different First Nations. All labour required for these retrofits was completed by First Nation members. Aki has developed a strong training strategy that means First Nation members are most qualified to do the installations but also the maintenance and trouble shooting.

The standard capital project model employed by Indigenous and Northern Affairs Canada makes it difficult for First Nations to capitalize on projects to create local training and employment opportunities. When capital projects go out to tender, First Nations rarely have the capacity to bid competitively against large, experienced contractors. When large contracting companies take on projects in Northern communities, they bring in experienced labour from the south. Where local sourcing requirements exist, they are often met in superficial ways, with no meaningful skills transfer to local community members. While this approach may make sense in some scenarios where work is highly technical, both energy efficiency retrofits and some elements of renewable energy development provide opportunities for job creation and local business development.

The second and more transformative step is to change the relationship between INAC and the First Nation so that a Band-owned and operated social enterprise is selling renewable heat and power to the Federal government rather than the Federal government paying outside companies to import energy from the outside.

Social enterprises are non-profit businesses. Governments all over the world are realizing the benefits of working with social enterprises because, in addition to providing goods and services at market rates, they can be set up to hire people with barriers to employment. This in turn reduces costs in other areas such as social assistance, policing, and court related costs.

Scotland decided 10 years ago to change it procurement practises so that social enterprises would be providing more goods and services. Every public tender issued in Scotland either must be negotiated with a social enterprise or include a community benefit clause. As a result, there are now 5,200 social enterprises there and 45 percent of these hire people with barriers to employment.

In Manitoba, Manitoba Housing hires social enterprises to do now over $6 million a year in trades based work. This makes sense to them because these social enterprises (including BUILD, Manitoba Green Retrofit, New Directions, Brandon Neighbourhood Development Corporation, and the North End Community Development Corporation) hire their tenants.

Social Enterprise for Community Development – A Social Enterprise is a modern business with Indigenous principles. Social Enterprises are more than just making money – it is about creating positive outcomes for the communities they operate in, and taking care of the planet.

Unlike a traditional business where the primary goal is to create profit for shareholders, a social enterprise has a 'triple bottom line' – people, planet and profit. This business model uses economic good sense to find solutions to problems such as poverty, high food prices, or building a healthier environment for future generations. This strategy provides several proposals looking at how to create business capacity and local training and employment opportunities through the sustainable development goals and objectives outlined in this document.

7.2 Creating Economic Development Through Smart Energy Investments

INAC can take a similar approach with social enterprises to ensure people living on First Nations can have access to work installing renewable energy and energy efficiency systems and then use these skills to springboard into other sectors such as HVAC, carpentry or plumbing, or to do work in other First Nations as the need for these services present themselves.

Residential and commercial energy efficiency upgrades are also labour intensive, highly repetitive and most aspects of the retrofit require a relatively low skill level to complete. Many of the skills gained performing energy efficiency upgrades are highly transferrable to the broader trades sector. Because of this, investments in energy efficiency upgrades provide an excellent opportunity to train and employ local tradespeople, creating local employment and economic development opportunities.

As will be shown in this report, there are plenty of local energy options that, over time, can eliminate the need for diesel usage in Northlands. Using local energy, rather than importing energy, is not a new concept in Northlands. As recently as the mid-90s, First Nations in Northern Manitoba heated their homes primarily with wood stoves, gathering wood from locally available sources. In contrast to diesel fuel, using wood for heat created local employment and income generation opportunities for anyone able to harvest wood to sell by the cord at the Band office or supply to meet their personal needs.

While we are not advocating a return to inefficient wood stoves for heat, this example demonstrates the shift that has occurred from using locally available resources which create employment and keeps wealth in the community, to energy sources that facilitate the transfer of large sums of money from First Nations to large energy companies while creating few or no local jobs and significant environmental damage.

In addition to the direct jobs created by training local installers to complete energy efficiency retrofits, there are indirect economic benefits resulting from household and community building energy bill reductions. These reductions will result in additional income available to households and the Band to spend on other priorities, resulting in positive multiplier impacts throughout the local economy.

Reduced energy use also means that residential and commercial consumers throughout the community are less vulnerable to rapid, significant increases in energy prices.

Like energy efficiency, smart investments in renewable energy creates opportunities to both reduce energy costs in First Nations communities and create local employment. ‘Renewable energy’ is a broad term that encompasses many different types of sustainable energy sources, many of which are discussed in this report. Solar energy, solar thermal (i.e., hot water heating), geothermal, biomass energy and wind are all examples of renewable energy sources.

While almost all renewable energy sources discussed in this report have the potential to create short-term employment opportunities when the system is installed, this section focusses on biomass energy, one of the major long-term job creation opportunities discussed in this report.

Until 1994, Manitoba’s off-grid First Nations relied on wood for heat. The required wood was harvested from the local environment for personal use, or sold by the cord at the Band Office, creating a source of income for people in the community. Modern day biomass systems are significantly more efficient and cleaner than traditional wood stoves. A single district biomass energy system could create heat for an entire community, connecting to households through a system of underground pipes and modern equipment can make it easier to harvest enough wood to meet the community’s needs. Biomass harvesting is low skilled and labour intensive, and flexible enough to be accessible to people who are looking for employment that accommodates traditional land use activities such as hunting and fishing, other seasonal employment or family commitments.

Business development opportunity – The implementation of the recommendations made in this report provide a significant business development and local employment creation opportunity. Energy efficiency retrofits on all cost effective residential and commercial buildings in the community would create multi-year employment for local construction crews. Permanent employment positions could be created operating and maintaining renewable energy systems, as well as harvesting local biomass energy sources.

Northlands Dënesųłiné First Nation has decided that it is in its own interests to establish its own social enterprise that would take the responsibility for:

a) Residential energy retrofits
b) Commercial energy retrofits
c) Operation and maintenance of renewable energy systems
d) Biomass wood harvesting and processing (where applicable)

In addition, the social enterprise would engage in:

e) Partnering with existing educational institutes such as Red River College, or non-profits training institutes such as BUILD Inc. to train local workers with the skills needed.
f) Negotiate the price for this heat with entities currently paying for that heat (school, nursing station, RCMP buildings, etc.
g) Collect the payments for supplying the heat.
h) Dedicate surpluses to expanding the renewable energy systems eventually to all buildings on the First Nation.
i) Create and maintain operating reserves from its revenues.
j) Provide routine maintenance and repair on renewable energy systems in the community.

We recommend that the firm be a social enterprise to make explicit that the goals are to maximize benefit to the community. The social enterprise can be operated as a partnership with INAC and outside resources can be hired when expertise is required. Goals of the social enterprise could would:

- Maximize the local benefit of money spent on heat
- Maximize local jobs.
- Maximize local economic development.
- Minimize and eventually eliminate the use of petroleum fuels.

As a revenue source, the energy management aspect of the company could have current purchasers of diesel enter into heating supply contracts with the company as a supplier of heat from renewable sources. While people not familiar with this approach may feel it is risky, it can be set up so that the social enterprise is compensated only for delivering the renewable heat. In this way, it is very accountable and transparent.

Aside from managing the harvesting and processing of biomass for wood heat, which would provide long term employment to community members, constructing and operating the renewable energy systems and implementing energy efficiencies represent significant opportunities for local jobs, and for economic and community development at Northlands. This can also be done below current diesel costs.

Much of the required work may initially need to be led by installers with expertise in renewable energy and energy efficiency installation. However, an essential provision of their contract needs to be a requirement to provide training and employment to local people.

Long term business development – In creating a local social enterprise responsible for building and maintaining renewable energy and energy efficiency systems, this project would be one of the first of its kind in Canada.

In addition to multi-year employment creation building and maintaining renewable energy systems, harvesting biomass and conducting energy efficiency retrofits on community buildings and households, there is room for continued business development providing training and services to other off-grid communities in the region.

Access to financing/equity – There are financial advantages to launching a social enterprise. Recent years have seen the development of a significant market in ethical investing, with investors interested in supporting and seeking financial returns through investments in companies whose work benefits communities and the environment. These investors will often provide patient capital, or capital with below market rates of return. There are investment funds specifically interested in developing and investing in Indigenous-owned social enterprise. These financing dollars are available if governments agree to pay investors back out of the savings (in this case utility bill reductions) that they are enjoying.

Access to grant funding – Incorporation as a social enterprise also allows opportunities for grant funding to support business expansion and initial capital investments in equipment and training. Social enterprises such as BUILD also require training dollars to support their employees. These dollars usually come in the form of government funding as training such as driver's licensing, trades-based tutoring, and financial literacy are not things that regular contractors offer. The best training approaches also include parenting, financial literacy, and access to Elders and cultural ceremonies.

7.3 Business Development Support

Aki Energy is an Indigenous, non-profit social enterprise that works with First Nations to support sustainable economic development. Aki Energy provides on-the-ground training and business development support to help communities build business, create local jobs and prosperity. Aki Energy can partner with Northlands Dënesųłiné First Nation to ensure success.

Aki Energy provides business development support in the form of mentoring and organizational capacity building including:

1. Administration management training
2. Financial management training
3. Project management training

Aki Energy can also offer trades training and support such as:

1. Energy efficiency installation training
2. Renewable energy system installation and maintenance training
3. Construction site management

Aki Energy has significant experience in working with First Nations to build create local jobs and build local businesses in the sustainable energy sector. To date, we have worked with six Manitoba First Nations to support the development of local renewable energy installation companies. After partnering with Aki Energy, Fisher River Builders from Fisher River Cree Nation are now some of the largest geothermal energy installers in Western Canada.

INAC can support Northlands to set up its own social enterprise and then to pay that social enterprise for delivering renewable heat and power at rates that they were going to pay anyway. The cost of providing this support would be $500,000 over five years with costs declining over time to be nil at the end of year 5. It would be recommended that INAC work with Northlands to determine how this money can best be spent to ensure the long-term sustainability of the social enterprise.

8.0 Recommended Next Steps

This section outlines the recommended next steps to finalize the Northlands Community Energy Plan, engage external stakeholders to support the CEP, and begin its implementation.

8.1 Step One – Complete Community Consultation

In addition to consultations that have recently occurred between representatives from Aki's Project Team, the Chief and Band Council, it is recommended that a further face-to-face meeting also occur in Northlands with community members. The purpose of this community meeting would be to:

- share a high-level overview of the energy supply and demand-side management options and issues presented in this report; and
- determine what is the community's preferred path and priorities that should be reflected in the Northlands Community Energy Plan.

Of importance will be gain a better understanding of how aggressively the community wants to be in its transition away from its reliance on diesel-generated electricity and heating oil that has begun with the ERAAES Project now underway.

8.2 Step Two – Finalize and Approve Community Energy Plan

Using feedback already received from the Chief and Council, plus the additional input from the community as described in Step One, a revised version of this report will be produced by Aki. Assuming this plan is acceptable to the Chief and Council, it is recommended that it be formally adopted as an extension of the Northlands Dënesųłiné First Nation Sustainable Development Strategy through a Band Council Resolution.

8.3 Step Three – Engage Support from Other Stakeholders

Implementation of the Northlands Community Energy Plan will require engaging key external stakeholders and gain their support, especially INAC, Manitoba Hydro and CMHC. Some adjustments to the CEP will likely be needed to reflect the discussions and negotiations with these stakeholders.

8.4 Step Four – Build Capacity to Maximize Community Benefits

A priority should be to begin building capacity through training and other measures as outlined in Section 7.0 of this report to maximize the benefits of the community economic and social benefits of the CEP. The momentum that has begun with the ERAAS Project should be sustained with other projects, such as the retrofitting of existing houses and buildings in the community, that can be quickly implemented.

8.5 Step Five – Track Progress and Update Plan

Finally, it will be important for the community's leadership to track progress in implementing the Community Energy Plan and communicating its progress with community members and external stakeholders. A commitment should also be made to periodically review and update the plan to adapt to changing circumstances, new information from any feasibility studies undertaken and opportunities that emerge.

Appendix A – Aki Project Team and Contact Details

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Appendix B – Energy related goals and objectives from Northlands Sustainable Development Strategy

Goals

Goal 1: Energy efficiency- The most cost effective way to reduce diesel usage is to reduce the amount of energy consumed. This is called energy efficiency.

Community value: "Self-reliance"

We can measure improvements in local heat energy in these ways:

- A decrease in the consumption of all sources of energy per capita

Goal 2: Local energy for space heating - Northlands First Nation has been completely dependent upon diesel fuel imported on the winter road for heating its buildings. There are potential sustainable alternatives of heat energy from local biomass and geothermal sources. *Community value: "Self-reliance"*

We can measure improvements in local heat energy in these ways:

- A decrease in percentage of diesel fuel used for space heating purposes

Goal 3: Local electrical energy - Northlands First Nation is currently dependent upon the Manitoba Hydro diesel generating plant for all of its electricity. There are potential alternative sources of electrical energy in the area from solar, wind, and run-of-river hydro. *Community value: "Self-reliance"*

We can measure improvements in local electrical energy in these ways:

- Increase in the proportion of electricity supplied from renewable energy sources

Objectives

- Develop a district biomass heat system, using wood sourced locally from within 25 kilometers of the community. There is an abundance of burnt wood resulting from forest fires. A design plan is currently under development (completed July 2016) to use biomass energy to heat the Petit Casimir Memorial School and as a complementary back-up heat source for the lakeside building cluster.

- Future project opportunities could include the expansion of the biomass district system design to heat additional residential and community buildings in the community.
- Develop a district geothermal heating system. A design plan is currently under development (completed July 2016) to use geothermal energy as the primary source of heat and cooling for the lakeside building cluster.
- Improve heating efficiency in public and private buildings through
    - Insulation and building envelope retrofit
    - Building energy management (e.g. heating system optimization)
- Developing renewable electrical energy resources to replace diesel for electricity
    - Solar photovoltaic (PV)
    - Wind turbine on the Big Hill
    - Run-of-river hydro
- Investigate ways to capture waste heat from diesel generation (Manitoba Hydro generating station), or the ice plant at the arena. This waste heat could be used to heat a greenhouse or nearby buildings.
- Improve energy efficiency of lighting within public buildings
- Improve energy efficiency of home appliances such as wash machines and refrigerators.

Appendix C – Summary of Energy Supply Recommendations

Imported, Non-Renewable Energy Options

Option	Include in Community Energy Plan?	Capital Cost [1]	Operating Cost [2]	Reliability [3]	Environmental Benefits [4]	Community Benefits [5]
SaskPower Electrical Grid Connection	✘	●	○	⦿	○	⦿
Natural Gas Service	✘	●	○	●	⦿	⦿
LNG or Propane Service	✘	⦿	●	⦿	⦿	○
Conventional Diesel (FSG)	✘	⦿	●	●	○	○
Advanced Diesel (VSG)	✔	⦿	⦿	⦿	⦿	⦿
Waste Oil Heating	✔	○	○	●	●	●

✔ – Yes
✘ – No

VSG – Variable-speed generators
FSG – Fixed-speed generators

● – High
⦿ – Medium
○ – Low

Notes:

1. Refers to capital cost per peak kW and annual kWh generation capacity relative to other options listed in table.
2. Includes annual cost of fuel supply and maintenance costs per kW and kWh relative to other options listed in table.
3. Based on subjective assessment of option's reliability specific to operating in a remote, northern community such as Northlands.
4. Relative to base case (i.e., conventional, fixed-speed diesel generation). Includes avoidance of negative impacts on residents, land, water and wildlife from transportation and storage of fuel; reductions in greenhouse gas emissions; and avoidance of other emissions that may negatively impact the local air quality in the community.
5. Includes reduction in energy costs plus opportunities for community ownership and creation of local employment in construction, operation and maintenance.

Local, Clean Renewable Energy Options

Option	Include in Community Energy Plan?	Capital Cost[1]	Operating Cost[2]	Reliability[3]	Environmental Benefits[4]	Community Benefits[5]
Manitoba Hydro Electrical Grid Connection	✘	●	○	●	●	●
Small-Scale Hydro	✘	●	○	⦿	●	●
Biomass (ORC)	✔	⦿	⦿	⦿	●	●
Solar	✔ Photovoltaics ✔ Solar Air Heating ✔ Passive Solar ✘ Concentrating Solar ✘ Solar Hot Water	● ○ ○ ● ●	○ ○ ○ ○ ○	● ● ● ○ ○	● ● ● ● ●	⦿ ⦿ ⦿ ⦿ ⦿
Wind	✔	●	○	⦿	●	⦿
Geothermal	✔ Low temperature (GSHPs) ✘ High/medium temperature (electricity generation)	⦿ ●	○ ○	● ●	● ●	● ⦿

✔ – Yes

✘ – No

ORC – Organic Rankine Cycle

GSHPs – Ground Source Heat Pumps

● – High

⦿ – Medium

○ – Low

Notes:

1. Refers to capital cost per peak kW and annual kWh generation capacity relative to other options listed in table.
2. Includes annual cost of fuel supply and maintenance costs per kW and kWh relative to other options listed in table.
3. Based on subjective assessment of each option's reliability specific to operating in a remote, northern community such as Northlands.
4. Relative to base case (i.e., conventional, fixed-speed diesel generation). Includes avoidance of negative impacts on residents, land, water and wildlife from transportation
   and storage of fuel; reductions in greenhouse gas emissions; and avoidance of other emissions that may negatively impact the local air quality in the community.
5. Includes reduction in energy costs plus opportunities for community ownership and creation of local employment in construction, operation and maintenance.

Northlands Denesuline First Nations
Building Energy Assessment Audits

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April 7, 2017

Final Draft

Limits of Liability

The information and opinions expressed in this report are prepared for the benefit of AKI ENERGY, for the sole purpose of evaluating the energy savings and cost avoidance estimates of the projects identified herein. No other party may use or rely upon the report or any portion thereof without the express written consent of Demand Side Energy Consultants Inc. (DSE). DSE accepts no responsibility for the accuracy of the report to parties other than AKI Energy. The material contained in this report reflects the best judgment of DSE in light of the information available at the time of preparation. Inaccurate, incorrect or invalid information supplied to us for the purpose of preparing this report may affect the findings, statements or conclusions expressed herein, for which DSE cannot be held responsible.

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NORTHLANDS NON-RESIDENTIAL BUILDING SUMMARY

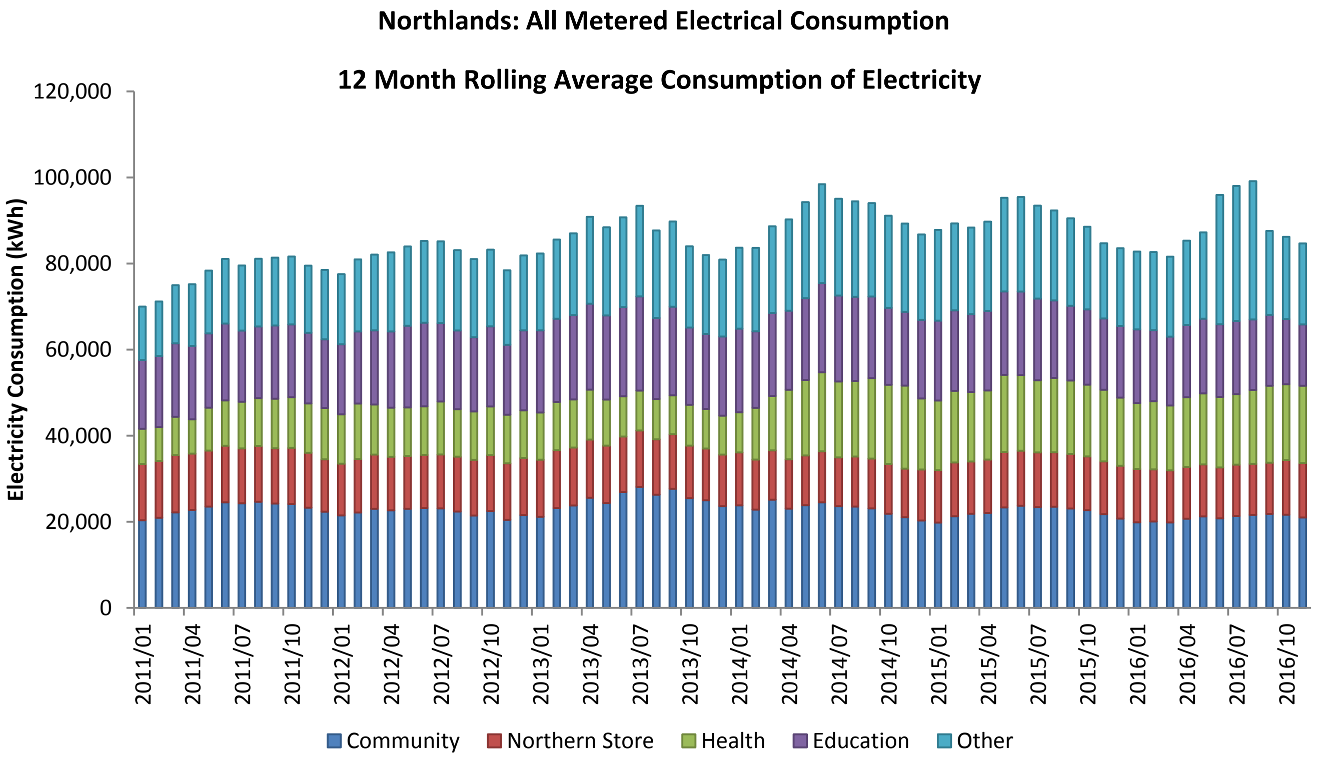
Demand Side Energy Consultants Inc. (Demand Side Energy) was retained by Aki Energy Inc. (Aki Energy) to provide a review of energy use, energy cost and cost avoidance opportunities for the Northlands Denesuline First Nation's (Northlands) non-residential buildings as a technical contribution to the development of a strategic and collaborative Community Energy Plan (CEP) among Aki Energy, three individual First Nations and communities served by Manitoba Hydro's generator stations (Brochet Metis Community) and Indigenous and Northern Affairs Canada (INAC).

The purpose of this CEP is to:

- Identify and prioritize measures to reduce the community's reliance on fossil fuels
- Improve the energy efficiency and reduce greenhouse gas emissions of existing buildings
- Characterize the contribution of the non-residential buildings to Hydro's peak electrical demand,
- Expand the community's long-term use of local renewable energy resources; and
- Identify water efficiency and conservation measures in community buildings.

To undertake this assignment a summary of facility energy and water audits were undertaken. This involved a community site visit to review facilities of interest, as well as an analysis of potential energy savings associated with energy conservation and building Heating Ventilation and Air Conditioning (HVAC) upgrades. Lighting systems were also assessed for their technical application, capital cost, and financial return to the community.

In 2006, Demand Side Energy conducted walkthrough energy audits for Northlands community buildings as part of the Aboriginal and Northern Community Action Plan (ANCAP) program. This previous effort informed the selection of buildings for verification audits by confirming the building use, energy use changes and equipment changes since the 2006 audit effort. These references allowed for a 10-year snapshot of the energy use at the building level and has provided added value to identify the impact of existing building energy performance in comparison to any newly constructed buildings (since 2006).



Northlands: All Metered Electrical Consumption

12 Month Rolling Average Consumption of Electricity

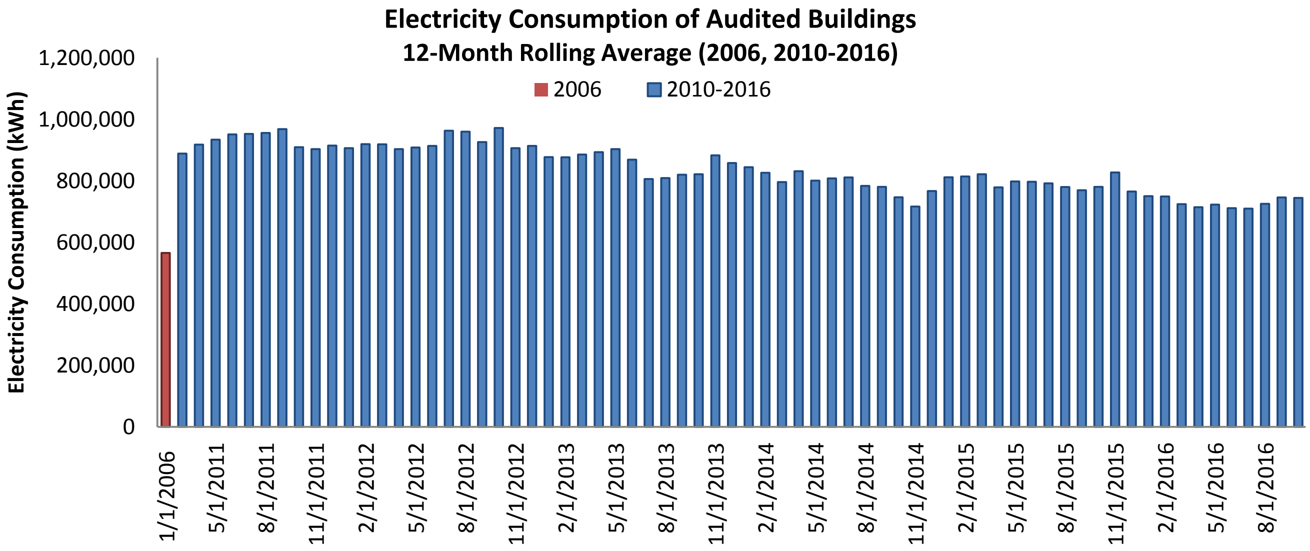
The study was conducted in three parts:

1. Conduct a utility analysis of the electricity purchases using Manitoba Hydro billing data and oil delivery estimates for the community and identify buildings of interest.
2. Select buildings for a site walkthrough to further identify energy service requirements and provide an ASHRAE Level 1 summary report which identifies energy conservation measures, and;
3. From the selected buildings, identify two large energy consumers for a more detailed ASHRAE Level 2 energy audits that identify specific energy projects for capital project considerations.

Building Name	Floor Area (m^2)	Electricity (kWh/yr)	Fuel Oil (l/yr)	Propane (l/yr)	Cost $/yr	BEPI (ekWh/m^2)	GHG (tCO$_2$e)
Petit Casimir Memorial School	2,602	244,441	93,751		$712,848	481.03	445
Water Treatment Plant	129	101,675	3,688		$38,302	1,096.95	87
Arena	2,257	95,760	10,537		$43,027	92.57	102
New Sewage Plant	31	20,273		1,581	$4,021	1,003.72	18
New Garage & Band Garage	627	12,726	14,752		$17,018	272.94	50
New Band Hall	446	10,392	8,429		$10,360	226.32	31
Northern Store	664	198,600	1,791		$11,591	328.08	156
Daycare	160	53,567	2,529		$3,350	504.61	48
Total	**6,917**	**737,434**	**135,477**	**1,581**	**$840,518**	**4,006**	**937**

Twelve (12) buildings were identified for walkthroughs and eight (8) of these facilities were selected for energy and water audits, which were performed from January 10th-13th, 2017. This report provides energy use and savings for six (6) of those facilities (shown above). The facilities were given preference if they a) were present in the 2006 audit, b) had sufficient energy data, and c) had reliable meter identification. Difficulties in matching meters with buildings along with partial oil delivery data were the predominant limiting factors. 2016 fuel consumption was estimated from i) partially available fuel oil delivery data, ii) references to the 2006 audits, and iii) an energy model of buildings loads and 2015-2016 weather.

When comparing the above buildings to the relevant 2006 data it was found that overall energy use has increased by 24% (565,390 kWh to 701,265 kWh). The graph below shows the changes in the aggregated energy consumption of the selected buildings from 2006 and 2016.



Each building is described in more detail in Appendix **D: Building Audits**.

Records from Manitoba Hydro were obtained for a full six (6) years: 2010 to 2016, inclusive. This data was used to generate the chart below, which is a 12-month rolling average for the ten year period. 2006 data was included for comparison purposes, and one can see a rise in electricity in 2010 that has slowly been reducing since. It should be noted that data was partial in many respects and efforts were made to cleanse the data of inconsistencies and provide a more accurate and robust representation of the facility energy consumption. A description of the data cleansing methodology is included in **Appendix A: Demand Energy Assessment**.

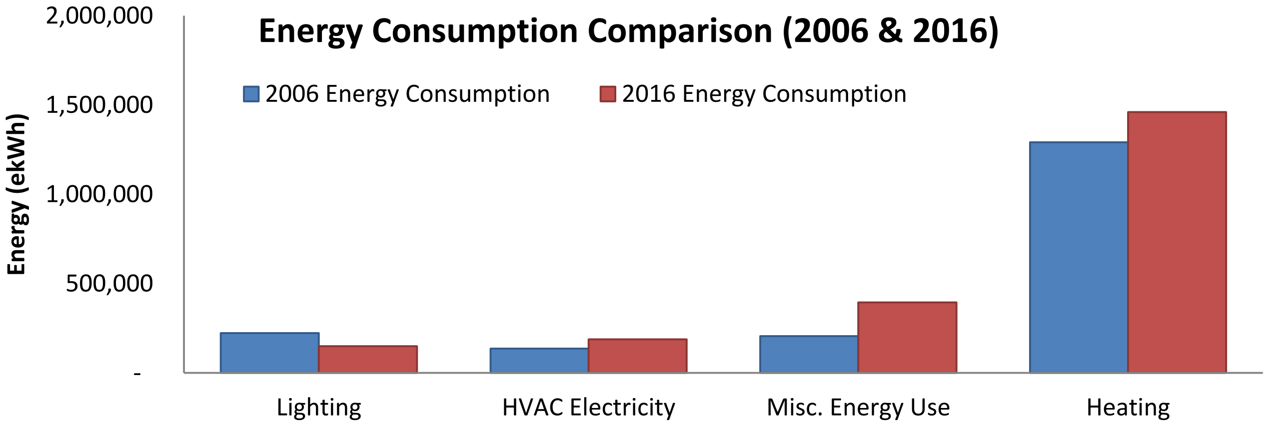
The community visit provided the opportunity to depict each building's heating ventilating and air conditioning (HVAC) system; operating and maintenance practices and equipment and envelope condition. The utility bills were provided to validate building energy use and energy intensities, though, as stated previously, they had to be augmented to reflect monthly consumption.

A typical community building's end uses for this level of walkthrough included: lighting, heating (building heating and ventilation air heating), HVAC electricity for fans and pumps, and miscellaneous electricity which was used to characterize other end uses ranging from computer labs in schools to process pumping for water treatment.

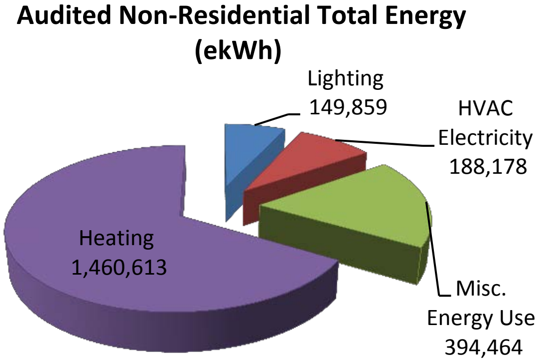
The chart below illustrates the energy profiles of six (6) out of the eight (8) facilities audited. The Waste Water Treatment Plant and Sewage Plant have been excluded since their loads are process loads.

Building Name	Floor Area (m^2)	Electricity (kWh/yr)	Fuel Oil (l/yr)	Cost $/yr	BEPI (ekWh/m²)	GHG (tCO_2e)
Petit Casimir Memorial School	2,602	244,441	93,751	$712,848	481.03	445
Arena	2,257	95,760	10,537	$43,027	92.57	102
New Garage & Band Garage	627	12,726	14,752	$17,018	272.94	50
New Band Hall	446	10,392	8,429	$10,360	226.32	31
Northern Store	664	198,600	1,791	$11,591	328.08	156
Daycare	160	53,567	2,529	$3,350	504.61	48
Total	**6,757**	**615,486**	**131,789**	**$789,195**	**1,906**	**831**

From the estimate of building energy end uses, a series of energy saving opportunities were reviewed. These energy saving opportunities reflect technology replacement opportunities, and the technologies have been chosen to reflect the building's energy rates.



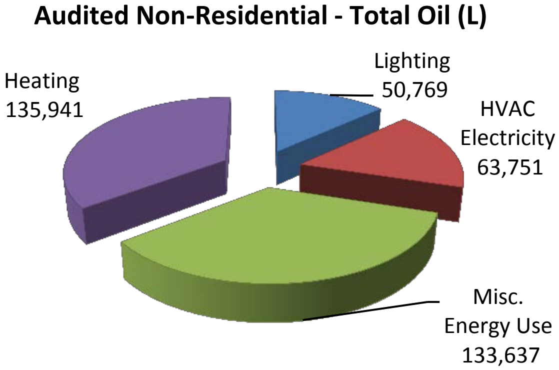
Northlands First Nation non-residential buildings are billed at the General Service Diesel (GSD) rate of 8.33¢/kWh for the first 2,000 kilowatt hours (kWh), and 42.6¢/kWh for every kilowatt hour over 2,000/month. This higher run off rate of 42.6¢/kWh provides a significant incentive to conserve energy.



Based on a technology bundle and operational opportunities a 20% reduction in energy use is estimated for the buildings that were audited.

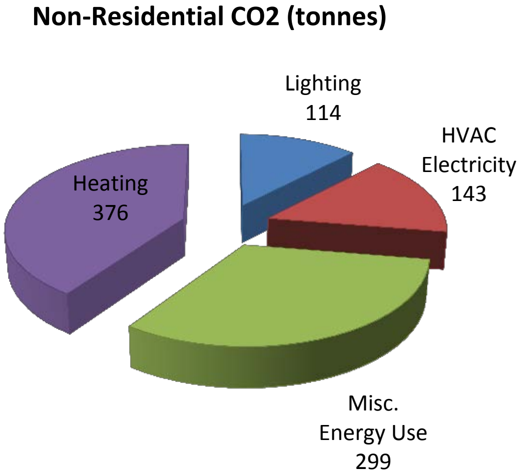
The audited building energy has been expressed in both total energy which includes electricity and fuel oil which has been converted into equivalent kilowatt-hours (ekWh), as well as in total fuel oil which includes electricity consumption generated by fuel oil in litres (L). These demarcations were made in order to show the carbon content of the respective energy sources.

Fuel oil calculations, below, were derived by taking the diesel generator fuel efficiencies (3.64 kWh/L) and applying that to the electrical loads. The generator efficiencies were provided by Manitoba Hydro.



The largest single energy use is building heating and ventilating comprising 79% of the total energy purchases. Building insulation levels are good and reflect the minimum insulation values recommended by Manitoba Hydro at the time of construction (R50 roof and R20 nominal walls). Building weather sealing is generally good with door weather stripping being a significant area of on-going maintenance.

Heating energy is segmented into heat loss though the building envelope and ventilation heating which is energy required to provide fresh outdoor air to the building occupants. Some smaller air systems employ heat recovery units to pre-heat the fresh air with out-going exhaust air. The schools are not equipped with heat recovery, although they represent the largest ventilation systems.



Lighting is predominately T8 with electronic ballasts and 32 Watt tubes. High-bay installations are a mix of T8 fluorescent fixtures and metal halide fixtures in the arena, gymnasiums. Exterior lighting is primarily high pressure sodium, and metal halide wall pack units.

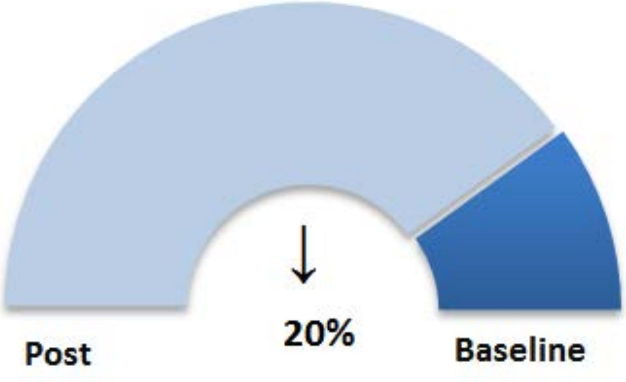
The HVAC end use savings include the fan and pump energy associated with delivering heating ventilating and air conditioning services to a building and approximately 11% of the energy savings are the result of modifying building equipment operating schedules and set points.

Individual building findings are provided in the Appendix, but for the purpose of providing a discussion on the scope of savings, the saving descriptions are provided on the overleaf.

Energy Conservation Measures

The savings presented in this energy audit survey are achievable based on energy performance project experience. Whether the projects are economic depends, in part, on the implementation strategy, financing options for capital projects and in some cases implementation strategies. Taking advantage of mid-life maintenance deferral or end of life replacement costs will reduce the costs associated with incremental energy efficiency costs.

The energy savings measures should be reviewed as a bundle of activities whose aggregate benefit is a 20% reduction or $55,274 annual reduction in energy and project cost is in the order of $47,253, providing the community with energy savings that offset the building energy improvement costs. The projects that are part of this bundled investment are summarized below.



Selected Energy Retrofit Measures	Est. kWh/yr	Est. ekWh/yr	Avoided Cost/yr	Est. Cost ($)	Payback (years)
HVAC Retro-commissioning for Petit Casimir	-	11,016	$3,150	$1,500	0.5
Increase Roof Insulation from R-40 to R-60	-	20,896	$2,043	$31,429	8.9
Improve weather sealing of windows and doors	-	8,265	$808	$960	1.2
Installation of Smart Meters	-	51,066	$4,992	$3,000	0.6
Install HRV timers/controls	7,087		$2,977	$5,000	1.1
Replace line thermostats with programmable units	1,871	23,831	$3,116	$3,834	1.2
CO_2 Monitoring & Demand Ventilation	14,199	35,420	$9,426	$2,880	(0.1)
Fluorescent to LED Retrofits	11,367	(4,035)	$4,380	$2,250	0.3
Metal Halide & High Pressure Sodium to LED Retrofits	48,001	-	$20,161	$1,400	0.1
Install lighting occupancy sensors	10,726	(2,895)	$4,222	$2,250	0.4
Total Estimated Project Benefits and Costs	**93,252**	**143,563**	**$55,274**	**$54,503**	**1**

Appendix B: Conservation Measures Summary provides the breakdown of recommended projects per building and further identifies the high-yield buildings and measures. The projects recommended for pre-design are briefly described below:

Heating Energy Savings

1. Retro-commission Petit Casimir's HVAC and control systems

   HVAC savings consider fan energy and pump operations that are in the building HVAC systems. Retro-commissioning efforts will decrease the fan and pump energy associated with the large air handling and the heating system pumps in Petit Casirmir. Retro-commissioning measures that reduce the amount of fresh air and/or reduce the on-time schedule of equipment will result in reduced fan and pump energy as well. Additionally the smaller heat recovery ventilators (HRVs) used in various buildings operate continuously and can be scheduled to operate for the occupied hours of the building and an addition al 10% of time for building freshen. In most cases this would save more than 50% of the operating time and energy of these units. Approximately 11,016 ekWh of fuel oil per year in energy avoidance is predicted at a cost of $1,500 and a payback of 0.5 years.

2. Increase attic insulation to R60.

   Community buildings are generally well insulated (nominal R20 walls and R40 roof), however the addition of insulation may remain economic for the attic roofs. An increase to R60 – the new code requirement – will reduce heating energy by 20,896 kWh/yr.

   A program to improve the insulation levels of the community roofs with an additional R20 insulation would cost the approximately $31,429 and insulate approximately 2,057m² of attic. With an incentive of $13,280 the payback would be 9 years.

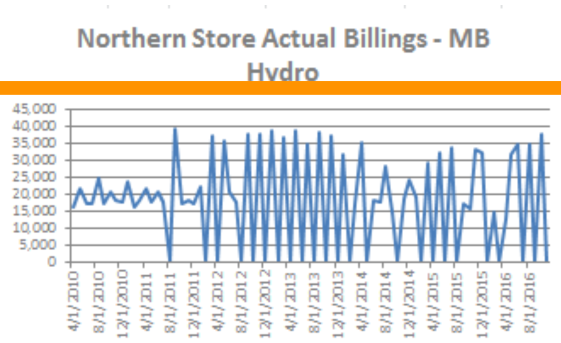
3. Improve weather sealing around doors and windows – employ vestibules in schools

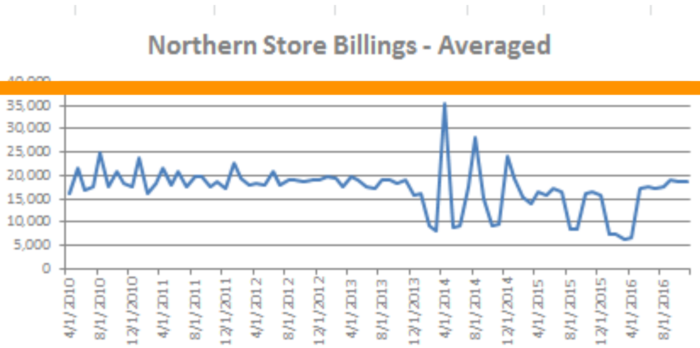
   Another opportunity for heating reduction includes improving the building weather sealing and weather stripping. This is a maintenance issue and it is evident that the community buildings are being maintained. Other measures to reduce air infiltration would involve re-hanging school exterior doors, re-installing school vestibule doors. The building with the most significant issue is the bus garage which requires service to all overhead doors. This building is unable to maintain indoor temperatures above freezing for most of the winter.

   Based on reducing air change rates due to infiltration, repairing windows and doors and weather sealing projects a reduction in air leakage energy is estimated at 8,265 per year at cost of $960 providing a 1.2 year payback.

4. Install Smart Meter Technology with Smart Metering Systems

   As stated above, one of the limiting factors to obtaining accurate metering data was a lack of reliable meter readings. Smart Meters and Smart Meter Systems are effective means to improving reliability of energy metering and promoting energy efficiency. The accuracy of Smart Meters, both in development and practice, has been confirmed to improve on the older electro-mechanical meter technology by providing: better access and data to manage energy use, more accurate and timely billing as well as power quality data.





The graphs above show both the actual billings for the arena, as well as the 'corrected' billings. In both cases there appears to be noticeable fluctuations in energy consumption, and a true representation of the arena's monthly operations is not presented in either rendering. As such, unreliable energy metering results in unreliable energy management: for example, it makes it difficult to determine from the data whether any of the spikes in consumption are due to an actual event on site, or are the result of meter adjustments. Smart Meters would eliminate these uncertainties and produce energy savings for all sites metered in that fashion.

Smart meters enable the reception of more timely information about energy consumption. Feedback tools allow users to better monitor energy use. Savings result from the ability to more effectively manage energy consumption. Savings vary, but 15% is typical, or 51,066 kWh/year. Meters cost $500 a piece.

HVAC Energy Savings

5. *Install HRV timers/controls to reduce operating time of units*

HRVs are operated on a continuous basis and the recommendation is to schedule them with an operations timer to coincide with occupancy hours, with an additional 1 hour of pre-ventilation to freshen the spaces before occupancy. Energy savings from the fan operation and the ventilation air heating are estimated at 10,957 kWh/year at an estimated cost of $4,600 resulting in an estimated less than one year payback.

6. *CO_2 Monitoring & Demand Ventilation*

Sensing carbon dioxide (CO_2) level as a means to reflect space occupancy is the most common technique to trim the volume of fresh air. The system currently in place, for most other buildings, simply approximates the volume of fresh air by controlling the mixed temperature of the fresh / return air, resulting in too little fresh air for floors of high density and more than required for those of lower density.

Demand ventilation tailors the volume of fresh air to the demand of the space to shave the energy required to pre-condition outside air. This greatly reduces the heating or cooling load during periods of low occupancy like the start / end of the day, on weekends, and holidays. It can also serve to safely trim the peak ventilation demand to a more reasonable level of 20 cfm per person. Savings are predicted to be 49,619 ekWh/year with less than one year payback.

7. *Replace thermostats with programmable units featuring electronic temperature control.*

Higher quality thermostats are available that can be programmed for temperature setback (small buildings only) and provide more comfort to occupants because these units maintain the space temperature more consistently. The overall impact is a predicted 25,702 ekWh/year avoided consumption with an estimated capital cost of $935 and a 1.2 year payback

Lighting Energy Savings

8. *Install lower wattage T8 Fluorescent Tubes on a burnout basis – community wide.*

   Indoor lighting energy use is an important energy user and a special note regarding lighting efficiency and building heating requirements must be taken into consideration. In northern climates, indoor lighting contributes to building heating and while more efficient light sources reduces the cost of lighting, the contribution of lighting energy to space heating is also reduced. This interactive effect of lighting and heating energy results in only 33% of estimated lighting energy savings being achieved when additional heat requirements are factored into the building energy requirement. This is a key consideration in the payback calculation and results in higher payback periods for interior lighting improvements. The most significant lighting technology improvement is to reduce the wattage of the fluorescent fixtures to 18W LEDs from 32 watt T8s on a burnout basis.

   Light level readings were taken in all facilities and the levels range from 650-800 lux, or somewhat higher than required. These light levels are typical of T-12 lighting to T8 conversions and a 18W LED replacement tube may be installed in place of the 32W tubes currently used on site. Avoided energy is estimated at 48,001 ekWh/year with an estimated cost to convert the lighting on a burnout or incremental cost basis of $2,250 providing a payback of less than a year.

9. *Metal Halide & High Pressure Sodium to LED Retrofits*

   High Bay interior lighting is provided by 450W Metal Halides – these are present in the school gyms and the arena ice rink. The majority of energy savings is available in the arena where the lower wattage lighting system will reduce the load on the arena ice rink. T5's offer significantly better colour reduction and will instantly turn on allowing the rink to reduce lighting levels between events.

   Outdoor lighting is generally provided with metal halide wall pack units, and these are prime candidates for replacement with LED units. LED lighting provides excellent colour and light cut-off performance. A well selected unit can improve the light levels while reducing stray lighting in the community. Additionally, improved lighting has been demonstrated to reduce crimes such as vandalism as the increased visibility deters potential offenders by increasing the risks that they will be recognized or interrupted in the course of their activities. Relatedly, lighting improvements may encourage increased street usage which could increase the likelihood of criminal deterrence while also providing a safer environment and provide a more positive image of the area through increased investment.

   Based on 2000 hours per year of operation the metal halide replacement fixtures will avoid approximately 48,001 kWh/year or $20,161 per year at an installed cost of $1,400 providing a simple payback less than a year.

10. *Install lighting occupancy sensors in offices and meeting rooms*

    Lighting is most significant in the schools and the classrooms employ two level lighting making occupancy sensor use somewhat more expensive. Offices and meeting rooms are also identified as candidates for motion and daylighting sensors where applicable. Energy savings for lighting in these areas is estimated at 30%, however with the heating consideration for interior lighting payback periods are not as attractive. A savings estimate is 7,831 ekWh/year at a cost of $4,222 and payback of less than a year.

Appendix A: Demand Energy Assessment

Northlands Energy Demand Assessment

When compiling a community energy study, a decision is made as to which data is included in the community's energy consumption. For the purposes of this study, it was decided that all buildings constructed within the reserve's boundaries would be included.

The data for the community energy demand assessment was collected using a variety of methods.

- Community building information was collected by Alex Fleming, who toured the largest energy-consuming buildings on the reserve to examine building heating and air handling, water heating, and building construction. Fuel oil delivery data was unavailable, so fuel oil use was estimated based on existing archetypes and on the capacity of the community tank farms.

- Electricity records from Manitoba Hydro were also obtained from January 1, 2010 to November 31, 2016.

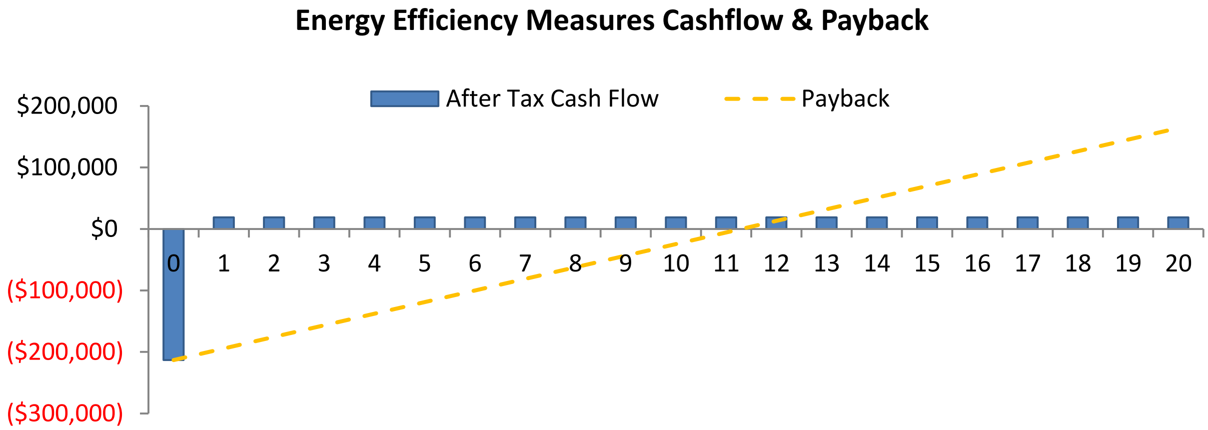
Community maps were obtained to ensure that the full set of data was collected for the community; however, housing lists were unavailable, so fuel type use for individual houses was estimated based on the community surveys, and on observations in the community. Available data was extrapolated to fill data gaps in the baseline analysis.

The extrapolation was performed by interpolating between two available meter readings (there were instances where data was missing for three months). The energy consumption during the period in question was averaged across the days in the consumption period, and then multiplied by the days in the billing period.

Appendix B: Conservation Measures Saving Sheets

Below is a description of the Energy Conservation Measures (ECMs). ECMs are the measures that were derived from the Level One energy audits performed on six (6) buildings. The buildings included: the Band Hall, the Northern Store, Daycare, Garage & Band Garage, the Water Treatment Plant, and Sewage Plant. These buildings were chosen for the Level One audits because they were representative of the community's operations.

System	Measure	Elec Savings (kWh)	Fuel Oil (litres)	Savings (ekWh)	Water Savings (m³)	GHG Savings (tCO2e)	Incentive	Payback
Heating	Roof Insulation	-	1,946	20,896		5.38	$13,280	8
	Weather Sealing	-	770	8,265		2.13		1
	Smart Metering/MT&R	-	4,755	51,066		13.14		1
HVAC	Programmable Thermostats	1,871	2,219	25,702		7.47		-
	Demand Ventilation	5,166	-	5,166		3.70		2
Lighting	Fluorescent to LED Conversion	4,495	-	4,495		3.22	$3,074	-
	MH & HPS to LED Conversion	4,420	(244)	1,798		2.49	$1,211	2
	Occupancy Sensors	4,641	(240)	2,063		2.66	$750	1
Water	6lpf toilets to 4.8 lpf				122			4
Total		20,594	9,204	119,450	122	40	$18,315	11.3

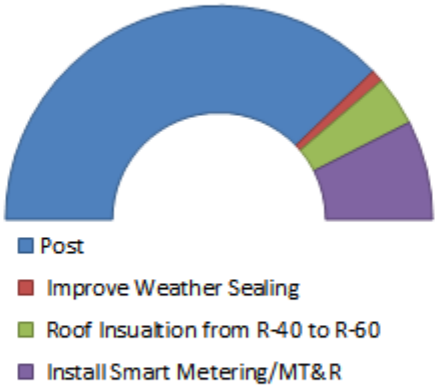

Energy Efficiency Measures Cashflow & Payback

The Level One audits segmented the audited building's systems into four (4) broad categories: heating, ventilation, lighting, and electrical equipment: each contains their own end uses.

Heating includes the end uses that utilize the building's heating systems which predominately rely on fuel oil. **Ventilation** includes the electrical use of the building's heating, ventilation and air conditioning (HVAC) systems. Dividing the heating system's energy consumption into fuel oil and electrical use enables the audit to more accurately identify energy savings across fuel types. **Lighting** includes the building's interior and exterior lighting systems and also included any lighting controls, such as occupancy sensors, if present. **Electrical equipment** included any electrical appliances that operate in the buildings: these included computers, kitchen appliances and office appliances.

These four categories act as general boundaries for the ECMs, and they are briefly described below:

Heading Energy Savings



1. *Improve weather sealing*

   Another opportunity for heating reduction includes improving the building weather sealing and weather stripping. Based on reducing air change rates due to infiltration, such projects would save 770 litres of fuel oil/year (8,265 ekWh).

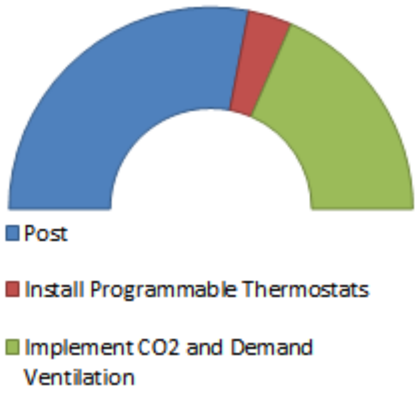
2. *Roof Insulation from R-40 to R-60*

   Community buildings are generally well insulated (nominal R20 walls and R40 roof), however the addition of insulation remains economic for the attic roofs. An increase to R60 will reduce heating energy by 1,946 litres of fuel oil/year (20,896 ekWh).

3. *Install Smart Metering/Monitor Tracking and Reporting (MT&R)*

   Smart meters enable the reception of more timely information about energy consumption. Feedback tools allow users to better monitor energy use. Typically, 15% savings result from the ability to more effectively manage energy consumption, which would be 4,755 litres of fuel oil/year (51,066 ekWh).

Ventilation Savings



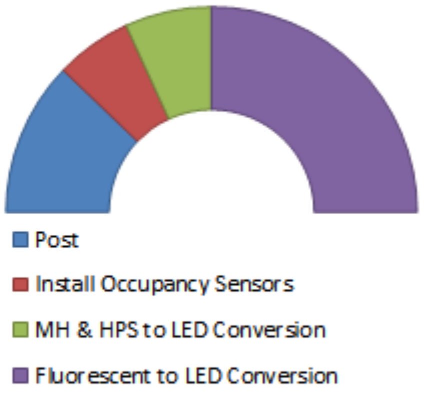
4. *Implement CO_2 Monitoring & Demand Ventilation*

   Sensing carbon dioxide (CO_2) level as a means to reflect space occupancy is the most common technique to trim the volume of fresh air. Such implementation would result in saving 5,166 kWh/yr.

5. *Install programmable thermostats*

   Higher quality thermostats are available that can be programmed for temperature setback (small buildings only) and provide more comfort to occupants because these units maintain the space temperature more consistently. The overall impact is a predicted 25,702 kWh/year in savings

Lighting Energy Savings



6. *Install lighting occupancy sensors in offices and meeting rooms*

   Offices and meeting rooms are also identified as candidates for motion and daylighting sensors where applicable. Energy savings for lighting in these areas is estimated at 30%, however with the heating consideration for interior lighting payback periods are not as attractive. An estimated savings 4,461 kWh/year.

7. *Metal Halide & High Pressure Sodium to LED Retrofits*

   Exterior perimeter lighting is provided by metal halides and high pressure sodium fixtures. These are candidates for a full LED replacement. Such a replacement would result in 4,420 kWh/year.

8. *Install lower wattage T8 Fluorescent Tubes*

   The most significant lighting technology improvement is to reduce the wattage of the fluorescent fixtures to 18W LEDs from 32 watt T8s resulting in savings of 16,237 kWh/year.

Level One and Level Two Energy Conservation Measures are described in more detail below.

Lighting Retrofit

Convert Exterior Lighting to LEDs

Measure description:

✓ **Recommended Retrofit Action**

For Information Only

Interior lighting is predominately provided by T8 fluorescent fixtures, though some T12 lamps are being utilized in areas.

LED lighting technology is quickly maturing, and most recently, 18W LED units are replacing 32W and/or 28W bulbs during maintenance or failure. Application of 18W linear LED units will lower electricity demand and energy consumption.

Retrofits of T8 fluorescents can be staged to coincide with a facility refit as T8s reach their end-of-service life, or when bulbs fail. It is, however, recommended to complete the whole facility to avoid illumination gradients.

Replacing the high-pressure sodium and/or metal halides with LED equivalents are also a recommended retrofit.

Utility:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

Calculations:

Est. load (watts) = # bulbs x watts per tube x # fixtures

Est. Energy (kWh) =(Est. load (Watts) ÷ 1000) x Est. Operating Hours

Energy Avoided = Energy use base case – Energy use proposed case

Savings Summary:

The hours of use for each area above are assumed to be the same before and after retrofit. The budget costs assume installation by facility personnel (net zero).

Incentives available through the Manitoba Hydro Commercial Lighting Program are estimated, and based on publically available Manitoba Hydro information; however, final incentive amount is to be determined by a Manitoba Hydro engineer.

	Electricity (kWh)	**Fuel Oil (ekWh)**
Savings (ekWh)	59,368	(4,035)
Cost avoidance ($)	$24,935	($394)

GHG reduction (t eCO$_2$)	41

Estimated Retrofit Cost ($)	$6,480
MBHydro Rebate ($)	$$5,191
Net Payback (years)	**1**

Install Occupancy Sensors and Dimming Controls on Interior Lighting

Measure description

Occupancy sensors can be ceiling mounted, centrally controlled or integrated into light switches, and are ideal for washrooms, classrooms, storage rooms, and board rooms. Up to 35% in energy and cost avoidance is estimated by implementing this technology; however, with the heating consideration for interior lighting payback periods are not as attractive.

✓ **Recommended Retrofit Action**

For Information Only

Utility Prices

Electrical Consumption price (blended)	0.42$^{¢}$/kWh
Fuel Oil price	$1.0000 /Litre

Assumptions:

- Occupancy sensors can be functionally installed on lighting circuits.
- Occupancy sensors will reduce lighting energy consumption by up to 35%.

Calculation for avoided consumption:

$$Est. Lighting\ Load\ \frac{W}{ft^2} \times\ Area \times (Current\ Op\ Hours - Proposed\ Op\ Hours) = Est. Savings$$

	Current	*Proposed*
Load (W/ft^2)	0.8	0.8
Annual Op. Hours	3,000	2,800
Annual Consumption (kWh)	74,520	69,552

Savings & Calculations

	Electricity (kWh)	**Fuel Oil (ekWh)**
Savings (ekWh)	10,726	(2,895)
Cost avoidance ($)	$4,505	($283)

GHG reduction (t eCO_2)	7

Estimated Retrofit Cost ($)	$2,250
MBHydro Rebate ($)	$750
Net Payback (years)	**0.4**

HVAC System

Thermostat Temperature Setback

✓ **Recommended Retrofit**

For Information Only

Measure description:

Buildings are typically occupied during daytime hours only, leaving it vacant for 70% of the week. While updating and recommissioning the control system, install and program settings which will allow the space temperature to drop when the building is unoccupied. Many control systems have the capability to program an optimum start sequence that allows the system to anticipate the amount of time it will take for the building to heat up to the desired temperature before the building's scheduled occupancy. A modest setback of 5ºF during unoccupied hours will significantly reduce the heating load on the building's HVAC equipment. Modifications to the setback timer could be used in conjunction with occupancy sensors to adjust the setpoint when areas are occupied beyond regular hours.

Assumptions:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

Current Practice

Description	**Hours**
Temperature setpoint of 73ºF	*24/7*

Proposed Practice

Description	**Hours**
Temperature setpoint of 73ºF	*8:00-16:00*
Temperature setpoint of 65ºF	*16:00-8:00*

Savings Summary:

Setting back operating temperature during unoccupied periods will greatly reduce the load for space heating. The building control system should be upgraded regardless of temperature setback.

	Electricity (kWh)	**Fuel Oil (ekWh)**
Savings (ekWh)	1,871	23,831
Cost avoidance ($)	$786	$2,330

GHG reduction (t eCO_2)	7

Estimated Retrofit Cost ($)	$935
MBHydro Rebate ($)	-
Net Payback (years)	**0.3**

Implement Demand Control Ventilation (CO2 Sensors)

Measure description:

✓ **Recommended Retrofit Action**

For Information Only

In areas such as conference rooms, or social halls, where the number of occupants varies significantly with time, it is possible to control ventilation based on the number of occupants. Typical mixed air systems bring-in certain amounts of fresh air based on temperature controls, no matter the occupancy needs. With a demand based ventilation system, fresh air volumes are controlled based on occupancy. As the number of occupants in an area increases, so does the amount of fresh air to that area.

Utility Prices:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

Assumptions:

	Current	Proposed
Fresh air	25%	variable
HVAC Hours	2920	2340

Summary:

	Electricity (kWh)	Fuel Oil (ekWh)
Savings (ekWh)	14,199	35,420
Cost avoidance ($)	$5,964	$3,463

GHG reduction (t eCO_2)	**19**

Estimated Retrofit Cost ($)	$3,834
MBHydro Rebate ($)	-
Net Payback (years)	**0.4**

Schedule Heat Recovery Ventilation

Measure description:

✓ **Recommended Retrofit Action**

For Information Only

Newer buildings have sophisticated energy control systems and modern equipment such as heat recovery ventilators and variable frequency drives. Some of the heat recovery ventilators (HRVs) used in various buildings operate continuously and can be scheduled to operate for the occupied hours of the building and an additional 10% of time for building freshen. In most cases this would save more than 60% of the operating time and energy of these units.

The proper maintenance and operation of this equipment should be reviewed regularly to both increase serviceable life and to avoid higher operating costs due to failure of components or increased system operating hours.

Utility Prices:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

Assumptions:

	Current	Proposed
Fresh air	25%	variable
HVAC Hours (wk)	168	50

Summary:

	Electricity (kWh)	Fuel Oil (ekWh)
Savings (ekWh)	10,953	-
Cost avoidance ($)	$4,600	-

GHG reduction (t eCO_2)	8

Estimated Retrofit Cost ($)	-
MBHydro Rebate ($)	-
Net Payback (years)	-

Envelope Measures

Roof Insulation Upgrade

✓ **Recommended Retrofit**

For Information Only

Measure description:

Consider improving the roof's insulation value to R-60 during re-roofing. Although not a good business case on its own, the incremental cost of insulating while re-roofing, including incentives from Manitoba Hydro, will have a payback of less than 20 years in most cases.

Assumptions:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

Current Practice

Description	
Roof insulation	*R-40*

Proposed Practice

Description	
Roof insulation	*R-60*

Calculation to determine annual avoided heating energy:

$$Q = U \times A \times \Delta T$$

$$Where\ U = \frac{1}{Rvalue}$$

$$Q\ Saved = \frac{A \times \Delta T}{Rvalue\ proposed - Rvalue\ current}$$

$$\boldsymbol{Incentive = [R - value\ added\ (Proposed - Existing)] \times roof\ area\ (ft^2)\ \times 3.0¢}$$

Savings Summary:

Increasing insulation levels on the roof will decrease heat loss through the building envelope and will lower the requirement for space heating.

	Electricity (kWh)	**Fuel Oil (ekWh)**
Savings (ekWh)	-	20,896
Cost avoidance ($)	-	$2,043

GHG reduction (t eCO_2)	5

Estimated Retrofit Cost ($)	$31,429
MBHydro Rebate ($)	$13,280
Net Payback (years)	**8.9**

Weather-stripping Maintenance & Window Replacement:

Measure description:

✓ **Recommended Retrofit**

For Information Only

Weather-stripping of doors and windows and sealing vents and dampers is very important for several reasons. A tightly sealed vent, door or windows will allow less cold air to enter a building, fresh air will enter a building only through controlled means, such as the air handling system, and it is easier to maintain propper static pressure control. In winter, poorely sealed dampers, door and windows will greatly affect heating. By maintaining and replacing worn wetherstripping, heating savings can be realized.

Assumptions:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

	Current	**Proposed**
HVAC Operation	168 hrs/wk	60 hrs/wk
Infiltration	.06 ACPH	.03 ACPH
Infiltration	4,122 CFM	2,764 CFM

Window Replacement

Measure description:

✓ **Recommended Retrofit**

For Information Only

Aging windows should be replaced with high performance models having an overall R-value of 3 or better to significantly reduce conductive heat loss. Sliding windows may be retained in certain cases (ie. for control of natural ventilation). Window shades or Low-E coatings should be considered for the windows on the south side of the building.

Assumptions:

Electrical Consumption price (blended)	0.42¢/kWh
Fuel Oil price	$1.0000 /Litre

- Replacing the windows will reduce infiltration by 5%
- Reduce infiltration by 0.1 ACH
- Cost of window replacement:
  - $25/ft² for triple pane
  - $14/ft² for dual pane

Current Practice

Description	
Window insulation	*R-3*

Proposed Practice

Description	
Window insulation	*R-6*

$$\boldsymbol{Incentive} = [\boldsymbol{U - value\ difference\ (Current - Proposed)}] \times \$\mathbf{150}\ \times \boldsymbol{window\ area\ (m^2)}$$

Savings & Calculations:

	Electricity (kWh)	**Fuel Oil (ekWh)**
Savings (ekWh)	-	8,265
Cost avoidance ($)	-	$808

GHG reduction (t eCO_2)	2

Estimated Retrofit Cost ($)	$960
MBHydro Rebate ($)	-
Net Payback (years)	**1.2**

Appendix C: Manitoba Hydro Rate Schedules: Diesel Communities

Diesel rates

Residential - Tariff no. 2016-03

Monthly basic charge not exceeding 60 Amp	$7.82
plus energy charge	7.930¢/kWh

Notes:
Minimum monthly bill is the monthly basic charge.
The residential rate applies to all residential services in the diesel communities, provided the service capacity does not exceed 60A, 120/240 V, single phase.

General service - Tariff no. 2016-40

Monthly basic charge	$21.20
plus energy charge:	
first 2,000 kWh @	8.329¢/kWh
balance of kWh @	42.617¢/kWh

Notes:
Minimum monthly bill is the monthly basic charge.
The general service diesel rate applies to all commercial accounts excluding those classed as Government and/or First Nation education.

Government and First Nation education - Tariff no. 2016-41

Monthly basic charge	$21.20
plus energy charge	$2.59382/kWh

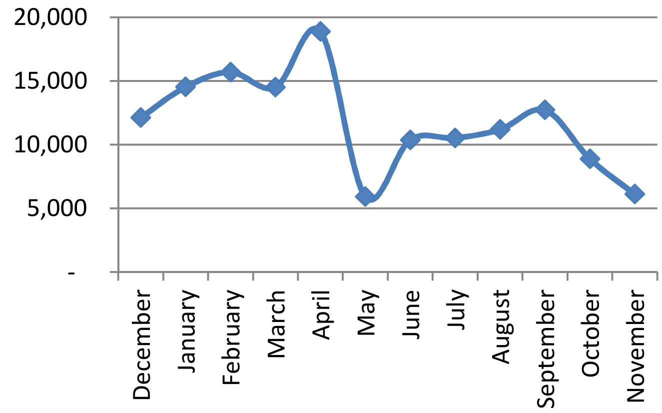
Notes:
Minimum monthly bill is the monthly basic charge.
The First Nation education rate is applicable to all diesel First Nation facilities providing instructional services for members of the diesel First Nations, including schools, teacherages and student residences.

Appendix D: Building Audits

Lac Brochet

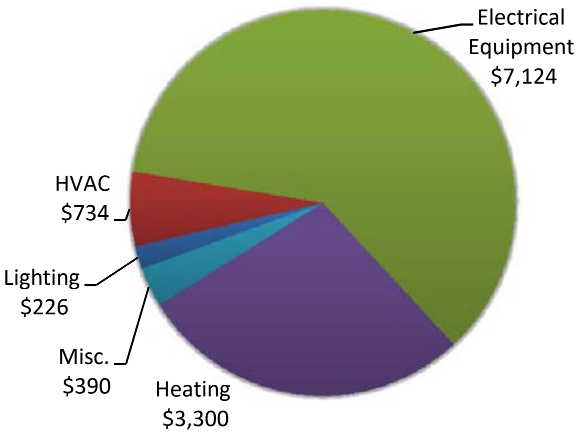
Building Name: ***Water Treatment***

Energy Consumption (ekWh/month)



Utility Breakdown

Estimated Annual End-use Costs



2015-2016 ekWh/m²

1096

Target ekWh/m²

913

Building Description

General Site

Building Use: water treatment process
Number of Floors: one
Total Floor Area: 129m²
Year of Construction: 1996
Building Condition: Good

Lighting

Interior: 2X4 32W T8 Fluorescents
Exterior: 70W High Pressure Sodium Wallpacks

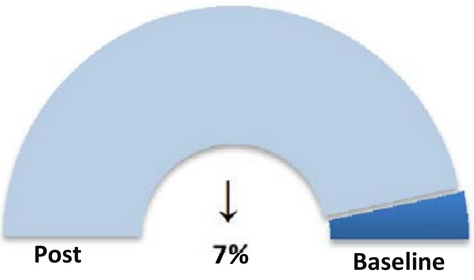
HVAC

Heating: Two Olsen Oil Furnace (78% seasonal efficiency) 118MBTU

Envelope

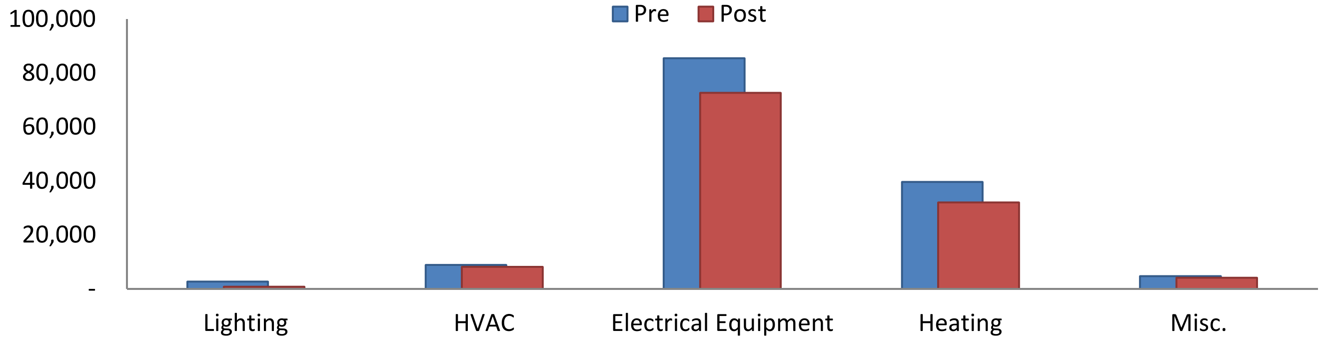
The envelope is steel frame with wood paneling with R-18, and it is in fair condition. The asphalt roof is R-30 and in good condition.

Potential Energy Savings (ekWh)



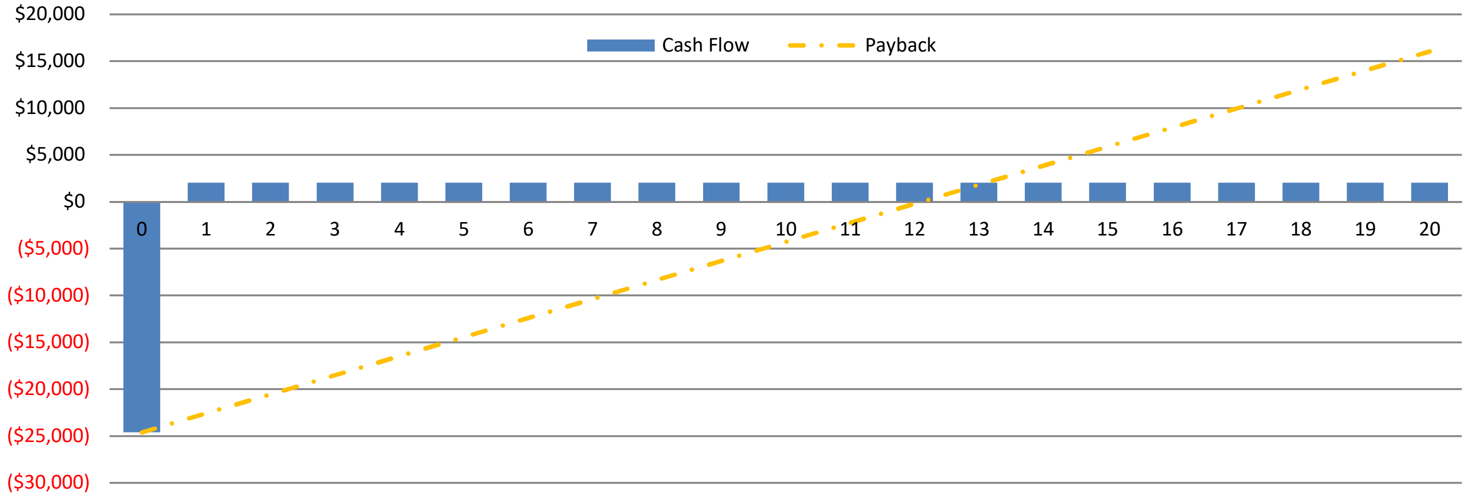
	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	141,357	39,626	111	$ 15,271
Post	138,760	29,990	107	$ 13,121
Estimated Savings	2,597	9,636	4	$ 2,151

Pre/Post Conservation Measures



Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m^3)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	1,310		$144	$1,971	$833	8
Improve Weather Sealing	-	347		$38	$60		2
Install Smart Metering/MT&R	-	5,944		$654	$500	$0	1
HVAC Measures							
Install Programmable Thermostats	617	2,774		$564	$170	$0	0
Implement CO2 and Demand Ventilation	-	-		$0	$639	$0	0
Lighting Measures							
Fluorescent to LED Conversion	864	(504)		$307	$198	$240	(0)
MH & HPS to LED Conversion	814	-		$342	$600	$223	1
Install Occupancy Sensors	302	(236)		$101	$600	$200	4
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			3	$8	$175		21
Energy Total	***2,597***	***9,636***		***$2,151***	***$ 24,613***	***$ 1,496***	**11**

Energy Conservation Measures Cashflow & Payback

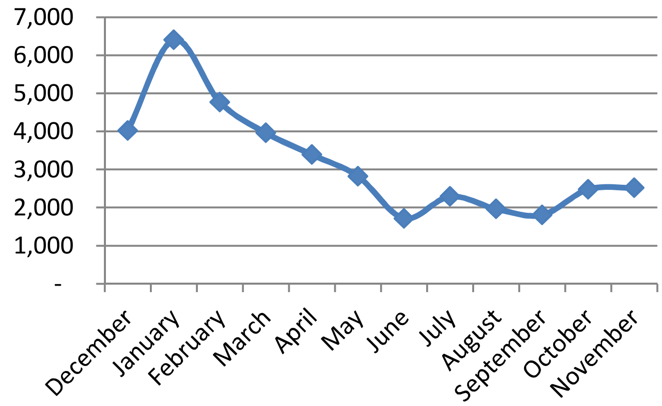


Lac Brochet

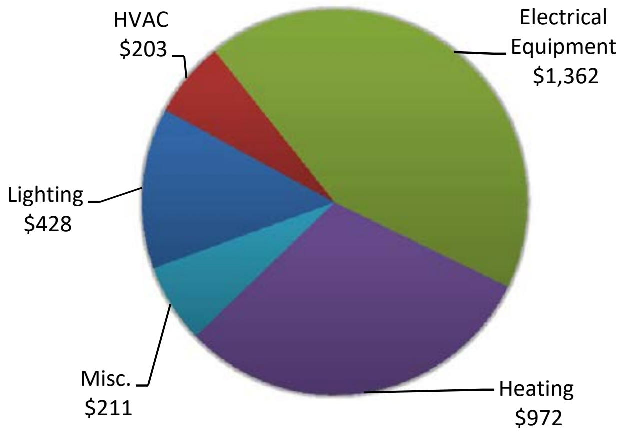
Building Name: ***Sewage Plant***

Utility Breakdown

Energy Consumption (ekWh/month)



Estimated Annual End-use Costs



2015-2016 ekWh/m²

1230

Target ekWh/m²

959

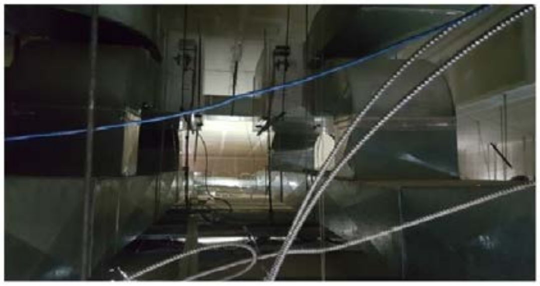
Building Description

General Site

Building Use: sewage process
Number of Floors: one
Total Floor Area: 31m²
Year of Construction: unknown
Building Condition: fair

Lighting

Interior: 2X4 32W T8 Fluorescents
Exterior: 70W Metal Halide Wallpacks



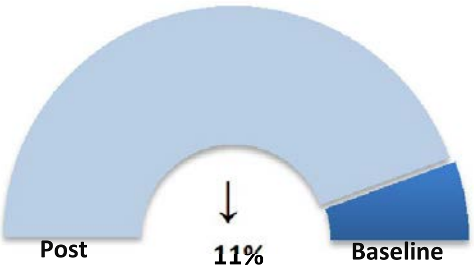
HVAC

Heating: Olsen Furnaces (~80% seasonal efficiency). Heated with propane.

Envelope

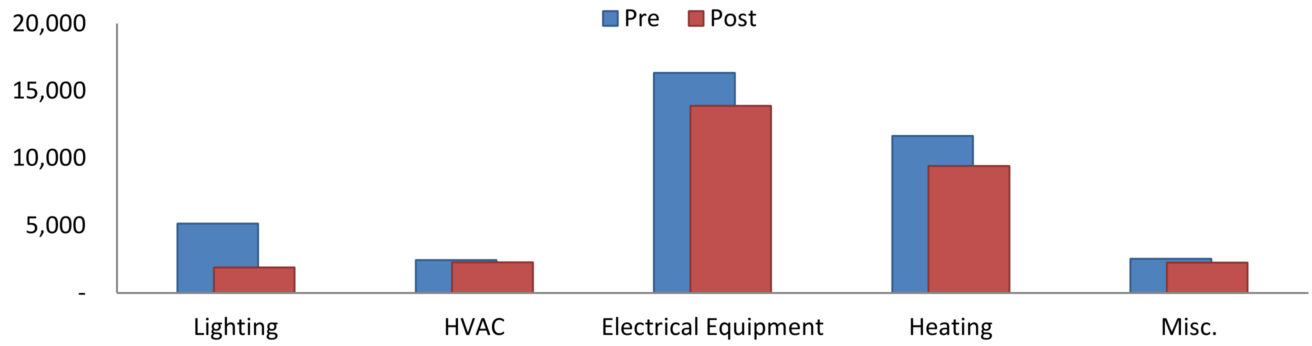
The envelope is woodframe with wood paneling with R-16, and it is in fair condition. The asphalt roof is R-30 and in good condition.

Potential Energy Savings (ekWh)



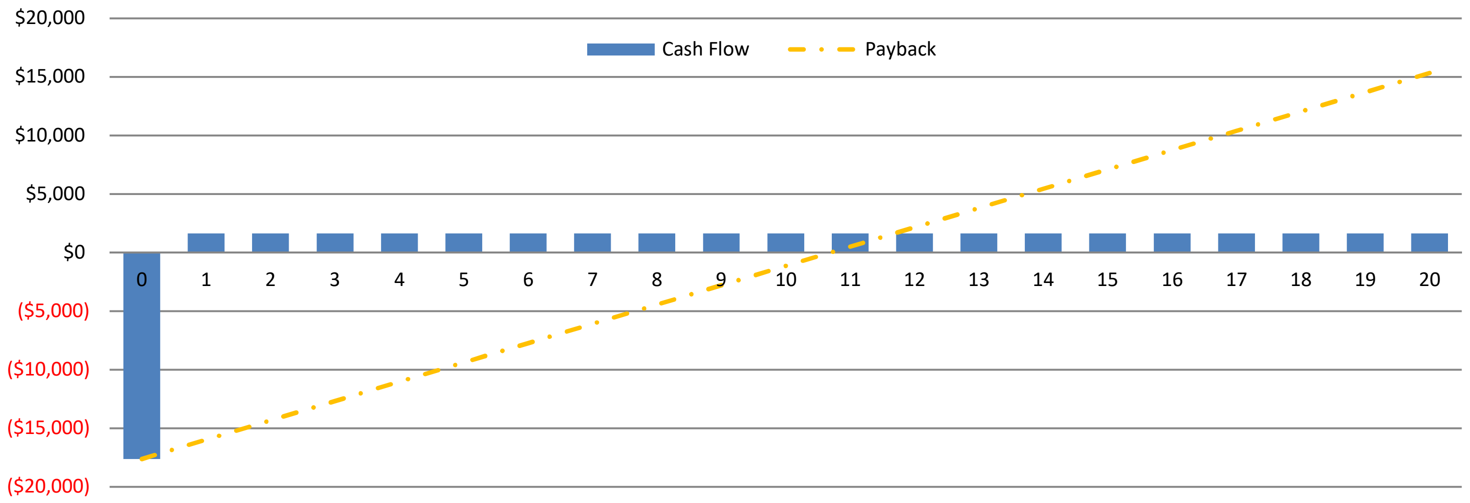
	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	38,138	11,668	30	$ 4,218
Post	34,702	9,575	27	$ 2,545
Estimated Savings	3,436	2,093	3	$ 1,673

Pre/Post Conservation Measures



Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m³)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	315		$35	$474	$200	8
Improve Weather Sealing	-	174		$19	$14		1
Install Smart Metering/MT&R	-	1,750		$193	$500	$0	3
HVAC Measures							
Install Programmable Thermostats	171	817		$162	$85	$0	0
Implement CO2 and Demand Ventilation	-	-		$0	$639	$0	0
Lighting Measures							
Fluorescent to LED Conversion	1,514	(883)		$539	$504	$757	(0)
MH & HPS to LED Conversion	1,221	-		$513	$900	$335	1
Install Occupancy Sensors	530	(79)		$214	$300	$100	1
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			3	$8	$175		21
Energy Total	***3,436***	***2,093***		***$1,673***	***$ 17,618***	***$ 1,392***	**10**

Energy Conservation Measures Cashflow & Payback

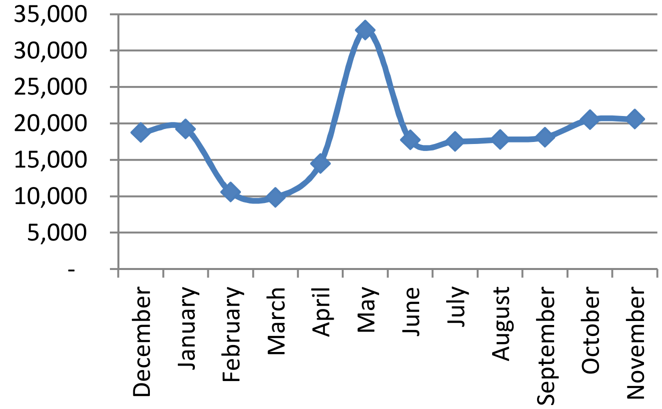


Lac Brochet

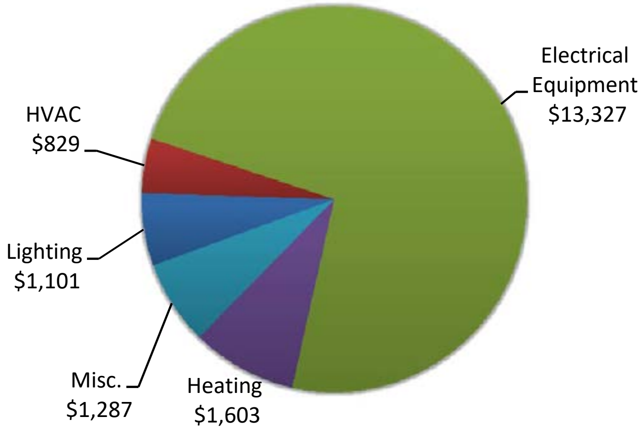
Building Name: ***Northern Store***

Utility Breakdown

Energy Consumption (ekWh/month)



Estimated Annual End-use Costs



2015-2016 ekWh/m²

328

Target ekWh/m²

262

Building Description

General Site

Building Use: grocery/retail
Number of Floors: one - concrete slab
Total Floor Area: 664m²
Year of Construction: 2011
Building Condition: Good

Lighting

Interior: 2X4 18W T8 Linear LEDs, cooler lights are 20W compact fluorescents.
Exterior: 100W Metal Halide Wallpacks

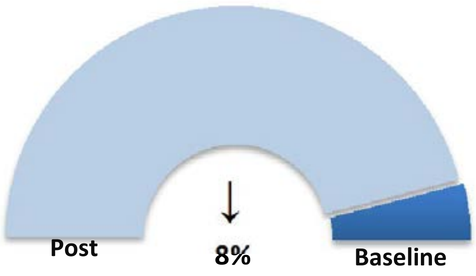
HVAC

Heating: Two Olsen Oil Furnace (~82% seasonal efficiency) 94,500 BTU

Envelope

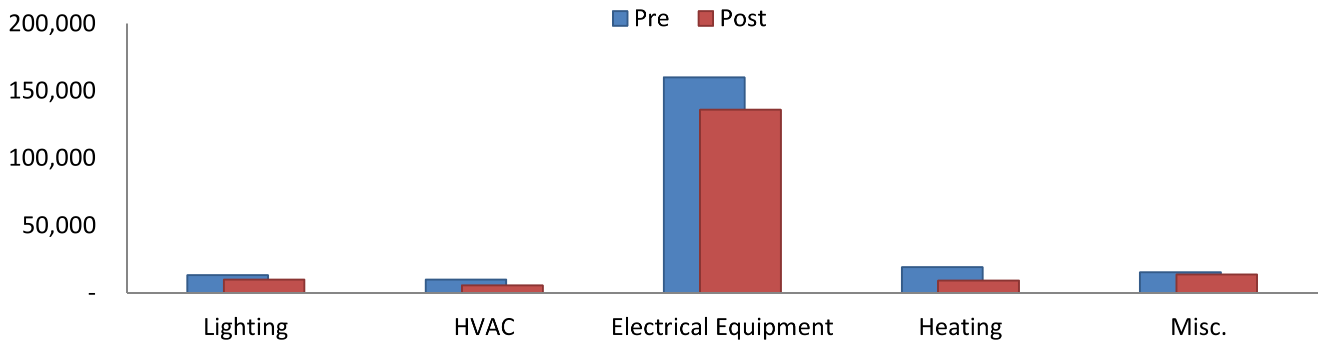
The envelope is concrete block that is insulated to R-30, and it is in fair condition. The steel roof is R-30 and in good condition. Windows are dual pane and R-2.8. There are five mandoors: two are R-3, two more are R-5 and one is R-7.

Potential Energy Savings (ekWh)



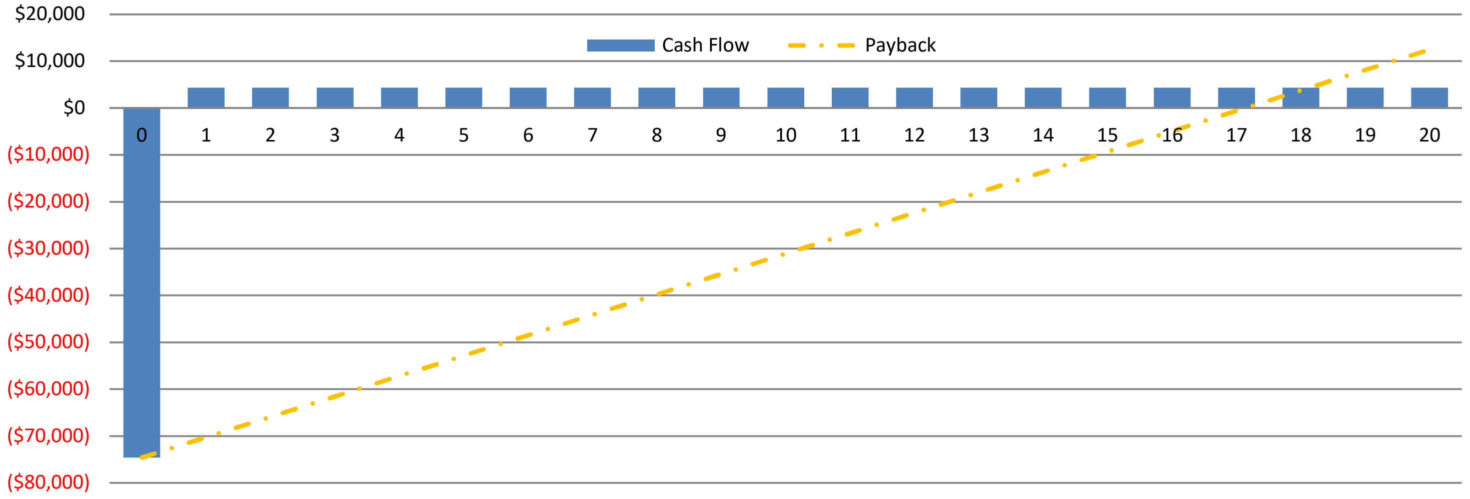
	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	217,874	19,243	161	$ 19,354
Post	210,076	8,203	152	$ 14,865
Estimated Savings	7,797	11,040	8	$ 4,489

Pre/Post Conservation Measures



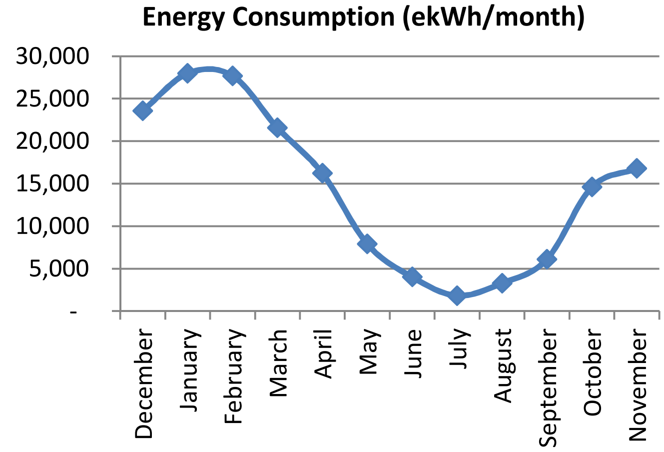
Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m³)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	6,745		$742	$10,145	$4,287	8
Improve Weather Sealing	-	521		$57	$310		5
Install Smart Metering/MT&R	-	2,886		$318	$500	$0	2
HVAC Measures							
Install Programmable Thermostats	697	1,347		$441	$170	$0	2
Implement CO2 and Demand Ventilation	3,683	-		$1,547	$639	$0	0
Lighting Measures							
Fluorescent to LED Conversion	-	-		$0	$1,080	$840	0
MH & HPS to LED Conversion	350	-		$147	$600	$96	3
Install Occupancy Sensors	3,068	(460)		$1,238	$300	$100	0
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			58	$164	$350		2
Energy Total	***7,797***	***11,040***		***$4,489***	***$ 74,608***	***$ 5,323***	**15**

Energy Conservation Measures Cashflow & Payback

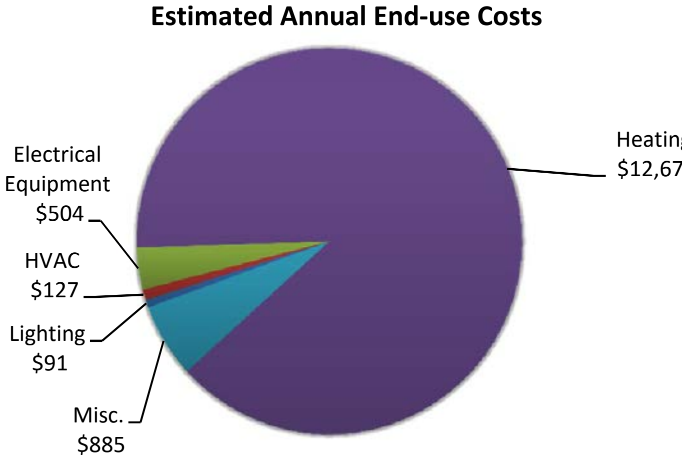


Lac Brochet

Building Name: ***Garage & Band Garage***


Energy Consumption (ekWh/month)

Utility Breakdown


Estimated Annual End-use Costs

2015-2016 ekWh/m²

273

Target ekWh/m²

216

Building Description

General Site

Building Use: warehouse and vehicle storage
Number of Floors: one
Total Floor Area: 627m²
Year of Construction: unknown
Building Condition: fair

Lighting

Interior: 2X4 32W T8 Fluorescents
Exterior: 70W Metal Halide Wallpacks

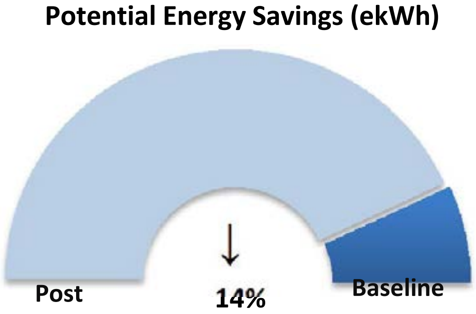
HVAC

Heating: Two Olsen Oil Furnace (~82% seasonal efficiency) 94,500 BTU

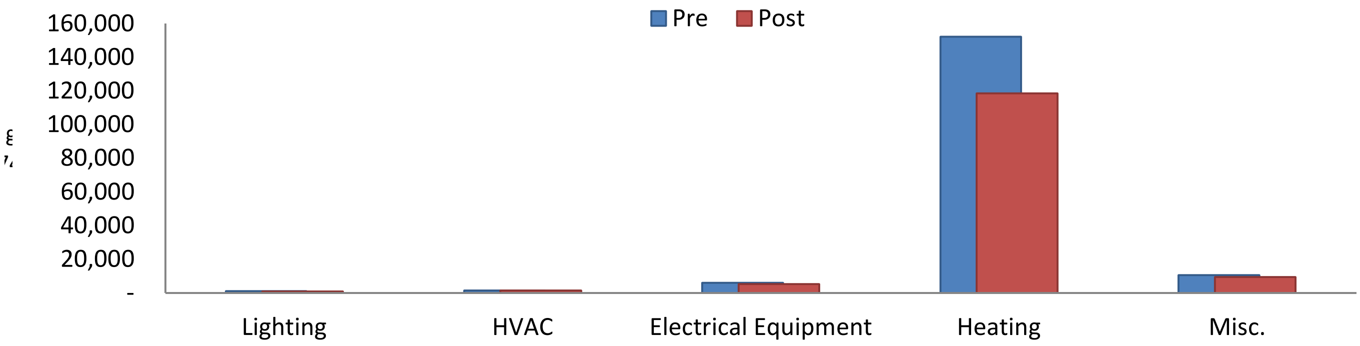
Envelope

The envelope is steel frame with steel siding that is insulated to R-30, and it is in fair condition. The steel roof is R-30 and in good condition.
Three overhead doors at R-16. The Garage's overhead door was repaired with a new R-16 door.

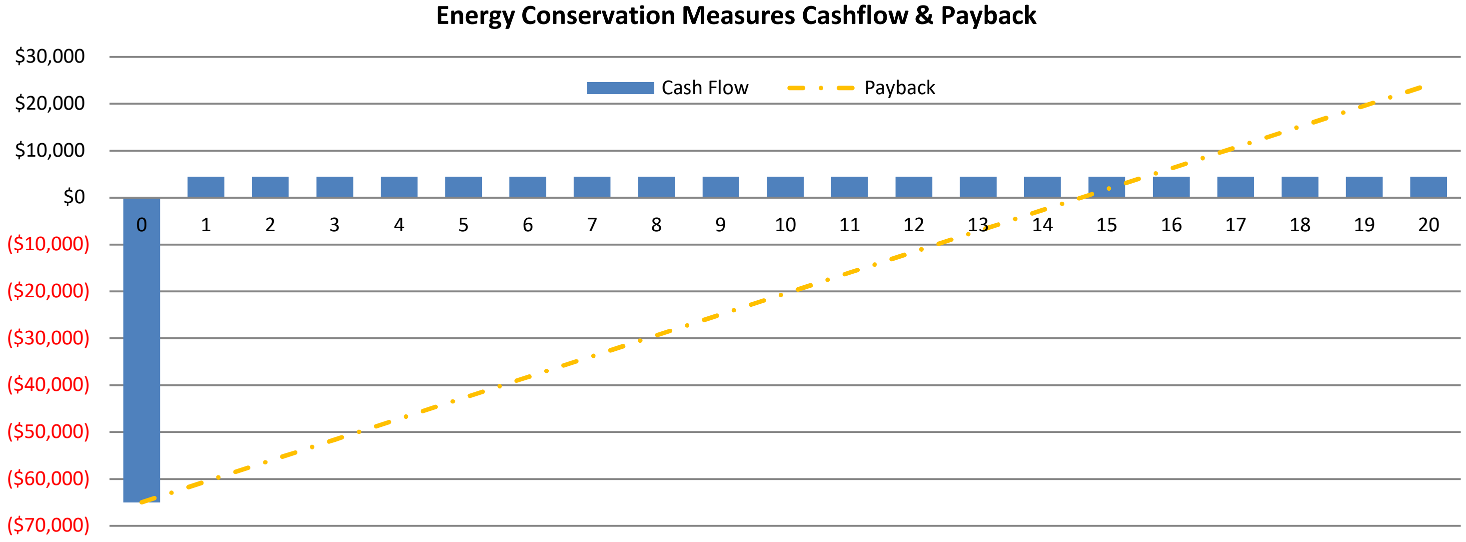
	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	171,452	152,162	162	$ 28,932
Post	171,142	107,967	150	$ 23,941
Estimated Savings	310	44,195	12	$ 4,992


Potential Energy Savings (ekWh)

Pre/Post Conservation Measures



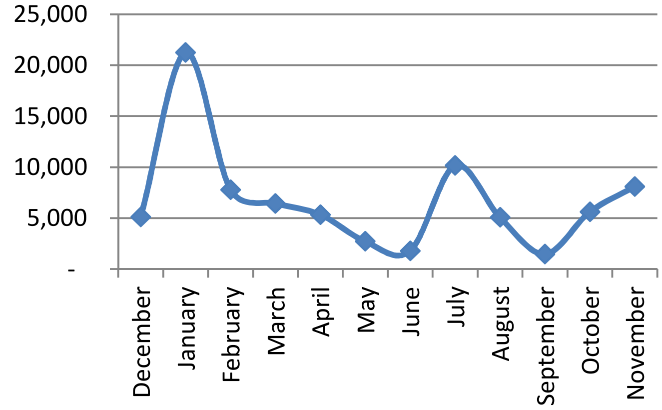
Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m^3)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	6,369		$701	$9,580	$4,048	8
Improve Weather Sealing	-	4,350		$479	$293		1
Install Smart Metering/MT&R	-	22,824		$2,511	$500	$0	0
HVAC Measures							
Install Programmable Thermostats	106	10,651		$1,216	$170	$0	1
Implement CO2 and Demand Ventilation	-	-		$0	$639	$0	0
Lighting Measures							
Fluorescent to LED Conversion	-	-		$0	$162	$102	0
MH & HPS to LED Conversion	204	-		$85	$150	$56	1
Install Occupancy Sensors	-	-		$0	$450	$150	0
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			12	$33	$175		5
Energy Total	***310***	***44,195***		***$4,992***	***$ 64,979***	***$ 4,355***	**12**


Energy Conservation Measures Cashflow & Payback

Lac Brochet

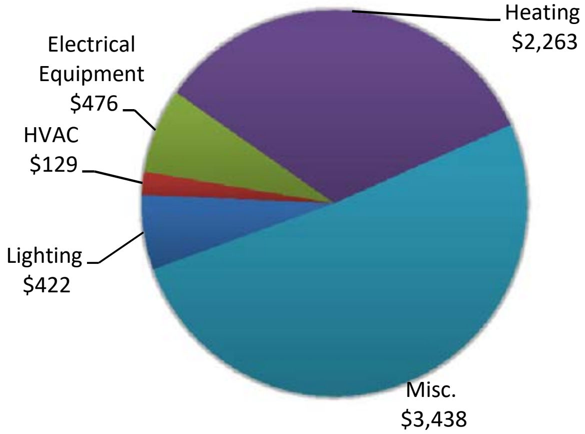
Building Name: ***Daycare***

Energy Consumption (ekWh/month)



Utility Breakdown

Estimated Annual End-use Costs



2015-2016 ekWh/m²

122

Target ekWh/m²

-

Building Description

General Site

Building Use: daycare

Number of Floors: one - crawlspace

Total Floor Area: 160m²

Year of Construction: 1995

Building Condition: Fair

Lighting

Interior: 2X4 32W T8 Fluorescents

Exterior: 70W High Pressure Sodium Wallpacks

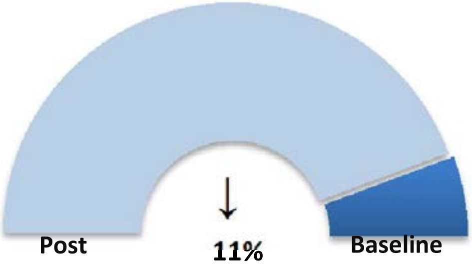
HVAC

Heating: Two Olsen Oil Furnace (~82% seasonal efficiency) 76,000 BTU. An 4.7kW electric heater heats the crawl space.

Envelope

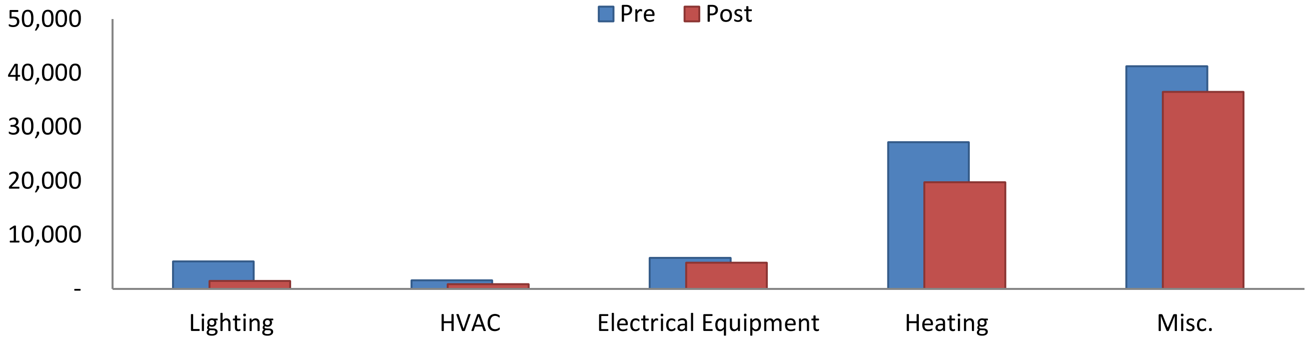
The roof is a pitched asphalt roof insulted to R-30. The windows are dual pane and insualted to R.2.5.
There are also two steel mandoors insualted to R-6. The envelope is in fair condition.

Potential Energy Savings (ekWh)



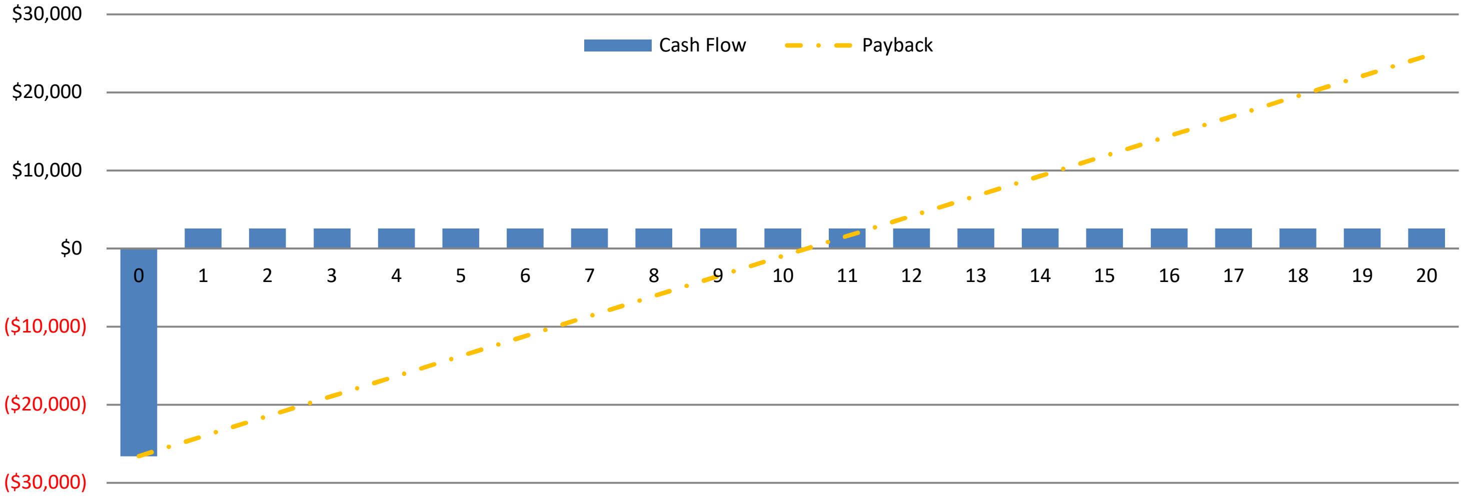
	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	80,777	27,173	65	$ 9,179
Post	76,516	19,268	60	$ 6,520
Estimated Savings	4,261	7,905	5	$ 2,659

Pre/Post Conservation Measures



Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m³)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	1,625		$179	$2,445	$1,033	8
Improve Weather Sealing	-	1,699		$187	$75		0
Install Smart Metering/MT&R	-	4,076		$448	$500	$0	1
HVAC Measures							
Install Programmable Thermostats	109	1,902		$255	$170	$0	1
Implement CO2 and Demand Ventilation	574	-		$241	$639	$0	3
Lighting Measures							
Fluorescent to LED Conversion	2,199	(1,282)		$782	$504	$1,099	(1)
MH & HPS to LED Conversion	611	-		$256	$450	$167	1
Install Occupancy Sensors	769	(115)		$310	$300	$100	1
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			17	$49	$175		4
Energy Total	*4,261*	*7,905*		*$2,659*	*$ 26,579*	*$ 2,400*	9

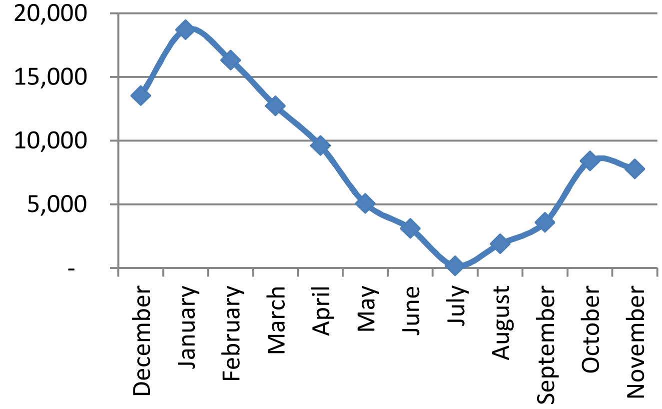
Energy Conservation Measures Cashflow & Payback



Lac Brochet

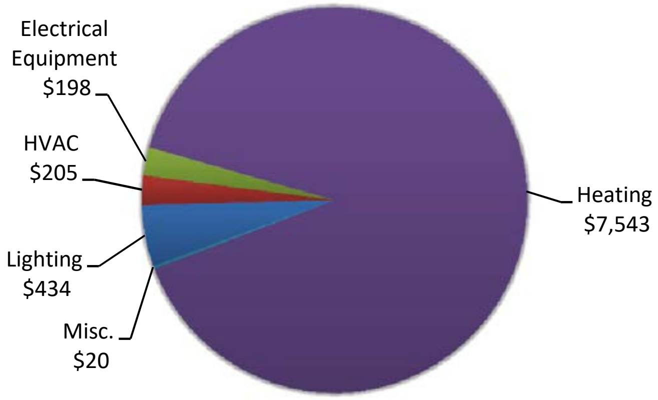
Building Name: ***Band Hall***

Energy Consumption (ekWh/month)



Utility Breakdown

Estimated Annual End-use Costs



2015-2016 ekWh/m²

226

Target ekWh/m²

171

Building Description

General Site

Building Use: community centre

Number of Floors: one - concrete slab

Total Floor Area: 466m²

Year of Construction: unknown (newer)

Building Condition: Good

Lighting

Interior: 2X4 32W T8 Fluorescents

Exterior: 70W Metal Halide Wallpacks

HVAC

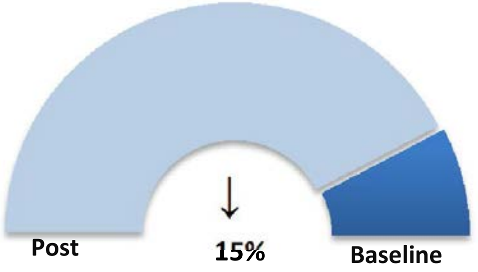
Heating: Two Olsen Oil Furnace (~82% seasonal efficiency) 94,500 BTU

Envelope

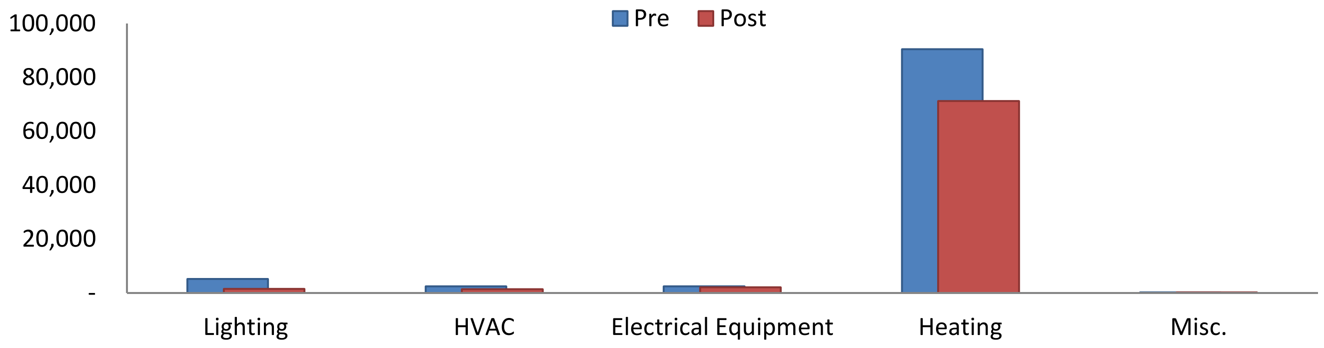
The envelope is wood frame with steel siding that is insulated to R-20, and it is in fair condition. The steel roof is R-40 and in good condition. Doors are steel and R-3. They are in fair condition and are in need of improved weatherstripping.

	Consumption			
	Elec (kWh)	Fuel (ekWh)	GHG	Cost
Pre	100,858	90,565	95	$ 17,125
Post	96,011	66,136	86	$ 12,402
Estimated Savings	4,847	24,429	10	$ 4,723

Potential Energy Savings (ekWh)

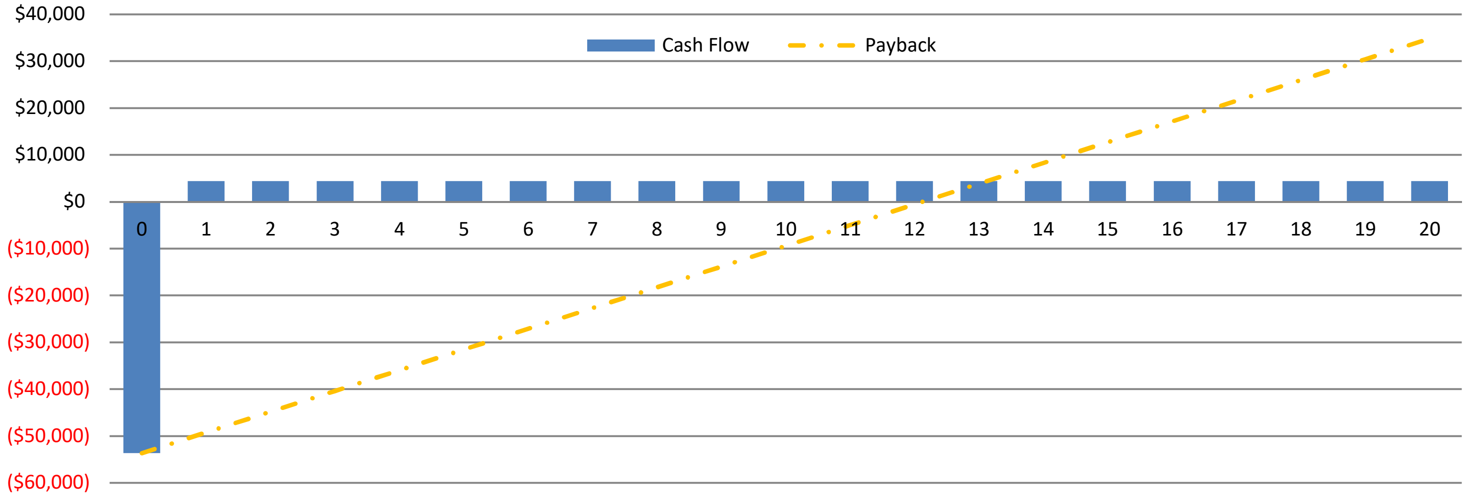


Pre/Post Conservation Measures



Measure	Electrical Savings (kWh)	Fuel Oil Savings (ekWh)	Water Savings (m^3)	Cost Savings ($)	Budget ($)	Incentive ($)	Payback (Years)
Heating System Measures							
Roof Insualtion from R-40 to R-60	-	4,531		$498	$6,815	$2,879	8
Improve Weather Sealing	-	1,173		$129	$208		2
Install Smart Metering/MT&R	-	13,585		$1,494	$500	$0	0
HVAC Measures							
Install Programmable Thermostats	172	6,340		$770	$170	$0	1
Implement CO2 and Demand Ventilation	909	-		$382	$639	$0	2
Lighting Measures							
Fluorescent to LED Conversion	1,884	(1,099)		$671	$432	$942	(1)
MH & HPS to LED Conversion	1,221	-		$513	$900	$335	1
Install Occupancy Sensors	660	(99)		$266	$300	$100	1
Water Saving Measures							
Replace 6lpf toilets with 4l8 lpf			29	$82	$350		4
Energy Total	***4,847***	***24,429***		***$4,723***	***$ 53,656***	***$ 4,256***	**10**

Energy Conservation Measures Cashflow & Payback



ASHRAE Level 2 Energy & Water Audit

Petit Casimir School

Site Visit Date: March 8, 2017

Site Contact:

Prepared for:

Glenn Sanderson
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April 7, 2017

Limits of Liability

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SITE SUMMARY

The Petit Casimir School, is a 3,200 m^2 (34,426 ft^2), single-storey building with approximately 260 students. It includes 13 original classrooms, a wood shop, home economics class, and a gymnasium.

The building has three fuel oil boilers (two original to the building, and one newer one) each with approximately 2,100 kbtu/hr inputs that provide heating to the building's glycol loop. The glycol loop serves the two air handlers, force flow and unit heaters, and perimeter radiation units. The building uses a DDC system. Two 113 gallon electric hot water tanks serve the building's domestic hot water load.

The original T12 fluorescent and metal hydride lighting in the building interior was upgraded to LED technology in 2015. One of the three boilers has been replaced. A second replacement boiler has been approved for the building. It is expected to operate on only the two boilers moving forward.

The building appears in good condition overall with some envelope damage by the air-intake roofline which is in urgent need of attention.

Table 1, below, provides a description of the facility's construction features.

Table 1: Construction Summary

Construction Date:	1995	Concrete Block, Steel Frame,	
Floor Area (m^2):	3,200	Number of floors:	One + Mezzanine
Volume (m^3):	11,800	Basement:	Crawl Space
Wall Area (m^2):	1,716	Wall R-value (hr.ft^2.°F/BTU)	20
Window Area (m^2):	397	Window R-value (hr.ft^2.°F/BTU)	2.8
Roof Area (m^2):	3,410	Roof R-value (hr.ft^2.°F/BTU)	30

The school only utilizes electricity which **Manitoba Hydro** charges for electricity consumption and demand. Fuel oil is purchased to serve the buildings hydronic boilers. The energy used in the most recent year of <u>December 2015</u> to <u>November 2016</u> is shown below:

Exhibit 1: Billed Utility Consumption

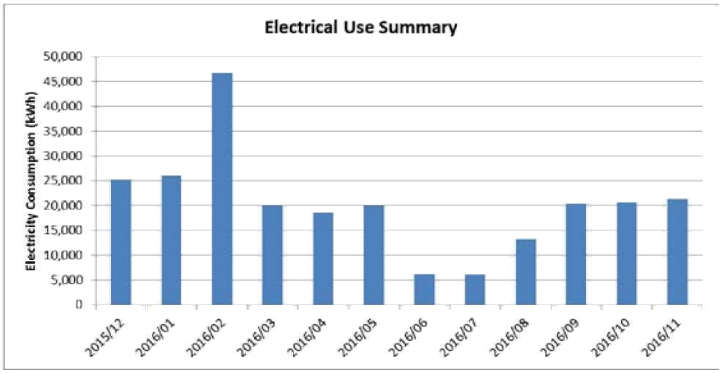
Utility	Billed Units	GJ	GHG (tonnes eCO2)	Cost	Cost Index (\$/m^2)	GHG (tonnes/m^2)	Energy Index (ekWh/m^2)
Electricity	244,440 kWh	880	1878	\$619,020	\$194	0.072 [1]	77
Fuel Oil	93,751 L [2]	3,834	266	\$93,751	\$29	0.132 [3]	335

1. Based on 7.68 kg CO_2 per kilowatt hour of electricity produced via diesel generator.
2. Approximate based on information gathered from site visit and RETscreen energy model. Exact billing data not available.
3. Based on 0.00284008257300931 tonnes per liter of light fuel oil combusted.

Exhibit 2 illustrates the historical electrical consumption and demand of the Petit Casimir School.

Exhibit 2: Billed Utility Consumption

Historical utility consumption for the facility is utilized as a benchmark platform to assess the building energy performance. The benchmark use provides the energy per floor area so that it can be compared with other facilities. Energy consumption is determined from the energy use trends set by the building during the past 12- month analysis period.



Demand Side Energy Consultants Inc. was commissioned by Aki Energy Inc. to conduct energy/water audit of the building in order to establish a baseline of energy and water use, benchmark the facility performance, and to conduct a walkthrough audit that determines energy and water end-uses.

Several retrofit measures are presented to reduce or to use energy more effectively. Each opportunity has gone through a process to screen the level of energy and/or carbon reduction, the resulting change in utility cost, and the capital investment needed to pursue the changes. The conservation measures considered are illustrated in the chart, overleaf, they fall into the following categories:

Exhibit 3: Retrofit Opportunities

Measure	Savings					
	Energy (ekWh)	Water Savings (L)	Cost ($)	Est. Costs ($)	Rebate ($)	Payback (Yrs.)
Convert exterior lighting to LEDs	10,731		$ 27,834	$ 21,000	$ 7,000	0.5
Install occupancy and dimming controls for interior lighting	3,046		$ 7,888	$ 15,000	$ 2,500	1.6
Install VFDs on hydronic heating pumps	9,550		$ 24,770	$ 25,000	$ 0	1.0
Schedule DHW recirc. pumps	1,466		$ 3,804	$ 500	$ 0	0.0
Implement Demand Control Ventilation (CO2 Sensors)	35,420		$3,150	$ 15,000	$ 0	4.3
Replace 6LPF toilets with 4.8 LPF units		253,134	$868	$4,900	$0	5.6
Total	60,193		$68,314	$81,400	$9,500	1

Implementing the above conservation measures will require estimated investment of $81,400 and result in utility avoided annual cost $68,314. Manitoba Hydro rebates total an estimated $9,500 and will result in 1.0 years simple payback period for the investment. In all, electricity will be reduced by 10% and fuel oil consumption will be reduced by 5%.

Water conservation measures will cost $4,900 to implement and save $868 per year resulting in a 5.6 year payback. Water consumption will be reduced by 15%.

BUILDING SUMMARY

ENVELOPE

Wall composition:

Exterior wall: two 5/8” type X gypsum board, 6” 20 gauge steel studs with two 5/8” type X gypsum board.

Recommendation:

Continue maintenance as per existing preventative maintenance schedule. Weather-stripping on the entrances and fenestration should be examined and renewed as required on an annual basis.

Roof:

Metal roof insulated to approximately R-30. The roof appears well maintained.

Recommendation:

Continue maintenance as per existing preventative maintenance schedule.

Windows:

Dual glazed non-operable windows with plexi glass. Approximately 20% window-to-wall ratio.

Recommendation:

Inspect and repair seals on an annual basis.

Doors:

Entrance doors are steel doors with glass. They are insulated to R-2.

Recommendation:

Inspect on an annual basis; repair/replace weather-stripping as required.

HVAC

Air Handlers:

AHU-1 has a 40 hp fan and is rated at 32,550 CFM and serves the school's interior. AHU-2 has a 15 hp fan and provides 13,600 CFM to the gym area. Both are on DDC controls and have VFD fan control.

Recommendations:

Preventative maintenance as per existing operating schedule. Trim fresh air to fit occupancy with CO_2 sensors in the gym.

Boilers:

Three 2,100 MBH boiler (input) boilers provide space heating to the school. One of the three (B-2 at right) has been replaced since construction in 1995 and a second replacement boiler is to be installed this year. Each boiler has a 1 hp circulation pump. Only one boiler generally operates at a time.

Recommendation:

Proceed with the planned boiler replacement.

Domestic Hot Water:

Two electric hot water tanks provide domestic hot water to the school's kitchen and washrooms (including showers). There are two 1/6HP domestic hot water pumps (one circulation, one re-circulation).

Recommendation:

Schedule or add a timer to the two hot water circulator pumps to operate only when the building is occupied and there is a demand for hot water.

Pumps:

Two 10 hp pumps (lead/ lag) circulate glycol to the heating coils around the building. Two 7.5 hp pumps serve the glycol heat recovery loop.

Recommendation:

Install and program DDC controls to modulate the pump power based on supply water temperature.

LIGHTING

Interior Lighting:

All interior lighting has been upgraded to LED technology recently.

Recommendation:

Controls?

Exterior Lighting:

Exterior lighting is provided by 70W High-pressure Sodium fixtures and metal hydride light standards.

Recommendation:

Consider replacing all fixtures with 20W LED exterior wall packs and 350W LED light standards.

PLUMBING

Toilets:

Toilets are a mixture of 13LPF and 6LPF.

Recommendation:

It is recommended to install 4.8 LPF toilets.

Faucets:

Faucets are 5.7 LPM manual units.

Recommendation:

It is recommended to install 1.9 LPM faucets with proximity sensors.

BILLING HISTORY

Manitoba Hydro delivers *electricity* to the facility through one service account that charges for metered consumption as well as demand. Fuel oil is purchased to serve the buildings hydronic boilers. **Table 1** summarizes all utility purchased by the building during the period noted.

Energy consumption is measured by volume, with electricity in kilowatt hours (kWh) and fuel oil in Liters (L).

Table 2: Billed Utility Consumption from December 2015 to November 2016

Utility	Billed Units	GJ	GHG (tonnes eCO2)	Cost	Cost Index ($/m²)	GHG (tonnes/m²)	Energy Index (ekWh/m²)
Electricity	244,440 kWh	880	1878	$619,020	$194	0.072 [1]	77
Fuel Oil	93,751 L [2]	3,834	266	$93,751	$29	0.132 [3]	335

1. Based on 7.68 kg CO_2 per kilowatt hour of electricity produced via diesel generator.
2. Approximate based on information gathered from site visit and RETscreen energy model. Exact billing data not available.
3. Based on 0.00284008257300931 tonnes per liter of light fuel oil combusted.

Figure 1 below illustrates the ratio of Electricity Consumption.

Figure 1: Electricity Consumption

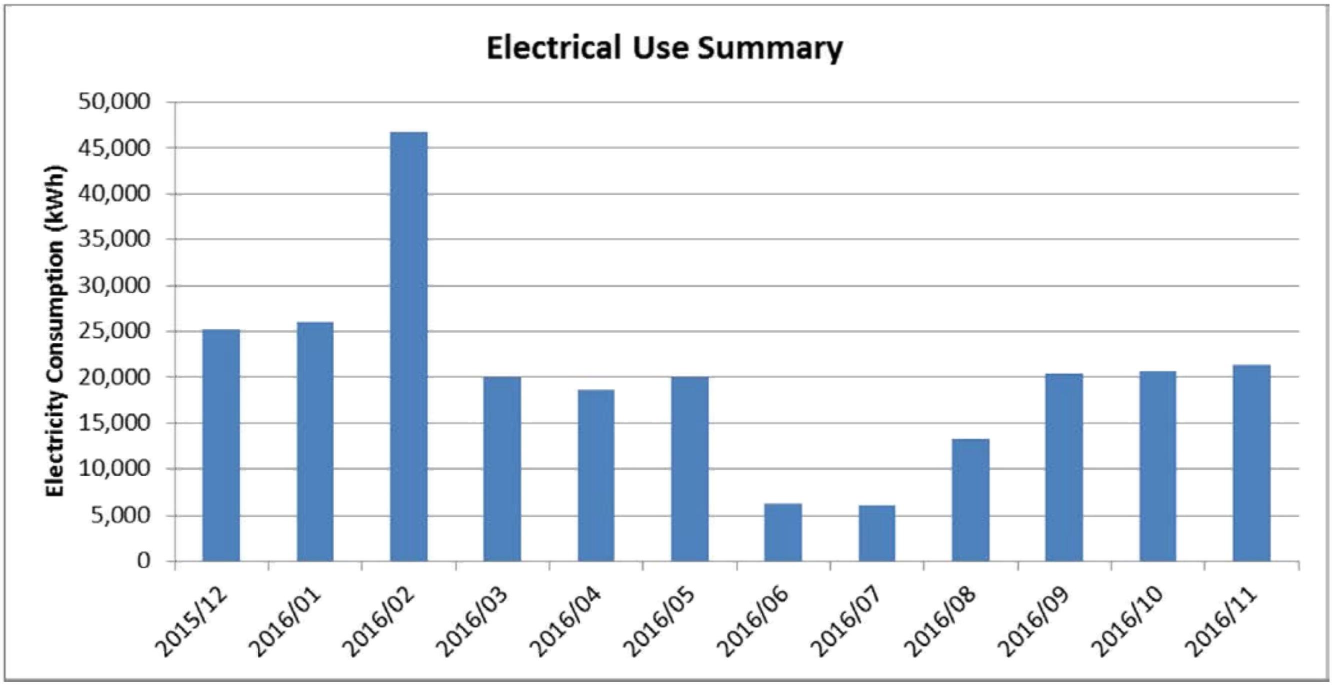
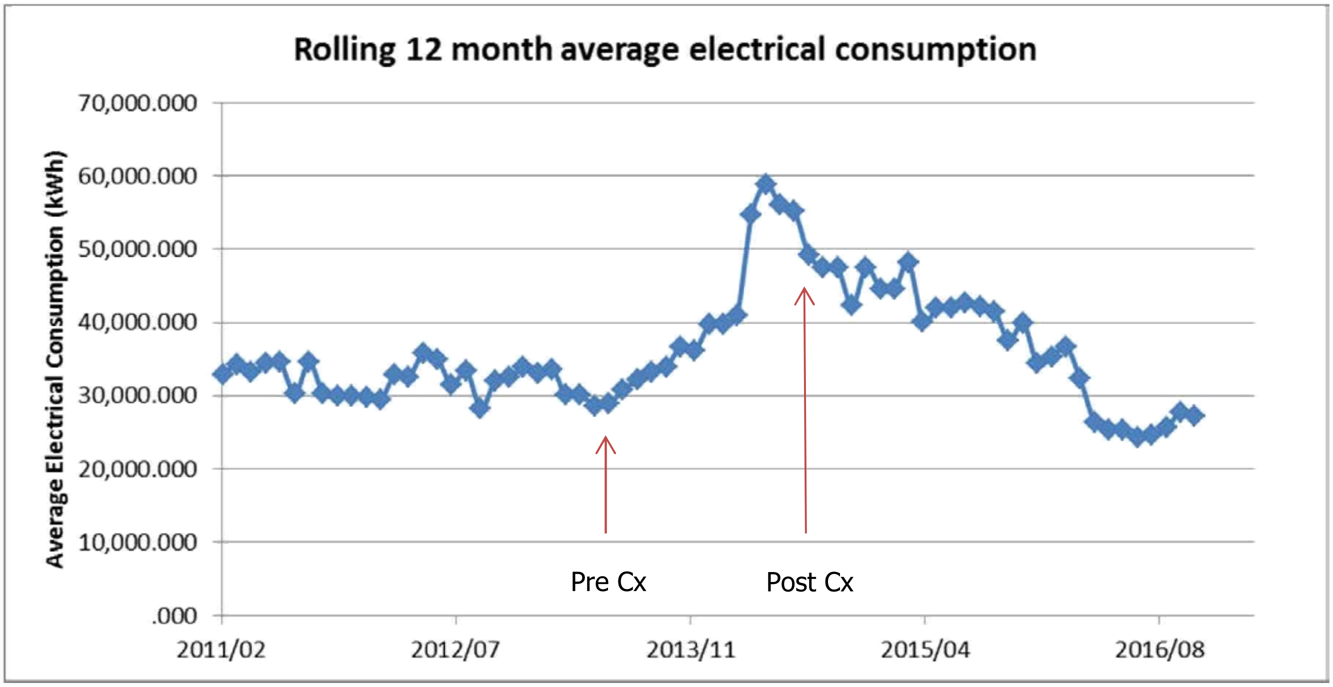


Figure 1 is the monthly electricity profile. The chart above indicates monthly electrical consumption with minimum electricity use during the summer season when minimal heating is needed and school is not in session.

The electricity baseline occurs in the summer, and this baseline electricity consumption accounts for the operation of lighting, minimal HVAC, and school plugloads. There is no cooling system present in the building as it relies on the outdoor air temperatures to meet its cooling requirements. It is also during this time that occupancy is at its lowest since classes are not in session; however, the school is still utilized for community events.

Note that in several cases the electrical meter reading were estimated, and then adjusted; in some cases the data was averaged over two or three months to show average monthly consumption. The 12 month rolling average electrical consumption starting in 2011 to present is presented below to show the trend in electrical consumption over time. Some event in early 2014 increased electrical consumption sharply. Consumption levels appear to have dropped since then; largely due to the interior lighting upgrades that have been implemented.

Figure 2: Electricity Consumption Rolling Average



The above graph shows a good example of the systems falling outside of intended operation, and then following a controls recommissioning, returning to normalized operations as demonstrated by the decrease in the rolling average.

ENERGY END USE

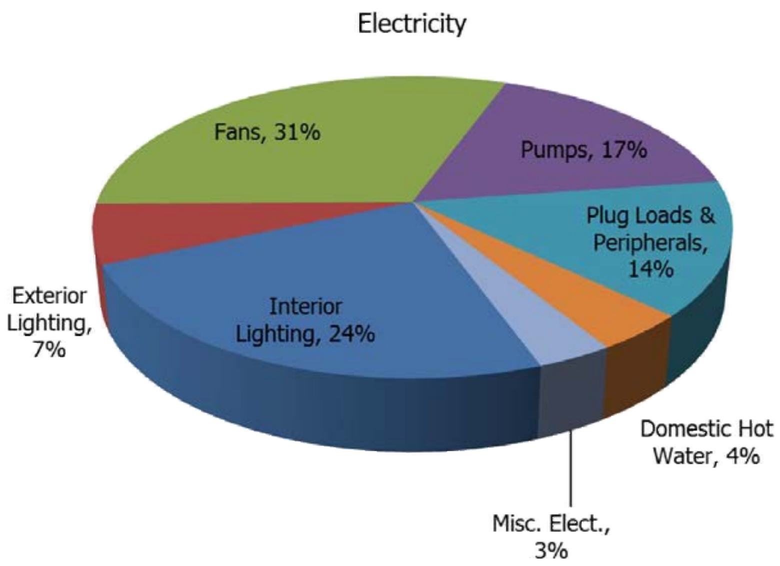
A thorough inventory of the building energy consuming equipment in the Petit Casimir School was conducted by DSE. **Table 5** provides an annual account of the building *end-use systems*, based on the inventory of energy consuming equipment, estimates of operating hours, and on-site observations and measurements.

Table 3: Audit Results

Energy End Use	Electricity (kWh)	Fuel Oil (L)	Energy (ekWh)	%	$/year	GHG (tonnes)
Space Heating	-	23,075	259,672	20%	$ 23,075	65.5
Ventilation Heating	-	51,926	51,926	60%	$ 51,926	147,5
Combustion Losses	-	18,750	18,750	20%	$ 18,750	53.3
Sub-total - Fuel Oil	**-**	**93,751**	**1,055,037**	**100%**	**$ 93,751**	**266.3**
Interior Lighting	58,642	-	58,642	24%	$ 148,506	54.9
Exterior Lighting	15,549	-	15,549	6%	$ 39,376	14.6
Fans	75,234	-	75,234	31%	$ 190,523	70.5
Pumps	41,945	-	41,945	17%	$ 106,222	39.3
Plug loads	35,050	-	35,050	14%	$ 88,760	32.8
Domestic Hot Water	9,960	-	9,960	4%	$ 25,222	9.3
Miscellaneous	8,060		8,060	3%	$ 10,156	7.5
Sub-total - Electricity	**244,440**	**-**	**244,440**	**100%**	**$ 619,020**	**228.3**
Total - Energy	**244,440**	**93,751**	**1,558,820**	**-**	**$ 712,771**	**495.2**

The end-use equipment energy and cost is categorized by energy requirements of the building systems that were part of the equipment inventory process. The final item in each category is “Miscellaneous Use”, which the energy is not accounted by the inventory process because its estimation is difficult or unreliable. In this case it is expected that most of the miscellaneous electricity goes to the daycare next door.

Figure 3: Electricity Energy End-Use



Fans and **pumps** for the HVAC account for 31% and 17% respectively of the electricity consumption. Fans are scheduled by the DDC system. There is no cooling in the facility as it relies on fresh air.

Interior Lighting is the second largest consumer of electricity at Petit Casimir School even after the LED lighting upgrade.

Exterior Lighting accounts for 7% of the electrical consumption. There are 18 70W high pressure sodium wall packs around the building façade and two 1000W metal hydride light standards on the grounds.

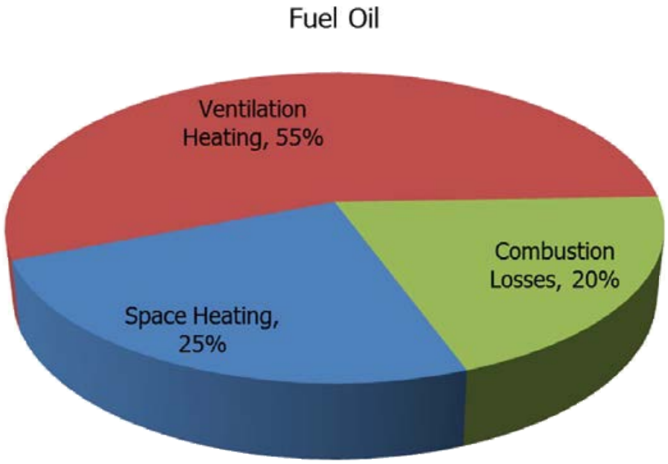
Plug loads are made up of the servers, computers, printers and photocopiers as well as other peripherals such as monitors. Kitchen appliances include fridges, ovens and grills, microwaves, toasters, and coffee makers. The energy consumption for these end-uses are approximated based on occupancy of the facility as well as the hours of operation. These accounts for approximately 14% of electricity.

Domestic and Service Hot Water are provided by two 54 kW electric hot water tanks. Only one operates at any one time, and account for 4% of the electricity.

Figure 4:Fuel Oil Energy End-Use

Approximately 20% of the fuel oil consumed is **combustion losses**. Three boilers provide heating to the school. One unit has already been replaced (85% thermal efficiency) and a second replacement has been approved for installation. The original boilers had a thermal efficiency of 80%.

An additional 20% of the fuel oil consumed goes to **space heating**, with the remaining 60% serving the building's **ventilation** system.



WATER END USE

An inventory of the building water consuming fixtures at the Petit Casimir School conducted by DSE. **Figure 5** provides an annual account of the building *water consumption*, based on the inventory of water consuming fixtures, estimates of daily uses, and flow rates. The information was analyzed based on the number of occupants and patterns provided by the United States Environmental Protection Agency's (USEPA) Water Use Benchmarks, several Provincial Water Use studies, and Environment Canada.

Using these statistics under the assumption that the male-to-female gender ratio of occupant is 50:50 was applied to the inventory of water use fixtures, resulting in the patterns seen in the **Figure 5** below. Miscellaneous water use includes kitchen appliances, as well as water leaks and dripping faucets.

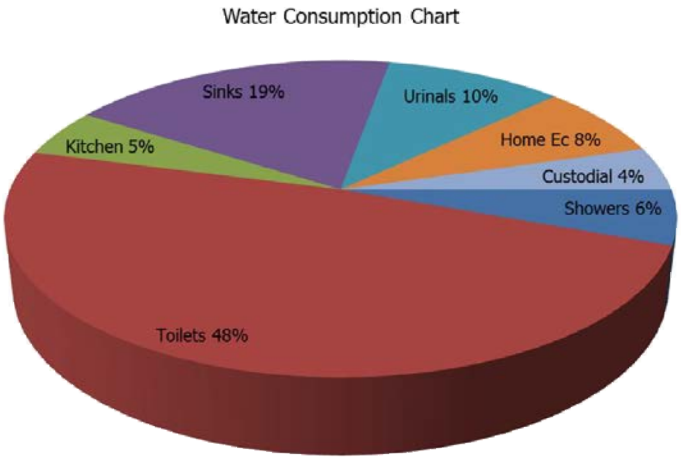
Figure 5: Water End-Use

The building water consumption is not metered but an estimate of annual of water consumption, based on the school population was made.

The majority of the facility's water consumption is estimated from washroom use.

Most toilets are 6 litre per flush (LPF) with manual flushers. Urinals are all 1.89 LPF and faucets are and 5.7 LPM with manual valves.

There are showers in the gym locker room. They are fitted with efficient 5.7 LPM shower heads.



The daily shower use was calculated as [(flow rate x minutes of use) x (number of people who use it)]. It was estimated as follows: [(5.7 x 8.2) x (10)] and accounts for roughly 6% of total water consumption.

Washroom usages account for 81% of the total water consumption for the Petit Casimir School. Handwashing is included in the washroom calculations - though there is some overlap between washroom sink use and kitchen sink use.

The home economics class w uses approximately 8% of the water consumption and the staff kitchen roughly 5%. Finally custodial work uses about 4% of total water consumption.

CONSERVATION MEASURES

Several retrofit measures are presented that may present opportunities to reduce energy use. Each opportunity has gone through a process to estimate energy reduction, the resulting change in utility cost, and the capital investment needed to implement these changes. All the proposed changes to the facility have been put forward for evaluation in this section.

Conservation measures are classified either as initiatives that pay back their full cost in a reasonable period, or as those that are incremental. Incremental measures may be considered when replacement of equipment that is near end-of life is requested.

Opportunities within these two categories are further analyzed below.

Table 4: Energy Savings Opportunities

	Savings					
Measure	Energy (ekWh)	Water Savings (L)	Cost ($)	Est. Costs ($)	Rebate ($)	Payback (Yrs.)
Convert exterior lighting to LEDs	10,731		$ 27,834	$ 21,000	$ 7,000	0.5
Install occupancy and dimming controls for interior lighting	3,046		$ 7,888	$ 15,000	$ 2,500	1.6
Install VFDs on hydronic heating pumps	9,550		$ 24,770	$ 25,000	$ 0	1.0
Schedule DHW recirc pumps	1,466		$ 3,804	$ 500	$ 0	0.0
Implement Demand Control Ventilation (CO2 Sensors)	35,420		$3,150	$ 15,000	$ 0	4.3
Replace 6LPF toilets with 4.8 LPF units		253,134	$868	$4,900	$0	5.6
Total	60,193		$68,314	$81,400	$9,500	1

Implementing the above conservation measures will require estimated investment of $81,400 and result in utility avoided annual cost $68,314. Manitoba Hydro rebates total an estimated $9,500 and will result in 1.0 years simple payback period for the investment. In all, electricity will be reduced by 10% and fuel oil consumption will be reduced by 5%.

Water conservation measures will cost $4,900 to implement and save $868 per year resulting in a 5.6 year payback. Water consumption will be reduced by 15%.

Lighting Retrofit

- *LED Conversion for Exterior Lighting Fixtures*

There are eighteen 70 Watt HPS lighting fixtures and two 1,000 Watt Metal Hydride light standards outside of the building. These fixtures can be replaced with 20 Watt LED wall packs and 350 Watt LED flood lights. The lighting retrofit will reduce electrical consumption for outdoor lighting by approximately 70%.

- *Install Occupancy Sensors and Diming Controls on Interior Lighting*

Installing occupancy sensors in areas of the building where the occupancy fluctuates throughout the day can reduce the lighting consumption by an estimated 30%. Installing occupancy sensors in areas such as the conference rooms, janitor areas and washrooms would be advantageous, and reduce energy consumption of these lighting systems by 20%.

Many rooms may be over lit and energy savings may be realized by installing diming controls to reduce the amount of light from artificial sources. Dimming control may be automatic based on available daylight or manual depending on the application.

HVAC System Optimization

- *Install VFD’s on heating pumps P-4/ P-5*

Variable frequency drives are means of controlling the speed at which a motor will rotate. Motors rotate at a fixed speed that is based on the frequency of the supply voltage.

The glycol loop at Petit Casimir employs two 10 hp motors of which one motor operates on continuous basis and at full speed during the heating season. During moderate weather conditions or unoccupied hours (when the ventilation system is off) the heating requirements for the building is reduced and a VFD allows for the pumps to modulate down and reduce energy consumption.

- *Schedule DHW Recirculation Pumps*

Two small circulators ensure a steady flow of hot water is available throughout the building is, however the two pumps are not scheduled (i.e. they run 24/7). Energy savings can be realized by installing mechanical timers to schedule running the circulators only during occupied hours.

- *Demand Ventilation in RTUs*

CO_2 monitors could be used to match ventilation requirements with carbon dioxide levels in the school. Total ventilation requirements will be reduced during sections of the day when the school is only partially occupied.

Water Savings

- *Replace 13 and 6LPF toilets with 4.8LPF units*

Replacing the current 13 and 6LPF toilets with 4.8 LPF flush toilets will reduce total water consumption by 15%. It will save an estimated 253 m^3 of water per year which amounts to $868/year. The cost of the replacements are around $4,900 and will result in a 5.6 year payback.

Appendix A: Energy Billing Data

Government and First Nation Education - Tariff no. 2016-41

Notes:

Minimum monthly bill is the monthly basic charge.

The First Nation education rate is applicable to all diesel First Nation facilities providing instructional services for members of the diesel First Nations, including schools, teacherages, and student residences.

Monthly basic charge	$21.20
plus energy charge	$2.59382 /kWh

ADDRCITY	LAC BROCHET
PREMCODE	6620800
CUSTCODE	8196589
OWNER	8196589
METER	749887
ADDRESS	FNC 197A
BFUNC$	SCHOOL

DATE	ELECREVENUE	ELECUSAGE
2010/04	$30,900.15	22,320.000
2010/05	.	.
2010/06	$28,658.79	20,700.000
2010/07	.	.
2010/08	$65,055.89	46,980.000
2010/09	$30,402.16	21,960.000
2010/10	$49,579.28	35,820.000
2010/11	$48,583.06	35,100.000
2010/12	$38,869.98	28,080.000
2011/01	$92,408.14	48,420.000
2011/02	$69,796.45	32,760.000
2011/03	$79,381.45	37,260.000
2011/04	$75,164.52	35,280.000
2011/05	$49,476.85	23,220.000
2011/06	.	.
2011/07	$75,182.90	35,280.000
2011/08	$.00	.000
2011/09	$146,111.90	68,580.000
2011/10	-$23,369.15	-10,980.000
2011/11	$67,880.05	31,860.000
2011/12	$59,828.65	28,080.000
2012/01	$99,318.85	46,620.000
2012/02	.	.
2012/03	$150,712.70	70,740.000
2012/04	.	.
2012/05	$111,606.46	52,380.000
2012/06	$55,611.55	26,100.000
2012/07	$3,852.55	1,800.000
2012/08	$38,741.95	18,180.000
2012/09	$40,125.83	17,820.000
2012/10	$60,491.35	26,640.000
2012/11	$84,598.75	37,260.000
2012/12	$92,770.75	40,860.000
2013/01	$86,641.75	38,160.000
2013/02	$88,276.15	38,880.000
2013/03	$73,975.15	32,580.000
2013/04	$70,706.35	31,140.000
2013/05	$79,471.79	34,020.000
2013/06	.	.
2013/07	$56,708.34	24,120.000

DATE	ELECREVENUE	ELECUSAGE
2013/08	.	.
2013/09	$65,589.45	27,900.000
2013/10	.	.
2013/11	$146,788.17	62,460.000
2013/12	.	.
2014/01	$156,515.10	66,600.000
2014/02	.	.
2014/03	.	.
2014/04	$266,490.90	113,400.000
2014/05	.	.
2014/06	$100,732.60	41,760.000
2014/07	$45,646.22	18,900.000
2014/08	$32,175.54	13,320.000
2014/09	$38,278.81	15,840.000
2014/10	.	.
2014/11	$63,896.82	26,460.000
2014/12	$202,099.63	83,700.000
2015/01	$105,177.93	43,560.000
2015/02	.	.
2015/03	$186,456.26	77,220.000
2015/04	.	.
2015/05	$138,222.54	57,240.000
2015/06	.	.
2015/07	$57,378.75	23,760.000
2015/08	$23,919.32	9,900.000
2015/09	$24,664.06	9,900.000
2015/10	$15,830.36	6,300.000
2015/11	$117,937.33	46,980.000
2015/12	.	.
2016/01	$128,306.15	51,120.000
2016/02	$117,465.11	46,800.000
2016/03	$97,138.16	38,700.000
2016/04	-$67,735.99	-27,000.000
2016/05	$117,937.33	46,980.000
2016/06	.	.
2016/07	$31,188.50	12,420.000
2016/08	$33,565.35	13,320.000
2016/09	$52,800.70	20,340.000
2016/10	.	.
2016/11	$108,827.21	41,940.000

Appendix B: RETScreen Analysis Results

RETScreen Energy Model - Energy efficiency measures project

Fuels & schedules
☑ Show data

Fuel	Fuel type 1	Fuel type 2	Fuel type 3	Fuel type 4	Fuel type 5	Fuel type 6
Fuel type	Electricity	Oil (#6) - L				
Fuel consumption - unit	MWh	L				
Fuel rate - unit	$/kWh	$/L				
Fuel rate	2.594	1.000				

Schedule	Unit		Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5	Schedule 6
Description			24/7	Occupied				
				Occupied	Occupied	Occupied	Occupied	Occupied
Temperature - space heating	°C		22.0	22.0				
Temperature - space cooling	°C		30.0	30.0				
				Unoccupied				
Temperature - unoccupied	+/-°C			0.0				
				Occupied				
Occupancy rate - daily			h/d	h/d				
Monday			24	9.0				
Tuesday			24	9.0				
Wednesday			24	9.0				
Thursday			24	9.0				
Friday			24	9.0				
Saturday			24	0.0				
Sunday			24	0.0				
Occupancy rate - annual	h/yr		8,760	2,346				
	%		100%	27%				
Heating/cooling changeover temperature	°C	8.0						
Length of heating season	d	224						
Length of cooling season	d	141						

Facility characteristics
☑ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Energy - base case	MWh	MWh	MWh	$	$	$	yr	☐
Heating system								
Boilers	0	-	-	0	2,287	0	0.0	☑
DHW Tanks	0	-	-	0	0	0	-	☑
Cooling system								
Building envelope								
Building	260	0	-	0	-201	0	0.0	☑
Ventilation								
AHU-1	412	0	-	0	1,577	0	0.0	☑
AHU-2 Gym	172	0	-	0	659	0	0.0	☑
Lights								
Exterior Lights	-	-	16	0	27,834	0	0.0	☑
Classroom Lights (Type C & D)	-	-	20	0	0	0	-	☑
Interior Lights	-	-	18	0	-3,347	0	0.0	☑
Night Lights	-	-	14	0	11,247	0	0.0	☑
Gym Lights (Type E & F)	-	-	6	0	0	0	-	☑
Electrical equipment								
Computer Equipment	-	-	16	0	0	0	-	☑
Home Economics	-	-	12	0	0	0	-	☑
Parking Receptacles	-	-	0	0	0	0	-	☑
Other	-	-	8	0	0	0	-	☑
Hot water								
Hot Water Use	9	-	-	0	0	0	-	☑
Pumps								
P-1 / P-2 / P-3 (Boiler Pumps)	-	-	3	0	0	0	-	☑
P-4 / P-5 (Heating Pumps)	-	-	28	0	33,200	0	0.0	☑
P-7 / P-8 (Heat Recovery Glycol)	-	-	8	0	0	0	-	☑
P-11 / P-12 (DHW Recirc)	-	-	2	0	3,804	0	0.0	☑
Fans								
AHU-1	-	-	20	0	0	0	-	☑
AHU-2	-	-	4	0	0	0	-	☑
EF-1 / EF-2	-	-	37	0	0	0	-	☑
Shops Exhaust Fans and Range Hoods	-	-	6	0	0	0	-	☑
Washroom Exhaust Fans	-	-	2	0	0	0	-	☑
Motors								
Unit Heaters & Force Flows	-	-	6	0	0	0	-	☑
Shops Equipment	-	-	7	0	0	0	-	☑
Process electricity								
Process heat								
Process steam								
Steam losses								
Heat recovery								
Compressed air								
Refrigeration								
Other								
Total	853	0	233	0	77,059	0	0.00	

Summary
☑ Show data

	Fuel			Base case		Proposed case		Fuel cost savings		
Fuel type	**Fuel consumption - unit**		**Fuel rate**	**Fuel consumption**		**Fuel cost**	**Fuel consumption**		**Fuel cost**	**Fuel saved**		**Fuel cost savings**

Fuel type	Fuel consumption - unit		Fuel rate	Fuel consumption		Fuel cost	Fuel consumption		Fuel cost	Fuel saved		Fuel cost savings
Electricity	MWh	$	2,593.820	243.5	$	631,476	215.4	$	558,737	28.0	$	72,738
Oil (#6)	L	$	1.000	93,751.1	$	93,751	89,430.0	$	89,430	4,321.1	$	4,321
Total					$	725,227		$	648,167		$	77,059

Project verification Fuel type	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Electricity	MWh	244.0	243.5	0%
Oil (#6)	L	116,796.5	93,751.1	-25%

Fuel consumption	Heating MWh	Cooling MWh	Electricity MWh	Total MWh
Fuel consumption - base case	1,065		233	1,298
Fuel consumption - proposed case	1,016		205	1,222
Fuel saved	49		28	77
Fuel saved - %	4.6%		12.0%	5.9%

☐ **Show data**

See benchmark database

Benchmark		
Energy unit	GJ	
Reference unit	m²	

☑ Emission Analysis

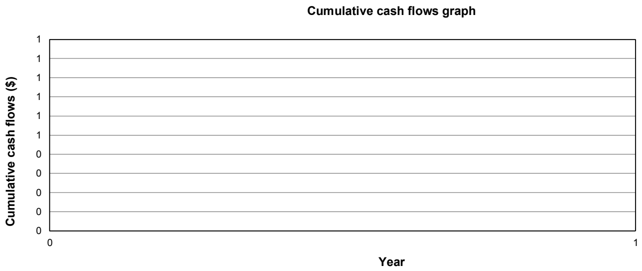
Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	Oil (#6)	0.833		0.833

GHG emission					
Base case	tCO2	486.7			
Proposed case	tCO2	450.3			
Gross annual GHG emission reduction	tCO2	36.4			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	36.4	is equivalent to	6.7	Cars & light trucks not used

GHG reduction income		
GHG reduction credit rate	$/tCO2	

Financial Analysis

Financial parameters			
Inflation rate	%		
Project life	yr		
Debt ratio	%		
Initial costs			
Energy efficiency measures	$	0	
Other	$		
Total initial costs	$	0	0.0%
Incentives and grants	$		
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	648,167	
Other	$		
Total annual costs	$	648,167	
Annual savings and income			
Fuel cost - base case	$	725,227	
Other	$		
Total annual savings and income	$	725,227	
Financial viability			
Pre-tax IRR - assets	%		
Simple payback	yr	0.0	
Equity payback	yr		



Appendix C: Savings Sheets

Lighting Retrofit

Convert Exterior Lighting to LEDs

✓	Recommended Retrofit Action
	For Information Only

Measure description:

There are eighteen 70 Watt HPS lighting fixtures and two 1,000 Watt Metal Hydride light standards outside of the building. These fixtures can be replaced with 20 Watt LED wall packs and 350 Watt LED flood lights. The lighting retrofit will reduce electrical consumption for outdoor lighting by approximately 70%.

Utility:

Electrical Consumption price (blended)	$2.59382 /kWh

Calculations:

Est. load (watts) = # bulbs x watts per tube x # fixtures
Est. Energy (kWh) = (Est. load (Watts) ÷ 1000) x Est. Operating Hours
Energy Avoided = Energy use base case – Energy use proposed case

Savings Summary:

The hours of use for each area above are assumed to be the same before and after retrofit. The budget costs assume installation by facility personnel (net zero).

Incentives available through the Manitoba Hydro Commercial Lighting Program are estimated, and based on publically available Manitoba Hydro information; however, final incentive amount is to be determined by a Manitoba Hydro engineer.

	Electricity
Savings (ekWh)	10,731
Cost avoidance ($)	$ 27,834
Estimated Retrofit Cost ($)	$ 21,000
Rebate ($)	$ 7,000
Payback (years)	**0.5**

Install Occupancy Sensors and Dimming Controls on Interior Lighting

Measure description

Occupancy sensors can be ceiling mounted, centrally controlled or integrated into light switches, and are ideal for washrooms, classrooms, storage rooms, and board rooms. Up to 35% in energy and cost avoidance is estimated by implementing this technology; however, with the heating consideration for interior lighting payback periods are not as attractive.

Utility Prices

Electrical Consumption price (blended)	$2.59382 /kWh

Assumptions:

- Occupancy sensors can be functionally installed on lighting circuits
- Occupancy sensors will reduce lighting energy consumption by up to 35%
- Estimated 50 units of occupancy sensors can be installed in the classrooms, washrooms and offices areas of the building. Installation of occupancy sensors or automatic shutoff controls should be avoided in shops classes where safety may be a concern.
- Manitoba Hydro rebate of $50/ sensor.

Savings & Calculations

	Electricity
Savings (ekWh)	3,046
Cost avoidance ($)	$ 7,888
Estimated Retrofit Cost ($)	$ 15,000
Rebate ($)	$ 2,500
Payback (years)	**1.6**

HVAC System

Install VFDs on Hydronic Heating Pumps

✓ Recommended Retrofit Action

For Information Only

Measure description

Variable frequency drives are means of controlling the speed at which a motor will rotate. Motors rotate at a fixed speed that is based on the frequency of the supply voltage. A four pole motor, has two paired poles, and given a supply voltage at 60 Hz, the motor will rotate at 60/2 revolutions per second, or 1800 rpm. VFD converts the fixed-frequency supply voltage to a continuously variable frequency, thereby allowing adjustable motor speed.

Glycol loop system at Petit Casimir employs two 10 hp motors of which one motors operate on continuous basis and at full speed during the heating season. During moderate weather conditions or unoccupied hours (when the ventilation system is off) the heating requirements for the building is reduced and a VFD allows for the pumps to modulate down and reduce energy consumption.

Utility Prices

Electrical Consumption price (blended)	$2.59382 /kWh

Assumptions:

	Current	Proposed
Pump size (HP)	10 hp	10 hp
Hours/ Year	5860	5860
Efficiency (%)	85	85
Loading (%)	55	55
Flow Type	Constant	Variable
Energy use (kWh/yr)	28,286	15,486

Modelled in RETscreen

Summary:

Savings are obtained by comparing the current energy cost of the pumps for the duration of operation. Estimated 30% to 40% in energy savings are perceived from installation and operation of VFD system on the two pumps.

	Electricity
Savings (ekWh)	9,550
Cost avoidance ($)	$24,770
Estimated Retrofit Cost ($)	$25,000
Rebate ($)	-
Payback (years)	**1.0**

Schedule DHW Recirculation Pumps

Measure description

✓ Recommended Retrofit Action

For Information Only

Often small pumps are used to circulate domestic hot water in a building. These pumps usually operate 24/7 even if there are no occupants within the building. A time-clock can be used to control the domestic hot water pump so it operates only when the building is generally occupied. Alternatively, if the building has an existing control system the domestic hot water pump can be included to construct a refined schedule. The electrical energy saved is due to reduced operating time of the pump.

Utility Prices

Electrical Consumption price (blended)	$2.59382 /kWh

Assumptions:

	Current	Proposed
Pump size (HP)	2 x 1/6	2 x 1/6
Hours	8760	2600
Efficiency (%)	75	75
Loading (%)	75	75
Energy use (kWh/yr)	2,085	619

Summary:

	Electricity
Savings (ekWh)	1,466
Cost avoidance ($)	$3,804
Estimated Retrofit Cost ($)	$500
Rebate ($)	-
Payback (years)	**0.1**

Implement Demand Control Ventilation (CO2 Sensors)

Measure description

✓ Recommended Retrofit Action

For Information Only

In areas where the number of occupants varies significantly with time, it is possible to control ventilation based on the number of occupants. Typical mixed air systems bring-in certain amounts of fresh air based on temperature controls, no matter the occupancy needs. With a demand based ventilation system, fresh air volumes are controlled based on occupancy. As the number of occupants in an area increases, so does the amount of fresh air to that area.

Utility Prices

Fuel Oil price	$1.0000 /Liter

Assumptions:

	Current	Proposed
Fresh air	25%	variable
HVAC Hours	2340	2340
Energy savings		35,420 ekWh/yr

Summary:

	Electricity
Savings (ekWh)	35,420
Cost avoidance ($)	$3,417
Estimated Retrofit Cost ($)	$15,000
Rebate ($)	-
Payback (years)	**4.3**

Water Efficiency Measures

Measure description:

The facility toilets are 13 and 6 LPF units with manual flush. The faucets are 5.7 LPM flow faucets with aerators.

Consider installing 4.8 LPF toilets to replace the 13 and 6LPF units. These would reduce toilet consumption by 31% and total water consumption by 15% for the school.

Utility Prices:

Electrical Consumption price (blended)	$0.0774/kWh
Water price	$3.90/m³

Assumptions:

- Approximately 450 students and staff with a male-to-female gender ratio of 40:60.
- Toilets – 3 uses per person/day; Visitors use facilities approximately once/day
- Hand washing – 75% of persons wash their hands after visiting the toilet (20 second avg. wash)

Summary:

Initiative	End-Use	Savings		Budget	Payback
		Volume	Cost		(years)
Toilets retrofit	Washroom	253	$868	$4,900	5.6
	Total	**253**	**$868**	**$4,900**	**5.6**

ASHRAE Level 2 Energy & Water Audit

Arena

Site Visit Date: March 8, 2017

Site Contact:

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April 7, 2017

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SITE SUMMARY

The Arena, is a 2,259 m^2 (24,3186 ft^2), two-storey facility that contains an ice rink, locker rooms, and a separated office area on the second floor. Approximately 25 people regularly occupy the space.

The office has two fuel oil furnaces each with approximately 117,000 BTU inputs that provide heating to the office. Two heat recovery ventilators (HRV) are implemented to transfer a portion of heat in the stale air being exhausted to the fresh incoming air from outside before being distributed throughout the space. There is a 3 kW electric hot water tank that serves the office space, and there is also a 189,000 BTU oil hot water tank, but it is not in use. Two one ton portable air conditioning (A/C) units also provide cooling to the office spaces.

450W metal halides provide lighting to the arena, and 32W T8 fluorescents provide lighting to the office areas. .

The building appears to be in fair condition.

Table 1, below, provides a description of the facility's construction features.

Table 1: Construction Summary

Construction Date:	~2000	Concrete Block, Steel Frame	
Floor Area (m²):	2,259	Number of floors:	Two
Volume (m³):	5,248	Basement:	none
Wall Area (m²):	1,728	Wall R-value (hr.ft².°F/BTU)	20
Window Area (m²):	34	Window R-value (hr.ft².°F/BTU)	2.5
Roof Area (m²):	2,249	Roof R-value (hr.ft².°F/BTU)	22

The arena only utilizes electricity which **Manitoba Hydro** charges for electricity consumption and demand. Fuel oil is purchased to serve the building's furnaces. The energy used in the most recent year of December 2015 to November 2016 is shown below:

Exhibit 1: Billed Utility Consumption

Utility	Billed Units	GJ	GHG (tonnes eCO2)	Cost	Cost Index ($/m²)	GHG (tonnes/m²)	Energy Index (ekWh/m²)
Electricity	95,760 kWh	345	736	$31,963	$14.15	0.326 [1]	42
Fuel Oil	10,537 L [2]	407	30	$10,537	$4.66	0.013 [3]	50

1. Based on 0.00768425124716553 tonnes per kilowatt hour of electricity produced via diesel generator.
2. Approximate based on information gathered from site visit and RETscreen energy model. Exact billing data not available.
3. Based on 0.00284008257300931 tonnes per liter of light fuel oil combusted.

Exhibit 2 illustrates the historical electrical consumption and demand of the Arena.

Exhibit 2: Billed Utility Consumption

Historical utility consumption for the facility is utilized as a benchmark platform to assess the building energy performance. The baseline energy consumption is determined from the energy use trends set by the building during the past 12- month analysis period.

Demand Side Energy Consultants Inc. was commissioned by Aki Energy Inc. to conduct energy/water audit of the building in order to establish a baseline of energy and water use, benchmark the facility performance, and to conduct a walkthrough audit that determines energy and water end-uses.

Several retrofit measures are presented to reduce or to use energy more effectively. Each opportunity has gone through a process to screen the level of energy and/or carbon reduction, the resulting change in utility cost, and the capital investment needed to pursue the changes.

Exhibit 3: Retrofit Opportunities

	Savings						
Measure	Electricity (kWh)	Fuel Oil Savings (ekWh)	Water Savings (litre)	Cost ($)	Est. Costs ($)	Rebate ($)	Payback (Yrs.)
Lighting Measures							
Convert Arena Lighting to 200W LED	32,850			$13,616	$22,500	$14,625	0.6
Convert T8 Lighting to 18W LED	4,906	(266)		$2,033	$2,078	$6,400	-
Install occupancy and dimming controls for interior lighting	2,351	(128)		$975	3,088	$840	2.3
HVAC Measures							
Schedule HRV and Furnace for setback	7,087			$2,976			-
Program HRV to operate on CO_2	3,866			$1,624			-
Water Measures							
Replace 6LPF to 4.8 LPF toilets			12,597	$43	$700		16.2
Water Subtotal			12,597	$43	$700		16.2
Energy Subtotal	51,060	(394)		$21,405	$27,666	$21,865	0.3

Implementing the above energy conservation measures will require estimated investment of $27,666 and result in utility avoided annual cost $21,405. Manitoba Hydro rebates total an estimated $21,865 and will result in 0.3 years simple payback period for the investment. In all, electricity will be reduced by 24%.

Water conservation measures will cost $700 to implement and save $43 per year resulting in a 16.3 year payback. Water consumption will be reduced by 12%.

BUILDING SUMMARY

ENVELOPE

Wall composition:

Exterior wall: two 5/8” type X gypsum board, 6” 20 gauge steel studs with two 5/8” type X gypsum board.

Recommendation:

Continue maintenance as per existing preventative maintenance schedule. Weather-stripping on the entrances and fenestration should be examined and renewed as required on an annual basis.

Roof:

Steel pre-engineered roof insulated to approximately R-22. The roof is in fair condition with compressed insulation.

Recommendation:

Windows:

Dual glazed non-operable windows. Approximately 5% window-to-wall ratio.

Recommendation:

Inspect and repair seals on an annual basis.

Doors:

Entrance doors are steel doors. They are insulated to R-2.

Recommendation:

Inspect on an annual basis; repair/replace weather-stripping as required.

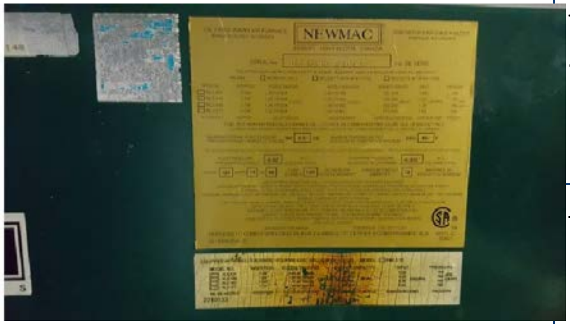
HVAC

Air Handlers:

Two HRVs (600 CFM each) operate to provide fresh air to the space. They exhaust stale air while also transferring a portion of its heat to the incoming fresh air. They are not scheduled for occupancy and operate on humidity.

Recommendations:

Preventative maintenance as per existing operating schedule. Schedule HRVs to occupancy and program them to operate on calls for CO_2.



Furnaces:

Two 117 MBH (input) oil furnaces provide space heating to the arena's change rooms. They each have a seasonal annual utilization efficiency (AFUE) of 80%. One furnace heats change rooms.

Recommendation:

Program furnaces to match occupancy along with the HRVs. Fans should be set to 'ON' during occupied and 'AUTO' when unoccupied.

Domestic Hot Water:

Two electric hot water tanks provide domestic hot water to the office kitchen and washrooms (including showers). One gas hot water tank is present but is never used.

Recommendation:

Schedule or add a timer to the two hot water circulator pumps to operate only when the building is occupied and there is a demand for hot water.

Pumps:

The ice making equipment has not been used for the several years – natural ice is used.

Recommendation:

LIGHTING

Arena Lighting:

Lighting in the arena is provided by 450W metal halides.

Recommendation:

Convert to 227W LED lamps.

Office Lighting:

Interior lighting for the offices spaces is provided by 32W T8 fluorescent units.

Recommendation:

Consider replacing all fixtures with 18W T8 Linear LEDs with occupancy sensors in offices, boardrooms and washrooms.

PLUMBING

Toilets:

6 LPF toilets are utilized in the arena.

Recommendation:

Consider installing 4.8 LPF or dual flush toilets

Faucets:

5.7 LPM faucets are used for the washrooms and kitchen.

Recommendation:

It is recommended to install hands free 1.9 LPM automatic flow control faucets.

BILLING HISTORY

Manitoba Hydro delivers *electricity* to the facility through one service account that charges for metered consumption as well as demand. **Table 1** summarizes all utility purchased by the building during the period noted.

Energy consumption is measured by volume, with electricity in kilowatt hours (kWh).

Table 2: Billed Utility Consumption from December 2015 to November 2016

Utility	Billed Units	GJ	GHG (tonnes eCO2)	Cost	Cost Index ($/m²)	GHG (tonnes/m²)	Energy Index (ekWh/m²)
Electricity	95,760 kWh	345	736	$31,963	$14.15	0.326 [1]	42
Fuel Oil	10,537 L [2]	407	30	$10,537	$4.66	0.013 [3]	50

1. Based on 0.00768425124716553 tonnes per kilowatt hour of electricity produced via diesel generator.
2. Approximate based on information gathered from site visit and RETscreen energy model. Exact billing data not available.
3. Based on 0.00284008257300931 tonnes per liter of light fuel oil combusted.

Figure 1 below illustrates the ratio of Electricity Consumption.

Figure 1: Electricity Consumption Profile

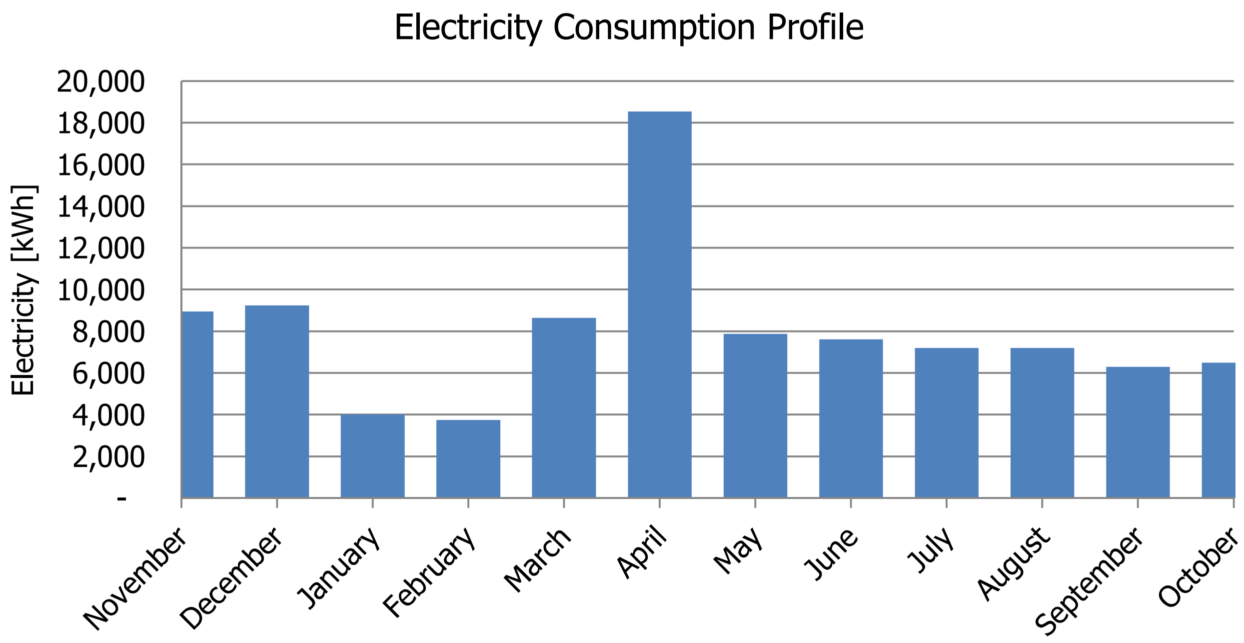


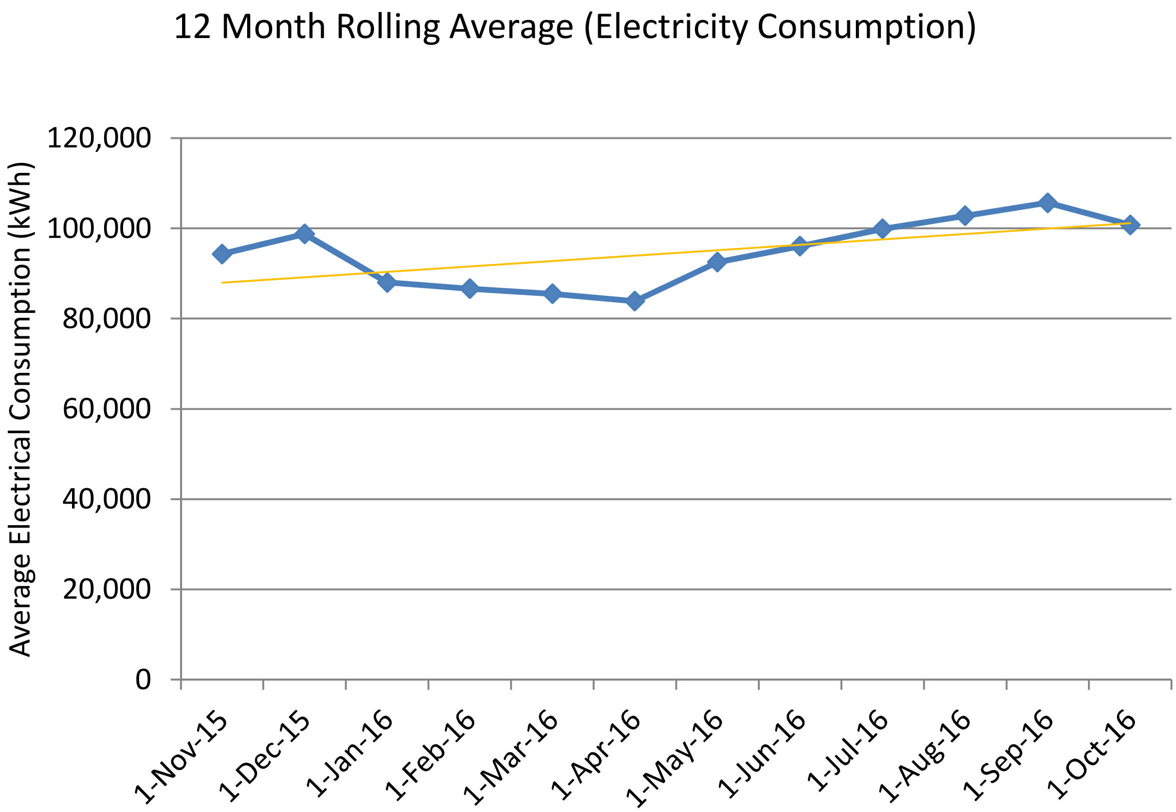
Figure 1 is the monthly electricity profile. The chart above indicates monthly electrical consumption with minimum electricity use during the winter season when minimal heating is needed.

The electricity baseline occurs in the winter (February and March), and this baseline electricity consumption accounts for the operation of lighting, minimal HVAC, and plugloads. There is no cooling system present in the ice rink area as it relies on the outdoor air temperatures to meet its cooling requirements, but there is a portable 1kW A/C unit for the office spaces. It is also used during the winter due to the …

Note that in several cases the electrical meter was not read or read incorrectly; in some cases the data was averaged over two or three months to show average monthly consumption.

Figure 2: Electricity – 12-month Rolling Average

The 12 month rolling average electrical consumption starting in 2011 to present is presented below to show the trend in electrical consumption over time. Some event in early 2011 increased electrical consumption sharply. Consumption levels appear to have dropped since then.



ENERGY END USE

A thorough inventory of the building energy consuming equipment in the Petit Casimir School was conducted by DSE. **Table 5** provides an annual account of the building *end-use systems*, based on the inventory of energy consuming equipment, estimates of operating hours, and on-site observations and measurements.

Table 3: Audit Results

Energy End Use	Electricity (kWh)	Fuel Oil (L)	Energy (ekWh)	Cost Portion	Cost [$/yr]	GHG (tonnes)
Fuel Oil						
Space Heating		9,282	99,687	70%	$9,282	26
Ventilation Heating		1,840	19,762	14%	$1,840	5
Combustion Losses		2,126	22,831	16%	$2,126	6
Internal Heat Gain		(4,470)	(48,004)	(34%)	($4,470)	(12)
Misc. Fuel		1,756	18,90	0%		5
Subtotal	-	10,537	113,165	100%	$13,248	29
Electricity						
Lighting	64,012		64,012	67%	$21,366	60
Fans	17,323		17,323	18%	$5,782	16
Pumps	1,981		1,981	2%	$661	2
Plug Loads & Peripherals	6,995		6,995	7%	$2,335	7
Domestic Hot Water	4,994		4,994	5%	$1,667	5
Misc. Elect.	455		455	0%	$152	0
Subtotal	95,760	-	95,760	100%	$31,963	90
Total Energy	95,760	10,537	208,925		$40,766	119

The end-use equipment energy and cost is categorized by energy requirements of the building systems that were part of the equipment inventory process. The final item in each category is “Miscellaneous Use”, which the energy is not accounted by the inventory process because its estimation is difficult or unreliable.

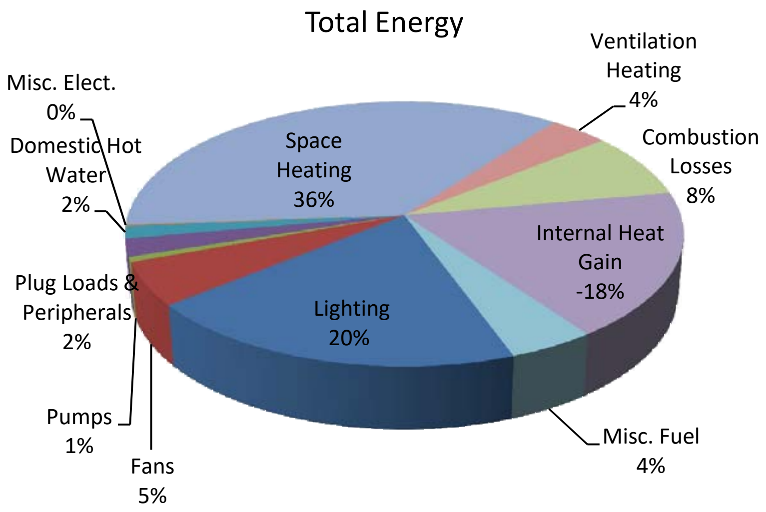
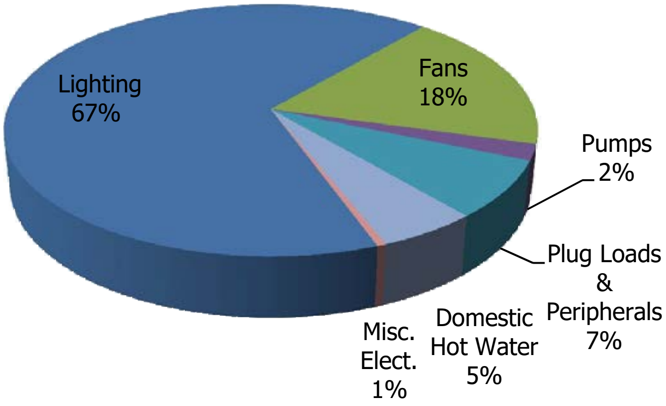


Figure 3: Electricity Energy End-Use



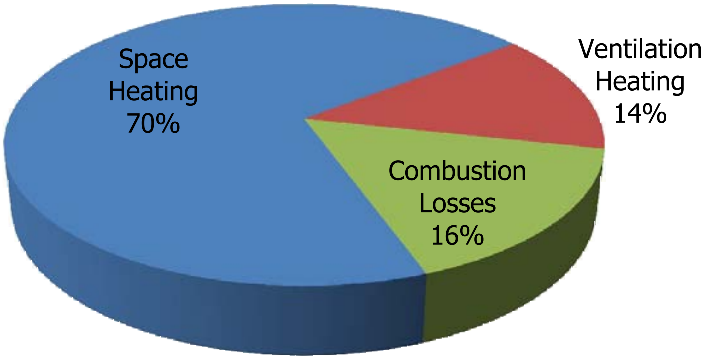
Interior Lighting is the largest consumer of electricity at the Arena. This is due to the forty five 450W metal halide fixtures that light the ice rink.

Fans and **pumps** for the HVAC account for 18% and 2% respectively of the electricity consumption. Fans account for the HRVs which operate continuously, as well as the furnace fans. These units are rated at 600CFM each. The pump energy is quite low since the Arena's ice making equipment has not been used in many years as natural ice is used. One portable one tonne air conditioner is used to cool the office spaces, and some space heaters are also used by office staff, though use is not easily tracked.

Plug loads are made up of the computers, printers and photocopiers as well as other peripherals such as monitors. Kitchen appliances include fridges, ovens and grills, microwaves, toasters, and coffee makers. The energy consumption for these end-uses are approximated based on occupancy of the facility as well as the hours of operation. These accounts for approximately 7% of electricity.

Domestic and Service Hot Water is provided to the by one 3 kW electric hot water tank, and account for 5% of the electricity. One oil hot water tank is also present, but it is not in use.

Figure 4:Fuel Oil Energy End-Use



Space heating is provided by two oil furnaces to the office spaces as well as the Arena change rooms. These units are 117,000 BTU with a seasonal AFUE of 80%. This end use accounts for 70% of the total fuel oil.

Ventilation is provided by two HRVs which are utilized to heat the office spaces and are scheduled to run continuously. Their operation accounts for 14% of the total fuel use.

Approximately 16% of the fuel oil is lost up the chimney as **combustion losses**.

WATER END USE

An inventory of the building water consuming fixtures at the ONR School conducted by DSE. **Figure 9** provides an annual account of the building *water consumption*, based on the inventory of water consuming fixtures, estimates of daily uses, and flow rates. The information was analyzed based on the number of occupants and patterns provided by the United States Environmental Protection Agency's (USEPA) Water Use Benchmarks, several Provincial Water Use studies, and Environment Canada.

Using these statistics under the assumption that the male-to-female gender ratio of occupant is 35:65 was applied to the inventory of water use fixtures, resulting in the patterns seen in the **Figure 4** below. Miscellaneous water use includes kitchen appliances, as well as water leaks and dripping faucets.

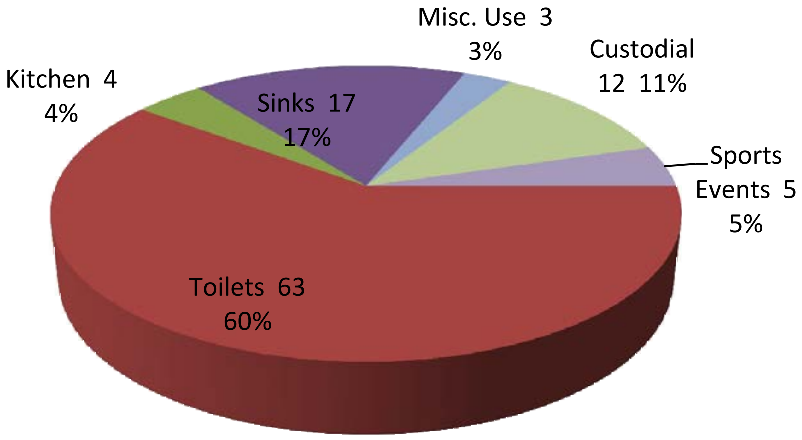
Figure 5: Water End-Use

The building water consumption is not metered but an estimate of annual of water consumption, based on the school population was made.

The majority of the facility's water consumption is estimated from washroom use.

Toilets are 6 litre per flush (LPF) with manual flushers, and faucets are 5.7 LPM manual fixtures.

Washroom usages account for 60% of the total water consumption. Handwashing is included in the washroom calculations - though there is some overlap between washroom sink use and kitchen sink use.



The staff kitchen use makes up roughly 4% of the total consumption, and 11% is consumed by custodial work in washrooms.

The Arena does host sporting events occasionally, and these would increase washroom and faucet use. It's estimated that about 5% of the water use is due to activity during sporting events.

Miscellaneous consumption includes dripping faucets and other undetected leaks, as well as other areas of consumption that, while accounted for, are not easily quantified via a walkthrough. This consumption accounts for 3% of the total.

CONSERVATION MEASURES

Several retrofit measures are presented that may present opportunities to reduce energy use. Each opportunity has gone through a process to estimate energy reduction, the resulting change in utility cost, and the capital investment needed to implement these changes. All the proposed changes to the facility have been put forward for evaluation in this section.

Conservation measures are classified either as initiatives that pay back their full cost in a reasonable period, or as those that are incremental. Incremental measures may be considered when replacement of equipment that is near end-of life is requested.

Opportunities within these two categories are further analyzed below.

Table 4: Energy Savings Opportunities

	Savings						
Measure	**Electricity (kWh)**	**Fuel Oil Savings (ekWh)**	**Water Savings (litre)**	**Cost ($)**	**Est. Costs ($)**	**Rebate ($)**	**Payback (Yrs.)**
Lighting Measures							
Convert Arena Lighting to 200W LED	32,850			$13,616	$22,500	$14,625	0.6
Convert T8 Lighting to 18W LED	4,906	(266)		$2,033	$2,078	$6,400	-
Install occupancy and dimming controls for interior lighting	2,351	(128)		$975	3,088	$840	2.3
HVAC Measures							
Schedule HRV and Furnace for setback	7,087			$2,976			-
Program HRV to operate on CO_2	3,866			$1,624			-
Water Measures							
Replace 6LPF to 4.8 LPF toilets			12,597	$43	$700		16.2
Water Subtotal			12,597	$43	$700		16.2
Energy Subtotal	51,060	(394)		$21,405	$27,666	$21,865	0.3

Implementing the above energy conservation measures will require estimated investment of $27,666 and result in utility avoided annual cost $21,405. Manitoba Hydro rebates total an estimated $21,865 and will result in 0.3 years simple payback period for the investment. In all, electricity will be reduced by 24%.

Water conservation measures will cost $700 to implement and save $43 per year resulting in a 16.3 year payback. Water consumption will be reduced by 12%.

Lighting Retrofit

- *32W T8 Fluorescent to Linear LED Conversion*

The majority of the Fluorescent fixtures are enclosed linear 4 foot fixtures with four tubes. A T8 conversion to 18W linear LED conversion (where practicable) is a candidate as lighting energy conservation retrofit. The low wattage fluorescent lighting retrofit will reduce office lighting consumption by approximately 20%.

- *450W Metal Halides to 200W LED Conversion*

The Arena ice rink is lit by forty five (45) 450W metal halide bulbs. These are a prime candidate for an LED lighting retrofit.

- *Occupancy Sensors in Low Traffic Areas*

Installing occupancy sensors in areas of the building where the occupancy fluctuates throughout the day can reduce the lighting consumption by an estimated 30%. Installing occupancy sensors in areas such as the conference rooms, janitor areas and washrooms would be advantageous, and reduce energy consumption of these lighting systems by 20%.

HVAC System Optimization

- *Schedule HRVs to Occupancy*

HRVs are operated on a continuous basis and the recommendation is to schedule them with an operations timer to coincide with occupancy hours, with an additional 1 hour of pre-ventilation to freshen the spaces before occupancy. Energy savings from the fan operation and the ventilation air heating are estimated at 7,087 kWh/yr at an estimated cost.

- *Program HRVs to run on CO2*

Sensing carbon dioxide (CO_2) level as a means to reflect space occupancy is the most common technique to trim the volume of fresh air. The system currently in place, for most other buildings, simply approximates the volume of fresh air by controlling the mixed temperature of the fresh / return air, resulting in too little fresh air for floors of high density and more than required for those of lower density. Energy savings from the fan operation and the ventilation air heating are estimated at 3,866 kWh/yr.

Water Savings

- *Replace 6LPF toilets with 4.8LPF units*

Replacing the current 6LPF toilets with 4.8 LPF flush toilets will reduce total water consumption by 12%. It will save an estimated 13 m³ of water per year which amounts to $43/year. The cost of the replacements are around $700 and will result in a 16 year payback.

Appendix A: Energy Billing Data

General service - Tariff no. 2016-40

Notes:
Minimum monthly bill is the monthly basic charge.
The general service diesel rate applies to all commercial accounts excluding those classed as Government and/or First Nation education.

Monthly basic charge	$21.20
plus energy charge:	
first 2,000 kWh @	8.329¢/kWh
balance of kWh @	42.617¢/kWh

ADDRCITY	LAC BROCHET
PREMCODE	6625124
CUSTCODE	8201828
OWNER	8201828
METER	790819
ADDRESS	FNC 197A
BFUNC$	RECREATION FACILITY

DATE	ELECREVENUE	ELECUSAGE
2010/04	.	.
2010/05	3,716	$12,420.00
2010/06	1,283	$4,680.00
2010/07	1,328	$4,680.00
2010/08	1,372	5,220.000
2010/09	1230.93	4,500.000
2010/10	2062.45	6,840.000
2010/11	1750.93	5,760.000
2010/12	1349.95	4,680.000
2011/01	3461.56	11,340.000
2011/02	2136.82	7,560.000
2011/03	2496.63	8,640.000
2011/04	1778.42	6,840.000
2011/05	1572.62	5,940.000
2011/06		.
2011/07	3414.73	12,960.000
2011/08	1806.53	6,660.000
2011/09	1338.11	5,580.000
2011/10	1023.71	4,320.000
2011/11	1302.53	5,220.000
2011/12	1131.62	4,680.000
2012/01	3677.86	12,420.000
2012/02		.
2012/03	4566.81	16,200.000
2012/04		.
2012/05	3573.63	13,140.000
2012/06	2457.64	8,820.000
2012/07	423.53	2,700.000
2012/08	1503.59	5,940.000
2012/09	907.88	3,960.000
2012/10	1701.11	6,120.000
2012/11	2794.74	9,000.000
2012/12	2823.1	9,180.000
2013/01	2400.88	8,100.000
2013/02	2621.68	8,640.000
2013/03	3801.84	11,700.000
2013/04	2056.2	7,020.000
2013/05	3189.97	10,080.000
2013/06		.
2013/07	1383.83	5,040.000

Appendix B: RETScreen Analysis Results

RETScreen Energy Model - Energy efficiency measures project

Fuels & schedules ☑ Show data

Fuel	Fuel type 1	Fuel type 2	Fuel type 3	Fuel type 4	Fuel type 5	Fuel type 6
Fuel type	Electricity	Oil (#6) - L				
Fuel consumption - unit	MWh	L				
Fuel rate - unit	$/kWh	$/L				
Fuel rate	0.080	1.050				

Schedule	Unit		Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5	Schedule 6
Description			24/7	Occupied				
				Occupied	Occupied	Occupied	Occupied	Occupied
Temperature - space heating	°C		20.0	18.0				
Temperature - space cooling	°C		22.0	22.0				
				Unoccupied				
Temperature - unoccupied	+/-°C			0.0				
				Occupied				
Occupancy rate - daily			h/d	h/d				
Monday			24	9.0				
Tuesday			24	9.0				
Wednesday			24	9.0				
Thursday			24	9.0				
Friday			24	9.0				
Saturday			24	0.0				
Sunday			24	0.0				
Occupancy rate - annual	h/yr		8,760	2,346				
	%		100%	27%				
Heating/cooling changeover temperature	°C	16.0						
Length of heating season	d	365						
Length of cooling season	d	0						

Facility characteristics ☑ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel consumption - base case	MWh	MWh	MWh	$	$	$	yr	☐
Heating system								
Oil Furnace	0	-	-	0	0	0	0.0	☑
Electric DHW	0	-	-	0	0	0	-	☑
Boiler	0	-	-	0	0	0	-	☑
Cooling system								
Portable A/C	-	0	-	0	0	0	-	☑
Building envelope								
Arena	90	0	-	0	-1,076	0	0.0	☑
Office	29	0	-	0	-341	0	0.0	☑
Ventilation								
HRV	13	0	-	0	361	0	0.0	☑
Lights								
Arena Lighting (450W MH)	-	-	59	0	2,628	0	0.0	☑
Office Lighting (T8)	-	-	11	0	392	0	0.0	☑
Electrical equipment								
Computer Equipment	-	-	7	0	0	0	-	☑
Hot water								
Hot Water Use	5	-	-	0	0	0	-	☑
Pumps								
DHW Recirc	-	-	2	0	0	0	-	☑
Fans								
HRV	-	-	11	0	393	0	0.0	☑
Furnance Fans	-	-	5	0	174	0	0.0	☑
Washroom Exhaust Fans	-	-	2	0	0	0	-	☑
Motors								
Process electricity								
Process heat								
Process steam								
Steam losses								
Heat recovery								
Compressed air								
Refrigeration								
Other								
Electric Heater	0	0	2	0	144	0	0.0	☑
Total	137	0	100	0	2,675	0	0.00	

Summary ☑ Show data

	Fuel		Base case		Proposed case		Fuel cost savings	
Fuel type	**Fuel consumption - unit**	**Fuel rate**	**Fuel consumption**	**Fuel cost**	**Fuel consumption**	**Fuel cost**	**Fuel saved**	**Fuel cost savings**
Electricity	MWh	$ 80.000	105.1	$ 8,407	58.4	$ 4,675	46.6	$ 3,731
Oil (#6)	L	$ 1.050	11,691.6	$ 12,276	12,698.0	$ 13,333	-1,006.4	$ (1,057)
Total				$ 20,683		$ 18,008		$ 2,675

Project verification **Fuel type**	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Electricity	MWh	95.7	105.1	9%
Oil (#6)	L	10,537.0	11,691.6	10%

Fuel consumption	Heating MWh	Cooling MWh	Electricity MWh	Total MWh
Fuel consumption - base case	137		100	237
Fuel consumption - proposed case	148		53	201
Fuel saved	-11		47	35
Fuel saved - %	-8.3%		46.7%	14.9%

☐ **Show data**

See benchmark database

Benchmark		
Energy unit	GJ	
Reference unit	m²	

☑ Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	Oil (#6)	0.833		0.833

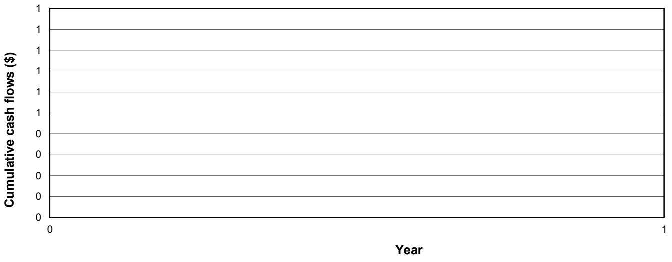
GHG emission					
Base case	tCO2	122.9			
Proposed case	tCO2	87.1			
Gross annual GHG emission reduction	tCO2	35.8			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	35.8	is equivalent to	6.6	Cars & light trucks not used

GHG reduction income		
GHG reduction credit rate	$/tCO2	

Financial Analysis

Financial parameters			
Inflation rate	%		
Project life	yr		
Debt ratio	%		
Initial costs			
Energy efficiency measures	$	0	
Other	$		
Total initial costs	$	0	0.0%
Incentives and grants	$		
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	18,008	
Other	$		
Total annual costs	$	18,008	
Annual savings and income			
Fuel cost - base case	$	20,683	
Other	$		
Total annual savings and income	$	20,683	
Financial viability			
Pre-tax IRR - assets	%		
Simple payback	yr	0.0	
Equity payback	yr		

Cumulative cash flows graph



Appendix C: Savings Sheets

Lighting Retrofit

Energy-efficient Building Lighting

✓	Recommended Retrofit Action
	For Information Only

Measure description:

It is recommended to install 18W linear LED T8 lighting in the offices rooms and compare the lumen output from the fixture and general lighting level in the task areas.

There are forty five 450W metal halides that light the ice rink. It is recommend that these be replaced by 227W LED fixtures. Typically, replacing these 450W units with the LEDs would result in loss of internal heat gains whioch would result in the heating system having to over compensate to make up for the lost heat provided by the lights. This will not be an issue for the Arena since it’s not heated thereby making for a more attractive payback period.

Utility:

Electrical Consumption price (blended)	$0.0774/kWh

Calculations:

Est. load (watts) = # bulbs x watts per tube x # fixtures

Est. Energy (kWh) = (Est. load (Watts) ÷ 1000) x Est. Operating Hours

Energy Avoided = Energy use base case – Energy use proposed case

Savings Summary:

The hours of use for each area above are assumed to be the same before and after retrofit. The budget costs assume installation by facility personnel (net zero).

Heat generated by lighting contributes to the space heating requirements of the building. Increasing the fixture efficiency reduces this heat, and this will increase the load on the heating system thereby increasing measure payback.

Incentives available through the Manitoba Hydro Commercial Lighting Program are estimated, and based on publically available Manitoba Hydro information; however, final incentive amount is to be determined by a Manitoba Hydro engineer.

	Electricity
Consumption (ekWh)	26,523
Savings (ekWh)	37,756
Cost avoidance ($)	$15,830
Estimated Retrofit Cost ($)	$24,578
Estimated MB Hydro Rebate ($)	$21,025
Payback (years)	**0.2**

Install Occupancy Sensors

Measure description

Occupancy sensors can be ceiling mounted, centrally controlled or integrated into light switches, and are ideal for washrooms, storage rooms, and board rooms. Up to 35% in energy and cost avoidance is estimated by implementing this technology; however, with the heating consideration for interior lighting payback periods are not as attractive**.**

Utility Prices

Electrical Consumption price (blended)	$0.0774/kWh

Assumptions:

- Occupancy sensors can be functionally installed on lighting circuits
- Occupancy sensors will reduce lighting energy consumption by up to 35%
- Estimated 20 units of occupancy sensors can be installed in the washrooms and offices areas of the building.

Savings & Calculations

Savings associated with the installation of occupancy sensors is calculated using reduced lighting operating hours.

Calculation for annual kilowatt:

$$\frac{Wattage}{Fixture} \times \frac{\#\, fixtures}{1000} = kW$$

Calculation for avoided consumption:

$$(\,kW\ current\ -\ kW\ proposed) \times Annual\ operating\ hours = Annual\ avoided\ kWh$$

Occupancy sensors	# rooms	Total Units	W/ unit	Hrs	kWh	Savings [kWh]	Savings [$]	Payback
Offices	5	20	34	3640	2,475	866		
Washrooms/ Change Rooms	4	16	34	5200	2,829	990		
Storage Rooms	4	8	34	5200	1,414	495		
Cost	$3,088	44				2,351	$975	2.3
Rebate	$840							

HVAC System

Schedule HRV and Furnaces for Occupancy

✓ Recommended Retrofit Action

For Information Only

Measure description

HRVs are operated on a continuous basis and the recommendation is to schedule them with an operations timer to coincide with occupancy hours, with an additional 1 hour of pre-ventilation to freshen the spaces before occupancy. Energy savings from the fan operation and the ventilation air heating are estimated to be 7,878 kWh/year.

Utility Prices

Electrical Consumption price (blended)	$0.0774/kWh

Assumptions:

	Current	**Proposed**
Fan HP	¾	¾
Hours/ Year	8760	2607
Flow Type	Constant	Schedule
Energy use (kWh/yr)	20,707	13,620

Summary:

	Electricity
Savings (ekWh)	7,087
Cost avoidance ($)	$2,976
Estimated Retrofit Cost ($)	-
Rebate ($)	-
Payback (years)	**-**

Program HRVs to operate on CO_2

Measure description

✓ Recommended Retrofit Action

For Information Only

The HRVs are programmed to operate on a humidity setpoint. Sensing carbon dioxide (CO_2) level as a means to reflect space occupancy is the most common technique to trim the volume of fresh air. The system currently in place, for most other buildings, simply approximates the volume of fresh air by controlling the mixed temperature of the fresh / return air, resulting in too little fresh air for floors of high density and more than required for those of lower density.

Utility Prices

Electrical Consumption price (blended)	$0.0774/kWh

Assumptions:

	Current	**Proposed**
Flow (CFM)	600	600
Hours/ Year	8760	2607
Flow Type	Constant	Schedule
Energy use (kWh/yr)	23,923	20,057

Summary:

	Electricity
Savings (ekWh)	3,866
Cost avoidance ($)	$1,624
Estimated Retrofit Cost ($)	-
Rebate ($)	-
Payback (years)	**-**

,

Water Efficiency Measures

Measure description:

The facility toilets are 6 LPF units with manual flush. The faucets are 5.7 LPM flow faucets with aerators.

Consider installing 4.8 LPF toilets to replace the 6LPF units. These would reduce toilet consumption by 25% and total water consumption by 12% for the Arena.

Utility Prices:

Electrical Consumption price (blended)	$0.0774/kWh
Water price	$3.90/m³

Assumptions:

- Approximately 25 equivalent full time employees with a male-to-female gender ratio of 40:60.
- Toilets – 3 uses per staff person/day; Visitors use facilities approximately once/day
- Hand washing – 75% of persons wash their hands after visiting the toilet (20 second avg. wash)

Summary:

Initiative	End-Use	Savings		Budget	Payback (years)
		Volume	Cost		
Toilets retrofit	Washroom	12 m³	$43	$700	16.3
	Subtotal	**12 m³**	**$43**	**$700**	**16.3**

Final Summary Report:

Residential Energy and Water Audits in Manitoba's Off-Grid First Nations

Prepared for:

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Winnipeg, Manitoba R2W 3N5

Prepared by:

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Prepared on:

March 31, 2017
(Revised May 31, 2017)

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1.0 Introduction and Background

1.1 Purpose of This Report

This report has been prepared for Aki Energy Inc. by prairieHOUSE Performance Inc., a Manitoba-based firm providing professional consulting, advice, commissioning, testing, and home energy evaluation services in the areas of home performance, building science, and green building.

Aki is facilitating development of Community Energy Plans (CEPs) for three of Manitoba's four off-grid First Nation that rely upon expensive diesel-generated electricity and heating oil. These communities include Lac Brochet (Northlands Denesuline First Nation), Brochet (Barren Lands First Nation) and Tadoule Lake (Sayisi Dene First Nation).

To support this effort, Aki contracted prairieHOUSE to conduct detailed energy and water audits on a sample of existing homes in each community. The purpose of this report is to summarize key findings and recommendations that have emerged from these audits with respect to potential energy efficiency and water conservation strategies for existing housing. The insights provided in this report are also intended to inform the development of green building criteria for future new housing to be built in these communities.

1.2 Project Objectives

The objectives for the detailed energy and water audits conducted this project were to:

- gain a deeper understanding of how energy and water is used in homes in each community;
- identify practical, cost-effective energy and water retrofit strategies for the existing housing stock in these communities that reflect the high cost of energy and challenging northern climates they face; and
- document performance, durability, indoor air quality and other concerns with existing houses in these communities that should be addressed in development of more appropriate building standards for new housing.

1.3 Climatic Context

For most houses in Manitoba, with exception of super-insulated, net-zero ready or passive-type houses, the largest component of annual energy use is almost always space heating followed by domestic water heating (i.e., showers, baths, laundry, cleaning, cooking, etc.).

The amount of heating energy a house requires to maintain a typical interior temperature of 21°C during the heating season depends on multiple factors such as the building envelope, orientation, mechanical systems, and operating conditions of the home in relationship to local climatic conditions.

The three communities addressed in this report are among Manitoba's most northern communities. 'Heating Degree Days' (HDD) is a measurement commonly used to quantify the energy required to heat a building in a typical year. The annual HDD of a location represents the difference between the mean daily temperature for that location and 18°C over 365 days.

Based on Government of Canada climatological data collected from 1940-1971, the three communities in this study experience approximately 8,450 to 9,125 HDD (Celsius). This is 49% to 61% higher compared to Winnipeg's 5,670 HDD. Furthermore, the outdoor design temperature, the coldest temperature that homes and buildings in these communities need to be designed for, is approximately -40°C.

In addition to high energy consumption for heating, houses and buildings in the north also experience significant durability, comfort and indoor air quality challenges due to the number of HDD, low (cold) design temperatures, high occupancy and housing conditions.

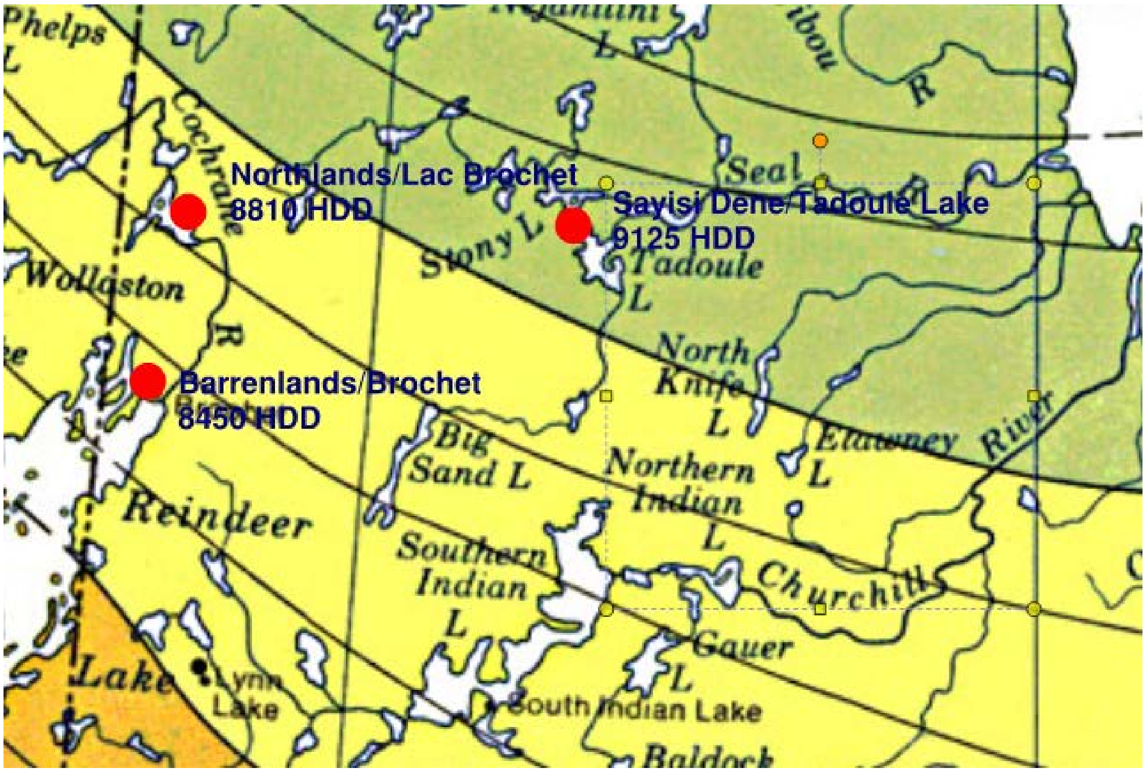

Figure 1 – Location and heating degree days for Lac Brochet, Brochet and Tadoule Lake

1.4 Distribution of Energy Consumption

All Manitoba homes require some type of energy in their operation. At the most general level the amount of energy used in each house will be determined by factors including the house location/orientation, size, envelope and mechanical characteristics, number of occupants and occupant behaviour, and electrical loads (i.e., appliances, lighting, pumps, devices, etc.). The typical house 'energy pie', therefore, is made up of energy for:

- space heating and cooling;
- domestic hot water

- appliances and lighting; and
- miscellaneous ‘plug loads’ (e.g., entertainment devices, computers, vehicle block heaters, pumps and fans, etc.); and

Some houses may have also atypical loads (e.g., hot tubs, pools, de-icing cables, trace heaters for water lines, outbuildings/shops, etc.).

An example of the projected annual energy use for an average size house in Lac Brochet occupied by two adults and two children under typical operating conditions is shown in Figure 2 below. The red section of the pie chart (‘Heating’) represents the amount of energy provided by heating oil burned at an annual combustion efficiency of 80 to 83%. The remainder of the pie chart represents diesel-generated electricity (produced at 32% efficiency) for all other end-uses.

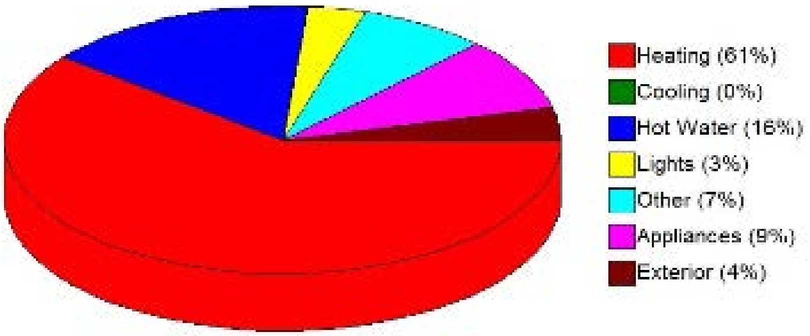

Figure 2 – Components of Annual Energy Consumption for a typical house in Lac Brochet

2.0 Energy and Water Audits

2.1 Sample Selection, Size and Audit Process

This summary report is based on a review of electricity consumption in all houses in each community in addition to the energy and water audits carried out in a sample of 27 homes in Lac Brochet (12 houses audited), Brochet (8 homes audited) and Tadoule Lake (7 houses audited) in early 2017.

This sample sizes represent approximately 6% to 8% of all homes in each community. Although this is a reasonable sample size, it cannot be guaranteed to be completely representative due to time constraints and selection methods. As a result, some caution must be exercised in drawing conclusions from the sample.

Manitoba Hydro provided six years of monthly electricity consumption data for all residential accounts in the three communities involved in this project. A six-year average consumption was calculated for each house, and average consumption calculated for each community.

Complete EnerGuide Rating System (ERS) energy evaluations were carried out in a selection of homes in each community. The EnerGuide Rating System was developed and is administered by Natural Resources Canada.

An ERS evaluation involves recording the geometries, surface area and thermal resistance (insulation) values of the entire envelope (windows, walls, attics, foundations), collecting mechanical information (ventilation, heating, domestic hot water equipment), and measuring of building airtightness by means of a blower door test.

The data collected is used to build a virtual (electronic) model of the house using HOT2000 software. Using this software, the ‘virtual house’ is then run through a year of operation using standard operating conditions (interior temperature set points, frequency of use of ventilation systems, appliance, lighting, and other base load energy use, and domestic hot water consumption) and long-term climatic data to evaluate how much energy the house is projected to use.

The HOT2000 software energy model is a powerful tool to help predict annual energy use and to quantify energy-saving opportunities. For example, using the HOT2000 model we can explore how much energy can be saved by upgrading different assemblies in the house or by changing heating or ventilation systems.

It is important to note that in addition to the physical attributes of a house (e.g., insulation levels, airtightness, mechanical systems, etc.), the energy use in a house is also influenced by occupants and their behaviour. For example, two otherwise physically identical houses might have very different energy consumption due to more showering/hot water consumption and laundry (washer and dryer) use due to lifestyle or different numbers of occupants in each home. As another example, one family might prefer an indoor thermostat setting of 23°C while another family might prefer a setting 18°C. One household might have multiple television and entertainment systems in the house on for long periods of time and another might have one television and satellite TV system used for only a few hours a day.

Therefore, to better understand energy use which is connected to occupant behaviour and household contents, we also collected data outside of a typical EnerGuide Rating Service. This included:

- Recording the number of occupants in each household.
- Measuring the flow of faucets and showerheads.
- Checking toilets for water use and leaks from tanks.
- Documenting, measuring and estimating annual consumption of fridges and freezers.
- Documenting all appliances in the house.
- Noting number and types of lighting fixtures in the home.
- Collecting indoor air quality info including interior temperature, relative humidity, and carbon dioxide levels.
- Collecting info on any other significant loads including trace heaters, entertainment systems/televisions/DVD players, etc.

2.2 Community Energy Use

The six-year average annual electricity consumption per home in Lac Brochet, Brochet and Tadoule Lake (see Table 1 below) is close to the Manitoba provincial average of 11,322 kWh for houses not heated with electricity reported by Manitoba Hydro. This is especially noteworthy given that:

- many of the homes in these three communities have a higher occupancy that the provincial average of 2.5 persons per household reported by Statistics Canada in 2011 Census; and
- the harsher climate of these communities which necessitates atypical loads (e.g., heat-trace on plumbing systems) or extended use of energy-using devices (e.g., furnace and ventilation fans, vehicle block heaters, etc.)

Community	Average No. of Persons Per Household	Annual Average Consumption (kWh)
Lac Brochet	7.5	13,679
Brochet	4.7	13,912
Tadoule Lake	2.5	11,307

Table 1 – Annual average electricity consumption (six-year average)

As expected, there was a considerable range of electricity consumption among homes in each community. Difference in consumption would be explained by house characteristics (size, design, insulation levels) and physical condition, operating conditions, and number of occupants and associated activities (especially domestic hot water consumption). Histograms showing annual electricity consumption for each community are shown below in Figure 3, 4 and 5.

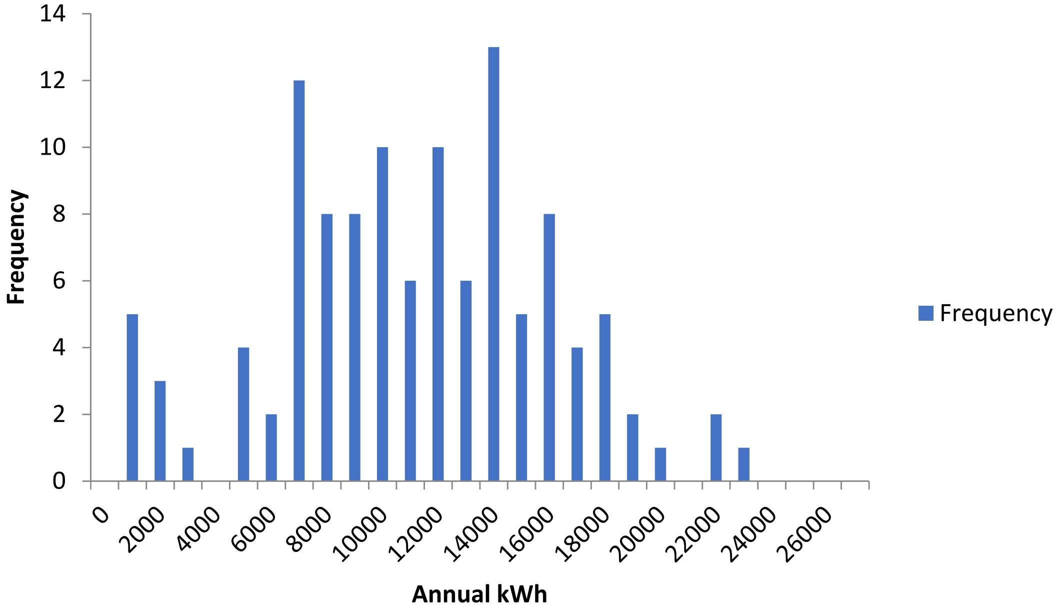

Figure 3 – Lac Brochet Annual Residential Electricity Consumption (kWh)

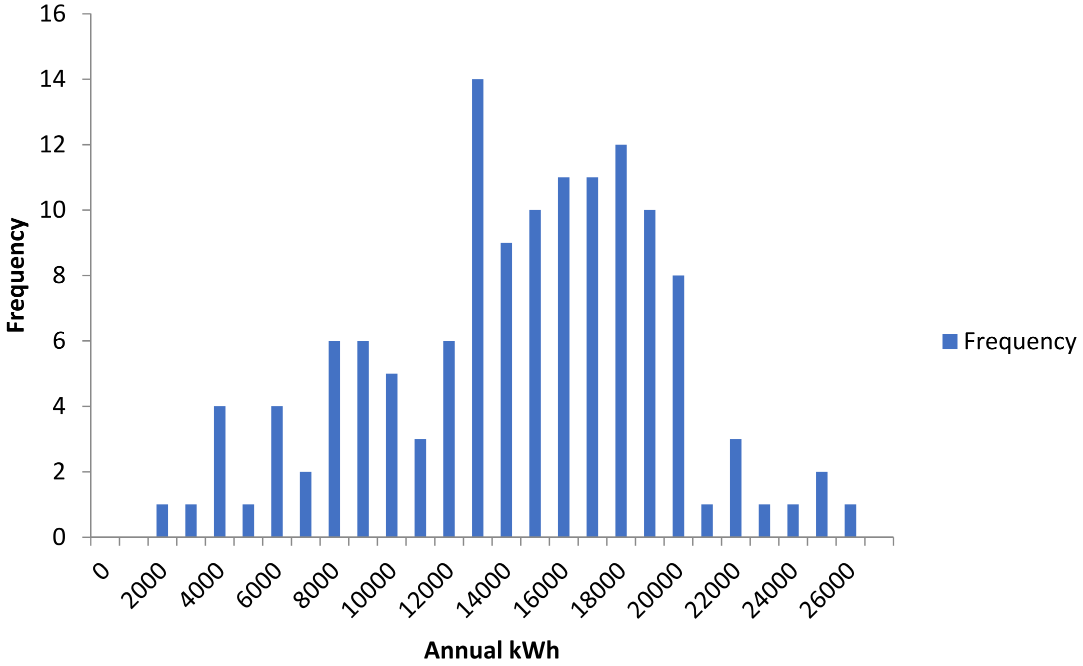

Figure 4 – Brochet Annual Residential Electricity Consumption (kWh)

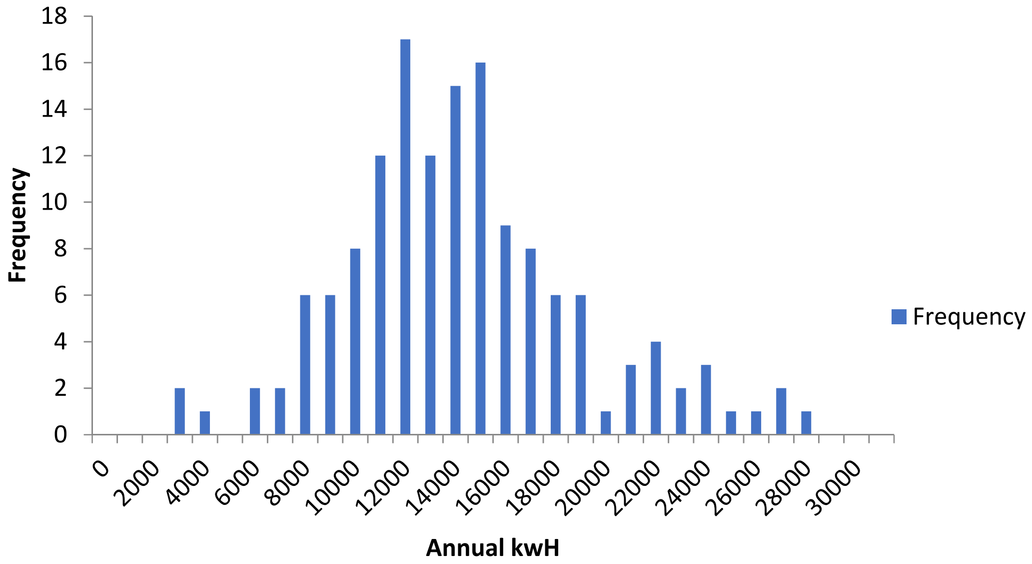

Figure 5 – Tadoule Lake Annual Residential Electricity Consumption (kWh)

Records of oil deliveries to individual houses in the communities often did not appear to be complete or inconsistent. As a result, it hasn't been possible to reconcile the energy modelling of house audited under this project with actual heating oil consumption. For example, although one source reported close to 4,700L of oil consumption per home, our energy modelling predicts an average annual heating oil consumption of approximately 2,600 L annually per home. Demand Side Energy Consultants had a similar estimate during previous studies completed in the communities.

If carried out, future longer-term energy monitoring should include more precise measurement of actual heating oil consumption.

2.3 Electricity End-Use

Without doing longer-term energy monitoring, it isn't possible to know for certain what the actual breakdown of the electricity loads are. However, we can approximate that depending on occupancy, water use and occupant behaviour, domestic hot water consumption appears to represent 25% to 50% of the annual electricity consumption in each household. The rest of the electricity consumption attributable to lighting, appliances (especially fridges and dryers), trace heaters for water lines, portable space heaters, furnace/ventilation fans, entertainment devices/gadgets, and exterior loads including vehicle block heaters.

All houses audited for this project are heated with oil-fired furnaces with wood heating only being used in some cases for emergency or supplementary heating. As a result, building envelope upgrades (e.g., adding insulation, replacing window, reducing air leakage) will not provide a significant reduction in electricity consumption except for a modest amount of furnace fan energy use or any auxiliary/supplemental electric resistance heat devices used in the home.

Due to the long heating season and interactive effects, most electricity-saving measures not related to domestic hot water, such as more efficient ENERGY STAR appliances/gadgets and lighting, will result in an increase in oil consumption for space heating. However, given that the diesel-generated electricity is currently produced at an annual efficiency of approximately 32%, and most of the furnaces used for heat operate at a seasonal efficiency 80 to 85%, strategies to reduce electrical consumption are still worthwhile and could be assigned a higher per kWh saved value than heating energy.

3.0 Energy-Saving Opportunities

3.1 Building Envelopes

Most houses audited in in the three communities were in poor/fair to good physical and cosmetic condition. Community members indicated, and we observed in the field, that many homes in the communities require substantial renovation/rebuilds due to rapid deterioration from a harsh climate, poor building quality, or intensive use due to overcrowding. For some homes, such ‘major refresh episodes may occur in 8 to 12 year cycles.

Although a detailed housing inventory does not appear to be available (and would be a useful and important next step), most of the housing in the three communities are less than 30 years old. They are a mixture of 38 x 89 mm, RSI 2.1 (2 x 4, R-12) exterior walls for older homes and 38 x 140 mm, RSI 3.5 (2x6, R-20) walls for newer (1990+) homes.

None of the houses audited in Lac Brochet had exterior rigid insulation on the walls. Only two of the seven houses audited in Tadoule Lake had better than RSI-3.5 (R-20) insulation in exterior walls. All but one of the homes visited in Brochet had RSI 3.5 (R-20) walls, with one of the eight visited homes having an additional RSI-1.32 (R-7.5) of rigid insulation.

Many of the windows in the homes in the communities are only dual-glazed. This is not considered to be appropriate for the climatic conditions of these communities from an energy, comfort and condensation resistance perspective.

Most attics were RSI 7.0 (R-40) or better, with only a few modest upgrade opportunities.

Blower door airtightness tests were performed to measure the amount of air leakage in each house audited. The airtightness of a house strongly influences its performance (i.e., energy use, comfort, durability, indoor air quality). Airtight homes are desirable provided that an adequate mechanical ventilation systems is installed, operated and maintained to ensure good indoor air quality.

There was a wide range of airtightness across the homes we tested – see Figure 6 on the next page. As a reference, most new houses in Manitoba would likely have an airtightness of between 1.25 and 1.75 air changes per hour at 50 pascals (ACH @ 50 pa). Although we did test a few houses that were either much tighter or much leakier than average, most of the houses we tested would be considered average in terms of airtightness for existing homes in Manitoba.

Much of the measured leakage was due to combustion air supplies and furnace flues. In most homes, targeted air sealing efforts during upgrades can probably improve airtightness levels by 10 to 20%. However, serious and concerted air sealing efforts should only be undertaken if a solid ventilation scheme is in place meaning that ventilation systems must be installed following the DICOM mantra (**D**esign **I**nstall **C**ommission **O**perate **M**aintain).

Community	Average Airtightness (ACH@50 pascals)	Range (ACH @ 50 pascals)
Lac Brochet	4.4	1.93 to 6.16
Brochet	4.7	1.76 to 10.87
Tadoule Lake	4.98	2.11 to 7.07

Figure 6 – Airtightness results

As is commonly the case with crawlspaces in Manitoba, poor construction and insulation details in these assemblies create significant energy, durability and indoor air quality problems. Some mold and rotting of wood was witnessed in a few of the crawlspaces.

Our HOT2000 energy modelling showed that modest envelope upgrades including air sealing, upgrading any windows being replaced to high performance triple, low-argon, a minimum of RSI 1.76 (R-10) exterior insulation added to all exterior walls and crawlspace/basement walls, and attic upgrades to a minimum of RSI 10.56 (R-60) would reduce heating oil consumption by an average of 25% to 33%.

Assuming an average annual consumption of 2,600 L of heating oil, this means that a modest upgrade package can provide a reduction of 650 to 850 L of heating oil annually per house. A deep energy retrofit (DER) approach, when properly executed and depending on target envelope levels, could reduce heating energy use by two-thirds or more, reducing heating oil consumption from about 2,600L to 700L or lower annually if heated with existing mid-efficient oil-fired furnaces, or less than 5,000 kWh per year of electricity if heating is switched to electric resistance.

When correctly executed, the addition of exterior insulation to the building envelope will not only save significant energy and improve comfort, but also improves the durability of the building by warming surfaces of sheathing and interior finishes reducing the potential for condensation in the assembly which can lead to moisture-related durability and indoor air quality issues from mold.

Once envelope upgrades are performed, buildings are unlikely to undergo another significant investment and upgrade for several decades, and effectively an energy saving opportunity is lost. Therefore, we recommend that careful thought and analysis go into evaluating optimum (DER) envelope specifications for these upgrades.

The common practice of upgrading houses in the community with poor quality, dual-glazed windows and sub-standard levels of exterior insulation should no longer be entertained.

3.2 Space Heating Systems

A challenge, whether upgrade scenarios are modest (as above) or more aggressive (in line with a deep energy retrofit approach) is that the forced-air oil-fired furnaces currently installed in homes in the communities are already significantly oversized, often by 200% or more.

Modest insulation upgrades will exacerbate over-sizing problems and may result in comfort or furnace performance problems due to short-cycling.

There are currently no low-output oil furnaces that are appropriate for lower-load houses on the market that we are aware of.

Aggressive, net-zero/super-insulation/deep energy retrofit scenarios for existing and new housing may require a switch to electric resistance heat, therefore adding to grid peak and annual electricity consumption loads which will need to be planned for.

The option of switching heating fuel to wood (as in a high efficiency wood stove in the home) creates challenges with both fire risk and depressurization and combustion spillage risks, in addition to potential community air quality issues. In super-insulated homes, overheating and combustion spillage risks are even higher and wood heat would likely be discouraged unless appropriate.

If it is decided not to eliminate heating oil in the community, alternative forms of heating with fuel oil should be explored. One example is using an oil-fired domestic hot water heater feeding a second storage tank coupled with an air handler with a heating coil. This would allow for houses with very small heating loads to be safely and comfortably heated via heating oil if electric resistance is not a viable option. This would also allow domestic hot water to be produced at a much higher efficiency than the current electric resistance scenario.

Other members of Aki's Community Energy Planning Team are exploring options for heating using renewable energy district systems which would likely feed a heating coil in an air handler. This approach merits serious consideration.

Regarding ground source heat pumps (geothermal), if a deep energy retrofit approach on existing homes and a net-zero ready/super-insulation approach is taken for new construction, the heating loads may be so small that the large capital cost and maintenance costs makes this technology a poor economic choice.

3.3 Domestic Hot Water

In addition to water-saving devices that reduce water and energy use, drain water heat recovery (DWHR) is another appealing technology which can offer cost-effective domestic hot water energy use savings. DWHR are usually vertical, and require a minimum horizontal height of 1.2 to 1.5 meters (4 to 5 feet) in a plumbing stack below showers. As most houses in the off-grid communities are built on crawlspaces, vertical drain water heat recovery is not feasible.

As an alternative, a horizontal DWHR device should be explored for installation in all homes – see example at this link: https://ecodrain.ca/en/products/A1000/. Potential energy savings will depend on several factors including occupant behaviour (i.e., number and length of showers), incoming cold water temperatures and showerhead flow rates. Given the above average occupancy in many houses in these communities, savings in the range of about 500 to 1,000kWh per year is probably reasonable.

Because DWHR will reduce average effluent temperatures entering the municipal or independent sewage systems, there should be an evaluation of whether this creates any downstream risks or problems with sewer lines, lift stations or waste water treatment facilities.

3.4 Major Appliances

Refrigerators and freezers – A proactive, community-wide strategy to replace fridges/freezers with ENERGY STAR models should be considered. Savings of about 300 to 500+ kWh/year are possible when older fridges are replaced with an ENERGY STAR fridge.

Clothes washers – It would be desirable to monitor clothes dryer usage to document the frequency of use and understand both the dryer energy use and dryer exhaust impact on heating loads.

High efficiency front loading washing machines would reduce (hot and cold) water consumption, energy use, and also dryer energy as the high spin cycles in front loading washing machines typically delivers lower moisture content in clothes at the end of the wash cycle.

Clothes dryers – Condensing dryers could reduce dryer energy use by 35% to 50% and save heating energy by both not removing 150 to 200 CFM of air from the house during their operation by leaving their residual operating heat in the home. The higher capital cost and challenges of complexity, unknown longevity, and repair may be problematic in remote communities and should be carefully considered.

Furthermore, replacing a vented dryer with a ventless dryer also effectively means that the house will experience less mechanical ventilation and indoor air quality in the home will suffer unless an adequate ventilation system is in place.

There may be an innovative solution to reducing dryer energy using a district energy system or developing a community laundry facility.

3.5 Lighting and Controls

Although some progress has been made on installing more efficient lighting there is still significant retrofit potential in all three communities, especially for LED lighting. A penetration rate of 60% penetration for LED/CFL lighting was observed in homes. Although the savings from lighting retrofits is modest, they can be achieved at a low cost.

3.6 Miscellaneous Electrical Loads

Vehicle engine block heaters – Over 75% of the homes audited report using a vehicle block heater during the winter. The amount of electricity being consumed per home or community-wide is not known. Smart power receptacles that do not require homeowner programming should be explored.

Manufacturer data reports energy savings of up to 65% – see: https://www.iplc.com. The popularity of large pick-up trucks in the communities means that the block heaters are likely larger in size and consume about 750 to 1,000 watts continuously when plugged in overnight.

Entertainment systems and devices – Most houses that were audited for the project have at least two TV/VCR/SAT/DVD systems in use. Both the standby and in-use loads of these can be considerable). Incentives should be considered to encourage band members to purchase ENERGY STAR entertainment systems and devices when replacing existing equipment or buying new systems.

4.0 Ventilation and Indoor Air Quality

Poor indoor air quality and mould growth is a common problem in First Nation housing. Although improper design and construction details can contribute to indoor air quality issues including excessive relative humidity levels leading to mould growth, the most common cause is almost always inadequate mechanical ventilation. Ensuring all homes have adequate and well-maintained mechanical ventilation should be high priority.

To be effective, all ventilation systems must follow the DICOM mantra:

- **Design**: Systems should be designed to meet appropriate code and context
- **Installation**: Systems should be properly installed following HRAI and manufacturer best practices
- **Commissioning**: Systems should be commissioned to verify proper flows
- **Operation:** Systems must be operated properly with appropriate automatic and manual controls
- **Maintenance**: All ventilation systems must be maintained. This usually requires seasonal servicing and inspection.

During the energy and water audits, relative humidity (RH) and carbon dioxide (CO_2) measurements were taken inside every house. Higher amounts of air leakage due to vented combustion furnaces and combustion air inlets contributed to slightly lower RH and CO_2 measurements than what we typically observe in communities with higher occupancy and sealed combustion or electric heat, but were still higher than desired in about 50% of homes. For example, a home in Lac Brochet with an occupancy of 10 people was alarmingly high with over 60% RH and around 2500 PPM of CO_2.

Four of the 12 houses audited in Lac Brochet had HRV systems. All of them were all either not working or in need of some maintenance (e.g., cleaning of filters) to function at optimum levels.

In Brochet, half of the eight houses audited had HRV systems, but only one of four was working properly.

In Tadoule Lake, all seven homes audited had HRV systems. Four of these were not working due to maintenance or mechanical issues.

All exhaust-only ventilation systems in Lac Brochet and Brochet appeared to be functioning, but we cannot know without monitoring if they are being operated appropriately (i.e., activated either manually or automatically when needed). Also, the presence of an exhaust-only ventilation system was not always a guarantee of good indoor air quality. There were homes with functioning exhaust only ventilation systems with high interior relative humidity and/or carbon dioxide levels.

In the future, all new homes and existing homes undergoing retrofits should be outfitted with an automatic dehumidistat control, preferably one that adjusts interior relative humidity to safe levels in relationship to outdoor temperatures. There are several products on the market that can do this.

It also makes sense to explore controls that activate ventilation system operation when there are higher than desirable carbon dioxide levels in the home.

With regards to specific ventilation system recommendations, a deficiency of functioning and well-maintained/operated ventilation systems, whether HRV or exhaust-only, is an issue in all three communities.

Provincial building codes, comfort, and energy efficiency compels us to recommend HRVs as the principal ventilation system in homes, but this strategy will only be successful if equipment is properly designed, installed, commissioned, operated, and maintained (DICOM). If proper maintenance and control of HRVs cannot be guaranteed then a redundant/fail safe ventilation strategy should be explored, although this will come with an energy and comfort penalty.

The establishment/training of individual(s) in each community whose major responsibility includes the seasonal maintenance and inspections of HVAC systems in each house is an approach that needs to be explored and executed. In addition to protecting housing stock (and the health of occupants) and saving the community money, this offers “green employment”.

5.0 Water-Saving Opportunities

All band-owned homes that were audited in the three communities had an electric domestic hot water (DHW) tank. However, the teacherage we audited in Northlands/Lac Brochet had an oil-fired DHW tank. The Manitoba Housing and teacherage houses we visited in Brochet had oil-fired DHW tanks.

Based on our audits and observations in the audited homes, there are modest, low-cost water saving opportunities in most homes:

- Five of 12 houses we visited in Lac Brochet, three of eight in Brochet, and two of seven in Tadoule Lake had conventional (non-low-flow) toilets.
- Toilet tank leakage was detected in four of 12 the houses in Lac Brochet and in three of eight houses in Brochet. No tank leakage was detected in the Tadoule Lake houses.
- None of the houses in Lac Brochet and Tadoule Lake yet had water-saving showerheads or faucet aerators installed and this will be a significant low-cost water and energy saving opportunity. Four of the eight homes in Brochet had water-saving showerheads.
- All homes audited had clothes washers and electric dryers. Many of the households reported that they were using cold-water only for washing clothes.
- There were very few ENERGY STAR, front-loading washing machines in the homes audited. Front loading washing machines will use less energy and water in a wash cycle. Due to their high centrifugal spin cycles, they will also reduce drying times, with dryer being a large source of electricity consumption (up to 1,000 kWh per year).

6.0 Summary and Recommendations

- A potential reduction of 25% to 33% in annual oil consumption for space heating is feasible for a significant portion of homes in Lac Brochet, Brochet and Tadoule Lake through modest, cost-effective building envelope upgrades to Manitoba Hydro's Power Smart standards (Note: Manitoba Hydro may be reluctant to provide Power Smart Home Insulation Program incentives for upgrading oil-heated homes).
- Give that the heating season is about 50% more severe than Southern Manitoba and the high cost of heating oil and diesel-generated electricity, more aggressive, community-wide deep energy retrofits and energy efficiency standards for new housing that go significantly beyond Power Smart requirements, targeting a minimum 66% or better reduction in heating energy use, should be considered.
- Current (oil) heating systems may be a significant challenge in existing and new homes once building envelopes are upgraded via deep energy retrofit, due to oversizing issues.
- Many of the standard construction details currently being executed pose considerable performance (durability, comfort, energy, IAQ) risks and need to be re-evaluated.
- Envelope upgrades need to be thoughtful using good building science 'house as a system' approach, and long-term outlooks, with durability, efficiency, and comfort in mind.
- Domestic hot water electricity consumption can be reduced through a combined strategy of low-flow showerheads/aerators and horizontal drain water heat recovery. Savings in the order of about 1000 kWh/year appear possible.
- Replace remaining conventional toilets with low consumption toilets, and repair any leaking toilets.
- Some low-cost install opportunities including LED lighting and pipe insulation are still available, saving up to perhaps a few hundred kWh per year, but may increase heating consumption due to interactive effects.
- Explore installing smart power receptacles to automatically control and reduce electricity use for vehicle block heater plugs.
- Modest electricity savings possible through ENERGY STAR appliance/gadget upgrades (especially fridges and front loader clothes washers and condensing dryers) when new items are being purchased, but some items may increase heating consumption due to interactive effects. Perhaps up to 1,000 kWh per year is savings may be achieved when fridges and laundry equipment upgraded to ENERGY STAR models.
- Longer-term monitoring of energy and water use in a few homes in each community would be valuable. Of particular interest is understanding:
  - How much heating oil is actually being used annually?
  - How often are force-air furnaces cycling and for how long?

- How much water (including DHW) is being consumed?
- What are the average effluent temperatures before and after installation of DHWR?
- How much energy do the trace heaters consume?
- What are the peak loads and their sources?
- What is the dryer/laundry frequency of use and energy consumption?

PROVISION OF TECHNICAL AND ECONOMIC STUDIES FOR A 100% RENEWABLE PENETRATION SCENARIO FOR BROCHET, LAC BROCHET, AND TADOULE LAKE

Final REPORT FOR AKI ENERGY

May 30, 2017

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1 EXECUTIVE SUMMARY

In Manitoba's Remote Communities of Barren Lands First Nation (Brochet), Northlands Denesuline First Nation (Lac Brochet) and Sayisi Dene First Nation (Tadoule Lake), diesel fuel currently represents the primary energy source for heat and electricity. This dependency upon diesel fuel has resulted in negative impacts on the local environment from oil spills, pollution, and indoor air quality issues, and consequentially, contributes toward human and environmental health and safety issues along with associated environmental remediation and health care costs.

Diesel fuel is shipped to these communities via a winter road system (posing challenges in and of itself). Due to transportation factors, fuel then arrives in these communities at a high cost, which has a negative impact upon heating and electricity pricing, impeding economic development and food security within Northern communities.

The current 60 Amp residential connection limit within the communities' results in a number of electricity usage restrictions. These factors hinder conveniences within the community homes due to the fact that electric heating load is prohibited by Manitoba Hydro. Comfort within community homes is also hindered as a result of Heat Recovery Ventilation (HRV) units being usually turned off in order to avoid higher energy costs. The bypassing of HRV units leads to high home humidity levels and subsequent mold formation. As such, Band Chief and Council and local members of affected communities have expressed a strong desire to explore alternative energy options that reduce and/or eliminate diesel fuel use and reduce electricity costs to avoid energy poverty amongst the Band Members. It is possible to provide 100 Amp residential service with a biomassed fueled organic rankine cycle generator. Loads can be managed with aggressive DSM and demand response control of the blowers at the sewage lagoon and control of any electric hot water tanks not on biomass or geothermal heating loops.

Clean and renewable energy from wind, solar, and batteries has been proven economic and reliable in other remote Northern communities in Alaska and the North West Territories. As one such example in Kotzebue Alaska, wind turbines and batteries are supplying approximately one-third of the town's annual electrical energy, displacing nearly 950,000 litres of diesel fuel per year. The remote community of Colville Lake in the North West Territories has recently installed a Solar PV, battery, and diesel-powered hybrid system that has significantly reduced the town's reliance on diesel fuel. Successful renewable implementations have reinforced the desire of Brochet, Lac Brochet, and Tadoule Lake to "get off oil" and employ similar proven renewable energy sources in each of their respective communities.

In response to the communities' desire to investigate alternative clean energy supply on behalf of their members, Indigenous and Northern Affairs Canada (INAC) has funded Aki Energy to develop a Community Energy Plan (CEP) for Brochet, Lac Brochet, and

Tadoule Lake by the spring of 2017. Shamattawa, the fourth remote community in Manitoba may also join this study at a later date. This CEP addresses both supply and Demand-Side Management (DSM) considerations for heat and electricity. In support of the CEP, Soft White 60 Corporation (SW60) has been engaged by Aki Energy to perform a pre-feasibility study of clean electricity supply alternatives that could be realized within the target remote communities over the next five years.

In performing its analyses, SW60 utilized HOMER Pro software to produce technically feasible electrical resource scenarios that are optimized for least value of the levelized cost of electricity (LCOE) and may be realized in the target remote communities. The study utilizes a 25-year planning horizon, taking into account hourly wind speeds and solar insolation levels, along with 15 minute existing fixed-speed diesel generator loading, and equipment data to represent battery, Organic Rankine Cycle (ORC) generation, and variable-speed diesels. The accuracy of the results of the HOMER Pro optimization process is related to the confidence level of the input of the technical and costing data. In this pre-feasibility analysis, in addition to data from manufacturer's equipment specifications and data embedded in the HOMER Pro generation data library, a portion of input data had to be estimated to represent specific generation and/or storage devices. SW60's HOMER Pro modelers have extensive experience in this area and surmise that the LCOE values presented in this report are equivalent to a Class 4 or Class D level, with accuracy estimated to be between -30% to +50%.

It is important to note that the wood supply for the ORC is available from two sources—local fire-killed trees which are still standing in forest burn areas near each community, and Forestry Management Units (FMUs) located along the shared winter road, and in the Lynn Lake area. Manitoba Sustainable Development's Forestry Branch and local university research reports indicate that there are abundant local wood resources of fire-burnt timber, providing at the present rate of electricity and heat consumption between 50 and 200 years of wood supply for 100% biomass heating and electrical generation near each community. If the feasibility study finds this source of biomass to be uncertain, then there are three Forestry Management Units (FMUs) that can be harvested—FMU 71, FMU 72, and the western portion of FMU 79 as shown in Figure 1 below. The sustainable Annual Allowable Cut (AAC) for these three FMUs exceeds the expected ORC fuel consumption for all three communities. The feasibility study will need to include a thorough survey of the available wood supplies, both from local fire-kill sources and from these FMUs. Although harvesting from these FMUs would require some use of diesel for equipment and transportation, it would be significantly less than the fuel required to transport the diesel currently brought into the three communities. These FMUs are clustered along the shared winter road and around Lynn Lake, while the diesel currently being consumed is usually transported from Alberta.

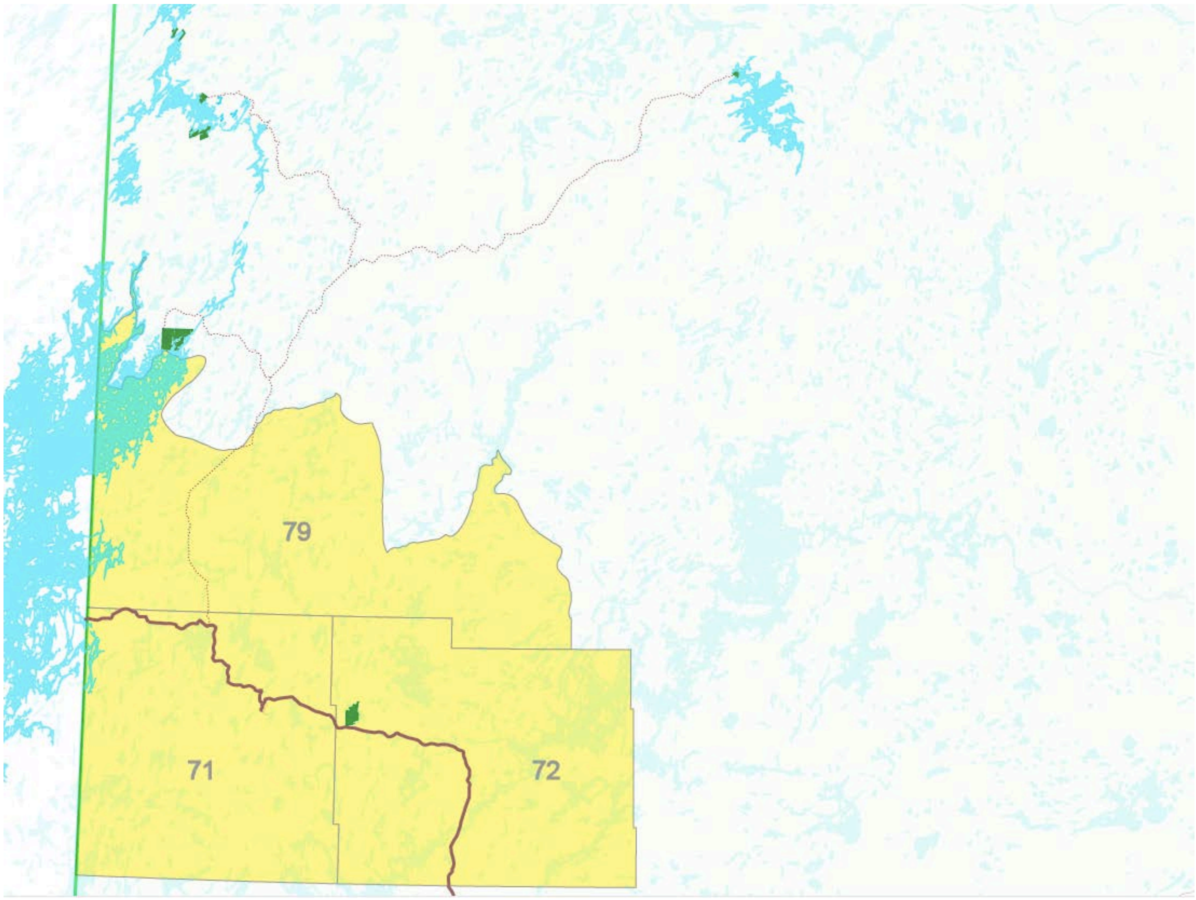

Figure 1: Map of FMU 71, FMU 72 and FMU 79

It has been determined that there is ample truck capacity and winter road season duration to supply all three communities with a full year's supply of wood at a sustainable, reasonable cost ($137/ tonne), which forms the basis for the wood cost data inputs in the aforementioned HOMER Pro analysis. It is envisioned that a significant reduction in diesel oil supply and transportation requirements will result within these communities once the ORCs are 100% operational.

As a corollary to the ORC being 100% operational, it is recommended that the existing Manitoba Hydro diesel units be maintained and left in place as back-ups with enough diesel fuel for one year of operation at 100% community loading. As the ORCs become 100% operational, the Manitoba Hydro diesels and associated tank farms may eventually be decommissioned. In all cases, the firm back-up electrical energy supply would then be transferred to additional ORC to provide an N-1 design within each community.

It is important to note that biomass-fueled ORC generation systems have proven reliable in numerous locations throughout Europe and North America, although none have yet been utilized in Northern, remote off-grid First Nations Communities in Canada. The current perception that ORC is more complex than diesel generators may be partially correct. However, it is envisaged that with adequate training of local personnel and appropriate maintenance contracts in place with reputable ORC equipment suppliers, the risk of failure of this technology may be effectively mitigated in the remote Northern First Nations Communities.

The study results indicate that the deployment of ORC, Solar PV, wind power and battery renewable electrical energy systems in all three communities could reduce the consumption of diesel fuel to nearly zero, which will result in almost a 100% reduction in greenhouse gas (GHG) emissions from electrical generation sources. HOMER Pro results show that a capital investment ranging from $17.4 million in Tadoule Lake and Brochet and $18.4 million in Lac Brochet for ORC, Solar PV, wind power and batteries for renewable electrical energy sources in these remote communities may achieve renewable electrical energy penetrations of 100%. These also achieve a lower LCOE of 59.2 ¢/kWh to 78.4 ¢/kWh than the "business as usual" case of the $1.13 to $1.19/kWh from fixed-speed diesel generators.

For a 100% renewable penetration of electrical generation technologies for Lac Brochet, Brochet and Tadoule Lake, the best economic resource selection is the combination of ORC, PV, wind power and battery. The LCOE varies from 59.2 ¢/kWh for Lac Brochet, 68.4 ¢/kWh at Brochet and 78.4 ¢/kWh at Tadoule Lake. The average annual operating costs vary from 29.3 ¢/kWh for Lac Brochet, 29.5 ¢/kWh at Brochet and 30.6 ¢/kWh at Tadoule Lake, which represents the lowest marginal operating costs of all cases evaluated by HOMER Pro. When using ORC, solar PV, wind power and batteries, the operating savings over fixed-speed diesel range from $50 million in Tadoule Lake to $82.5 million in Lac Brochet over a 25-year period. The best technical configuration would also be the one with the greatest diversity of proven renewable supply options, also represented by ORC, PV, wind power and battery. There is also ample waste heat from the ORC to heat the entire communities with 200% heat available in La Brochet, 140% in Brochet and 160% in Tadoule Lake. The excess waste heat available can be used for additional uses; including food security systems such as freezers and greenhouses, or additional economic development via hotels and laundromats.

The addition of batteries is always required to make intermittent solar PV and wind power options realizable for all communities. In all cases, the introduction of solar PV and wind hardly change the LCOE and the benefits of resource diversity are significant, and either some solar PV, wind, or both could be included, with a preference given to solar PV due to its ease of maintenance over the more complicated nature of wind power systems. Supplemental benefits include local job creation within the community energy sector in the areas of wood harvesting, transportation, and electricity and heat generation O&M, as well as further economic development through community-owned generation facilities and businesses.

There were cases studied where no cost of capital for the equipment and construction of the facility was included. However, this cost may be beyond the boundary acceptable for these community projects if INAC has a limit on its budgeted capital expenditures. Other factors such as diversity of supply, dispatchable resources, redundancy, operation and maintenance issues, ease of grid integration, environmental issues, DSM, demand response, available incentives, policy issues, local climate, and maturity of technology also need to be considered.

Based upon these preliminary results, it is recommended that a full feasibility study be pursued for the electrical energy and associated heating options for Brochet, Lac Brochet, and Tadoule Lake.

**NOTE: Due to the fact that simulations, economic analyses, price forecasts, and the types of information contained in this report represent material of a complex and predictive nature, and the recognition that a portion of the underlying data is based upon assumptions and inputs derived and provided from various independent sources, Soft White 60 Corporation cautions readers and users of this report alike to be aware that any real world deviation from the underlying assumptions and data contained in this report may result in differences in relation to the results obtained.*

2 INTRODUCTION

Aki Energy has contracted SW60 to perform a pre-feasibility study of renewable electricity supply alternatives that could be realized within the remote communities of Brochet, Lac Brochet, and Tadoule Lake over the next five years. In so doing, these renewable options will be compared against one other, traditional fixed-speed diesel generation, and new advanced variable-speed diesel generators.

In addition to the Executive Summary and Introduction, this report is organized into four primary sections. Section 3 – DESCRIPTION OF GENERATION OPTIONS IN THE REMOTE COMMUNITIES describes the following electrical generation technologies: biomass (wood chip)-fueled ORC generation, solar PV, wind power, fixed-speed (traditional) diesel generation, variable-speed (advanced) diesel generation, and batteries. Section 4 – HOMER CASE STUDIES describes the HOMER Pro software tool that optimizes the amount and mix of generation technologies proposed as the best solution based upon the least value of the levelized cost of electricity (LCOE). Section 5 – ANALYSIS OF SIMULATION RUNS describes the various combinations of renewable technologies selected by SW60 to be analyzed by the HOMER Pro software tool and the resulting HOMER Pro selection of technologies and LCOE results. Section 6 – Action Items and next Steps discusses follow-on activities pertinent to this study. The final and aptly named Section 7 – CONCLUSIONS AND RECOMMENDATIONS discusses the conclusions and recommendations based upon the HOMER Pro results and SW60's analysis.

The LCOE values presented in this report are estimated to be at a Class 4 or Class D level with accuracy estimated to range from -30% to +50%. This level is typical for a pre-feasibility study that has an incomplete definition of the final characteristics of the project. It is important to note that an appropriate amount of contingency should to be applied to the capital and operating costs in order to achieve this level of accuracy. Normally a 25% contingency on capital costs and a 50% contingency on operating costs are used in a prefeasibility study. These contingencies (higher capital and operating costs) have not been applied in this prefeasibility study because the recommended full feasibility study would provide a better LCOE accuracy.

This report on electricity supply options is one of four reports related to methods to reduce diesel fuel consumption on the remote communities. The other three reports relate to heat supply options, DSM on electricity consumption, and DSM on heating systems. Aki Energy will collate all four reports and produce a comprehensive Master Report, based on these four components.

3 DESCRIPTION OF GENERATION OPTIONS IN THE REMOTE COMMUNITIES

3.1 Organic Rankine Cycle (ORC) for High Temperature Biomass in Remote Communities

The use of biomass Combined Heat and Power (CHP) is a strong contender for Manitoba's remote communities, as a sustainable supply of biomass may be found within relatively close proximity, along with a viable back-up supply option for wood delivered via winter roads.

The biomass (wood chips) can be used productively, supplying 16% of its energy as electricity and over 50% of its energy as heat for small-scale systems at about 1.0 MW or less. The application of biomass is well established for providing heat-only, using combustion systems over a wide range of scales; however, generating CHP at small-scale is relatively rare in Canada, while small-scale biomass CHP systems are common in Europe where electrical power is more expensive in comparison to North America. This is shown on a world map of ORC units in Figure 2 below where each site on the map is available for interactive investigation via the following link: http://orc-world-map.org/. Note that there are biomass ORCs in operation in northern BC and Alberta as well as in the Nordic countries of Europe. Biomass ORC started in commercial operation in Europe in the late 1990's and have been expanding worldwide ever since, with over 150 biomass ORC installations worldwide as of August 2016.

Figure 2: Map of ORC Units in the World as of 08/16/2016

ORC is well-suited for applications within Manitoba's remote communities, allowing heat to be delivered at district heating temperatures of 90°C. The ORC system is coupled to a high temperature biomass combustor that produces a flue gas temperature between 750°C and 1,000°C (see Figure 1.0). Like a steam-based system, the relatively high temperature heat is used to vaporize a working fluid that then turns a turbine, driving a generator to produce electricity.

An organic fluid is used as the working fluid in an ORC. The lower working fluid pressures eliminate the need for a 24/7 operator to be in attendance. The efficiency of ORC units depends upon the temperature output of the combustor. At the highest end, 1,000°C flue gas temperatures will provide an efficiency of 16.3%. Depending upon operation set-up and the moisture content of the wood chips, more than 50% of the energy in the wood chips can provide heat (hot water) at 90°C, which can be injected into a district energy system, achieving a CHP efficiency of at least 65%.

The system is typically sized to match the community electric power loads while supplying heat in excess of the community's total heating needs. ORC systems often have a high availability of 97%, and generator can load follow well down to 10% of its rating while still providing heat for the district energy system. ORC systems require trained personnel to be on hand at major overhauls and it may be possible for local Band members to be trained to fill these roles. Otherwise, there may be additional expenses to obtain qualified service (if not available locally). To ensure speedier repairs, it is recommended that key replacement components and an appropriate inventory of spare parts be kept on-site.

ORC System Energy Diagram

Figure 1 below shows an overall energy balance diagram for an ORC system. The efficiency of the cycle is only part of the energy balance and is included in the diagram. An ORC system is an indirect fired system, meaning that a standalone combustion system generates a hot flue gas by combining air with biomass inside a combustion chamber. The generated hot flue gas transfers most of its heat to a thermal oil using air-to-liquid and air-to-vapor heat exchangers. Inside these heat exchangers circulates a thermal oil within a closed loop piping arrangement. This thermal oil powers the turbine after it has vaporized. There are a few issues that can be overlooked when looking at the energy balance:

1) Higher Heat Value (HHV) versus Lover Heating Value (LLV): The biomass fuel HHV energy content is used in North America. In Europe, they remove the latent heat energy content of the water formed during combustion from the HHV and quote energy efficiency based on LHV. LHV leads to higher efficiencies. In Figure 1 we assume that the energy balance is based on HHV as it would be incorrect to make such a diagram based on LLV and not write so in the diagram.
2) System efficiency versus cycle efficiency: The proper approach is to have the energy balance based on the overall system efficiency using the HHV based on bone dry wood; however, cycle efficiency is often shown. Cycle efficiency only starts after the energy has been transferred to the heat exchangers.
3) Theoretical or real system: A theoretical cycle will always have a higher system efficiency than an actual system that is built. When building a real system, there are constraints that reduces the theoretical efficiency like limiting the

rotational speed of the turbine, maximum temperature a commercially steel can withstand, and limiting combustion temperatures to prevent thermal NOx from forming.

4) The moisture content of the wood will affect how much water vapor is contained in the flue stack and slightly change overall system performance.
5) There will be small variations between summer and winter performance.

The energy balance in Figure 1 is as follows:

1) The HHV of the wood per bone dry ton is converted to a hot gas and this is the 100% energy mark. In the diagram the amount of excess air introduced controls the flue gas temperature to 950°C which is on the high end for small-scale biomass combustors.
2) 1.2% of the heat is lost through the furnace combustor walls to the air in the room that the system is located in.
3) 2.0% of the hot flue gas is extracted to control the grate temperature of the combustor. The grate is where the fuel ultimately rests upon to combust when not air born in the combustor. This 2% all goes to add energy to the hot water and is not lost; however, it is unavailable to make electricity and thus slightly lowers the electrical efficiency of the ORC system.
4) 3.1% of the energy taken from the thermal oil is reintroduced in the flue gas.

The energy in the flue gas located inside the furnace: 100% – 1.2% – 2.0% + 3.1% = 99.9%

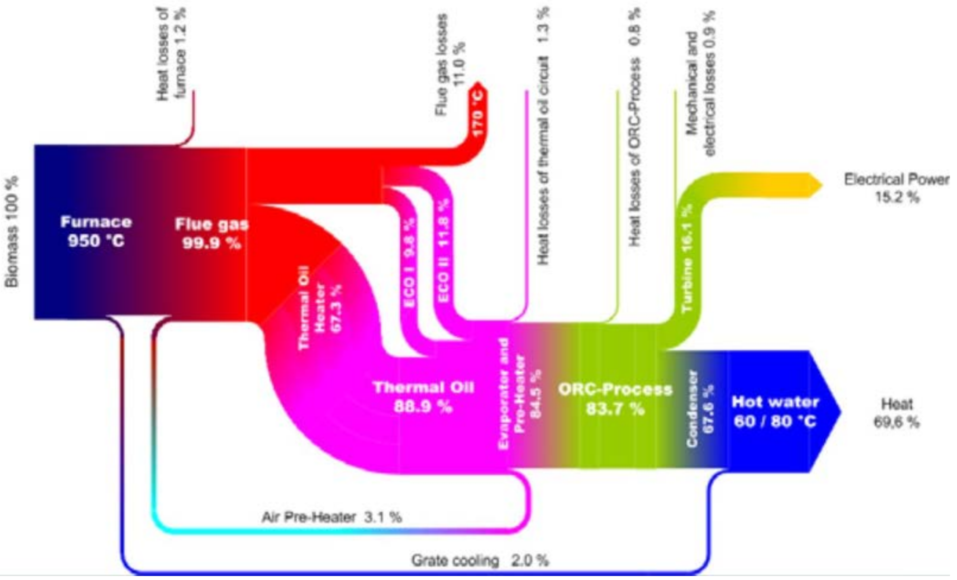

Figure 3: Example for the energy flow diagram for a typical ORC system

Here the diagram shows the overall energy efficiency and we assume it is based on HHV. The ORC performance can be changed to produce less power and higher temperature heat as a tradeoff. We also assume that a relatively high combustor system is used with the convection heat exchanger located at the back end of the combustor.

1) Of the 99.9% of the energy in the flue gas, 67.3% is transferred to the thermal oil via the thermal oil heat exchanger, 9.8% via the first economizer heat exchanger, and 11.8% via the second economizer heat exchanger.
2) The flue gas has now been cooled down but not enough to condense the water vapour in the flue gas. 11% of the energy in the flue gas escapes though the chimney and is released to the air. This value goes up if the wood has more moisture.

The energy available to make electricity contained in the thermal oil: 99.9% – 11% = 88.9%

3) 3.1% of the thermal oil energy is sent back to the flue gas to preheat the combustion air (see point 4 above)
4) 1.3% of heat in the thermal oil is lost to the air that surrounds the piping system
5) 0.8% of heat in the thermal oil is lost to the air when making electricity with the ORC

The energy available to make electricity contained in the thermal oil: 88.9% - 1.3% - 3.1% - 0.8% = 83.7%

6) Now the cycle efficiency of the ORC is 18.1% (not shown) and is able to convert the 83.7% of energy in the oil to yield 15.2% electricity and 67.6% heat contained in hot water
7) During this process 0.9% of heat and power is lost

The energy balance: 87.7% - 0.9% => yields 15.2% electricity and 67.6% hot water

8) Finally, 2.0% of heat is added to the hot water from the furnace to cool the grate (see point 3) so 69.6% of net heat is generated

The energy balance for the heat: 67.6% + 2.0% = 69.6%

3.2 Solar Photovoltaic (PV) Systems in Remote Communities

A photovoltaic (PV) system generates electricity by means of photovoltaic effect using semi-conductors. PV panels operate without any moving parts, are silent, and have no environmental emissions after they have been manufactured. Furthermore, no operator is required to operate PV systems.

A typical PV system is composed of rows of solar panels that convert sunlight directly into DC electricity at approximately 20% efficiency. Additionally, PV systems also require inverters to convert the DC current to AC current, as well as racking for mounting the panels, cabling, combiner boxes, disconnect switches to bring the PV power to a common location, and for grid connected systems, a step-up transformer to convert the PV system voltage to a utility compatible voltage (see Figure 2).

A two-axis solar tracking system can be used to improve the system's overall energy capture by about 25% to 30% over fixed tilt systems. Although tracking systems today can make economic sense in certain applications, they also add complexity of moving parts to a PV system. It is recommended to use fixed tilt systems in Manitoba's remote communities, as availability of land space is not an issue, and as such, simply adding more PV panels is instead, preferred. The use of tracking should only be considered if it would be beneficial to produce more power at times close to sunrise and sunset.

PV systems have developed from being a high-cost niche market application 20 years ago into a competitively-priced mature technology used for mainstream electricity generation today. Installed prices in southern Manitoba for commercial scale PV systems are approximately $2.50/Wdc, while installations in Manitoba's remote communities are estimated at approximately $7.50/Wdc due to remote transportation, logistics, and installation factors. PV panels alone (without additional hardware, engineering, and installation costs) are currently available for less than $1.00/Wdc.

PV systems are relatively insensitive to deployment scale when compared to other forms of generation. In Manitoba's remote communities, there is substantial room to reduce the present cost of solar PV once installers have gained more experience in remote communities. Moreover, there are opportunities to train First Nations people to install PV racks and panels while maximizing the use of local materials to anchor the racks.

Off-grid systems often include an integrated BESS to smooth out daily variations due to clouds or other shading and to move daytime energy to night-time use. They may also be necessary to permit safe and stable grid interconnection to an existing micro-grid consisting of fixed speed diesel generators.

An area of concern in small micro-grid applications such as Manitoba's remote communities relates to the fact that there is substantially more solar energy available in summer, reducing the ability to meet community loads with solar PV in winter months. Moreover, PV generation is subject to large fluctuations due to passing clouds, increasing the possibility of voltage sags and frequency fluctuations. As such, PV needs to be properly integrated into each community, with detailed planning of the complete generation and grid system.

Of particular concern in Manitoba's remote communities is ensuring that other generation technologies that may be used there can accommodate the intermittent nature of PV electrical energy, especially relating to the fact that no Solar PV generation is available at night. As such, installing only PV with batteries in these communities is not a wise choice. The amount of batteries and costs required to do so would be prohibitive, and the design would have significant GHG's embedded into the manufacturing of such large quantities of batteries. Therefore, an integrated approach to renewables that minimizes the amount of kWh of batteries is also required.

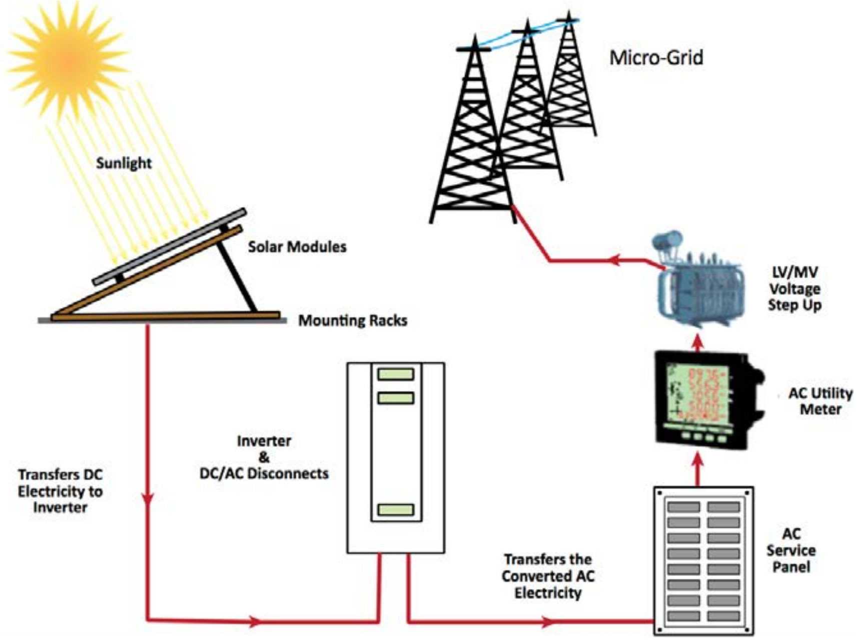

Figure 4: Overview of Solar PV Power Plant Courtesy of International Finance Corporation

3.3 Wind Power in Remote Communities

In many jurisdictions across North America, wind power is the lowest cost resource, often yielding electric power for no more than a few cents per kWh. However, this requires access to a good wind resource with relatively high capacity factors, large scale deployments (>100 MW), a large utility that can address wind intermittent generation within its grid, an absence of ice and cold weather impacts upon turbines, and access to skilled labor for operation and maintenance.

For Manitoba's remote comminutes, most of these conditions are not applicable or available. Wind resource information is poor in these remote communities and needs to be verified by monitoring as suggested in Marc Arbez's report to the Community Energy Plan "Development of a Wind-Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations". Wind generation can provide substantial benefits to remote communities, allowing generating power when Solar PV cannot. Wind Power in the areas of the three remote communities is stronger in winter when the energy is needed the most. Wind Power capacity above a 20% of the dispatchable generation level is likely to require storage to manage wind ramping due to wind gusts and for stabilizing the micro-grid. However, in order to be effective, it is critical to evaluate wind power from a remote community point of view, and not from a large utility point of view, as power costs have the potential to exceed $1.00 per kWh in these locations. With proper data gathering and analysis, there is substantial room to adapt this technology to remote communities.

Unlike biomass, solar, and diesel generation which are located in or near the community, wind power generation requires reviewing the wind resource location and its impact on how long a transmission line may be required. In this study, simulations are performed with HOMER Pro using simulated meteorological data that is not specific to Brochet and Lac Brochet while using measured wind data at Tadoule Lake. As such, Northlands may have a better wind resource on one of its nearby hills, requiring a 10 km transmission line. As these hills all surround lakes, it may be possible to use pumped storage and eliminate the need for batteries. It is important to note that such approaches require detailed assessments that are beyond the scope of this study. Moreover, wind turbines for remote communities are still underdeveloped and lack examples of demonstrated long-term proven sites.

While Nordic developed wind turbines are rugged, typically smaller than large utility scale wind turbines, require no large crane, and are relatively low efficiency, however, they may be capable of withstanding the harsh winter conditions within the remote communities. In this study, wind turbines that can withstand the icing that can occur in these remote communities were selected for analysis.

Since annual average wind speeds are generally lower in Northern Manitoba compared to acceptable industry standards, wind power will likely have a low capacity factor, unless turbines can be placed in locations that have micro climate conditions leading to a better wind resources. As described previously, such placements are beyond the scope of this particular study.

3.4 Batteries in Remote Communities

Utility-scale battery storage is undergoing a predictable price decrease. As lithium-ion battery costs (uninstalled) decrease to $150/kWh, down from $500 and even

$1,000/kWh just a few years ago, and with battery cycle life improvements and energy density increases (along with corresponding battery pack size decreases), these developments will in the near future permit high density modular battery trailers to be deployed in Southern Manitoba at approximately $200/kWh. The current cost for large scale installation in Southern Manitoba is estimated to be $1000/kWh and current installed costs of lithium-ion batteries in the remote communities are estimated to be $2500/kWh. Additionally, the issue of cold weather and its impact upon batteries is not a technical challenge and has been addressed, with overheating in summer remaining more of an issue. Finally, remote communities will not be impeded due to their location other than in terms of transportation costs and access to trained personnel. While the need for batteries can vary significantly, many kWh of batteries is still required to support 1 kW of load if the system is not designed properly.

Battery storage can be used in remote communities to:

- Support the micro-grid to address short temporal variations. The storage capacity in such cases is relatively small compared to the load.
- Power short time intervals to address periods when no power is available during forced and planned outages for base load generators such as biomass and diesel.
- Provide large storage capacity to address relatively long periods of intermittent generation from a few hours to a few days. For this scenario, other solutions that can be considered include:
    - Biomass CHP systems
    - Variable speed diesel engines
    - Pumped water storage

3.5 Fixed and Variable Speed Diesels in Remote Communities

Although there is an inherent goal to eliminate diesel fuel use in remote communities, diesel use may still be required for limited conditions and for some time. In remote communities, power systems must have at least an N-1 factor of redundancy (loss of one largest generator and still meet system load). It is difficult for wind power and Solar PV to provide base load power, let alone provide system redundancy.

Additionally, the high cost of replacing diesel engines may be mitigated by installing portable and containerized diesel gensets, similar to those used in winter camps. As the renewable energy systems are installed, portable gensets may be sized more appropriately. The important lesson in this case is to consider diesel engines as part of the planning process for renewables. Of critical importance is a departure from "business as usual" and viewing the diesel engine as only providing power when renewable energy systems are unable to address current loads. The antiquated notion of having diesel engines serving as the preferred dispatchable power source needs to be updated and effectively eliminated within remote communities.

Fixed-speed diesel generators do not integrate well with renewable energy. These diesels cannot operate at low partial loads (below 30% of rating), and may require solar PV and wind power to be run back (spill available power by effectively turning off the Solar PV panels or the wind turbines), even when it can be produced at no additional cost. A better approach that favours renewables involves decoupling engine speed from electrical frequency. That is, by adopting a variable-speed drive, the engine operates at the most advantageous operating speed at any given load. By being able to operate at low load (10% of rating), variable-speed diesels do not waste fuel when partially loaded, and achieve considerable fuel savings over fixed-speed diesel generators.

The outcome of this synergy is reduced emissions. Additionally, variable-speed diesels operate at lower speeds when compared to fixed-speed diesels so that wear and tear is reduced, incomplete combustion at low load is avoided, and periods between overhauls is extended, resulting in reduced maintenance costs.

4 HOMER CASE STUDIES

4.1 Modelling Approach

This study is focused upon evaluating options for generating electricity that serves the existing loads in each of the three communities under review. The typical approach to evaluating electrical power options is to seek out the least-cost system configuration, from among reasonably available technical options that could be realized within five years, due to the fact that at current loading levels, some existing diesels will need to be replaced within this timeframe.

This approach therefore excludes small hydro, which typically takes between 7 and 10 years from concept development through to in-service date. While connection to Manitoba Hydro's grid is also an option, due to high costs ($300 to $500+ million) it is considered out of scope for this study.

Thus, it has been determined that the technical options to be evaluated in this study include:

- Solar PV
    - Note that the Northlands Denesuline First Nation in Lac Brochet will be installing a 280 kW Solar PV system that has already been designed and fully funded for installation in 2017/2018. This has been modelled as a 300 kW Solar PV system in the HOMER Pro cases that are analysed in section 5.
- Wind turbines
- Li-Ion batteries
- ORC power generation
- Variable-speed diesel generation

Fixed-speed Diesel generation has also been included in this analysis, in order to provide a benchmark cost against the results of the other configurations that were evaluated.

SW60 used HOMER Pro v.3.8.6 to construct its study models. All technical options were incorporated into each of the three communities, with the goal of determining which combinations and sizes of each option were technically feasible and then calculating their associate economics within each community.

HOMER Pro utilizes a levelized costing methodology to determine the rank order of proposed system configurations. This is essentially a Net Present Cost (NPC) evaluation of all capital, fuel, variable and fixed O&M, and a final negative cost for the salvage value of the investment. This represents the typical approach to determining the best option for addressing the objective, which results in the least-cost option to serve the electricity load. The metric HOMER Pro derives is called the LCOE (Levelized Cost of Electricity), which represents the discounted present value of all costs, divided by the discounted volume of energy generated. It should be noted that an approach to exclude capital costs and treat them as sunk costs (usually a policy decision) is an alternate method for determining the best option of new energy sources. In this case, electrical generation technologies with low operating costs are favoured over others that have higher operating costs such as fuel purchases.

INAC has also requested that SW60 provide an evaluation that does not include capital and capital replacement costs, but only annual fuel and O&M costs. In the current Manitoba Hydro diesel electric generation system, as mandated by the Manitoba Public Utilities Board (PUB) only these costs are currently borne by the local community. Since HOMER Pro attempts to seek out the least-cost system configuration, when capital and replacement costs are cancelled, HOMER Pro will attempt to maximize the capacity of all generation resources having low or zero variable costs. This will result in a significantly different system configuration than HOMER Pro proposes under a full capital costing evaluation.

Accordingly, SW60 has done the electric resource option evaluation both ways, with related discussion following the sub-sections where each approach is presented below.

4.2 Global Parameters for the Model

HOMER Pro seeks to optimize the system configuration by simulating all possible combinations to determine which of these are the feasible cases to meet current load and a stipulated reserve requirement (20% in these cases). The reserve requirement is a safety margin that ensures that there is sufficient power generation capability online to address load spikes. However, instead of utilizing a larger reserve margin in the remote communities, it may be possible to use load shifting when the peak hits a critical level to automatically trip off all the electric hot water tanks (of which there are over 100, each rated at least 4.5 kW each). Options such as this should be studied further in the future proposed feasibility study, and have not been modelled in this high-level pre-feasibility analysis.

In order to facilitate the speed of processing for many possible combinations of generation components and their sizes, HOMER Pro performs simulations on a single year basis, assuming no annual changes in weather or load profiles. To take into consideration the time value of costs, HOMER Pro extrapolates annual simulated results for as many years as programmed within the model, and discounts these costs back to the present value.

HOMER Pro assumes that all costs are unchanged in real terms, although it is possible to perform a multi-year run to reflect time-changing effects such as real cost escalation, equipment deterioration, and load growth. However, optimization is not possible in a multi-year run, so the system configuration must first be determined in an annual run and equipment sizes must be locked-down by the modeler.

The following are the primary global parameters that HOMER Pro uses in the context of how it performs its simulations:

- Discount rate used
    - 5.88% real (8% nominal cost of capital, less 2% inflation: (1+8%)/(1+2%)-1)).
    - This is the same discount rate used by Manitoba Hydro and recommended by the Treasury Board of Canada.
    - Since the general intent of the economic evaluation of various technology configurations in this report was to rank-order and thus compare the options, changing the discount rate would not change the rank-order of the options and thus only a single discount rate was used.
- Reserve Margin
    - 20% reserve is ensured to be available in the current time-step (one hour was used).
    - HOMER Pro can accommodate time steps as low as one minute. One hour time steps are adequate for a pre-feasibility study.
    - This is about twice the reserve margin used in highly interconnected grids and offers the additional safety needed for a small grid to meet sudden load changes.
- Wood Resource cost
    - Costs for wood, transport, and chipping were provided by INAC, which were derived from University of Manitoba research, Manitoba Sustainable Development - Forestry Branch, MIT, and local wood harvesting and transportation company consultations. An average cost at the community was taken between the range of high and lower estimates, with an average cost of $137.37/tonne used in HOMER Pro.
- Diesel fuel cost for Variable-Speed Generators
    - Manitoba Hydro produces a Diesel fuel price forecast that would be used for projecting fuel costs for each of their isolated generation facilities in the three communities. These costs are given in 2015 CAD dollars, and are then inflated to 2017 CAD dollars using the Manitoba CPI figures provided by Manitoba Hydro within the forecast document.
    - The latest forecast is dated July 2016, and forms the basis for the price used in the HOMER model for each location.

- Note that this latest diesel fuel forecast is 30% lower than the Manitoba Hydro's 2014 diesel fuel price forecast, which needs to be kept in mind when comparing the study's results to those of prior studies completed in 2014.
- Additional costs of 2.3 cents per litre to account for a GHG tax of $10.00/tonne of GHG and future remediation costs of 30 cents per litre have been added to the 2016 diesel forecast price derived by Manitoba Hydro.
- This results in fuel costs at Lac Brochet: $1.2441 per litre; Brochet: $1.1331 per litre; Tadoule Lake: $1.2701 per litre

4.3 Community Load Data

SW60 developed a separate model for each community to reflect their unique electricity load patterns, and in the case of Lac Brochet, to incorporate the expected divergence from historical patterns owing to the construction of the new health centre, aerated sewage lagoon, biomass district heating pumps and geothermal district heating pumps that will soon be there.

Community annual loads were derived by averaging the hourly loads reported by Manitoba Hydro for the period between January 01, 2013 and December 31, 2016. Where anomalies were identified in individual annual datasets, they were averaged out.

The following figures show the adjusted load data for the four years. The hourly loads are on the Y-axis in kW, and the X-axis represents the hour number beginning in the first hour of Jan. 01, 2013. In this data set the load is flat in Lac Brochet and decreasing in Brochet and Tadoule Lake. Load growth appears non-existent and warrants more investigation. It is thought that some electric heaters are used as the winter peak load correlates well to the heating degree days (more load on cold days). This should not be the case with oil heat, if the homes were heated with oil alone. In the case that biomass or geothermal heat is realized in these communities, then it is likely that the electric heaters will disappear and the winter peak load could be reduced.

There is more rationale to assume zero load growth in the remote communities. Two recent DSM Reports on these communities, one from Alex Fleming of Demand Side Energy Consultants and another from Gio Robson of Prairie House Performance suggests that 20 to 25% load reductions are possible. The electric hot water tanks in these communities represent a substantial portion of the electric load. If a full biomass district heating or ORC district heating is realized in these communities then the electric hot water tanks can be replaced with district energy sourced hot water tanks. The existing fuel oil furnaces will also be replaced with district heating. It should be noted that during the recent DSM audit, that 100% of the sampled houses had electric dryers and these would all be replaced with heat pump dryers or biomass water loop dryers when the district heating system is in place. This together with DSM measures could likely ensure zero load growth for many years (25 years in SW60 assumption).

The renewable energy systems that would be employed in the remote communities would be part of a smart grid which is an operational scenario involving smart meters, smart controllers and communications, energy storage, renewable energy resources, energy efficiency and smart appliances. This would allow the control of the production and distribution of more reliable electricity with more resilience and fewer voltage and current spikes and less harmonics.

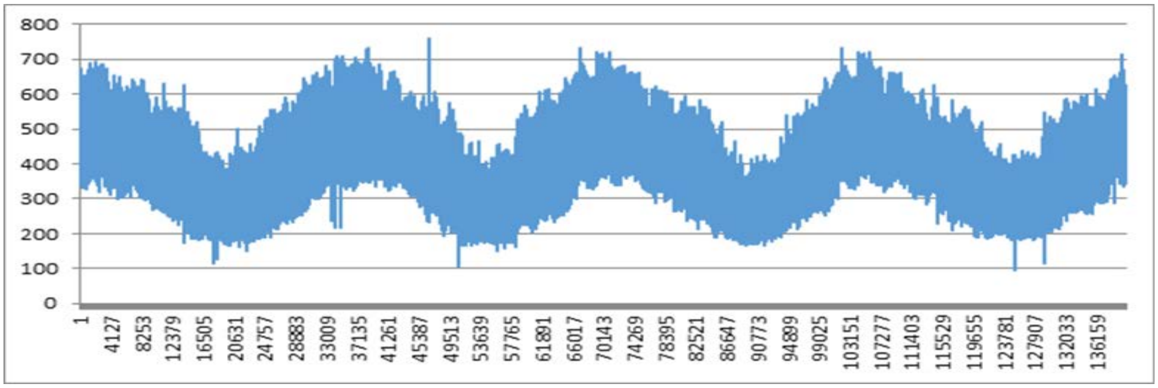

Figure 5: Lac Brochet Historical Hourly Load (2013-16)

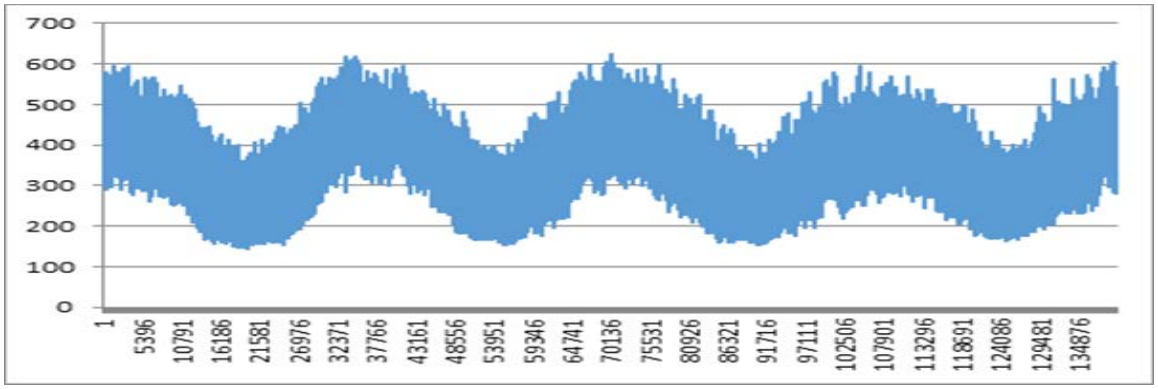

Figure 6: Brochet Historical Hourly Load (2013-16)

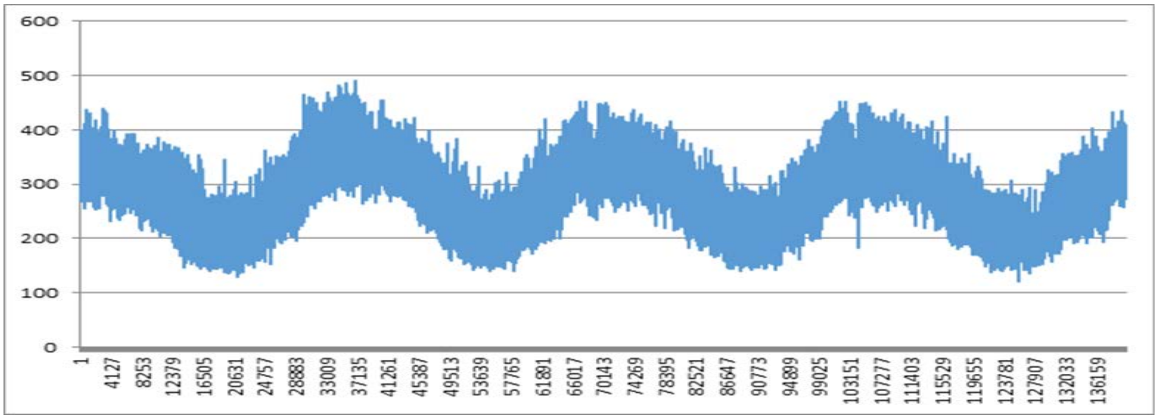

Figure 7: Tadoule Lake Historical Hourly Load (2013-16)

HOMER Pro processes the four years of data for each community, and establishes a typical year's load profile. The following figure displays the results for Lac Brochet, as an example.

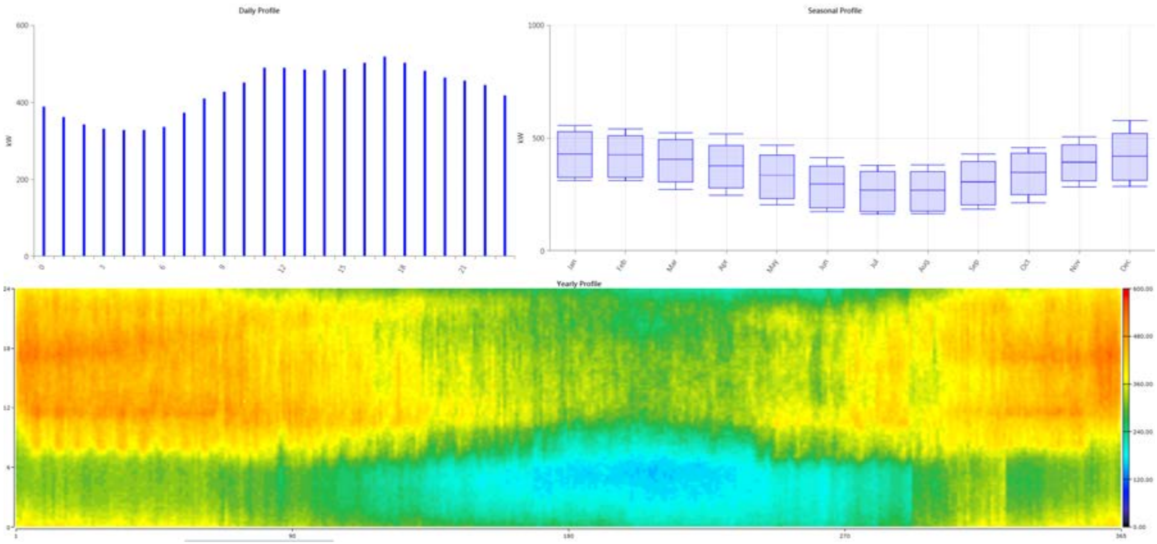

Figure 8: Lac Brochet Load Profile

The top-left component in Figure is the average hourly load during a given day for Lac Brochet. The load is on the Y-axis in kW, and the X-axis represents the hour during the day. The boxplot on the top right is the monthly range of loads, with the months on the X-axis.

The bottom of Figure 6 is a heat map which displays both the hourly and seasonal patterns in one place. Each day's specific hourly load is represented by one thin vertical strip moving across the X-axis, and the seasonal pattern can be discerned by the changes in colour. The colour legend is on the right, with blue being low load, and growing to red with higher loads. The load profiles for the other communities are similar, except for having lower loads on the X-axis, as evidenced in the earlier historical load figures.

4.4 Weather Data

Weather data for each community was drawn from two different web sources on the Government of Canada web sites. Wind speeds are found on Environment Canada's Homogenized Surface Wind Speed Data page, and monthly average solar data was taken from NRCan's Photovoltaic and Solar Resource Maps page. Wind speed data collected at a 10m height was available for The Pas, and this was assumed appropriate for Lac Brochet and Brochet and it was elevated to a 50 m hub height in HOMER Pro. Tadoule Lake wind speed data was collected and cleansed by Marc Arbez (Wind Power Consultant) at a 20m height, and this was used and elevated to a 50 m hub height in HOMER Pro. Marc Arbez also submitted his wind "Development of a Wind-Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations Report" as part of the overall Community Energy Plan for the Manitoba Remote Communities.

The weather data used by HOMER Pro includes the wind speed (m/sec) at the assigned hub height above ground (50 m in our case) and for solar, Global Horizontal Incidence (GHI) at ground level. When the wind data is collected at a different height, HOMER will apply a conversion procedure to bring the input numbers to the target height.

GHI is a measure of all direct and indirect light that is available to a horizontal surface that the location, and is measured in kW/m^2 per day. The following Figures for Tadoule Lake illustrate the weather data that is similar for the other two communities.

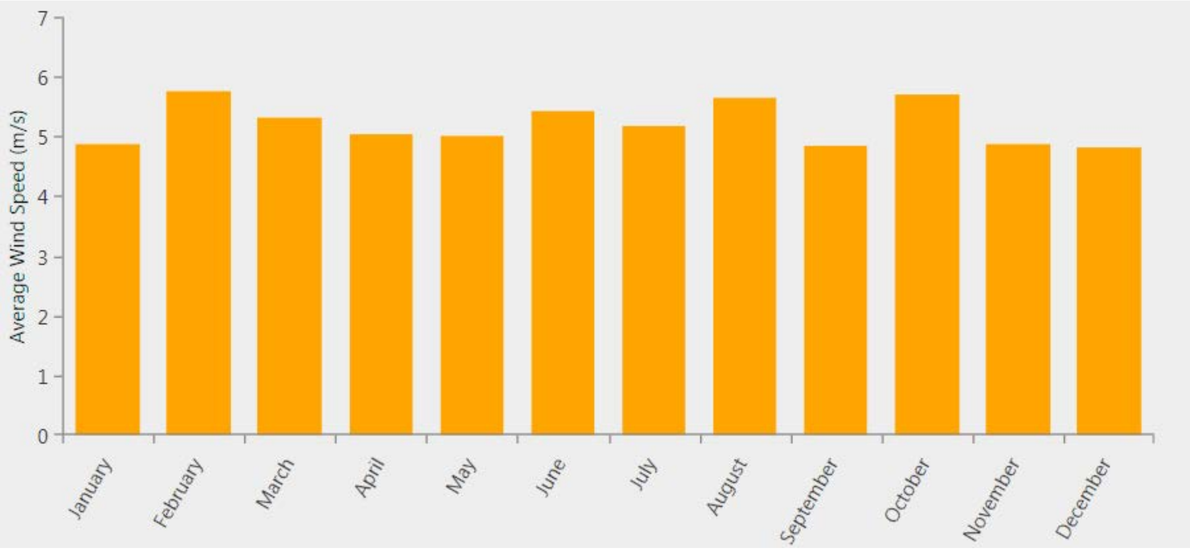

Figure 9: Tadoule Lake Wind Data at 50 m Height

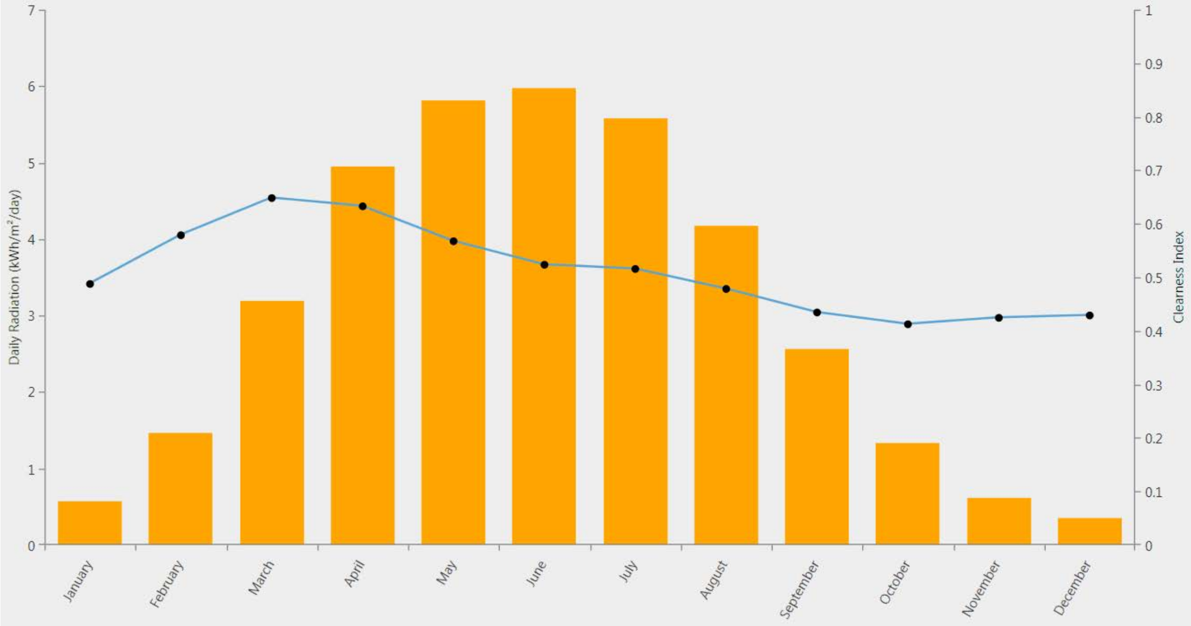

Figure 10: Tadoule Lake GHI Data

4.5 Indicative Electricity Generation Components Selected

To provide the needed power generation, the following equipment were selected:

- Solar PV
  - Canadian Solar manufacturer, model All-Black CS6K-290MS
  - Nominal rating: 290 W per panel
  - Tilt-angle set at 50°
  - Wind turbine
- Northern Power Systems manufacturer, model NPS100C-21
  - Nominal rating: 100 kW each
  - A 50 m tilt-up tower was assumed available from another manufacturer
- ORC generator
  - HOMER Pro-supplied generic biogas generator was used to model the ORC
  - The biogas generator model was modified to reflect capacity and efficiencies of Turboden 600 kW or 280 kW units as used in the studies.

- Variable-speed Diesel generator
    - Innovus manufacturer, model VSG600
    - Nominal rating: 590 kW
- Battery
    - Tesla manufacturer, model Powerpack 2
    - Nominal rating: 210 kWh
    - Expected life increased to 20 years to reflect newer similar alternatives from other manufacturers

All but the ORC generator was already in HOMER Pro's database of equipment, and all technical and performance specifications therein were unmodified except the Tesla Powerpack 2 cycle life was set to 20 years. Installed costs, maintenance scheduling, and costing for all components were estimated by SW60.

4.6 Selected Configurations Evaluated

The following cases were evaluated in order to allow HOMER Pro to determine the optimal balance of sizes that minimize the LCOE for each case:

1. ORC, solar PV, battery
2. ORC, Variable-Speed Diesel Generator (VSDG)
3. ORC, PV, wind turbine, battery
4. VSDG, PV, wind, battery
5. ORC, wind, battery
6. ORC, VSDG, PV, battery
7. ORC only
8. VSDG only
9. Typical Fixed-speed Diesel Generator (FSG) only – for reference

Some components may be automatically sized for optimally minimizing LCOE by HOMER Pro, whereas others have a fixed size relating to the manufacturer or standard usage. The components that have pre-determined sizes include the ORC units (standard sizes determined from Turboden manufacturer's catalogue) and the diesel generators (determined by Innovus Power the manufacturer for VSG, along with typical sizes for standard FSG units). The PV field is assumed to be infinitely sizeable, in sub-1 kW increments, and the selected wind turbines are in 100 kW increments, with the number of wind turbines selected by HOMER Pro. Batteries are utilized in increments of 210 kWh modules.

When optimizing, HOMER Pro selects the capacity for each of PV, wind, and batteries to suit the load and reserve required in the current time step. The ranging on these sizes is restricted to be within a range set by the modeler. In this way, one can allow technologies such PV to be automatically sized by HOMER Pro during a run, but constrained to be less than 2,000 kW, as one such example.

An important metric for any generation technology is its capacity factor. The capacity factor of a generation technology is the ratio of an actual electrical energy output of a generating device over a specified period of time to the maximum possible electrical energy output over the same amount of time. In this report, HOMER Pro is calculating annual average capacity factors, which can if desired also be calculated weekly, monthly, etc. A high annual capacity factor (> 50%) is desirable as it means the generating asset is very well used instead of sitting idle much of the time.

The term capex refers to the installed cost of the generation asset. It typically includes the equipment cost (generator and balance of plant), labour for installation, grid connection, land, security and project management. The term opex refers to the cost of the operation and maintenance cost of the generating asset. It includes fixed and variable costs. Fixed costs typically include insurance, taxes and legal fees. Variable costs typically include fuel costs, labour costs and consumables like oil filters etc.

5 ANALYSIS OF SIMULATION RUNS

Initially, the various cases were run with full estimated capital costs included in the calculation of the LCOE. A summary of results is presented below, split into three segments to fit standard page width.

Analysis and discussion begins with Lac Brochet.

5.1 Lac Brochet

		Lac Brochet											
		1. ORC, Solar PV, Battery				2. ORC, Variable Speed Diesel Gen				3. ORC, Solar PV, Wind, Battery			
All costs in 2017 CAD		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	4,373.1	91.74%	41.6%	880	4,691.5	98.44%	60.9%	1,200	4,308.4	90.38%	41.0%
Variable Speed Diesel		0	0.0	0.00%		590	74.5	1.56%	1.4%	0	0.0	0.00%	
Solar PV		300	393.8	8.26%	15.0%	0	0.0	0.00%		250	328.2	6.88%	15.0%
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		100	130.2	2.73%	14.9%
Batteries	kWh	420				0				420			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		4,766.9	100.00%			4,766.0	100.00%			4,766.7	100.00%	
Total Capex	$, million	$ 18.0				$ 14.0				$ 18.4			
Annual Opex	$, million	$ 1.4				$ 1.6				$ 1.4			
LCOE	$/kWh	$ 0.589				$ 0.554				$ 0.592			
Annual Avg Operating Cost	$/kWh	$ 0.296				$ 0.327				$ 0.293			
Fuel and Heat													
Wood for ORC	tonnes/yr	2,965				3,193				2,921			
Diesel	L/yr	0				19,230				0			
Total Thermal Available from ORC	MWh/yr	17,006				18,245				16,755			
Heat Equivalent in Heating Fuel Oil	L/yr	1,586,093				1,701,566				1,562,621			
Actual Heating Fuel Oil used	L/yr	756,758				756,758				756,758			
Value of F.O. Saved (using lesser of above)	$/yr	$ 941,483				$ 941,483				$ 941,483			
Relevent Figures													
Wood Cost	per tonne	$ 137				$ 137				$ 137			
Diesel Cost	per Litre	$ 1.244				$ 1.244				$ 1.244			
Annual Peak Load	kW	867				867				867			
Annual Load Served	MWh/yr	4,765.6				4,765.6				4,765.6			

Lac Brochet

All costs in 2017 CAD		4. VSG, Solar PV, Wind, Battery				5. ORC, Wind, Battery				6. ORC, VSG, Solar PV, Battery			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		0	0.0	0.00%		1,200	4,512.9	94.55%	42.9%	600	4,181.0	87.61%	79.5%
Variable Speed Diesel		1180	4,182.7	87.67%	40.5%	0	0.0	0.00%		590	197.5	4.14%	3.8%
Solar PV		250	328.2	6.88%	15.0%	0	0.0	0.00%		300	393.8	8.25%	15.0%
Wind Turbine		200	260.4	5.46%	14.9%	200	260.4	5.45%	14.9%	0	0.0	0.00%	
Batteries	kWh	630				630				630			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		4,771.2	100.00%			4,773.3	100.00%			4,772.2	100.00%	

		4. VSG, Solar PV, Wind, Battery	5. ORC, Wind, Battery	6. ORC, VSG, Solar PV, Battery
Total Capex	$, million	$ 12.1	$ 17.6	$ 14.7
Annual Opex	$, million	$ 2.8	$ 1.4	$ 1.5
LCOE	$/kWh	$ 0.778	$ 0.574	$ 0.552
Annual Avg Operating Cost	$/kWh	$ 0.582	$ 0.288	$ 0.312

Fuel and Heat		4. VSG, Solar PV, Wind, Battery	5. ORC, Wind, Battery	6. ORC, VSG, Solar PV, Battery
Wood for ORC	tonnes/yr	0	3,051	2,823
Diesel	L/yr	1,060,193	0	51,066
Total Thermal Available from ORC	MWh/yr	0	17,550	16,259
Heat Equivalent in Heating Fuel Oil	L/yr	0	1,636,807	1,516,416
Actual Heating Fuel Oil used	L/yr	756,758	756,758	756,758
Value of F.O. Saved (using lesser of above)	$/yr	$ 0	$ 941,483	$ 941,483

Relevent Figures		4. VSG, Solar PV, Wind, Battery	5. ORC, Wind, Battery	6. ORC, VSG, Solar PV, Battery
Wood Cost	per tonne	$ 137	$ 137	$ 137
Diesel Cost	per Litre	$ 1.244	$ 1.244	$ 1.244
Annual Peak Load	kW	867	867	867
Annual Load Served	MWh/yr	4,765.6	4,765.6	4,765.6

Lac Brochet

All costs in 2017 CAD		7. ORC only				8. VSG only				9. FSG only			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,480	4,766.0	100.00%	36.8%	0	0.0	0.00%		0	0.0	0.00%	
Variable Speed Diesel		0	0.0	0.00%		1770	4,766.1	100.00%	30.7%	0	0.0	0.00%	
Solar PV		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Batteries	kWh	0				0				0			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		1600	4,765.6	100.00%	34.0%
Total	MWh		4,766.0	100.00%			4,766.1	100.00%			4,765.6	100.00%	
Total Capex	$, million	$ 17.8				$ 10.2				$ 8.8			
Annual Opex	$, million	$ 1.5				$ 3.4				$ 4.7			
LCOE	$/kWh	$ 0.604				$ 0.879				$ 1.133			
Annual Avg Operating Cost	$/kWh	$ 0.315				$ 0.714				$ 0.990			
Fuel and Heat													
Wood for ORC	tonnes/yr	3,246				0				0			
Diesel	L/yr	0				1,213,204				1,400,106			
Total Thermal Available from ORC	MWh/yr	18,534				0				0			
Heat Equivalent in Heating Fuel Oil	L/yr	1,728,597				0				0			
Actual Heating Fuel Oil used	L/yr	756,758				756,758				756,758			
Value of F.O. Saved (using lesser of above)	$/yr	$ 941,483				$ 0				$ 0			
Relevent Figures													
Wood Cost	per tonne	$ 137				$ 137				$ 137			
Diesel Cost	per Litre	$ 1.244				$ 1.244				$ 1.244			
Annual Peak Load	kW	867				867				867			
Annual Load Served	MWh/yr	4,765.6				4,765.6				4,765.6			

General Observations

In Case 1, ORC, PV, and batteries are selected as the basis for configuring a system that will meet the Lac Brochet load. HOMER Pro suggests that in this mix, the majority of the energy (92%) should be provided by ORC, as this leads to the least-cost production of electricity, with solar PV providing just 8% of the energy. This reflects the high capital cost of solar PV relative to the amount of energy collected, the costs of the requisite battery capacity, and the difference in the capacity factor of the two technologies.

Although there is relatively little PV capacity in this configuration, which is typically of limited contribution during winter when load is highest, the battery capacity is contributing by providing needed backup reserves when one of the two ORC generators is down for scheduled or unscheduled outages during the peak load season. This is shown by the significant drawdowns in the batteries' state of charge in the figure below.

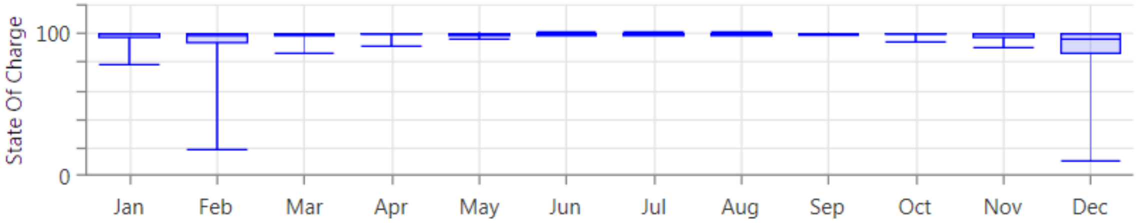

Figure 11: Lac Brochet - Case 1 - Battery state of charge

In Case 2 (ORC and VSG), nearly all of the energy is provided by the ORC generators (1@600 kW and 1@280 kW). Although generally we used a standard 600 kW ORC size, in this case two ORC sizes were selected (600 and 280 kW) to avoid skewing the LCOE economic comparisons overtly with too much overcapacity in one technology relative to the other. The minimum size of VSG modeled is 590 kW and having two 600 kW ORCs and one 590 kW VSG would be an investment in overcapacity. Consequently, VSG is the only available backup for either ORC unit, as there is no other power source available in this configuration.

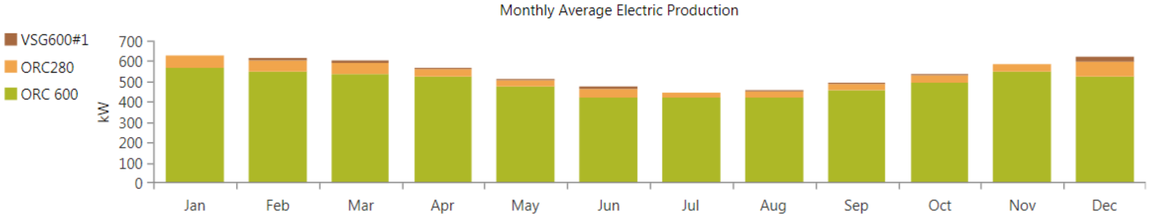

Figure 12: Lac Brochet - Case 2 - Minimal use of VSG, as backup

In Case 3 (ORC, PV, wind, battery) ORC is again the primary energy supplier, with the other renewables providing energy when weather permits and also when one ORC is down for maintenance. There is a significant battery capacity needed to store the intermittent energy from wind and solar to follow the community load when one ORC is down. This case has the lowest operating cost of the three so far, although only marginally better than Case 1, where more PV is provided and no wind turbines. That being the case, having both solar and wind resources available provides better diversity of supply, especially since wind power is available day and night, summer and winter.

In Case 4 (VSG, PV, wind, battery) the VSG is the primary energy supplier and the renewables are providing energy when one VSG is down for maintenance. There is a relatively large battery capacity needed to store the intermittent energy from wind and solar to follow the community load when one VSG is down. Annual average operating costs and overall levelized costs in this case are considerably higher than in all prior cases. Although VSG is less costly then ORC, the levelized cost is higher because of the relatively high fuel operating cost.

It can be noted that although VSG generates net GHGs and ORC does not, this VSG technology in diesel generation is 17.5% more efficient than FSG, and therefore produces less GHGs than the FSG discussed in Case 9.

In Case 5 (ORC, wind, battery) there is again a significant battery component to assist in meeting the load when one of the two 600 kW ORC units is down for maintenance. Since there is not much margin for this community's load with only 1,200 kW ORC capacity, any outage will require sufficient battery capacity to bridge the relatively low capability of the two 100 kW wind turbines. It might have been possible to have one less battery if wind power capacity was increased, but HOMER's optimization found otherwise.

In Case 6 (VSG, ORC, PV, battery), there is a mix of both diesel and ORC-renewable generation. ORC still dominates in the share of total energy supplied, indicating its relative operating cost advantage even though its initial capital cost is higher. Solar makes up 8% of production, with VSG used for backup and to assist solar PV for battery charging.

The next three cases are presented as reference for comparing the pure costs of each major non-intermittent technology, and are offered as "business-as-usual" options for supplying the communities.

In Case 7 the ORC-only configuration is the highest capital cost technology of the non-intermittent options by far. However, its levelized and average annual operating costs are the lowest within the set of all three fully dispatchable technologies.

In comparing the LCOE across the cases, which includes initial and replacement capital costs, the configurations with ORC have the lowest levelized costs when VSG is also part of the mix. The lowest average operating costs occur with ORC when intermittent power and batteries are present, however, the total capital cost is also highest.

In considering the ORC and intermittent systems, items including capex, LCOE, and operating costs are all approximately the same. On balance, it may be decided that a policy decision is the final determinant, especially if environmental and community acceptance are particular goals. The best technical configuration would also be the one with the greatest diversity of renewable supply, represented by Case 3 where both wind and solar power are present. Case 6 has diversity but it's not 100% renewable, and does not garner as much heating fuel oil credits as does Case 3, for example. The lowest marginal operating cost is with Case 3, while offering the most diverse energy source outside of use of diesel, and this makes it a primary contender for both the best policy and economic choice.

The Cases where ORC and VSG are present (2 and 6), have almost the same capex and opex, but case 6 provides for additional renewable options that allow for extra peak capacity and less reliance on ORC and its associated feedstocks. These two cases have the lowest LCOE by a small margin, but have somewhat higher operating costs than the cases where ORC is used instead of VSG. The comparative economics moderately favour biomass-fueled ORC over diesel VSG.

This commentary for Lac Brochet's tables of results is indicative of the general contents in the remaining two sets of tables, for Brochet and Tadoule Lake. There is enough in common between all three sites to be able to generalize the following points:

- Incorporating the cost of capital into the method for selecting an optimal system configuration tends to preclude much capacity in intermittent energy sources. This is a function of the significant capital cost relative to the requirement to provide electricity when it is needed.
- Solar PV can offer a good source of electricity, however, the further north the location, the greater the divergence between when it is needed (winter) and when it is most available (summer).
- In order to better enable solar PV and wind turbines to meet electricity demand, even on a daily basis, a significant further investment in battery capacity is inevitable to capture this intermittently supplied energy.
- Variable-speed diesel generation is quite cost-effective, especially compared to fixed-speed diesel generation.

ORC generation can offer the side benefit of significant amounts of waste heat from the combustors. HOMER Pro's economic evaluation of technical options does not include the value of this waste heat in potentially providing an offset in the consumption of diesel fuel for central heating. To help indicate the potential benefit in recoverable waste heat from the ORC combustor, the tables provide additional estimates for the value of displaced heating fuel oil if this waste heat is used for district heating within the communities. The waste heat from the ORC plant offers significant parallel benefits to the community by displacing the cost of fuel oil and reducing or eliminating its deleterious environmental impact and indoor air quality health impacts. **This aspect of implementing a biomass power plant to replace the reliance on diesel fuel should be considered a strong decision point in the final determination of power options.**

Where intermittent generation is present, a significant battery capacity must also be available, especially for solar. During the summer, there is a relatively large amount of solar energy available, but the electricity load is at its lowest and the excess solar energy cannot be stored very long. Wind power is somewhat less a contributor to this effect because it can charge the battery at any time during the day and across all seasons. This connection between cost per kW of intermittent power and the necessary battery capacity tends to make all intermittent sources more expensive from an initial capital outlay perspective than would be expected in other regions.

Incorporating VSG with ORC in the configuration provides the most complete capability to meet the risk of outages. To have both ORC and VSG means both technologies can be relied upon for base load and load following capabilities, and each is not reliant on the other. This may be an issue if there is any near-term concern in using ORC technology. However there remain several fixed-speed diesel generators in Manitoba Hydro's plant that may have their operating life extended for several more years, and accumulated experience with the ORC plant should lead to comfort with regard to its reliability and economic operation. Therefore, the ORC VSG combination need not be pursued as the ORC FSG would be occurring by default anyway.

5.2 Brochet

Brochet

All costs in 2017 CAD		1. ORC, Solar PV, Battery				2. ORC, Variable Speed Diesel Gen				3. ORC, Solar PV, Wind, Battery			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	3,186.0	90.41%	30.3%	600	3,415.8	96.93%	65.0%	1,200	3,055.8	86.72%	29.1%
Variable Speed Diesel		0	0.0	0.00%		590	108.2	3.07%	2.1%	0	0.0	0.00%	
Solar PV		250	337.8	9.59%	15.4%	0	0.0	0.00%		250	337.8	9.59%	15.4%
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		100	130.2	3.69%	14.9%
Batteries	kWh	210				0				210			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		3,523.8	100.00%			3,524.0	100.00%			3,523.8	100.00%	

Total Capex	$, million	$ 17.0	$ 10.6	$ 17.7
Annual Opex	$, million	$ 1.1	$ 1.1	$ 1.0
LCOE	$/kWh	$ 0.672	$ 0.550	$ 0.684
Annual Avg Operating Cost	$/kWh	$ 0.298	$ 0.318	$ 0.295

Fuel and Heat				
Wood for ORC	tonnes/yr	2,174	2,321	2,088
Diesel	L/yr	0	27,837	0
Total Thermal Available from ORC	MWh/yr	12,390	13,284	11,884
Heat Equivalent in Heating Fuel Oil	L/yr	1,155,544	1,238,886	1,108,317
Actual Heating Fuel Oil used	L/yr	765,925	765,925	765,925
Value of F.O. Saved (using lesser of above)	$/yr	$ 949,747	$ 949,747	$ 949,747

Relevent Figures				
Wood Cost	per tonne	$ 137	$ 137	$ 137
Diesel Cost	per Litre	$ 1.240	$ 1.240	$ 1.240
Annual Peak Load	kW	580	580	580
Annual Load Served	MWh/yr	3,522.7	3,522.7	3,522.7

Brochet

All costs in 2017 CAD		4. VSG, Solar PV, Wind, Battery				5. ORC, Wind, Battery				6. ORC, VSG, Solar PV, Battery			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		0	0.0	0.00%		1,200	3,393.8	96.31%	32.3%	600	3,096.2	87.86%	58.9%
Variable Speed Diesel		1180	3,055.9	86.72%	29.6%	0	0.0	0.00%		590	89.9	2.55%	1.7%
Solar PV		250	337.8	9.59%	15.4%	0	0.0	0.00%		250	337.8	9.59%	15.4%
Wind Turbine		100	130.2	3.69%	14.9%	100	130.2	3.69%	14.9%	0	0.0	0.00%	
Batteries	kWh	210				210				210			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		3,523.9	100.00%			3,523.9	100.00%			3,524.0	100.00%	

		4. VSG, Solar PV, Wind, Battery	5. ORC, Wind, Battery	6. ORC, VSG, Solar PV, Battery
Total Capex	$, million	$ 10.1	$ 15.7	$ 13.2
Annual Opex	$, million	$ 2.2	$ 1.0	$ 1.1
LCOE	$/kWh	$ 0.858	$ 0.641	$ 0.603
Annual Avg Operating Cost	$/kWh	$ 0.635	$ 0.297	$ 0.313
Fuel and Heat				
Wood for ORC	tonnes/yr	0	2,310	2,112
Diesel	L/yr	778,223	0	22,930
Total Thermal Available from ORC	MWh/yr	0	13,198	12,041
Heat Equivalent in Heating Fuel Oil	L/yr	0	1,230,898	1,122,971
Actual Heating Fuel Oil used	L/yr	765,925	765,925	765,925
Value of F.O. Saved (using lesser of above)	$/yr	$ 0	$ 949,747	$ 949,747
Relevent Figures				
Wood Cost	per tonne	$ 137	$ 137	$ 137
Diesel Cost	per Litre	$ 1.240	$ 1.240	$ 1.240
Annual Peak Load	kW	580	580	580
Annual Load Served	MWh/yr	3,522.7	3,522.7	3,522.7

Brochet

All costs in 2017 CAD		7. ORC only				8. VSG only				9. FSG only			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	3,524.0	100.00%	33.5%	0	0.0	0.00%		0	0.0	0.00%	
Variable Speed Diesel		0	0.0	0.00%		1180	3,524.2	100.00%	34.1%	0	0.0	0.00%	
Solar PV		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Batteries	kWh	0				0				0			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		1200	3,523.9	100.00%	33.5%
Total	MWh		3,524.0	100.00%			3,524.2	100.00%			3,523.9	100.00%	

		7. ORC only	8. VSG only	9. FSG only
Total Capex	$, million	$ 14.4	$ 6.8	$ 6.6
Annual Opex	$, million	$ 1.1	$ 2.3	$ 3.5
LCOE	$/kWh	$ 0.616	$ 0.804	$ 1.130
Annual Avg Operating Cost	$/kWh	$ 0.300	$ 0.655	$ 0.985
Fuel and Heat				
Wood for ORC	tonnes/yr	2,397	0	0
Diesel	L/yr	0	895,563	1,041,844
Total Thermal Available from ORC	MWh/yr	13,704	0	0
Heat Equivalent in Heating Fuel Oil	L/yr	1,278,127	0	0
Actual Heating Fuel Oil used	L/yr	765,925	765,925	765,925
Value of F.O. Saved (using lesser of above)	$/yr	$ 949,747	$ 0	$ 0
Relevent Figures				
Wood Cost	per tonne	$ 137	$ 137	$ 137
Diesel Cost	per Litre	$ 1.240	$ 1.240	$ 1.240
Annual Peak Load	kW	580	580	580
Annual Load Served	MWh/yr	3,522.7	3,522.7	3,522.7

General Observations

In Case 1, ORC, PV, and batteries are selected as the basis for configuring a system that will meet the Brochet load. Similar to Lac Brochet, HOMER Pro suggests that in this mix, the majority of the energy (90%) should be provided by ORC, as this leads to the least-cost production of electricity, with solar PV providing 10% of the energy. This again reflects the high capital cost of solar PV relative to the amount of energy obtained, the costs of the requisite battery capacity, and the difference in the capacity factor of the two technologies. This particular mix of technologies is among the higher initial capital cost systems having intermittent capacity, yet does not have a significant advantage over the others in terms of operating costs.

In Case 2 (ORC and VSG) once again, the bulk of energy is provided by the ORC generator, with VSG accounting for only 3%. VSG is used when necessary as an adjunct to ORC when it is down for maintenance, as there is no other power source available in this configuration.

In Case 3 (ORC, PV, wind, battery) ORC is again the primary energy supplier, with the other renewables providing energy when weather permits and also when one ORC is down for maintenance. In this case, solar provides slightly more energy than at Lac Brochet. Once again, this case has the lowest operating cost of the three thus far.

In Case 4 (VSG, PV, wind, battery) the VSG is the primary energy supplier and the renewables are again providing energy when conditions permit and when one VSG is down for maintenance. Similar to Lac Brochet, the LCOE and annual average operating costs are significantly higher in this case than in almost all other configurations with intermittent power.

In Case 5 (ORC, wind, battery) there is only a small battery component to assist in meeting the load when one of the two 600 kW ORC units is down for maintenance. Only 100 kW of wind have been recommended by HOMER Pro in this instance, and while the annual operating cost is among the lowest so far, the LCOE remains significantly higher than in Case 2 where less ORC capacity was modeled.

In Case 6 (VSG, ORC, PV, battery), there is a mix of both diesel and renewable generation. ORC still dominates in the share of total energy supplied, indicating its relative operating cost advantage, even though its initial capital cost is higher. The VSG is used to augment production, partially because HOMER Pro determined that it is more cost effective to limit the capital investment in ORC and make up the balance of capacity using renewables (primarily PV) and VSG.

The results of the next three reference cases essentially mirror the patterns observed for Lac Brochet.

Case 2 (ORC, VSG) has the best apparent economics for Brochet, given its second lowest capex, lowest LCOE, and on-par marginal operating cost. However, if a higher renewable penetration level is desired, along with a more diverse generation mix, Case 6 presents the next most attractive overall alternative. Again, as with the discussion of Lac Brochet, Government policy and community preferences may guide where the priorities lie. Case 3 has the lowest overall marginal operating cost, and a diversified renewable strategy offers the most flexibility in weather- and economic-related security of power supply. Weather-related security comes from no over-reliance on one element of the environment (sunny or windy days) and economic security comes from reducing exposure to the risk of oil cost increases. In this context, again the full mix of Case 3 offers potentially better future cost and environmental stability.

The final observations from Lac Brochet also generally apply here.

Another observation may be made for Brochet by comparing the LCOE for each case against that for Lac Brochet, in that they are all higher. This is generally the result of using the same fixed sizes of ORC and VSG for both Lac Brochet and Brochet analyses.

Lac Brochet has the largest load of the three. The minimum standard size for VSG units, as selected from the supplier with the variable-speed patent, is 590 kW nominal.

To avoid skewing the economic comparisons between cases, it was necessary to select a representative ORC size, and as such, 600 kW was used. For each community having a lower load than Lac Brochet, these sizes still represent what is available, and therefore must be selected within the model. Typically, this results in greater overcapacity for Brochet than for Lac Brochet, which increases the LCOE due to the fact that less energy is produced from the same capital investment. In this context, the marginal cost of operations is more representative of the actual economics of each case.

It may be possible to select ORC unit sizes more closely aligned to the community load, however, there are presently few options in VSG sizing.

5.3 Tadoule Lake

		Tadoule Lake											
		1. ORC, Solar PV, Battery				2. ORC, Variable Speed Diesel Gen				3. ORC, Solar PV, Wind, Battery			
All costs in 2017 CAD		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	2,535.7	88.50%	24.1%	600	2,786.3	97.24%	53.0%	1,200	2,326.3	81.14%	22.1%
Variable Speed Diesel		0	0.0	0.00%		590	79.0	2.76%	1.5%	0	0.0	0.00%	
Solar PV		250	329.5	11.50%	15.0%	0	0.0	0.00%		250	329.5	11.49%	15.0%
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		100	211.1	7.36%	24.1%
Batteries	kWh	210				0				210			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		2,865.2	100.00%			2,865.3	100.00%			2,866.9	100.00%	
Total Capex	$, million	$ 17.0				$ 10.6				$ 17.7			
Annual Opex	$, million	$ 0.9				$ 1.0				$ 0.9			
LCOE	$/kWh	$ 0.775				$ 0.618				$ 0.784			
Annual Avg Operating Cost	$/kWh	$ 0.316				$ 0.332				$ 0.306			
Fuel and Heat													
Wood for ORC	tonnes/yr	1,747				1,909				1,610			
Diesel	L/yr	0				20,158				0			
Total Thermal Available from ORC	MWh/yr	9,861				10,836				9,047			
Heat Equivalent in Heating Fuel Oil	L/yr	919,680				1,010,581				843,750			
Actual Heating Fuel Oil used	L/yr	525,150				525,150				525,150			
Value of F.O. Saved (using lesser of above)	$/yr	$ 651,186				$ 651,186				$ 651,186			
Relevent Figures													
Wood Cost	per tonne	$ 137				$ 137				$ 137			
Diesel Cost	per Litre	$ 1.240				$ 1.240				$ 1.240			
Annual Peak Load	kW	430				430				430			
Annual Load Served	MWh/yr	2,865.4				2,865.4				2,865.4			

Tadoule Lake

All costs in 2017 CAD		4. VSG, Solar PV, Wind, Battery				5. ORC, Wind, Battery				6. ORC, VSG, Solar PV, Battery			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		0	0.0	0.00%		1,200	2,654.1	92.63%	25.2%	600	2,465.5	86.05%	46.9%
Variable Speed Diesel		1180	1,939.3	66.82%	18.8%	0	0.0	0.00%		590	70.2	2.45%	1.4%
Solar PV		250	329.5	11.35%	15.0%	0	0.0	0.00%		250	329.5	11.50%	15.0%
Wind Turbine		300	633.3	21.82%	24.1%	100	211.1	7.37%	24.1%	0	0.0	0.00%	
Batteries	kWh	420				210				210			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total	MWh		2,902.1	100.00%			2,865.2	100.00%			2,865.2	100.00%	
Total Capex	$, million	$ 12.2				$ 15.7				$ 13.2			
Annual Opex	$, million	$ 2.0				$ 0.9				$ 1.0			
LCOE	$/kWh	$ 1.010				$ 0.729				$ 0.690			
Annual Avg Operating Cost	$/kWh	$ 0.673				$ 0.307				$ 0.334			
Fuel and Heat													
Wood for ORC	tonnes/yr	0				1,824				1,698			
Diesel	L/yr	498,953				0				17,957			
Total Thermal Available from ORC	MWh/yr	0				10,321				9,588			
Heat Equivalent in Heating Fuel Oil	L/yr	0				962,618				894,221			
Actual Heating Fuel Oil used	L/yr	525,150				525,150				525,150			
Value of F.O. Saved (using lesser of above)	$/yr	$ 0				$ 651,186				$ 651,186			
Relevent Figures													
Wood Cost	per tonne	$ 137				$ 137				$ 137			
Diesel Cost	per Litre	$ 1.240				$ 1.240				$ 1.240			
Annual Peak Load	kW	430				430				430			
Annual Load Served	MWh/yr	2,865.4				2,865.4				2,865.4			

		Tadoule Lake											
		7. ORC only				8. VSG only				9. FSG only			
All costs in 2017 CAD		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	2,865.3	100.00%	27.3%	0	0.0	0.00%		0	0.0	0.00%	
Variable Speed Diesel		0	0.0	0.00%		1180	2,865.3	100.00%	27.7%	0	0.0	0.00%	
Solar PV		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Wind Turbine		0	0.0	0.00%		0	0.0	0.00%		0	0.0	0.00%	
Batteries	kWh	0				0				0			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		1200	2,865.2	100.00%	27.3%
Total	MWh		2,865.3	100.00%			2,865.3	100.00%			2,865.2	100.00%	
Total Capex	$, million	$ 14.4				$ 6.8				$ 6.6			
Annual Opex	$, million	$ 0.9				$ 2.2				$ 2.9			
LCOE	$/kWh	$ 0.703				$ 0.946				$ 1.190			
Annual Avg Operating Cost	$/kWh	$ 0.314				$ 0.763				$ 1.011			
Fuel and Heat													
Wood for ORC	tonnes/yr	1,963				0				0			
Diesel	L/yr	0				730,677				845,392			
Total Thermal Available from ORC	MWh/yr	11,143				0				0			
Heat Equivalent in Heating Fuel Oil	L/yr	1,039,243				0				0			
Actual Heating Fuel Oil used	L/yr	525,150				525,150				525,150			
Value of F.O. Saved (using lesser of above)	$/yr	$ 651,186				$ 0				$ 0			
Relevent Figures													
Wood Cost	per tonne	$ 137				$ 137				$ 137			
Diesel Cost	per Litre	$ 1.240				$ 1.240				$ 1.240			
Annual Peak Load	kW	430				430				430			
Annual Load Served	MWh/yr	2,865.4				2,865.4				2,865.4			

General Observations

In Case 1, HOMER Pro again directs the majority of the energy (89%) to be provided by ORC (as this leads to the least-cost production of electricity), with solar PV providing 11% of the energy. As previously noted, this reflects the high capital cost of solar PV relative to the amount of energy obtained, the costs of the requisite battery capacity, and the difference in the capacity factor of the two technologies.

In Case 2 (ORC and VSG), nearly all of the energy is provided by the ORC generator. VSG is again used when necessary as an adjunct to ORC when it is down for maintenance, as there is no other power source available in this configuration.

In Case 3 (ORC, PV, wind, battery) ORC is again the primary energy supplier, with the other renewables providing energy when weather permits and also when one ORC is down for maintenance. Although this case has the lowest operating cost of the three so far, its LCOE is considerably higher than Case 2.

In Case 4 (VSG, PV, wind, battery) the VSG is the primary energy supplier, with the renewables providing energy when practical and when one VSG is down for maintenance. Due to better wind resource data at Tadoule Lake, and to compensate for the high cost of diesel fuel, considerably more wind is utilized in this case than at Lac Brochet and Brochet.

However, the LCOE and annual operating costs in this scenario are the highest among Cases 1-6 for this location.

In Case 5 (ORC, wind, battery), ORC dominates the energy supply, with only 100kW of wind being practical under this scenario. This case has the lowest operating cost by a small margin, and among the lowest LCOEs.

In Case 6 (VSG, ORC, PV, battery), there is a mix of both diesel and ORC-renewable generation, with VSD being used relatively little. ORC still dominates in the share of total energy supplied, again indicating its relative operating cost advantage, even though its initial capital cost is higher. Solar and VSG are used to augment production, partially because HOMER Pro determined that it is more cost effective to limit the capital investment in ORC and make up the balance of capacity using solar and VSG. Due to the reduced ORC capacity, the capital cost of this scenario is less than that in Case 5.

The results of the next three reference cases again essentially mirror the patterns observed for Lac Brochet (and Brochet).

As with Brochet, Tadoule Lake's Case 2 (ORC, VSG) has competitive economics, given a low capex, lowest LCOE, and reasonably low annual opex and marginal annual operating costs. As with Brochet, if a slightly higher renewable penetration level is desired, along with a more diverse generation mix, Case 6 presents the next most attractive economic alternative. For a 100% renewable penetration for Lac Brochet, Brochet and Tadoule Lake, this policy then directs the decision on resource selection to the more community and environmentally acceptable option, Case 3.

It is noted that the LCOE for Tadoule Lake is higher than the other two communities, the reason for which was discussed at length in the Brochet commentary, in relation to Lac Brochet.

In all instances, it is important to note that various factors will need to be considered in the ultimate decision regarding which option to pursue. These factors may include financial constraints such as initial capital expenditure costs and annual operating and maintenance costs, as well as other items including GHG emissions, economic development, and environmental impacts, as well as political and community considerations.

These items, along with additional data and analysis should be studied in the feasibility study phase of this initiative, as articulated in Section 6 – ACTION ITEMS AND NEXT STEPS – of this Report.

5.4 System Configuration and Operating Cost under no-Capex Assumption

SW60 was requested to evaluate the scenario where capital costs were not to be incorporated into the development of an optimal generation system, where HOMER Pro would size components based on a least-LCOE metric, but with capital costs being set to zero. That is, in this configuration, the generation asset is considered to be a sunk cost.

When capital costs are not part of the discounted present cost calculation, HOMER Pro will only incorporate fuel, operating, and maintenance costs. This leads to optimal system configurations where generation technology with the least overall operating cost will dominate, and thus, HOMER Pro will attempt to select very large PV and wind turbine capacities. There are physical limits (nearby suitable space requirements and distances to the grid) and financial limits on amounts available to cover the sunk costs. As such, SW60 estimated that likely maximums are 2,000 kW for a solar PV field, and 1,000 kW of wind power.

By forcing these capacities into the mix, HOMER Pro can then determine what the sizes will be for the remaining technologies, and an estimate can then be made for the annual operation costs for this system configuration.

The following table illustrates the effect on the system configuration and operating costs for each community. The "Total Capex" shown in the table is the actual cost of this system configuration given the maximum capacities for solar PV and the wind turbine resource.

All costs in 2017 CAD		Lac Brochet								Brochet								Tadoule Lake							
		3. ORC, Solar PV, Wind, Battery				4. VSG, Solar PV, Wind, Battery				3. ORC, Solar PV, Wind, Battery				4. VSG, Solar PV, Wind, Battery				3. ORC, Solar PV, Wind, Battery				4. VSG, Solar PV, Wind, Battery			
		Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor	Capacity kW	Production MWh/year	Percent of Total kWh	Capacity Factor
Organic Rankine Cycle		1,200	2,557.3	39.44%	24.3%	0	0.0	0.00%		1,200	1,700.5	29.81%	16.2%	0	0.0	0.00%		1,200	1,193.6	20.09%	11.4%	0	0.0	0.00%	
Variable Speed Diesel		0	0.0	0.00%		1180	2,434.6	38.27%	23.6%	0	0.0	0.00%		1180	1,591.5	28.44%	15.4%	0	0.0	0.00%		1180	905.8	16.02%	8.8%
Solar PV		2000	2,625.3	40.49%	15.0%	2000	2,625.3	41.27%	15.0%	2000	2,702.8	47.38%	15.4%	2000	2,702.8	48.30%	15.4%	2000	2,636.0	44.37%	15.0%	2000	2,636.0	46.63%	15.0%
Wind Turbine		1000	1,301.8	20.08%	14.9%	1000	1,301.8	20.46%	14.9%	1000	1,301.8	22.82%	14.9%	1000	1,301.8	23.26%	14.9%	1000	2,111.0	35.53%	24.1%	1000	2,111.0	37.34%	24.1%
Batteries	kWh	210				630				210				420				210				420			
Fixed Speed Diesel		0	0	0.00%		0	0	0.00%		0	0	0.00%		0	0	0.00%		0	0	0.00%		0	0	0.00%	
Total Produced	MWh		6,484.4	100.00%			6,361.6	100.00%			5,705.0	100.00%			5,596.1	100.00%			5,940.6	100.00%			5,652.8	100.00%	
Excess Energy	MWh		1,719.8				1,592.6				2,161.2				2,071.4				3,138.7				2,749.3		
Net Load Served	MWh		4,764.6				4,769.1				3,543.8				3,524.6				2,801.9				2,903.5		

Total Capex	$, million	$ 38.2	$ 31.7	$ 38.1	$ 31.1	$ 38.2	$ 31.1
Annual Opex	$, million	$ 1.6	$ 2.5	$ 1.3	$ 1.9	$ 1.2	$ 1.6
LCOE	$/kWh	$ 0.957	$ 1.029	$ 1.217	$ 1.235	$ 1.466	$ 1.400
Annual Avg Operating Cost	$/kWh	$ 0.247	$ 0.386	$ 0.235	$ 0.348	$ 0.210	$ 0.284

Fuel and Heat							
Wood for ORC	tonnes/yr	1,767	0	1,198	0	864	0
Diesel	L/yr	0	619,731	0	407,640	0	234,494
Total Thermal Available from ORC	MWh/yr	9,945	0	6,613	0	4,642	0
Heat Equivalent in Heating Fuel Oil	L/yr	927,527	0	616,747	0	432,928	0
Actual F.O. used	L/yr	756,758	756,758	765,925	765,925	525,150	525,150
Value of F.O. Saved (using lesser of above)	$/yr	$ 941,483	$ 0	$ 764,767	$ 0	$ 536,830	$ 0

Relevent Figures							
Wood Cost	per tonne	$ 137	$ 137	$ 137	$ 137	$ 137	$ 137
Diesel Cost	per Litre	$ 1.244	$ 1.244	$ 1.240	$ 1.240	$ 1.240	$ 1.240
Annual Peak Load	kW	867	867	580	580	430	430
Annual Load Served	MWh/yr	4,765.6	4,765.6	3,522.7	3,522.7	2,865.4	2,865.4

In interpreting the results from these cases, it should be understood that no cost of capital for the equipment and construction of the facility was used by HOMER to size the PV and wind turbines in this analysis. HOMER Pro would allow even more of these renewables, but they were capped for practical reasons. The amount of Solar PV was capped at 2,000 kW and the wind power was capped at 1,000 kW in these cases due to local space and distance concerns.

The capital cost associated with these renewables may be beyond the boundary acceptable for these community projects if INAC has a limit on its budgeted capital expenditures. In this context, SW60 does not recommend solely sizing the system based on an optimization on annual operating costs. Other factors such as diversity of supply, dispatchable resources, redundancy, operation and maintenance issues, ease of grid integration, environmental issues, DSM, demand response, available incentives, policy issues, local climate, and maturity of technology also need to be considered.

6 ACTION ITEMS AND NEXT STEPS

Moving forward, it is recommended that INAC proceed with conducting a comprehensive technical and economic feasibility study for the preferred option in each of the communities, including:

- Definition of evaluation criteria and selection of the preferred solution(s) for feasibility evaluation purposes
- Technical feasibility evaluation
- Economic feasibility evaluation
- Risk identification, mitigation, and management
- Sustainability analysis
- Community and stakeholder consultations
- Environmental Impact Assessment
- Socio-economic Impact Assessment
- Source(s) of funding
- Financial structure
- Ownership
- Stakeholder responsibilities (Band, Manitoba Hydro, etc.)
- Support, O&M, and training and capacity building requirements
- Gauging of capabilities and interest from contractors
- Outline of next steps including detailed design, procurement, and construction

7 CONCLUSIONS AND RECOMMENDATIONS

- For a 100% renewable penetration of electrical generation technologies for Lac Brochet, Brochet and Tadoule Lake, the best economic resource selection is Case 3 of ORC, PV, wind power and battery. This is also likely a better community and environmentally acceptable option. The LCOE varies from 59.2 ¢/kWh for Lac Brochet, 68.4 ¢/kWh at Brochet and 78.4 ¢/kWh at Tadoule Lake. The average annual operating costs vary from 29.3 ¢/kWh for Lac Brochet, 29.5 ¢/kWh at Brochet and 30.6 ¢/kWh at Tadoule Lake, which represents the lowest marginal operating costs of all cases evaluated by HOMER Pro. The best technical configuration would also be the one with the greatest diversity of proven renewable supply options, also represented by Case 3 where ORC, wind and solar power are present. There is also ample waste heat from the ORC to heat the entire communities with 200% heat available in La Brochet, 140% in Brochet and 160% in Tadoule Lake. The excess waste heat available can be used for additional uses; including food security systems such as freezers and greenhouses, or additional economic development via hotels and laundromats. **This aspect of implementing a biomass power plant to replace the reliance on diesel fuel should be considered a strong decision point in the final determination of power options.**
- Manitoba Sustainable Development's Forestry Branch and local university research reports indicate that there are abundant local wood resources of fire-burnt timber, providing at the present rate of electricity and heat consumption between 50 and 200 years of wood supply for 100% biomass heating and electrical generation near each community.
- If upon further investigation, the fire-burnt source of biomass appears uncertain, then there are three Forestry Management Units (FMUs) that can be harvested: FMU 71, FMU 72, and the western portion of FMU 79. The sustainable Annual Allowable Cut (AAC) for these three FMUs exceeds the expected ORC fuel consumption for all three communities. Thus, the recommended feasibility study will need to include a thorough survey of the available wood supplies, both from local fire-kill sources and from these FMUs.
- It has been determined that there is ample truck capacity and winter road season duration from FMU 71, 72 and 79 to supply all three communities with a full year's supply of chipped (at site) wood at a sustainable and reasonable cost of $137 per tonne.
- A significant reduction in diesel oil supply and transportation requirements will result within these communities once the ORCs are 100% operational.
- It is recommended that the existing Manitoba Hydro diesel units be maintained and left in place as back-ups with enough diesel fuel for one year of operation at 100% community loading. As the ORCs are 100% operational, the Manitoba Hydro diesels and associated tank farms may eventually be decommissioned. In all cases,

the firm backup electrical energy supply would then be transferred to the additional ORC to provide an N-1 design within each community.

- It is recommended to supply high–level training to local personnel so the ORC can be maintained with a local labour force and to also secure appropriate maintenance contracts with reputable ORC equipment suppliers to offset the risk of failure of this technology in the remote Northern First Nations Communities.
- Community benefits include local job creation within the community energy sector in the areas of wood harvesting, transportation, electricity O&M and district heating system O&M, as well as further economic development through community-owned generation facilities and businesses. There are opportunities to train Band Members to install Solar PV racks and panels and use local materials to anchor the racks.
- It is recommended that key replacement components for ORC, Solar PV, Wind Power, and Batteries be kept on-site to ensure speedier repairs.
- The addition of a Battery Energy Storage System (BESS) is always required to make variable Solar PV and wind power options realizable for all remote communities.
- It is recommended to use fixed tilt Solar PV systems in Manitoba's remote communities, as availability of land space is not an issue, and as such, simply adding more PV panels is instead, preferred. The use of tracking should only be considered if it would be beneficial to produce more power at times close to sunrise and sunset. Although tracking systems today can make economic sense in certain applications, they also add complexity of moving parts to a PV system.
- There is substantially more solar energy available in summer, reducing the ability to meet community loads with solar PV in winter months. PV generation is also subject to large fluctuations due to passing clouds, increasing the possibility of voltage sags and frequency fluctuations. As such, both Solar PV and wind power need to be properly integrated into each community, with detailed planning and high-level grid interconnection studies required for the complete generation and grid system.
- Wind resource information is poor in the remote communities and needs to be verified by monitoring as recommended in Marc Arbez's report to the Community Energy Plan "Development of a Wind-Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations".
- Wind generation can provide substantial benefits to remote communities, allowing generating power when Solar PV cannot (at night). However, in order to be effective, it is critical to evaluate wind power from a remote community point of view, and not from a large utility point of view, as diesel power costs have the potential to be near or exceed $1.00 per kWh in these locations. With proper analysis, there is substantial room to adapt this technology to remote

communities.

- Wind turbines for remote communities are still underdeveloped and lack examples of demonstrated long-term proven sites and thus currently there would there be more risk of underachieving expected energy production in Manitoba's Remote Communities.
- Even with batteries, it is difficult for wind power and Solar PV to provide base load power, let alone provide system redundancy.
- The high cost that has recently been reported to replace diesel engines may be mitigated by installing portable and containerized diesel gensets, similar to those used in winter camps. As the renewable energy systems are installed, portable gensets may be sized more appropriately (smaller units used) to provide better load following at lower system loading.
- Fixed-speed diesel generators (FSG) do not integrate well with renewable energy as these diesels cannot operate at low partial loads (below 30% of rating), and may require Solar PV and wind power to be curtailed. Variable speed diesel generators (VSG) are able to operate at low load (10% of rating) and are more efficient than FSG when partially loaded, resulting in VSG achieving considerable fuel savings (up to 35%) over fixed-speed diesel generators.
- Demand response options such as load shedding electric hot water tanks during peak load times to reduce system peaks are recommended to be studied further in the proposed feasibility study.
- There is information that the load growth in these communities can be flat for 25 years due to DSM measures and potential for a biomass district heating system to replace electric hot water tanks. The electric generation facilities would then not need upsizing for 25 years.
- It is possible to provide 100 Amp residential service with a biomassed fueled organic rankine cycle generator. Loads can be managed with aggressive DSM and demand response control of the blowers at the sewage lagoon and control of any electric hot water tanks not on biomass or geothermal heating loops.
- It is recommended that in the feasibility study that a detailed emission study be undertaken of the ORC, VSG and FSG.
- The connection between the high cost per kW installed of intermittent power in the remote communities and the necessary battery capacity tends to make all intermittent sources more expensive from an initial capital outlay perspective than would be expected in other regions where the installed cost is less.
- In the cases where HOMER Pro excluded the capital costs, large amounts of renewables (wind power and Solar PV) are selected due to their low operating costs. An approach to exclude capital costs and treat them as sunk costs (usually a policy decision) is an alternate method for determining the best option of new

electrical energy sources. Other policy decisions can be made about the rates needed to recover the operating costs such that the residential rate is the same as now (7.92 ¢/kWh) and commercial and government rates make up the difference, which would be much less than the rates paid today if renewables are used.

- In this case, electrical generation technologies with low operating costs are favoured over others that have higher operating costs such as fuel purchases. However, their capital cost may be beyond the boundary acceptable for these community projects if INAC has a limit on its budgeted capital expenditures. In this context, SW60 does not recommend solely sizing the system based on an optimization on annual operating costs. Other factors such as diversity of supply, dispatchable resources, redundancy, operation and maintenance issues, ease of grid integration, environment al issues, DSM, demand response, available incentives, policy issues, local climate, and maturity of technology also need to be considered.
- The renewable energy systems that would be employed in the remote communities is recommended to a smart grid which is an operational scenario involving smart meters, smart controllers and communications, energy storage, renewable energy resources, energy efficiency and smart appliances. This would allow the control of the production and distribution of more reliable electricity with more resilience and fewer voltage and current spikes and less harmonics.
- This pre-feasibility study shows that renewable electricity sources have good potential to be realizable in the remote communities and thus it is recommended that a full feasibility study be pursued for the electrical energy and associated heating options for Brochet, Lac Brochet, and Tadoule Lake.

Development of a Wind-Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations

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Submitted by:
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March 31, 2017

Executive Summary

The four northern Manitoba communities of Brochet, Lac Brochet, Tadoule Lake and Shamattawa rely exclusively on diesel fuel for their electrical generation. Wind resource development potential in northern Manitoba has yet to be properly assessed. Electricity from wind turbines may be a viable option to reduce the dependence of these communities on expensive and non-renewable diesel.

Before wind turbine installations can be considered, wind resources must be properly assessed. This report proposes a wind monitoring program that would collect the data necessary to evaluate the wind resources at potential turbine locations in these communities.

The two communities of Brochet and Tadoule Lake appear to have favourable wind resources, based on a relatively sparse amount of wind information. Wind resources are unknown at Lac Brochet and appear to be limited at Shamattawa.

It is proposed that initially, a wind monitoring program be implemented in the three communities of Brochet, Lac Brochet and Tadoule Lake. Wind monitoring in Shamattawa should be considered in the future, pending results of the wind resource analyses at the other three communities.

A series of wind monitoring recommendations are made throughout this report. These are summarized in the order that they are presented in the report:

Recommendation #1: A rigorous, site-specific meteorological evaluation is required for a minimum of one year to assess the wind resources at any location of interest.

Recommendation #2: A relatively tall meteorological (met) tower with multi-height anemometers is required to properly evaluate wind resources at potential wind turbine heights. Based on available monitoring equipment and wind turbine size limitations, a 34-metre met tower is recommended.

Recommendation #3: A satellite-based data communications system is required to relay information that is collected from met towers in remote sites.

Recommendation #4: Met tower wind data should be collected from the communities of Brochet, Tadoule Lake and Lac Brochet to determine their wind resource potentials. Wind resources need to be assessed before considering the inclusion of windgenerated electricity to the energy mix at any of these communities.

Recommendation #5: Wind resource monitoring in the Shamattawa area should be delayed, pending wind resource analysis results from the other three communities. Based on available data, wind resources appear less promising at Shamattawa than at the other three diesel communities.

Recommendation #6: Wind monitoring location maps should be created for the communities of Brochet, Lac Brochet and Tadoule Lake. These maps would identify where there are restrictions on the placement and height of obstacles like met towers or wind turbines, near airports. The maps would also identify the greatest acceptable distribution line distance from the diesel generation station to one or more wind turbines that would be tied into the station for each community.

Recommendation #7: Locations where topographic features (trees, etc.) or man-made obstructions negatively impact wind flow are to be avoided when conducting a preliminary survey of potential wind sites.

Recommendation #8: Site selection for met towers and wind turbines should be limited to areas that have road access to the community of interest.

Recommendation #9: A potential wind monitoring site must offer sufficient open space to allow an installation crew to fully assemble the met tower on the ground prior to the tower being tilted up. The site must also provide enough space to account for the met tower's footprint.

Recommendation #10: Met tower installations should be limited to areas outside of sacred sites and ecologically-sensitive areas.

Recommendation #11: Community acceptance of proposed met tower sites (potential wind turbine sites) must be garnered before considering the installation of the met towers.

Recommendation #12: The Lidar *Windcube* system is not recommended for wind data collection because of the cost and risk involved.

Recommendation #13: A minimum of one NRG 34-metre met tower should be installed at one potential wind site in each of the diesel communities of Brochet, Lac Brochet and Tadoule Lake. If economically feasible, more than one met tower should be considered for installation at each of these communities. The odds of selecting a good wind site for a community are increased if more than one met tower is installed. Multiple met tower installations also permit the consideration of integrating more than one wind turbine to a single community.

Recommendation #14: A handful of potential met tower sites should be considered for each of the communities of interest. Final tower sites would be selected once a preliminary land survey is completed.

Recommendation #15: The following met tower sensor configuration is recommended for a 34-metre met tower:

- 2 anemometers, booms and cable at the 10-metre height • 2 anemometers, booms and cable at the 20-metre height
- 2 anemometers, booms and cable at the 34-metre height
- 1 wind vane, boom and cable at the 10-metre height
- 1 wind vane, boom and cable at the 34-metre height
- 1 barometric sensor
- 1 temperature sensor
- 1 pyranometer
- 1 datalogger
- 1 satellite communication system for timely data transfer

Recommendation #16: Local community resources should be utilized for this project whenever and wherever possible. The valuable skills and knowledge that members of these communities have acquired can help create a more successful wind monitoring program. Some examples where local resources can be utilized are:

- A community member with knowledge pertaining to local ecologicallysensitive areas, sacred sites, topography, ground cover and access could help with preliminary tower siting efforts. For example, community members from Brochet refer to an elevated area near the community called the 'Big Hill'. The 'Big Hill' may offer a promising wind site;[7]
- One or more community members could be involved with met tower installation(s) and removal(s);
- It is imperative that periodic met tower site visits be made to identify any visible problems relating to the met towers and their sensors (i.e. guy wire tension, etc.). Issues could be forwarded in a timely manner by a member of the community to the appropriate individual(s);
- If one or more wind turbines were to be eventually installed, there could be opportunities to train members of the community on wind turbine maintenance. Local assistance for turbine maintenance could be provided on an ongoing basis.

Wind resources need to be evaluated in the diesel communities in northern Manitoba. The installation of wind monitoring equipment in the north, and subsequent data collection for analysis pose many challenges, but none of these challenges are insurmountable. By applying a systematic and logical approach to wind analysis, the potential for wind-generated electricity in the north can be properly assessed.

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Development of a Wind Energy Resource Assessment Strategy for Manitoba's Off-Grid First Nations

1.0 Introduction

To this day, wind resources in northern Manitoba remain largely unknown and untapped. The four remote Manitoba communities of Shamattawa, Tadoule Lake, Brochet and Lac Brochet rely solely on expensive, non-renewable diesel-generated electricity. Electricity from wind could potentially be used to displace a portion of the diesel that is transported to and consumed at the communities. A comprehensive analysis of the wind resources in an around these communities is required before windgenerated electricity can be considered as a potential contributor to the electrical energy mix at the diesel communities in northern Manitoba.

Several recommendations that pertain to proposed wind monitoring programs and to the ranking of diesel communities in terms of their potential wind resources, will be made throughout the report.

1.1 Definitions

The following definitions are intended to provide the reader information on wind resource terminology:

Met tower: meteorological tower - a vertical metal pipe that has a series of monitoring sensors (anemometers, wind vanes, etc.) that are attached to the tower with horizontal booms; a met tower is held up with a series of guy wires that are moored to the ground at anchor points away from the tower.

Met tower footprint: the area required to install a met tower and attach it to the ground at several anchor points that are relatively far away from the met tower itself.

Lidar: a small box-shaped data recording system that emits pulses of light to generate high quality multiheight wind data such as wind speed and wind direction.

Anemometer: a sensor for measuring the speed of the wind.

Wind speed distribution profile: a statistical function describing the probability that a given wind speed will occur; the distribution of the observed frequency of occurrence of wind speeds that are measured by an anemometer at a monitoring site.

Ux: wind speed measured in metres per second (m/s) by an anemometer at height 'x'; for example, U10 =3.4 m/s denotes a wind speed of 3.4 m/s at an anemometer height of 10 metres above ground level.

Wind direction in degrees: wind direction is reported by the direction from which it originates, recorded in degrees clockwise from due north; 90 degrees is due east, 180 degrees is due south, 270 degrees is due west and 360 degrees is due north, and 0 degrees denotes calm winds.

Wind shear: a unitless measure of the frictional impact of the earth's surface roughness on wind; wind shear results in a decrease in wind speed with an decrease in height above ground level; wind shear is used to predict wind speeds at heights that are greater than anemometer recording heights.

Small wind turbine: a wind turbine that has a maximum rated power output capacity from 20 watts to 100 KW.[1]

Medium wind turbine: a wind turbine that has a maximum rated power output capacity from 100 KW to 1 KW.

Large wind turbine: a utility-scale wind turbine that has a maximum rated power output capacity of 1 MW or more.[2]

Wind turbine power curve: the quantity of power that is produced by a wind turbine, as a function of wind speed; power is measured in watts (W), kilowatts (KW), or megawatts (MW) of rated capacity, depending on the size of the turbine.

Wind turbine hub height: the vertical distance from the ground to the centre-line of a wind turbine rotor (where all the turbine blades converge); the hub height is used as a reference height at which wind speeds and power production are assessed.

2.0 Existing Wind Information

The following information on wind resources is currently available for the four northern communities.

2.1 Canadian Wind Energy Atlas

There are two versions of the Canadian Wind Energy Atlas (CWEA). The ‘Level 0’ version is a seamless 25 km X 25 km resolution national map. It is based on many wind modelling calculations and displays the 5-year mean wind energy potential from January 1996 to December 2000. Wind energy is presented in watts/m^2 (of turbine blade area) at a hub height of 50 metres.[3]

The ‘Level 1’ version of the CWEA is a mosaic wind map of Canada with a 5 km X 5 km resolution. Numerical simulations on wind data were performed on several data ‘tiles’ throughout Canada. These ‘tiles’ of information were then combined in a large mesh to create a complete wind map of the country. The ‘Level 1’ map is an interactive map which presents mean wind speeds (m/s) and mean wind energy (w/m^2) at heights of 30, 50 and 80 metres above ground level. Values on the map are based on 43 years of meteorological (met) observations.[4]

2.2 Manitoba Hydro 80-Metre Wind Map

In 2006, a wind resource company called Helimax was commissioned by Manitoba Hydro to produce a seamless high resolution (136 m X 136 m) wind resource map. The Helimax map is considerably more detailed than the Canadian Wind Energy Map.

The Manitoba Hydro wind map shows estimated average wind speeds in m/s at an 80-metre hub height. Although hub heights of 80 metres are feasible in southern Manitoba, they cannot currently be considered as an option in remote northern communities in the province. This is because several significant physical and financial constraints severely limit transportation, installation and maintenance options for large turbines in northern Manitoba.

2.3 Environment Canada 10-Metre Wind Speeds

Environment Canada (EC) weather stations are scattered throughout the province of Manitoba. Some of these stations record hourly wind speeds throughout the year at an industry standard 10-metre height above ground level. Wind speed data from Environment Canada weather stations serve only as initial indicators of wind resources. A strong wind regime at a height of 10 metres is often indicative of relatively good wind resources at greater heights as well.

The actual siting of a weather station strongly impacts wind speeds that are recorded at the site. For example, if an EC weather station tower is located relatively close to a man-made structure or natural barrier (such as trees near the tower), anemometer readings will be negatively impacted and will not accurately reflect optimum wind speeds that exist at more favourable sites in the area.

Of the four northern communities of Tadoule Lake, Brochet, Lac Brochet and Shamattawa, only Tadoule Lake and Brochet have EC weather stations. The Tadoule Lake EC weather station has recorded hourly temperature, relative humidity, atmospheric pressure, wind direction and 10-metre wind speed data since November 2000. The station is located 200 metres east of a 7-metre high terminal building at the

Tadoule Lake airport. It is still actively recording hourly weather data. The Environment Canada recording tower was not optimally-sited because it is not exposed to unimpeded wind flow from all directions.

The Brochet EC weather station is located on a bare patch of gravel on high ground adjacent to the airport runway. The tower has relatively clear exposure in all directions, so anemometer readings probably reflect optimal or near-optimal wind speeds in the area. The Brochet EC weather station records hourly temperature, relative humidity, atmospheric pressure, wind direction and wind speed data. The station operated from January 1953 to December 1979, at which point it was decommissioned. The Brochet A EC weather station recorded data very sporadically after 1969. Although there is no historical account of the anemometer height at this station, it is very likely that wind speed readings have been recorded at an industry-accepted standard height of 10 metres above ground level throughout the monitoring period.

2.4 Temporary 20-Metre Met Towers at Tadoule Lake and Shamattawa

The Province of Manitoba commissioned the Pembina Institute to install two 20-metre met towers in the fall of 2006. The first met tower was installed in a clearing at the north end of the community of Shamattawa. Following initial communication challenges and sensor malfunction issues, usable wind data was obtained from the tower from February 2008 to December 2008. The tower recorded wind direction along with multiple-height wind speed data over this period. Anemometers were installed at 10, 15 and 20 metres above ground level. Data quality issues that plagued the monitoring tower at Shamattawa will be addressed later in this report.

The second 20-metre tower was installed in October 2006 on a small island just east of the community of Tadoule Lake. The island is connected to the mainland by a short causeway. The Tadoule Lake met tower was installed on a site with considerable exposure to open water and low-lying shrub except for a cluster of short, sparse trees to the north. Two anemometers and one wind vane were installed at the 20-metre height above ground level. The met tower recorded wind speed and wind direction until February 2008. As was the case with the Shamattawa met tower, data quality issues occurred during the monitoring period. These will be discussed in more detail later in this report.

3.0 Analysis of Existing Wind Information

There is a lack of usable wind data at the four northern Manitoba diesel communities. It is not currently possible to conduct the type of rigorous wind resource assessment that is required before considering the possible integration of wind turbines into the energy supply mix at any of the remote communities. Existing wind data can only be used to make a very preliminary assessment of wind resources at three of the four communities.

3.1 Wind Maps

The Canadian Wind Energy Atlas (CWEA) provides regional estimates of average wind speeds. The CWEA map shows that the 30-metre hub height wind speeds in and around the four northern Manitoba communities are as follows:

Lac Brochet:	U30 = 6.0-7.0 m/s

Brochet: U30 = 6.5-7.5 m/s
Tadoule Lake: U30 = 6.0-7.0 m/s
Shamattawa: U30 = 5.0-6.0 m/s

A definitive wind resource analysis is not possible when using data that is based on wind speed estimates that range by as much as 1 m/s. The reason for this is that wind speeds strongly influence wind turbine performance.

The average wind speed alone does not provide a complete picture of the wind speed distribution profile (percentage of varying wind speeds) at a site of interest. Wind-generated energy production estimates require a site's complete wind speed distribution profile, not just the average wind speed.

The Manitoba Hydro provincial wind speed map provides more precise wind speed estimates than the CWEA. Information obtained from the Manitoba Hydro map applies to wind turbine hub heights of 80 metres above ground level. Given that wind turbines would likely be restricted to heights of 30 to 50 metres in northern Manitoba, wind resource assessments for those specific heights are required. The desired 30 to 50-metres wind speeds cannot currently be extrapolated from the 80-metre wind map.

Recommendation #1: Regional wind maps provide useful preliminary information on wind resources. They do not account for very subtle nuances in local geography and topography that can significantly impact wind speeds. A rigorous, site-specific meteorological evaluation is required for a minimum of one year to assess the wind resources at any location of interest. [5]

3.2 A Closer Look at the Four Diesel Communities

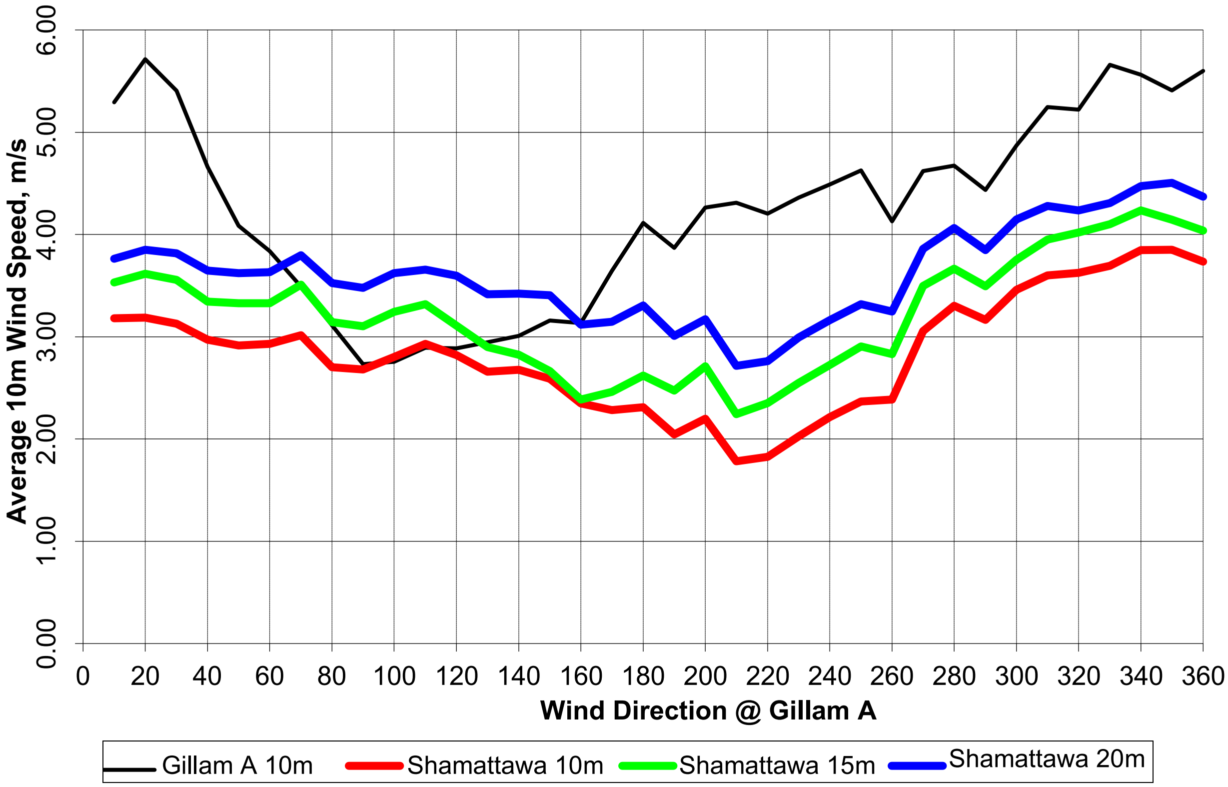
3.2.1 Shamattawa

There are no Environment Canada weather stations at or near the community of Shamattawa in northeastern Manitoba. A 20-metre met tower was installed in Shamattawa in September 2006. Anemometers were mounted at 10, 15 and 20 metre heights on the met tower. Because of significant communication issues and datalogger and sensor failure, all wind data was lost from September 2006 to February 2008. Following a February 2008 tower visit for monitoring equipment replacement, usable wind data was collected from February 2008 to December 2008. The average wind speeds for this period were:

U10 = 2.9 m/s
U15 = 3.2 m/s
U20 = 3.7 m/s

The closest EC weather station is in the town of Gillam, Manitoba. Gillam is 150 kilometres northwest of Shamattawa. The average 10-metre wind speed at the Gillam weather station is 4.2 m/s. Figure 1 compares average multi-height wind speeds obtained from the Shamattawa met tower to the Gillam EC tower. The wind speeds for Shamattawa and Gillam have been time-matched. Except for winds that originate from the east, the 10-metre wind speeds in Gillam are greater than the 20-metre wind speeds at Shamattawa.

Figure 1: Shamattawa and Gillam Wind Speeds (2008)



Shamattawa wind shear estimates are based on multi-height anemometer wind speeds and are included in Appendix A. Based on average wind speeds that were recorded at 10, 15 and 20 metres above ground level, the estimated wind shear at the met tower site is relatively high at 0.34. Considering the mosaic of open and thinly forested area near the met tower, a wind shear of 0.34 seems ‘intuitively’ acceptable.

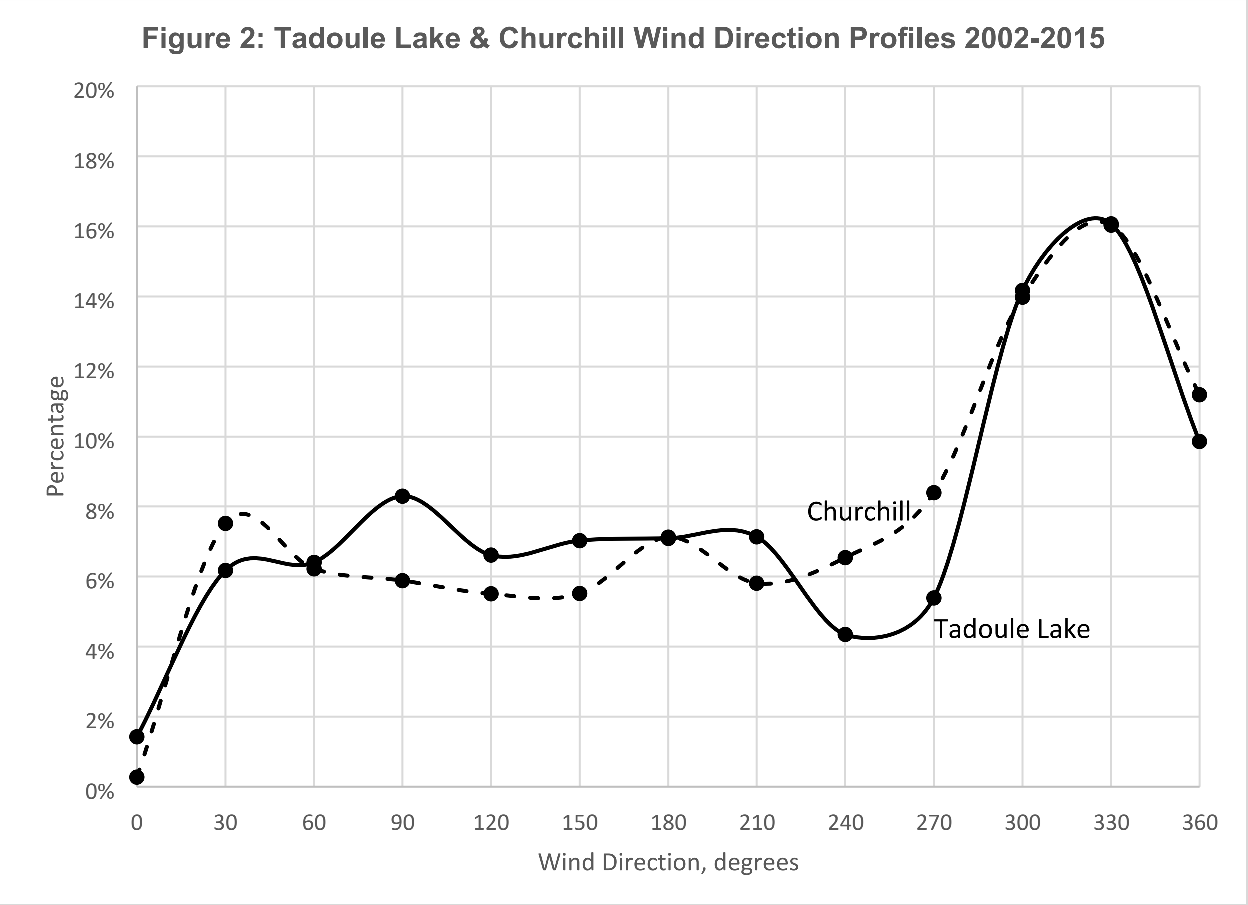
There is a relatively small difference in height between the three anemometer locations on the Shamattawa 20-metre met tower. Consequently, there is a very low level of confidence in the shear estimate of 0.34. Nevertheless, by applying a wind shear of 0.34 to an average recorded wind speed of 3.7 m/s at 20 metres above ground level, the average wind speeds at potential wind turbine hub heights of 30, 40 and 50 metres, are estimated to be 4.2, 4.7 and 5.1 m/s, respectively. These are considered low wind speeds for these heights. Detailed wind speed extrapolation calculations are included in Appendix A.

The unfavourable wind resources measured at the 20-metre met tower could either indicate that the met tower itself was poorly sited or that wind resources in the general area are not promising.

3.2.2 Tadoule Lake

The Tadoule Lake EC weather station has been recording wind data since 2000. A 20-metre met tower collected additional wind data near the community from 2007 to 2008. Knowledge about the wind resources at potential wind turbine hub heights remains unknown at Tadoule Lake for reasons provided later in this report.

Figure 2 shows that northwest winds predominate at both Churchill and Tadoule Lake. This indicates that both locations have similar wind regimes, in terms of predominant wind directions.



The historical average 10-metre wind speed at the Tadoule Lake EC station from 2002 to 2015 is 3.2 m/s. Over the same period, the average 10-metre wind speed at the Churchill EC station is considerably greater than 6.0 m/s. It must be kept in mind that wind speeds at Churchill are very high.

A 20-metre met tower was installed on an island to the east of the community of Tadoule Lake in October 2006. Two anemometers were installed at the top of the tower, along with one wind vane. Wind data was collected from the three sensors from October 2006 to February 2008. Some sensor failures occurred over this period, resulting in a limited amount of useable wind data.

Both Tadoule Lake met tower anemometers eventually failed and were subsequently replaced. One of the 20-metre anemometers was replaced with an anemometer at the 10-metre height. Due to sensor malfunction issues, by the end of the monitoring period, simultaneous 10-metre and 20-metre wind speeds were available for a total of only 6 days. A wind shear estimate could not be assessed, based on so little data. A detailed account of sensor failures and replacements is included in a Province of Manitoba report.[6]

The average 20-metre wind speed at the met tower site was 5.2 m/s. Although this is lower than the long-term average 10-metre wind speed of 6.0 m/s at Environment Canada weather station at Churchill, it does indicate that the Tadoule Lake met tower site may have favourable wind resources.

The wind shear at the Tadoule Lake met tower is expected to range considerably, from as low as 0.18

(calculated for open prairie sites) to as high as 0.34 (calculated for semi-forested sites), based on previous wind analysis work. If these two wind shears are considered, the average 40-metre wind speed varies from 5.9 to 6.6 m/s. More precise wind shears are required to accurately determine wind speeds at turbine hub heights.[5]

Although taller towers introduce greater logistical challenges in terms of their transportation and installation in remote northern sites, towers that exceed the 20-metre height are required. Renewable NRG Systems (NRG) is an established supplier of wind monitoring sensors and towers. They provide a large selection of met towers that range in height from 10 to 80 metres. NRG has a 34-meter met tower that is probably well-suited for wind data collection in northern Manitoba. With a 34-metre tower, multi-height monitoring sensors can provide enough data to properly assess wind resources at anticipated wind turbine hub heights.

Recommendation #2: **A relatively tall met tower with multi-height anemometers is required to properly evaluate wind resources at potential wind turbine heights. Based on available monitoring equipment and wind turbine size limitations, an NRG 34metre met tower is recommended.**

The 20-metre met towers that were installed in Tadoule Lake and Shamattawa downloaded information to a data card at the base of the tower. This data card had to be regularly retrieved and sent away for analysis. This system failed to provide data in a timely manner because sensor and datalogger failures remained undetected for extended periods of time.

Recommendation #3: **A satellite-based data communications system is required to relay information that is collected from met towers in remote sites.**

3.2.3 Brochet

There is a very limited amount of wind data at Brochet. The Brochet EC weather station recorded hourly wind speeds and wind directions from 1953 to 1979. Wind data that was recorded after 1969 is not usable.

The wind direction profile at the Brochet EC tower is distinctly different than at Tadoule Lake or Churchill. Figure 3 shows that predominant winds at Brochet originate from the northwest, the south, and, to a lesser degree, the east. At both Tadoule Lake and Churchill, there is a predominance of NW winds only.

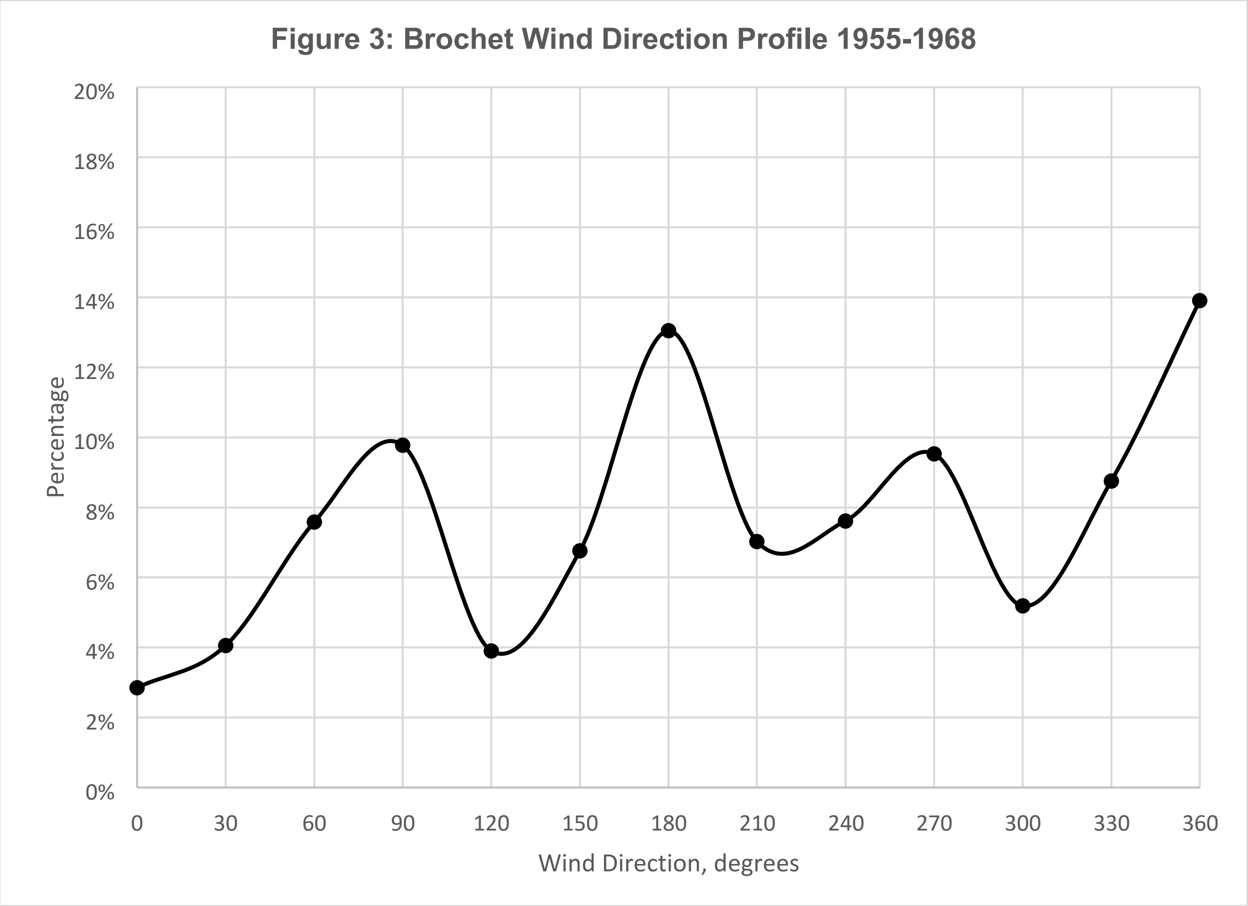


Figure 4 compares the 10-metre wind speed distribution profiles for the Brochet EC 10-metre weather station, the 10-metre Tadoule Lake EC weather station, and the 20-metre Tadoule Lake met tower site. Based on historical data, the wind speed distribution profile at the Brochet 10-metre weather station appears more promising than those obtained at both the 10-metre Tadoule Lake EC weather station and the 20-metre Tadoule Lake met tower site.

The average 10-metre wind speed at the Brochet EC weather station is 4.1 m/s, compared to 3.9 and 3.2 m/s at the 20-metre Tadoule Lake met tower site and the 10-metre Tadoule Lake EC weather station, respectively. Because the three met towers collected wind data over different time periods, their respective wind speeds cannot be directly compared. The Brochet EC data collection period was from 1955 to 1968. The Tadoule Lake data collection periods were from 2002 to 2015 for the EC station and from 2007 to 2008 for the 20-metre met tower.

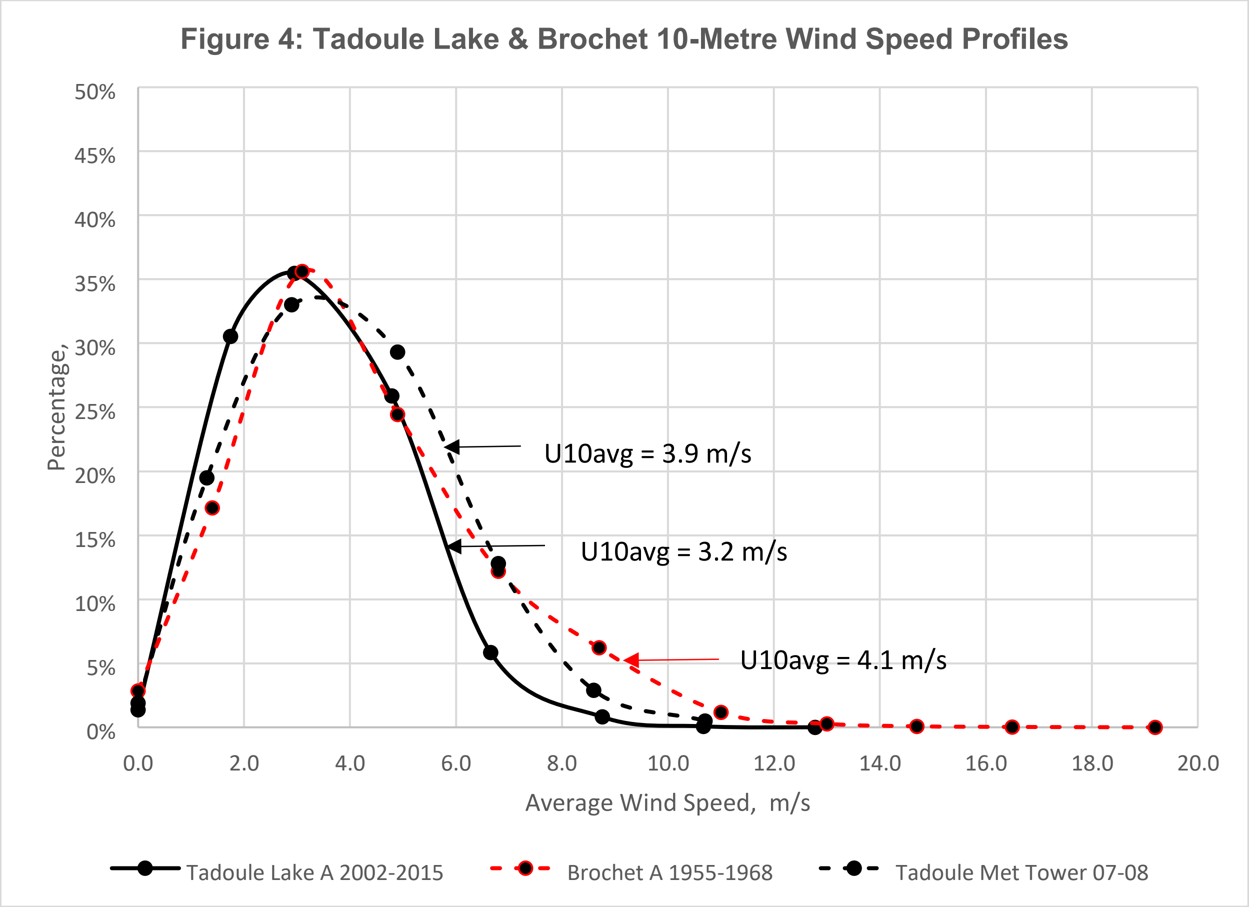
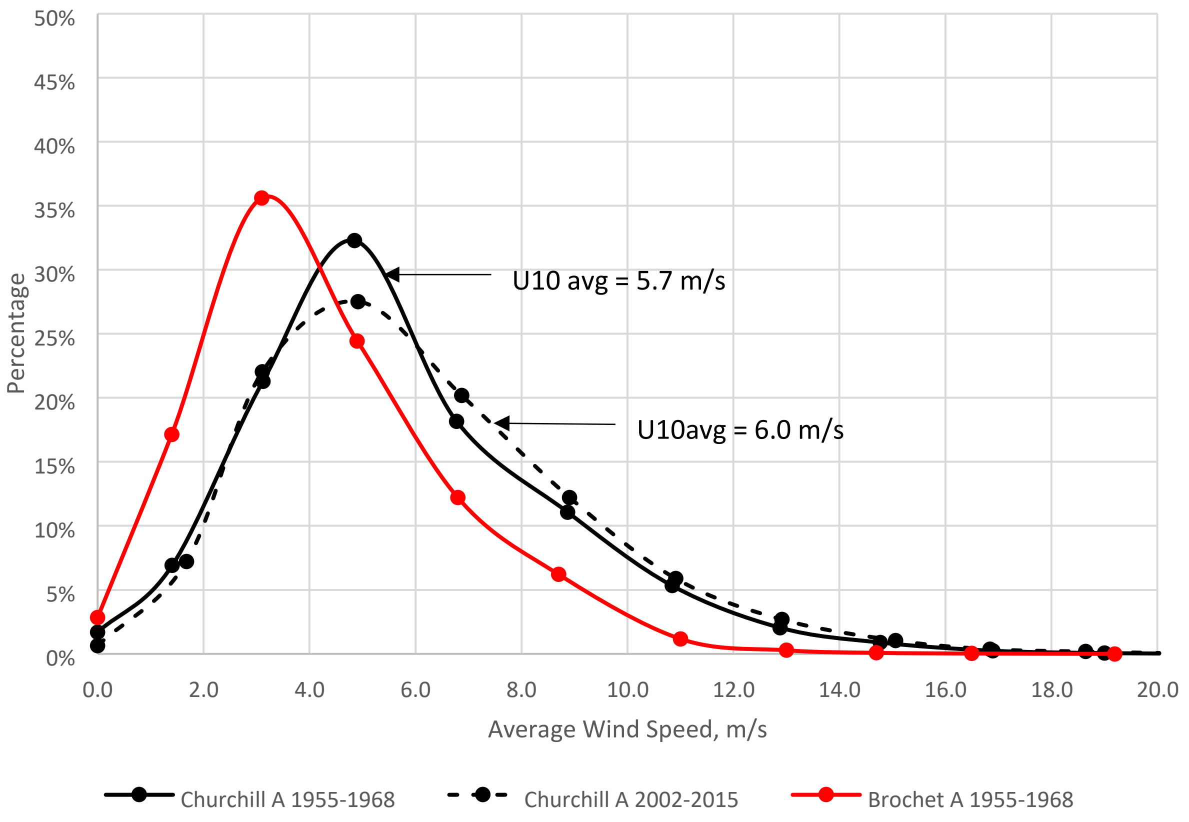


Figure 5 shows that at the Churchill Environment Canada weather station, the wind speed distribution profile (U10 = 5.7 m/s) between 1955 and 1968 is almost identical to the wind speed distribution profile (U10 = 6.0 m/s) between 2002 and 2015 (see Appendix B for details). If this type of historical consistency in wind speeds also applies to Brochet, the average 10-metre Brochet wind speeds from 2002 to 2015 would be similar to those recorded from 1955 to 1968. Although this approach is not scientifically rigorous, it may indicate that the average 10-metre wind speeds at the Brochet EC weather station are comparable to or better that those recorded at 10-metres at the 20-metre met tower site in Tadoule Lake. The Brochet area deserves consideration for a more detailed assessment of its wind resources.

Figure 5: Historical Churchill 10-Metre Wind Speed Profiles



3.2.4 Lac Brochet

Other than the Canadian Wind Energy Atlas and the Manitoba Hydro wind map, little or no wind data is available from the Lac Brochet area. In a recent report by AKI and Northlands First Nation, a recommendation was made to monitor winds on top of the 'Big Hill' near Lac Brochet.[7] Local knowledge about potential wind sites (like the 'Big Hill') must be seriously considered if wind resources are to be investigated.

4.0 Northern Community Selection for Wind Data Collection

It is difficult to rank the communities of Brochet, Lac Brochet, Tadoule Lake and Shamattawa, in terms of wind resources, because of a lack of reliable quantitative wind data. Based on available information, the top-ranked community is Brochet, followed by Tadoule Lake, Lac Brochet, and Shamattawa. Details of a proposed wind monitoring strategy are presented later in this report.

4.1 Brochet

- The average 10-metre Environment Canada wind speed was 4.1 m/s from 1955 to 1968.

- Although Brochet wind speed data cannot be time-matched to the Tadoule Lake wind data, it appears that Brochet 10-metre wind speeds may rival or surpass those recorded at the same height from the promising Tadoule Lake 20-metre met tower site.
- Very little is known in terms of the wind resources at Brochet. A met tower should be installed at Brochet so that the wind resources are assessed.

4.2 Tadoule Lake

- The average 10-metre wind speed at the Tadoule Lake Environment Canada weather station was 3.2 m/s from 2002 to 2015.
- The average wind speeds recorded at a 20-metre met tower located near the community were:
  ○ U10 = 3.9 m/s (November 29, 2007 – February 7, 2008) ○
  U20 = 5.2 m/s (October 4, 2006 – November 28, 2007)
- Based on theoretical wind shears from 0.18 to 0.34, the estimated average 40-metre wind speeds range from 5.9 to 6.6 m/s at the 20-metre met tower site. Although the actual wind shear cannot be calculated at the site, 40-metre wind speeds are considerably greater at the Tadoule Lake 20-metre tower site than at the Shamattawa 20-metre met tower site.
- The 20-metre met tower on the island immediately to the east of the community showed promise in terms of wind resource potential. If feasible, a taller met tower with multi-height anemometers should be installed at the same site.

4.3 Lac Brochet

- No quantitative wind data is available at Lac Brochet. Apparently, some wind data may have been collected at the airport. The data is not collected by Environment Canada and as such, is not available for analysis.
- Based on local knowledge, an area called the 'Big Hill' may be a potential wind site. The 'Big Hill' is located over 10 kilometres from the airport.[7]
- Wind resources at Lac Brochet should be investigated by installing a met tower to record wind data.

Recommendation #4: **Met tower wind data should be collected from the communities of Brochet, Tadoule Lake and Lac Brochet to determine their wind resource potentials. Wind resources need to be assessed before considering the inclusion of windgenerated electricity to the energy mix at any of these communities.**

4.4 Shamattawa

- Based on data collected from a 20-metre met tower from February 2008 to November 2008, the average wind speeds are: ○ U10 = 2.9 m/s ○ U15 = 3.2 m/s ○ U20 = 3.7 m/s
- A wind shear estimate of 0.34 is used to extrapolate from an average 20-metre wind speed of 3.7 m/s to an average 40-metre wind speed of 4.7 m/s. There is a low level of confidence in this shear estimate because of the small (10-metre) height separation between the three anemometers. The margin of error is simply too large when attempting to make wind shear estimates from only 10 and 20-metre anemometer heights.

- It is uncertain if the 20-metre met tower site at Shamattawa was a poor location for wind resources or if the wind regime in the area is generally poor. If wind resources are to be further investigated, an alternate location to the 20-metre met tower site that was previously selected (near the northern end of the community) must be considered.

Recommendation #5: **Wind resource monitoring in the Shamattawa area should be delayed, pending wind resource analysis results from the other three communities. Based on available data, wind resources appear less promising at Shamattawa that at the other three diesel communities**.

5.0 Wind Monitoring Protocol

A wind monitoring protocol has been established, based on previous wind resource analysis work conducted for the Province of Manitoba.

5.1 Prospecting Criteria for Met Tower Siting

5.1.1 Wind Monitoring Location Map

Transport Canada and Nav Canada (a national civil aviation services provider) impose restrictions on the location and height of obstacles that are introduced relatively close to airports. These restrictions are enforced because obstacles cannot be allowed to impede the visual site lines for take-off and landing to and from airports. Transport Canada and Nav Canada must be consulted to establish what height and distance restrictions might apply to potential met towers and wind turbines near the communities.

Electrical distribution line costs that are associated with the linkage of wind turbines to existing diesel generation stations also need to be considered. At some point, line costs become exorbitant and outweigh the benefits associated with the inclusion of wind turbines to a community energy mix. A distribution line cut-off distance will need to be established for each community.

A wind monitoring location map that identifies an area where wind turbine siting is acceptable is based on the two previously-mentioned constraints (obstacle restrictions by Transport Canada/Nav Canada and power distribution line limitations). It would be pointless to consider a promising wind site for monitoring and subsequent analysis if ultimately, a wind turbine cannot be installed at that site because of Transport Canada/Nav Canada restrictions and distribution cost limitations.

Recommendation #6: **Wind monitoring location maps should be created for the communities of Brochet, Lac Brochet and Tadoule Lake. These maps would identify where there are restrictions on the placement and height of obstacles like met towers or wind turbines, near airports. The maps would also identify the greatest acceptable distribution line distance from the diesel generation station to one or more wind turbines that would be tied into the station for each community.**

5.1.2 Land Survey - Topography and Vegetation

Recommendation #7: **Locations where topographic features (trees, etc.) or man-made obstructions negatively impact wind flow are to be avoided when conducting a preliminary survey of potential wind sites.**

5.1.3 Access

Recommendation #8: **Site selection for met towers and wind turbines should be limited to areas that have road access to the community**.

5.1.4 Met Tower Footprint

NRG met tower kits include several 7-foot long metal tube sections. The sections must be fitted together on the ground at the met tower site before the tower is tilted into a vertical position. Once lifted into place, met towers are tethered to the ground with a set of guy wires that are moored to anchors. The met tower anchors are inserted relatively far away form the tower. Once standing, the met tower itself does not require a large surface area. The guy wire assembly, on the other hand, requires a relatively large area that is referred to as the met tower 'footprint'.

Recommendation #9: A potential wind monitoring site must offer sufficient open space to allow an installation crew to fully assemble the met tower on the ground prior to the tower being tilted up. The site must also provide enough space to account for the met tower's footprint.

5.1.5 Sacred and Sensitive Sites

Recommendation #10: Met tower installations should be limited to areas outside of sacred sites and ecologically-sensitive areas.

5.1.6 Community Approval

Recommendation #11: Community acceptance of proposed met tower sites (potential wind turbine sites) must be garnered before considering the installation of the met towers.

5.2 Wind Monitoring System Options: Lidar vs. Conventional Met Towers

Two types of recording systems can be used to monitor wind. The first system is the Lidar system. As previously mentioned, the Lidar system emits pulses of light to generate high quality multi-height wind data such as wind speed and wind direction. NRG offers a portable lightweight Lidar system called the *Windcube.*

The second wind monitoring system is the conventional met tower. A series of anemometers and wind vanes along the tower are used to record wind data. Multiple-height wind speed data is assessed to make wind shear estimates that are in turn used to predict wind speeds at heights that are usually beyond the tower height. Several other sensors that record temperature, atmospheric pressure and solar radiation can also be added to the met tower. NRG offers an array of met towers for wind data collection.

5.2.1 Advantages and Disadvantages of Both Monitoring Systems

The advantages and disadvantages associated with the Lidar and met tower options are summarized below.

Lidar Advantages:

- lightweight and highly portable at only 45 kgs.;
- provides high-quality wind data up to a height of 290 metres;
- measures wind speed, wind direction and shear at 12 different heights simultaneously;
- can be set up to operate immediately.

Lidar Disadvantages:

- very expensive-the NRG Lidar *Windcube* costs $150,000 US or $200,000 CD;
- cannot collect wind data from multiple sites simultaneously unless more than one unit is available;
- more time would be required to collect a full year of wind data from multiple sites unless you have more than one unit;
- likely restricted to only one unit due to cost limitations; if the unit is damaged, only source of data collection is eliminated.

Met Tower Advantages:

- considerably less expensive per unit than the Lidar system
- can install multiple towers to collect and compare wind data from several sites simultaneously;
- if one sensor on a met tower is damaged or temporarily inoperable, the remaining tower anemometers will still record usable data;
- could involve local help for periodic inspections of met towers to identify any problems.

Met Tower Disadvantages:

- bulkier and considerably heavier than the Lidar system – logistically more challenging and costly to transport to the site and to install and remove from the site;
- cannot be set up to operate immediately due to transport and installation challenges (discussed in more detail later in this report).

Recommendation #12: The Lidar *Windcube* system is not recommended for wind data collection because of the considerable cost and risk involved.

5.2.2 Met Tower Height

With large-scale wind turbines and hub heights of 80 metres or more, most met towers are verticallychallenged in terms of providing actual wind data at potential hub heights. A 34-metre met tower would provide wind data at heights at or near wind turbine hub heights that are likely to be considered in northern Manitoba.

A well-designed wind monitoring program that involves a series of met towers that simultaneously record wind data is an appropriate option for remote Manitoba sites. A 34-metre NRG met tower appears to be a good compromise between a smaller 10-metre NRG tower and a larger 50-metre tower. Although they are bulkier, considerably heavier and more challenging to install than 10-metre towers, 34-metre towers will measure winds at or near the potential wind turbine hub heights.

Data from a 10-metre tower can only be used as a preliminary indicator of a site’s wind resources and cannot be used to estimate wind speeds at turbine hub heights. A 50-metre tower would provide wind data from a higher elevation than a 34-metre tower. A larger and heavier 50-metre tower would be considerably more challenging to ship to the site and install than a 34-metre tower. Due to probable height limitations for wind turbines, a 34-metre met tower will likely suffice.

Recommendation #13: A minimum of one NRG 34-metre met tower should be installed at one potential wind site in each of the diesel communities of Brochet, Lac Brochet and Tadoule Lake. If economically feasible, more than one met tower should be considered for installation at each of these communities. The odds of selecting a good wind site for a community are increased if more than one met tower is installed. Multiple met tower installations also permit the consideration of integrating more than one wind turbine to a single community.

Recommendation #14: A handful of potential met tower sites should be considered for each of the communities of interest. Final tower sites would be selected once a preliminary land survey is completed.

5.3 Met Tower Configuration for Wind Monitoring:

Recommendation #15: The following met tower sensor configuration is recommended for a 34-metre met tower:

- **2 anemometers, booms and cable at the 10-metre height* • 2 anemometers, booms and cable at the 20-metre height***
- **2 anemometers, booms and cable at the 34-metre height***
- **1 wind vane, boom and cable at the 10-metre height**
- **1 wind vane, boom and cable at the 34-metre height**
- **1 barometric sensor**
- **1 temperature sensor**
- **1 pyranometer (to measure solar radiation)**
- **1 datalogger**
- **1 satellite communication system**

*At times, the actual met tower itself can interfere with anemometer wind speed recordings. When the tower happens to lie between the wind source and the anemometer, a condition called tower shadowing occurs and actual wind speeds are misrepresented by the affected anemometer. When this happens or when an anemometer is defective or malfunctioning, additional wind speed recordings at the same height are necessary. Because of this, it is standard practice to install redundant anemometers at all anemometer heights on a met tower.

The initial cost estimate for a 34-metre met tower kit is $12,449 US or $16,557 CD (U.S. exchange rate of 1.33 as of March 22, 2017). A link to a detailed price quote from NRG is included in Appendix C.

5.4 Wind Data Analysis

The following wind analysis tasks are recommended once met towers are installed and wind data is being recorded:

1) A minimum of one year of continuous wind data is required to make a comprehensive evaluation of the wind resources in the diesel communities. All data will be recorded in industry-standard 10-minute intervals. Throughout the data collection period, weekly data downloads (via satellite) will be made to a wind analyst so that sensor and datalogger issues are immediately identified and rectified. This way, the likelihood of having tong-term data loss is reduced.

2) Initial wind data is recorded in a raw format. The raw data files will be converted to workable Excel-based files when they are received.

3) Following data format conversion, several corrections will be made to the data to account for events that impact anemometer readings (sensor malfunction, suspected icing events, tower shadowing, etc.)

4) Wind direction and wind speed distribution profiles will be statistically analysed at the 10, 20 and 34-metre anemometer heights.

5) Potential hub heights will be determined, based on wind turbine availability and applicability. Met tower wind speed profiles will be extrapolated to potential hub heights, based on the distribution profiles at the 10, 20 and 34-metre anemometer heights.

6) Wind speed distribution profiles at potential hub heights will be matched to appropriate wind turbine power output curves to make *monthly and yearly energy estimates*. Data obtained from the temperature and barometric pressure sensors will be combined to calculate air density and used to adjust turbine power output.

7) The multi-height anemometer data from the met towers will be time-matched and correlated to 10-metre wind data from the nearest Environment Canada weather station. This correlation will be used to make *long term multi-height wind speed distribution profile and wind-generated energy estimates.*

8) Solar radiation data obtained from met tower pyranometers can ultimately be used as PV and/or passive solar data. NRG offers a variety of pyranometers. One of their devices, called the Delta-T SPN 1 Sunshine Pyranometer, measures both Global Horizontal Irradiance (GHI) and Diffuse Horizontal Irradiance (DHI). Solar irradiance is measured in units of watts/m^2.

5.5 Logistical Challenges for Wind Monitoring Met Towers

Several financial and physical challenges limit options that are available for wind monitoring in northern Manitoba.

Perimeter Airlines and Calm Air are the only airline companies that provide flight services to the diesel communities in Manitoba. The 34-metre NRG tall tower kits are shipped in 91” long crated packages that weigh 1,334 pounds. Neither airline company can handle a kit this size and weight on a regular flight.

Chartering a freighter plane was proposed as a shipping option by Calm Air. Calm Air's ATR42 model has an 11,000-pound cargo weight limit. Depending on the number and size of wind monitoring tower kits, the cost of chartering a plane to fly the equipment to Brochet, Lac Brochet and Tadoule Lake combined in a single run is approximately $12,000.[8] Shamattawa can not be included in this charter run because it is situated too far away from Tadoule Lake. Refueling for Shamattawa is not possible along this charter run. A dedicated charter flight from Thompson to Shamattawa would be required. The Thompson-toShamattawa charter flight would cost approximately $11,000.[9]

A second shipping option is to haul the met tower kits to the communities via winter roads. According to the Province of Manitoba, a winter road is typically open from Lynn Lake to Brochet from the second week of January to the third week of March. The winter road from Brochet to Lac Brochet is open from the third week of January to the third week of March and the winter road from Lac Brochet to Tadoule Lake is open from the first week of February to the third week of March.[10] The cost of hauling equipment on winter roads is unknown at this point.

5.6 Installation of Met Towers

The Prairie Agricultural Machinery Institute (PAMI) is an accredited applied research, development, and testing organization that serves agriculture and industry in western Canada. PAMI's Manitoba office is in Portage la Prairie. Over the years, PAMI has successfully installed and removed several met towers in the province. PAMI has been contacted and will provide preliminary installation and removal cost estimates for the diesel communities. Total project cost estimates will be forward to AKI once PAMI provides price quotes for the installation and removal of met towers.

5.7 Wind Monitoring Schedule

Prior to met tower installation, several tasks need to be completed. A timeline estimate for these tasks is provided here:

1)	Wind Monitoring Location Maps	2 to 4 weeks
2)	Prospecting for Met Tower Sites	1 to 2 weeks
3)	Met Tower Permits from Transport Canada/Nav Canada*	12 weeks
4)	Met Tower Order/Delivery to Winnipeg	unknown
	Total time required:	**15 to 18 weeks plus tower delivery**

*Approvals for the installation of man-made obstacles such as temporary met towers are required from Transport Canada and Nav Canada. Each airport is unique and as such, individual permits are required for each community. An average of 12 weeks is normally required for met tower permit approvals.

If approval for wind monitoring work were to be granted by the beginning of May 2017, met tower installations would not likely be possible before sometime in September or October 2017. If the charter plane shipping option is chosen, tower installations could be completed by the fall of 2017. Assuming one year of data collection, analysis of wind resources could be completed by late 2018. If the winter road hauling option is chosen, the met towers could be installed by the spring or summer of 2018. Wind data would be collected for a minimum of one year and complete analysis of wind resources would be finalized by mid to late 2019.

5.8 Wind Turbine Suitability

There are two large-scale wind farms in southern Manitoba. These are the St. Leon and St. Joseph wind farms. The farms consist of several large-scale (rated capacity of 1.6 to 2.3 MW) wind turbines. Road access to the wind turbines at these wind farms is available year-round. The four diesel communities in northern Manitoba are only temporarily connected to the south by winter roads from January to March.

Weight and size restrictions are imposed on material that is transported on winter roads. Long and heavy wind turbine masts and nacelles as well as massive cranes that are required to install and maintain large turbines like those in the commercial wind farms of southern Manitoba cannot be transported to the remote north. At this point, the actual size and weight limitations for winter roads have not been investigated. Wind turbines no larger than those in the 30 to 50 metre hub height range could likely be shipped up north. It is possible that the 30 to 40 metre range may be more realistic.

Not only does the size and weight of wind turbines need to be considered up north. Arctic version wind turbines are required because they perform better under prolonged severe cold-weather conditions than conventional models. Permanent road access from the community to the wind turbine site is also required to install, then maintain the turbines year-round. Because of the excessive cost of maintenance, low-maintenance turbines need to be seriously considered.

There are disadvantages to using small-scale wind turbines. Power output curves for small turbines are not always reliable because tests conducted on small-scale turbines to determine their power curves are not held to the same stringent standards as for large-scale turbines. Small-scale wind turbines are known to underperform, based on their power output curves.
Smaller wind turbines are typically installed at considerably lower heights (10 to 20 metres) compared to larger turbines (80 metres or more). As a result, smaller turbines suffer from a significant height penalty. The higher you go, the stronger the winds. If small wind turbines were to be selected for integration into remote diesel communities, they would likely produce relatively minimal amounts of electricity. Because of this, small wind turbines would be ineffective in displacing significant amounts of diesel at a community electrical generation station.

No medium-scale wind turbines have ever been installed in northern Manitoba (rated capacity 100 KW1 MW). Several physical and economic issues that are unique to northern Manitoba must be addressed before such wind turbines can be considered as viable options in the northern part of this province.

One wind turbine that deserves consideration is manufactured by Northern Power Systems (NPS). NPS has a long history of providing wind turbines in Alaska.

Northern Power Systems manufactures the following 100 KW wind turbines:

1) NPS100-21: This turbine has a 21-metre rotor diameter
2) NPS100-24: This turbine has a larger 24-metre rotor diameter (using blade extenders on the 21metre rotor); can generate 10 to 15% more energy than the NPS100-21.

3) NPS100-24-new version: once available, this turbine will have 24-meter diameter full-span blades; it will likely generate 12% more energy than the NPS100-24.
4) The NPS100 is normally available in 23, 30 and 37 metre tubular towers; in the future, a 48metre lattice tower option is planned.[11]

5.9 Potential for Local Community Resources

Throughout the process of land surveying/prospecting, monitoring and possibly operating a wind turbine, there are some opportunities for local help.

- A community member with knowledge on local ecologically-sensitive areas, sacred sites, topography, ground cover and access could help with preliminary tower siting efforts. For example, community members from Brochet refer to an elevated area near the community called the 'Big Hill'; the 'Big Hill' may offer a promising wind site;[7]
- Community members could be involved with met tower installation(s) and removal(s);
- It is imperative that periodic met tower site visits be made to identify any visible problems relating to the met towers and their sensors (i.e. guy wire tension, etc.). Issues could be forwarded in a timely manner by a member of the community to the appropriate individual(s);
- If one or more wind turbines were to be eventually installed, there could be an opportunity to train members of the community on wind turbine maintenance. Local assistance for turbine maintenance could be provided on an ongoing basis.

Recommendation #16: Local community resources should be utilized for this project whenever and wherever possible. The valuable skills and knowledge that members of these communities have acquired can help create a more successful wind monitoring program.

6.0 The Next Step

Wind resources have not been properly evaluated in the diesel communities in northern Manitoba. The installation of wind monitoring equipment up north, and subsequent data collection for analysis pose several logistical challenges, but these challenges are by no means insurmountable. By applying a systematic and logical approach to wind analysis, the potential for wind-generated electricity in the north can be successfully addressed.

If approval is granted for a wind monitoring program, the steps identified in "**5.0 Wind Monitoring Protocol"** need to be put into motion. A wind resource analysis of the diesel communities would provide information that is necessary to consider the integration of wind energy to the community energy mix.

7.0 References

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2) Windustry; (Accessed March 28, 2017); Retrieved from: http://www.windustry.org/resources/what-commercial-large-scale-wind
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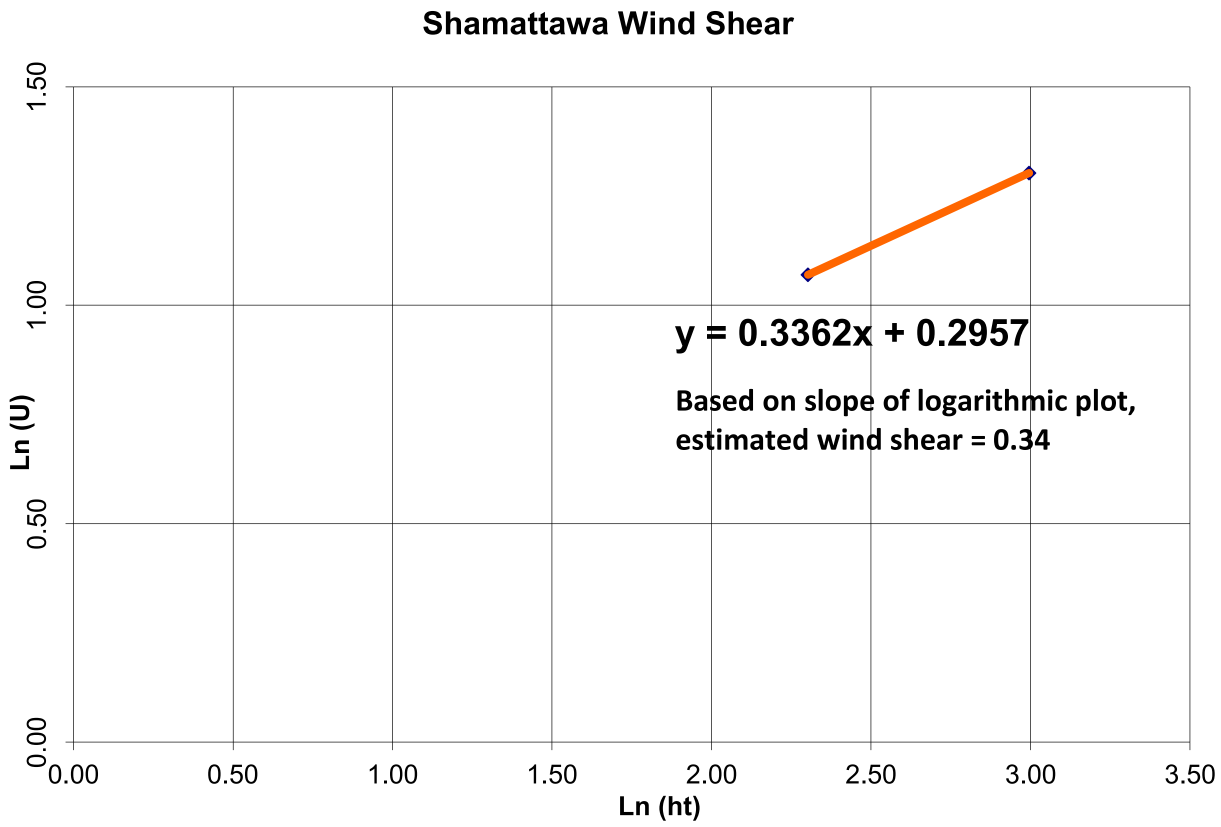
Appendix A: Shamattawa Wind Shear and Extrapolated Wind Speeds

Source: Arbez, M; 2009 calculations Part 1: Shamattawa Wind Shear Estimate for 20-Metre Met Tower 2008



Part 2: Wind Speed Extrapolation Estimates for Shamattawa:

1) U30:

Shear = (ln(U30)-ln(U20)/ (ln (30)-ln (20))

0.34 = (ln(U30)-ln (3.7))/ (ln (30)-ln (20))

U30 = 4.2 m/s 2) U40:

Shear = (ln(U40)-ln(U20)/ (ln (40)-ln (20))

0.34 = (ln(U40)-ln (3.7))/ (ln (40)-ln (20))

U40 = 4.7 m/s 3) U50:

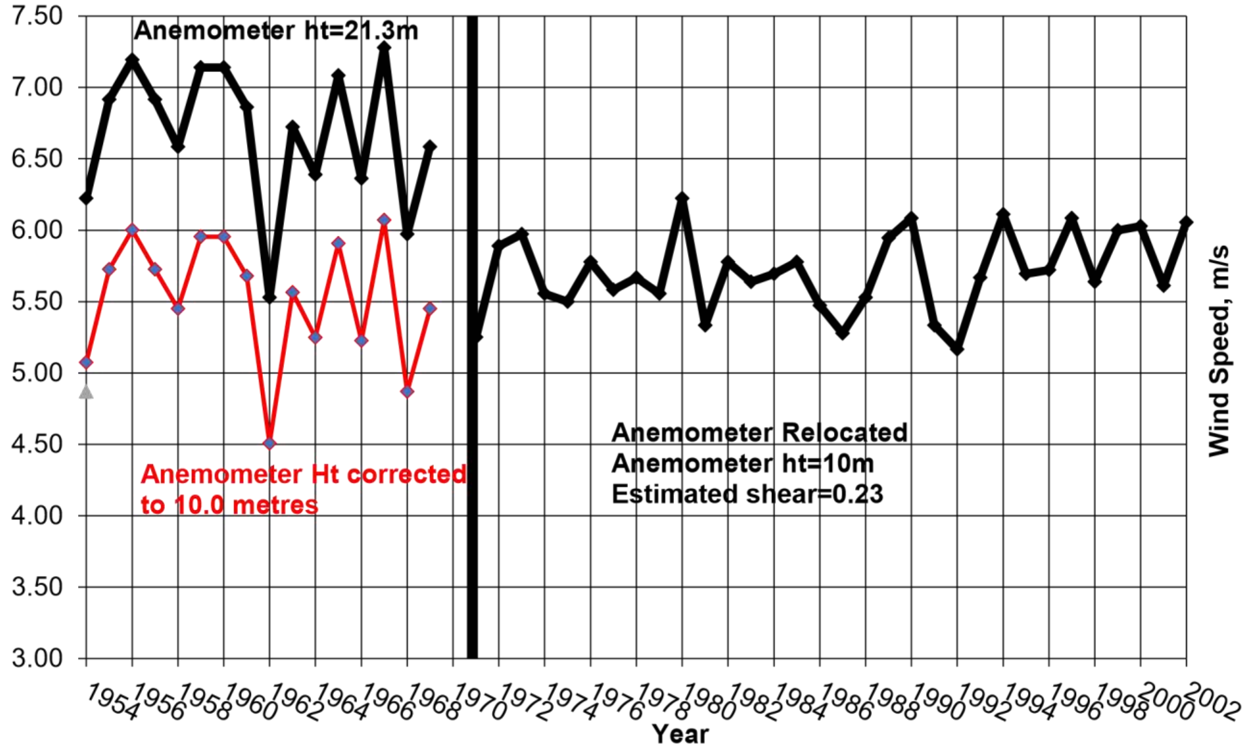
Shear = (ln(U50)-ln(U20)/ (ln (50)-ln (20))

0.34 = (ln(U50)-ln (3.7))/ (ln (50)-ln (20))

U50 = 5.1 m/s

Appendix B: Historical Environment Canada Churchill Wind Speeds

Source: Arbez, M; 2009 calculations



Appendix C: Renewable NRG Systems Met Tower Price Quote (link)

Q0058278.pdf