THE ECONOMIC FEASIBILITY OF REPLACING DIESEL WITH RENEWABLE ENERGY RESOURCES IN REMOTE FIRST NATION COMMUNITIES IN NORTHERN ONTARIO

By

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ABSTRACT

Ontario has many First Nation communities in the remote northern region that use diesel fuel to generate part or the whole of their energy requirements. There is a huge financial and environmental cost associated with shipping diesel fuel by air transport in the spring, summer, and autumn months and over ice roads during winter months to these remote communities. A significant portion of the electricity produced from diesel fuel is used to heat community buildings and homes during the extreme cold winters in the remote northern Ontario region. Biomass district heating is a cleaner and sustainable heat source commonly used in European communities. However, biomass has not been used successfully in Ontario for district heating, despite the existence of plentiful forest biomass resources. Solar and wind power, representing cleaner and renewable energy opportunities, have grown in Ontario since the introduction of the Green Energy Act in 2009.

The purpose of this thesis research was to determine the socio-economic feasibility and benefits associated with using forest biomass for district heating combined with solar and wind power for electricity production in remote northern Ontario First Nation communities to offset part of the current energy load. Two remote First Nation communities, one an off-grid, fly-in community (Sachigo Lake) and the other an on-grid, drive-to community (Lac Seul), participated in the study. Information related to the present costs of energy in the communities, the types of heating devices used in the community buildings, and the forest resources available for biomass district heating was collected. Solar and wind resources were evaluated using publicly available wind and solar maps and commercially available tools and software. A specialized Forest Resource Inventory was also done in both communities. Solar resources were evaluated and measured in both communities to determine actual average sun hours per day. The site data was used to evaluate average annual savings for different solar power scenarios in each community, along with the cost of a project, which was factored into payback time calculation in years. Analysis suggests that there is a sufficient sustainable supply of biomass available for both communities for use in biomass district heating, and the payback time for the off-grid community is much shorter than for the on-grid community.

Lac Seul First Nation has forestry operations in the reserve and crown forest and should be able to access equipment and personnel as well as possibly biomass residues from a nearby sawmill for biomass heating. The Lac Seul arena currently has electric hydronic boilers that could be replaced by biomass boilers with solar thermal pre-heating as this site also has good solar resources. Sachigo Lake First Nation does not have forestry operations or a forest management plan but good solar resources at the school and at the diesel generator plant at the airport. Sachigo Lake First Nation pays the higher Standard “A” rate for diesel derived electricity and ample space at the airport for a ground-mounted solar array, and was found to have good potential saving and short payback times for a potential solar project. A full list of recommendations is found in the Conclusions and Recommendations section.

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INTRODUCTION

This report is divided into six sections. The first section, the introduction, outlines the project that this report was written from, its background, the objectives, project methodology, the participant communities and information about those communities, energy costs and usage in those communities and challenges they face past and present. The second section outlines biomass district heating, the availability of biomass in each community, costs of proposed biomass heating projects and long-term payback of each project. Section three outlines the initial evaluation of solar and wind resources of the participant communities and how the project narrowed its focus to just solar power. Section four outlines in-depth solar power analysis in the participant communities, including savings analysis and long-term payback calculations. Section five, the discussion, sums up the results of previous sections with comparison of the results from both communities. Section six, conclusions and recommendations, contain recommendations for both communities based on the results and future possibilities.

The first section of the introduction, section 1, outlines the current energy system in northern Ontario including how electricity is generated, how it is used, prices and the challenges communities face as a result of the current system. Section 1.1 provides background on fossil fuels and renewable energy and section 1.2 provides information on how the project was initiated and conducted. The next section, 1.3, outlines the project objectives. Section 1.4 provides background on remote communities in Canada and Ontario generally and for Sachigo

Lake and Lac Seul First Nations specifically. Section 1.5 outlines the energy resources, costs and how they are used in Sachigo Lake and Lac Seul and section 1.6 outlines historical challenges in First Nation communities. The final section, 1.7, outlines the project methodology for the overall project.

Northern Ontario has 34 remote First Nation communities that run diesel generators for power and are not connected to the Ontario power grid (Hydro One, 2013). The Independent Electrical Systems Operator (IESO, which merged with the Ontario Power Authority in January 2015), has the responsibility of delivering electric power to all Ontario communities in accordance with Section 26 of the provincial Electricity Act, 1998, which is meant to ensure non-discriminatory access to electric power. The intent of the Electricity Act is to provide the residents of Ontario with access to electrical power regardless of location. Hydro One Remote Communities Inc. is the division of Hydro One that operates and is responsible for electricity production and distribution in 21 of the 34 communities (HORCI, 2013). The remaining communities have locally owned and run electrical grids and are responsible for their own distribution and production systems.

The IESO states that diesel-derived electricity costs 3-10 times the average cost of power production in Ontario (IESO, 2011). According to IESO, the cost of diesel-generated energy was $0.46 kWh in 2013 and was projected to cost $0.53 kWh in 2023, and $0.59 kWh in 2033 (IESO, 2016). Independent studies have verified that the actual average cost of diesel-derived electricity production in 175 off-grid communities in Canada is $1.30/kWh, while in Ontario it is between $0.40/kWh and $1.20/kWh (Arriaga, 2013). Diesel engine technology is over 100 years old and is a reliable and affordable technology that was installed in many remote communities decades ago, and was likely the easiest option to install at that time. There are no all-weather roads into the 34 remote communities, and there is no connection to the Ontario provincial electrical transmission lines. Concerns about the volatility of fossil fuel prices leading to rising diesel fuel prices in northern Ontario and the health and environmental impacts of diesel emissions has led to investigations and deployment of cleaner renewable energy sources in Ontario and worldwide in remote communities.

Diesel fuel is a heavy energy dense fuel that is refined from crude oil; it has 1.1 times the energy density of gasoline, and 3 times the energy density of compressed natural gas (EIA, 2013). Diesel fuel is heavier than gasoline and is also more stable and evaporates much slower, which makes it better suited for transport and long-term storage. The ability to store diesel for extended periods of time makes it easier to continuously use it when delivery is difficult, expensive, and not always timely.

Remote communities transport diesel fuel by truck tankers on ice roads that are built on frozen rivers and lakes during the short winter road season, and by air transport at all other times of the year, which adds significantly to the total cost and emissions in remote communities. The province of Ontario budgeted $5.8 million to build and operate the 3,160 km winter roads system in 2017-2018 to 31 First Nations communities and the town of Moosonee (OMNDM, 2017). The winter road system typically operates from mid-January to late March (OMNDM, 2017). Milder weather in winter due to climate change can reduce ice thickness and the number of days the ice roads operate and reduce the amount of weight each vehicle can carry, which increases costs and emissions for every kilogram of goods delivered. Direct greenhouse gas emissions from burning diesel for electricity in remote communities serviced by

Hydro One Remote Communities Inc. in 2011 were 43,405 t CO_2e, which was about 59% of total emissions for these communities (HORCI, 2011). Emissions from air transport of diesel fuel into these communities in 2011 were 30,285 t CO_2e, which was about 41% of the total greenhouse gas emissions for these communities (HORCI, 2011).

Transportation of diesel fuel across winter ice roads using heavy transport trucks also has the potential for spills through leaks, accidents, and transferring of fuel to local storage tanks. Because winter ice roads are built on rivers and lakes that have frozen thick enough to allow transport truck traffic, diesel spills on these roads can contaminate the waterways of the boreal forest, where most remote communities in Ontario are located. Further, storage tanks within these communities can leak and spill during fuel transfer, and may contaminate ground water that is used for drinking water. This may necessity the need to drill new drinking water wells, adding another financial and environmental cost to communities.

In addition to the problem of greenhouse gas emissions, adverse health effects from diesel fuel emissions have been documented by many health agencies. Diesel engine exhaust is a combination of gasses and fine particulates that affects lungs. Health hazards from prolonged exposure to diesel exhaust have been associated with respiratory illnesses and lung cancer (USEPA, 2002; Weeks, 2012; Weir, 2002). The Canadian Medical Association, the California Air Resources Board, and the United Nations have all classed diesel emissions as being toxic and having harmful effects on humans.

The diesel fuel used to power electricity generators is imported into remote communities from a fossil fuel refinery or distributor; thus, this money permanently leaves the community, whereas harvesting energy locally creates jobs and keeps money paid for local wages and revenues circulating within the community. Further, fossil fuels are a finite resource and the long-term available supply will likely decrease, which increases the price per litre of diesel fuel. Energy created locally from hydro, forest biomass, wind, and solar power resources could not only diversify energy sources and save money, but also give remote communities control over some of their energy supply. A diverse local energy supply may offer some protection against fuel shortages, blackouts, and generator failures since one source of energy generation can possibly take over the electrical load from another for short periods.

Northern Ontario has cold winters and space heating in residential homes and larger community buildings is a significant load on a local electrical grid. Space heating accounts for 40% of average energy use in institutional and commercial settings in Canada (NRCAN, 2010). Space heating and domestic water heating makes up 80% of energy use in an average residence in Canada (NRCAN, 2010). A breakdown of national average residential energy use is shown in Figure 1.

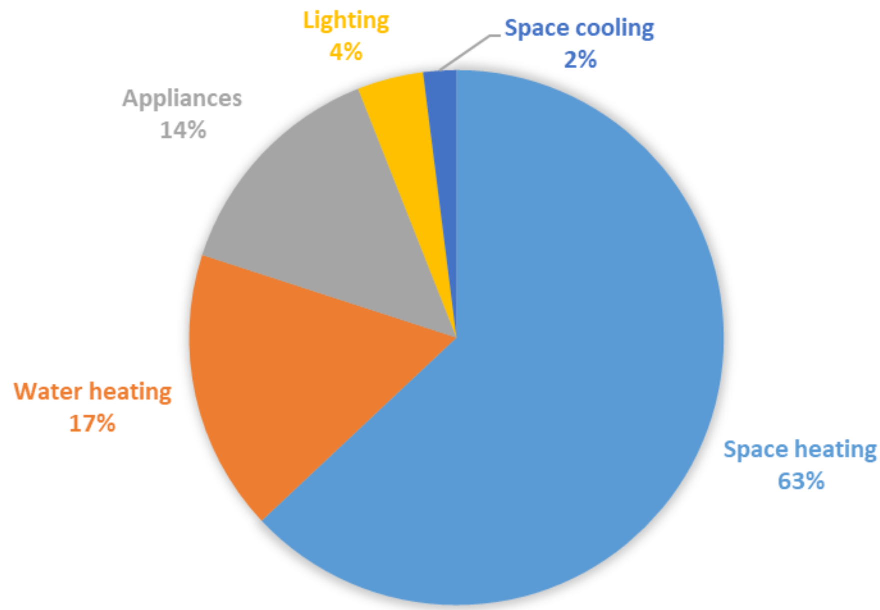

Figure 1: Residential Energy Use in Canada by Activity, 2010
Source: NRCAN 2010

Inefficiencies are introduced when using electricity as a primary source of heating, particularly when using diesel generators to generate electricity and then using that electricity to generate heat. Using a fuel that will generate heat directly when burned or harvested, whether heating oil, firewood, biomass, or solar thermal heat, without first converting it to electricity, eliminates a step in the energy chain and the inefficiencies and extra fuel use built into that extra step. Directly using a fuel for heating also reduces the total electrical load in remote communities that would normally be used for heating, which can then be re-directed for other uses, such as adding to the local grid new homes for growing families and buildings for local businesses.

Many diesel-powered communities in Ontario are at, or past, the maximum average generating capacity of 75-85% of the communities' maximum generator rating, at which point a moratorium on adding new connections to the local grid is put into place (HORCI, 2011). New homes and community buildings can be built, but cannot be used since these cannot be connected to a power supply. Blackouts and brownouts thus have occurred for hours, days, and occasionally for weeks during the coldest times in winter, when heating loads and demands to the local grid are at their maximum (Watay Power, 2013). Health clinics and schools in some remote northern Ontario communities are forced to purchase and run their own diesel back-up emergency generators, which increases costs and harmful emissions (Watay Power, 2013). Economic development and expansion of housing are difficult to implement when there is not enough and reliable power source available.

Power outages in remote communities can affect medical supplies that are stored in special refrigeration units. For example, loss of refrigeration due to loss of electrical power can spoil expensive flu vaccines and other medications like insulin that must be ordered well ahead of time to supply a remote community's health needs. Loss of medications can leave a community short of the needed supplies and endanger the health of vulnerable residents, who must then travel long distances from their community to hospitals and clinics, usually by expensive air transport. An option that has proved helpful in remote areas of Africa and Vietnam is the use of a vaccine fridge in their health units that requires less power; the World Health Organization has tested and approved a vaccine fridge manufactured in Germany by Sun Frost that can be powered by two or three solar panels (minimum 200 watts each) and a small battery bank that can be sized to last the length of a potential blackout (Sun Frost, 2014), which can be a week to 10 days in remote northern Ontario communities (Watay Power, 2013).

1.1 Renewable Energy and Fossil Fuels

Fossil fuels are general terms for hydrocarbons that can be burned to release energy, usually heat; these hydrocarbons originate from animal and plant matter that have been compressed and decaying for millennia and are currently mined for human use. Petroleum is a liquid that comes from decayed animal matter that can be refined into gasoline, diesel, kerosene, and other liquid fuels. Coal is a solid that comes from ancient decayed plant matter that is mined and burned to create heat. Natural gas, propane, and butane are gases that can be compressed into liquid form and are created from decaying plant matter.

Natural gas, which consists mostly of methane, is abundant in North America and is currently used as a heating fuel in most of North America. Natural gas is considered a less expensive and relatively clean form of energy compared to coal (IEA, 2017). Coal was used in the late 19th and 20th century and is currently used in some steel production and electricity production (USDOE, 2017). Methane is not considered a renewable resource except when harvested from landfills or human waste and refined into a synthetic form of natural gas. Natural gas pipelines cover most of North America and the southern part of Ontario, as well as much of the region along the Ontario-US border. The communities in remote northern Ontario are north of the natural gas network and cannot access natural gas use electricity, propane, heating oil and wood for heating and as the primary source of energy. Fossil fuels create emissions when burned and are generally not replaced on a human time scale after being mined or harvested.

Energy sources are considered renewable when they are replenished on a human time scale. There are many definitions of renewable energy, two of which are: “*Energy obtained from the continuous or repetitive currents of energy recurring in the natural environment”* (Twidell and Weir, 1986), and, “*energy flows which are replenished at the same rate as they are used”* (Sorensen, 2000).

Renewable energy sources are also considered to have fewer or less harmful emissions during energy production or during the manufacture of their components (NREL, 2017). There are many types of renewable energy that are used for electricity or heat production today; in this project, we looked at only solar photovoltaic, solar thermal, wind, and biomass since each of these technologies can be scaled down for use in smaller and remote communities and are currently in use in some parts of the world. Further, analysis of the feasibility of each of these technologies can be done with currently available public and commercially available resources with minimal time spent on the ground in a community.

Renewable energy resources are sometimes referred to as sustainable energy resources. The concept of sustainability is a relatively recent term connected to the idea of sustainable development, which was defined in 1987 by the United Nations’ Brundtland Commission as: “Development that meets the needs of the present generation without compromising the ability of future generations to meet their needs” (United Nations, 1987). Sustainable energy sources, according to Everett et al. (2012) fulfill three requirements:

(1) These sources are not significantly depleted by continuous use;
(2) These sources do not entail the emission of pollutants or other hazards to human or ecological and climate systems on a significant scale; and

(3) These sources do not involve the perpetuation of significant social injustices.

Renewable and sustainable energy sources are flows of energy that are replenished continuously by natural processes, whereas fossil fuels are not replenished and thus are considered “stocks” of energy. Conventional fossil fuels are burned to create heat directly or burned to create heat for a medium like steam that powers turbines to create electricity and used to power engines for generators that create electricity or for transportation vehicles. Heating oil units and gas and diesel generators can be scaled down for use in small communities or in individual homes. Diesel fuel and heating oil, which is similar to diesel fuel, can be stored for longer periods and more easily than gasoline, and are used in home heating and mid-sized generators in remote communities. Gasoline is used primarily for automobiles, all-terrain vehicles, snow-machines, and small generators for home use in Sachigo Lake (see Figure 8). Solar photovoltaic, wind power, and biomass can also be scaled down and used to create electricity for home or community use in place of fossil fuel sources. Solar thermal and biomass can also be used to create heat for space heating or domestic hot water in place of fossil fuel sources.

Biomass fuels release emissions during the harvesting, transportation and refining process as do fossil fuel sources. Biomass sources, however, which can include trees, shrubs, peat, agricultural wastes, and algae, can be re-grown in months or years (except peat, which takes centuries) after harvesting and are considered renewable. Carbon dioxide released from burning biomass fuels can be re-captured over time by plants, which require carbon dioxide for photosynthesis and that can be re-grown in the biomass harvest cycle. Many remote communities in northern Ontario are surrounded by large tracts of boreal forest or peat bogs along the Hudson Bay and James Bay coasts, which could possibly be used as a biomass supply. Energy harvest processes, including those for biomass, that require the burning or combustion of fuels will produce emissions and require maintenance and cleaning. Long-term maintenance is often a hidden financial cost in energy production with the disposal of waste products also adding a possible environmental cost in addition to the financial cost. Fuel burning systems frequently need electricity for control and fuel feeding systems and, in some cases, emissions monitoring equipment that let workers know when equipment needs to be cleaned, emptied, or serviced. Waste ash from biomass burning (biochar) is currently being studied for use as a possible soil amendment, which would reduce the cost of disposal as well as make it a useful and environmentally neutral by-product (Berruti, Masek, & Ocone, 2012).

Biomass burners used in district heating systems require a reliable electricity supply to power the control, monitoring, and feeding mechanisms, which makes having a reliable backup power system critical when the local grid loses power. A backup generator or wind and/or solar power system with battery backup would make a biomass heating system autonomous from the local grid, which is critical in remote communities during cold winter days when losing heat in schools, health clinics, or residential homes could be life-threatening. Wind and solar power, while intermittent, do not have emissions during energy production but do have emissions associated with the manufacturing process and transportation. Wind and solar electrical generating systems could reduce overall emissions in remote communities even if used just as backup systems with battery storage or for powering biomass district heating systems independent of the local electricity grid. Wind turbines have moving parts that need to be serviced whereas solar electric systems have no moving parts and require less maintenance (White & Doherty, 2017).

Some newer, lower maintenance battery systems that can store intermittent wind and solar energy are currently available and, in some cases, have larger storage capacities than conventional lead-acid batteries; examples include large lithium ion batteries, liquid vanadium redox flow batteries, aqueous salt water batteries, and absorbed glass mat (AGM) batteries. These battery systems do not give off minimal gasses or emissions unlike the older lead-acid batteries, which produced hydrogen when under heavy loads or during charging cycles. (Hydrogen can be explosive if trapped in a container and exposed to sparks or high heat.) Battery technology has improved dramatically in the last few years with the increasing popularity of hybrid and electric cars, and off-grid solar and wind systems; higher sales and economies of scale have benefitted both manufacturers and customers (Gunter & Marinopoulos, 2016). Utility scale battery storage is also slowly being adopted experimentally in regions where intermittent wind and solar power is being integrated into the energy supply (IESO, 2017).

Coal and gas-fired power plants currently act as on-demand power sources in many areas, and frequently have no energy storage or battery back-up to store excess electricity (IESO, 2016). Solar and wind power are considered intermittent forms of electricity generation and require DC (direct current) disconnects to isolate the wind or solar power (when the grid fails) safely from the AC (alternating current) used by most electrical grids (Di Napoli, Guerriero, d' Alessandro, & Daliento, 2015). Grid connected wind and solar power systems with no battery back-up have fewer parts, are much cheaper and less complex to install and are common in areas in or near large urban centres with a large reliable electrical grid with many diverse sources of electricity generation (Sentinel Solar, 2016). Natural gas-powered electricity plants can adjust power output quickly and are used as peaking generation in Ontario, when wind and solar plants are not producing and when electricity grid demand is high (IESO, 2015). Solar and wind generators are occasionally powered down when electricity supply exceeds demand or sold off at below cost to other jurisdictions. Grid-sized battery back-up systems are slowly being tested in Ontario and elsewhere to evaluate cost effectiveness and power performance of the two-way flow of electricity using smart meters. Smart meters are also used to track how much energy is being put back into the grid from residential-sized solar or wind generators as well as customer usage allowing utilities to calculate a final bill or rebate.

Smaller utility grids that are common in remote communities have fewer different sources of electrical power generation and little or no power storage for excess electrical power generated and are less resilient and less able to integrate intermittent sources of power into their grids. Diesel generators can respond to different electrical loads quickly but cannot go beyond their rated capacity and are less efficient when not running at a constant load. Solar and wind generators can add capacity to a diesel-powered electrical grid but when the total electrical load goes beyond the generator's capacity and the wind stops blowing or the sun stops shining, a blackout or brownout can occur since the generators cannot supply power beyond their capacity rating. A battery bank that can store wind or solar generated power can increase the capacity and reliability of a small diesel generator-powered grid particularly when there are high electrical loads beyond the generators' capacity, and wind and solar are not producing. A battery bank can also reduce diesel use when solar and wind power are generating at their maximum and batteries are fully charged and able to discharge excess electrical power into the grid, offsetting a portion of the diesel generators load.

1.2 Project Background

The project was initiated by Brian Kurikka of Confederation College in Thunder Bay, while setting up a biomass heating facility that used urban tree waste to heat a portion of the college. The heating facility was also set up as a research and training centre to educate students and community groups of the potential of biomass heating and the use of emission monitoring equipment that was to be installed on each heating unit. Remote First Nation communities in northwestern Ontario were contacted to see if they were interested in having a presentation in their community about a potential research project. The potential project was to study one off-road community using diesel-derived electricity and the other an on-road community beyond the natural gas network, with both communities situated in the boreal forest. The project had multiple sources of funding and it was stressed to each potential community that there would be no cost to the community and the research team would hire guides and purchase food, supplies and lodging in the communities for ten days of field research in summer. The communities were also asked to provide community heating data if available and access to larger buildings to examine and record heating unit type and rating. Presentations and reports of results were to be given in each community and permission was sought for public communication of these results at conferences and forestry industry expos. Sachigo Lake First Nation and Lac Seul First Nation were the two communities that agreed to participate in the project.

The project was part of a larger pre-feasibility study conducted by Confederation College, Lakehead University, and BioThermic Energies Inc. called, “Biomass heat as a catalyst for community development in the boreal forest.” The purpose of the larger study was to determine if two remote northwestern Ontario First Nations communities located within the boreal forest would be viable candidates for implementing biomass district heating and/or other renewable energies in their communities; a comparison of the two was also part of the project (Kurikka, 2014). The study was conducted in collaboration with two First Nations communities: Sachigo Lake is a remote fly-in community powered by diesel generators and Lac Seul is a road-accessible community on the provincial electricity grid but beyond the provincial natural gas network. For the portion of the project reported in this thesis, I and another graduate student, Stephanie Seymour, collected field data in each community over 20 days in the summer of 2014, with the help of two research assistants, Paul Robitaille and Christiane Sater Melnik, and guides from both communities. Other relevant data used in this thesis, namely on community heat loads needed for projections, were collected with other team members, Brian Kurikka of Confederation College and Vince Rutter of Biothermic Energies Inc.

Electricity is the primary heat source in both communities with fuel oil (diesel), propane, and firewood being minor sources of heat. Locally sourced firewood is used as primary or back-up heat in many residential homes, but not in larger community buildings that have higher heating loads. A survey of heat sources in residential homes done in Sachigo Lake by the Windigo Tribal Council showed that 89.7% of homes burned wood for heat using an average of 5.6 cords per year. Electricity in the road access community comes from the provincial grid and is administered by Hydro One. Diesel generators provide the electricity in the air access community through Hydro One Remote Communities Inc. In both, electricity and diesel fuel are imported from outside the communities, whereas firewood is sourced from local forests. According to the Canadian Forest Service, white birch has the highest published air-dry density of all boreal tree species at 647 kg/m^3, with a published oven-dry gross heat of 19.1 MJ/kg (Seymour, 2016). Residents will typically harvest whichever species are available and dry it in whatever way is most convenient. One of the main objectives of the project was to look at the feasibility of using locally sourced energy (biomass, wind, and solar) to replace expensive imported energy.

As noted above, energy harvested locally keeps money in the community instead of leaving the community when paying for electricity whether through fueling diesel generators or sourcing from the provincial grid. Employment opportunities associated with using biomass for district heating within the two communities was also evaluated as part of the economic analysis. Multiple scenarios using biomass district heating were evaluated for their economic feasibility, including heating the entire community, heating a cluster of buildings, and heating a single large building. The economic analysis included projected project costs and payback times for each scenario and was done by Biothermic Energies™. The biomass availability analysis was done by research team member, Seymour (2016), and is summed up in a later section.

The initial results of the research teams analysis were summed up in awritten report for each community and a presentation was made to each of the two communities, in public presentations by individual reseachers and at university and professional conferences with the title of “Biomass Heat as a Catalyst for Community Development in the Boreal Forest: Pre-Feasibility Study” for Lac Seul First Nation and Sachigo Lake First Nation. A series of reports were produced for and given to the two communities which were also given to each of the funders of the research project in print and electronic formats. Information from these reports was used in this research paper. The reports produced for this project were:

- "Assessment of the Available Forest Biomass for the Biomass Community Heating Prefeasibility Study" by the Lakehead University Wood Science Testing Facility.
- "District Heating Pre-Feasibility Study for Lac Seul First Nation" (2015) by Biothermic™ Renewable Energy Systems Inc.
- "District Heating Pre-Feasibility Study for Sachigo Lake First Nation" (2015) by Biothermic™ Renewable Energy Systems Inc.
- "Solar and Wind Resource Evaluation: Lac Seul First Nation" (2015) by Mike Hosszu.
- Solar and Wind Resource Evaluation: Sachigo Lake First Nation" (2015) by Mike Hosszu.
- "Biomass District Heating Regulatory Analysis: Lac Seul First Nation" (2015) by Stephanie Seymour, Chris Walton, Dr. Peggy Smith and Paul Robitaille.
- "Biomass District Heating Regulatory Analysis: Sachigo Lake First Nation" (2015) by Stephanie Seymour, Chris Walton, Dr. Peggy Smith and Paul Robitaille.
- "Greenhouse Report: Lac Seul First Nation" (2015) prepared by Paul Robitaille.
- "Greenhouse Report: Sachigo Lake First Nation" (2015) prepared by Paul Robitaille.

Each of the reports produced are kept on file in electronic format at Confederation College in Thunder Bay, Ontario.

1.3 Project Objectives

Just to review, the four main objectives for the larger project were to:

1. estimate the availability of forest biomass and its heating potential for district heating in Sachigo Lake and Lac Seul;
2. analyze the availability of solar and wind resources to replace non-heating electrical loads in these two communities;
3. compare the cost savings of proposed solar energy projects in the two communities; and
4. calculate the long-term payback time of proposed solar energy projects in the two communities.

The second, third and fourth objectives made up the majority of the work for my portion of the project. There were also some secondary objectives that were looked at by the research team and the other partners in the project as possible savings and economic opportunities for the communities, including: small, inexpensive energy saving upgrades to buildings, including insulation and efficient lighting; using a small sawmill to create wood products for use or sale using wood from the local forest; manufacturing wood pellets locally for use in the local community and for export sale, harvested from the local forest; and building a greenhouse to grow vegetables locally to assist with local food security, possibly heated with biomass or waste heat from the diesel generators or powered and heated with solar power.

1.4 Remote Communities

Remote communities generally refer to communities that are long distances from urban centers. Canada is a vast country that measures approximately 5400 km from east to west and 4600 km north to south (Google Earth, 2015). The majority of Canada's population lives within 250 km of the southern border with the United States with the remainder spread out in the country's interior and northern, eastern, and western coastal areas (Natural Resources Canada, 2014). Domestic and imported goods become more expensive as these are transported over longer distances from manufacturing and shipping ports to remote communities.

The Government of Canada published a report in 2011 titled, "The Status of Remote/Off-Grid Communities in Canada," which defined remote communities as any community not currently connected to the North American electrical grid nor the piped natural gas network that is a permanent or long-term (5 years or more) settlement with at least 10 dwellings. The off-grid community of Sachigo Lake matches this definition while the on-grid community of Lac Seul is connected to the North American electrical grid, but is beyond the natural gas network.

Sachigo Lake First Nation and Lac Seul First Nation have a high percentage of residents of Aboriginal identity. There were 1,400,685 people of Aboriginal identity in Canada out of a total population of 31,241,030 in the 2011 census (Government of Canada, 2018). Ontario had 301,425 people of Aboriginal identity out of a total population of 12,028,895 according to the 2006 census (Government of Canada, 2018). (Note that not all numbers were available from the 2011 census since not all of the information gathered had been released as of August 2017.)

Both communities have higher than average numbers of young people when compared to the province of Ontario overall. In Ontario, 16.4% of the population are in the 0-14 years age group (Government of Canada, 2017a), whereas in Lac Seul First Nation, they represent 32.0 % of the population (Government of Canada, 2017a) and in Sachigo Lake First Nation, 37.9 % of the population (Government of Canada, 2017b). The demographics in these First Nations communities show that the communities are growing and will need improved and expanded infrastructure in the near future.

Transportation costs in remote communities are higher because of longer distances from urban centres where goods and services are available and having to use expensive air transport and winter ice roads for the limited winter road season. Some remote communities have paid for studies to research the cost, feasibility, and benefits of building an all-weather road to replace the ice roads or air transport into their communities and nearby mines. For example, the Mushkegowuk Tribal Council intends to put together a plan to link many communities with electrical transmission lines and all-weather roads, which would allow the use of standard transport vehicles and cars, reducing the need for air transport or ice road transport of goods to the communities. Doing so would improve the logistics and therefore the costs of supplying their communities and improving infrastructure like power and communications systems (Louiseize, 2006). Having a plan for improving infrastructure is an important step, but a critical component of such projects is the huge amounts of funding required to make them happen and questions about who will pay for them, the public sector, private sector, or a combination of the two. All weather roads allow the use of standard transport vehicles and cars, reducing the need for air transport or ice road transport of goods to the communities

Modern communications infrastructure is a challenge in remote communities since the farther a community is from large urban centres or major highway corridors, the less likely that telecommunications companies will invest in infrastructure for the relatively few customers in remote areas. Wireless communications coverage in Ontario extends north along Highway 11 in northern Ontario with a narrow corridor north to Red Lake and a narrow corridor north to Sioux Lookout with minimal coverage north of these areas (CRTC, 2016; ERTYU, 2017). Communications infrastructure using license-exempt or unlicensed frequency bands (spectrum) to deliver wireless internet to communities is considered to be as critical as sewers in terms of infrastructure importance since many government services need to be accessed online. The Lac Seul network is supported by K-Net, an Aboriginal community-oriented, non-profit communications company that has a mandate to bring wireless to many First Nations communities, and that encourages interactions among its users. K-Net relies on local, provincial and federal funding to build and maintain its infrastructure and began as an initiative of the Keewaytinook Okimakanak Tribal Council as a not-for -profit organization representing six First Nations in Northwestern Ontario (Middleton & Crow, 2008; IEEE, 2009).

Another example of communications innovation is happening in the small remote community of Washaho Cree First Nation at Fort Severn, Ontario. They have started a local cellular telephone service called the Keewaytinook Mobile (KM), which has some service agreements with the major telecommunications carriers to extend the service beyond their community (O’Donnell et al, 2011). Being better connected to the rest of the world through advanced high-speed communications would enable communities to keep abreast of technological and social advancements.

In terms of power systems, smaller transmission lines with lower capacities are common in smaller communities (whether on or off grid), and smaller point-of-use generation projects that use mini-hydro, solar, and wind can be used to fill up capacity without having to upgrade the size of the line (Gorrie, 2009). Increasing the efficiency of a grid by utilizing all or most of its capacity also increases the cost effectiveness of the grid regardless of the transmission source.

1.4.1 Sachigo Lake First Nation

The community of Sachigo Lake First Nation is a primarily an Oji-Cree remote, air access and winter ice road access community 633 km northwest of Thunder Bay. Sachigo Lake is an adherent to Treaty 9 and is located in the Unorganized Kenora District. Sachigo Lake has a total registered population of 789 people with an on-reserve[1] population of 428 as of 2013 (AANDC, 2013). The Windigo First Nations Council is the regional administrative council for Sachigo Lake

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[1] According to the federal government's Indigenous and Northern Affairs Canada (2013) (https://www.aadnc-aandc.gc.ca/eng/1100100034737/1100100034738#ch2), "As identified in the *Indian Act*, reserve land is 'a tract of land, the legal title to which is vested in Her Majesty, which has been set apart by Her Majesty for the use and benefit of a band'. Reserve lands are different from other land in that:

- Legal title to reserve lands is held by the [federal] Crown rather than by individuals or organizations;
- First Nations have a recognized interest in reserve land that includes the right to exclusive use and occupation, inalienability and the communal nature of the interest;
- The land cannot be seized by legal process or be mortgaged or pledged to non-members of a First Nation; and
- The Minister must approve or grant most land transactions under the *Indian Act*.

and six other First Nations in the same geographical area. Bearskin Lake, North Caribou Lake, Cat Lake, Koocheching, Whitewater First Nations and Slate Falls First Nation, and Sachigo Lake all have membership on the Windigo First Nations Council (Windigo, 2015), a tribal council organized in 1977. The community is also a member of Nishnawbe-Aski Nation (NAN), a political territorial organization representing the political interests of its 49 members (NAN, 2017).

Electricity in Sachigo Lake is supplied by Hydro One Remote Communities Inc. (HORCI), which owns and operates three diesel generators that supply the majority of the electricity used by the community. The diesel generators are set up in an “A+B=C” configuration where the two smaller generators, A and B, are together equal in electrical output to generator C to allow for generators to be taken offline for servicing without a drop in power output. This configuration also allows the smaller generators to be used individually when power demand is low in the summer, allowing the generator to run more efficiently. There are no natural gas lines supplying to Sachigo Lake. Many health and government services can be accessed only in Thunder Bay or Sioux Lookout by expensive air transport. Sachigo Lake’s location in northern Ontario is shown in Figure 2 with other remote communities with the winter roads highlighted in red and other communities with the all-weather roads in black. A blue line from Thunder Bay to Sachigo Lake is shown for reference on a western Ontario map in Figure 2.

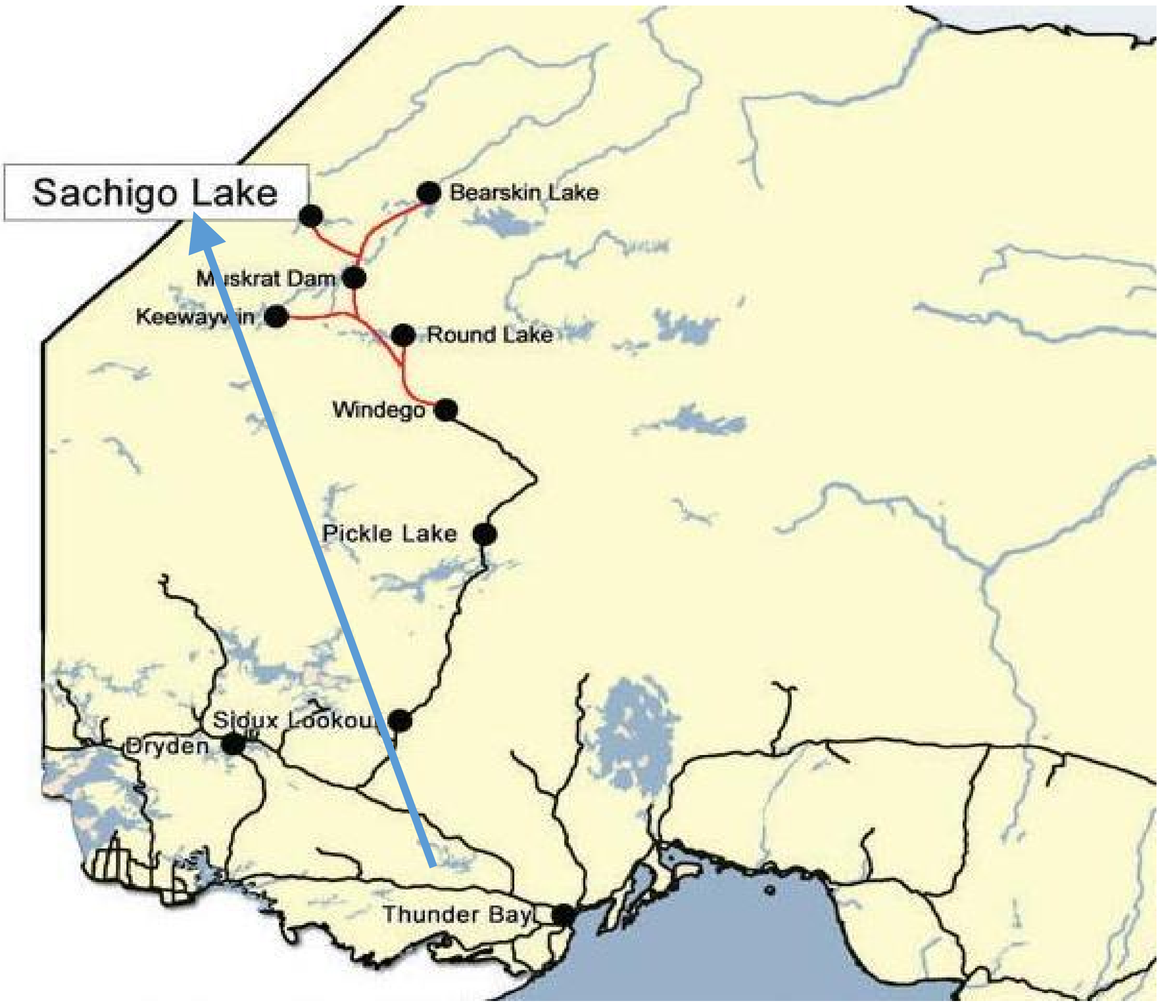


FIGURE 2: LOCATION OF SACHIGO LAKE IN ONTARIO
SOURCE: MAPSOURCE 2014

The Sachigo Lake community is made up of three different parcels of land that are spread out from each other. The main parcel of the community of Sachigo Lake 1 Indian Reserve has the majority of the community infrastructure and most of its people, and measures 3,588 ha (AANDC, 2015). Sachigo Lake 2 Indian Reserve is 1,723.6 ha and Sachigo Lake 3 Indian Reserve is 2,833 ha (AANDC, 2015). Sachigo Lake 2 and 3 are generally seasonal lands that are used for hunting, trapping, harvesting firewood and forest products, and community gatherings. The three land parcels are each about 20 km by trail apart with parcel 2 requiring a boat across Ponask Lake after the trail ends at the lakeshore. The only road that leads into

Sachigo Lake 1 from outside the community is the winter ice road that comes from Sioux Lookout and goes through the community to just beyond the airport. There are no all-weather roads that connect each of the three parcels of the community together. Only rough trails connect the three parcels that are navigable by snow machine in winter and all-terrain vehicles and four-wheel drive trucks and SUV's in summer. A map put together from GIS imagery of the three parcels of land that make up Sachigo Lake is shown in Figure 3. The red line represents the winter roads.

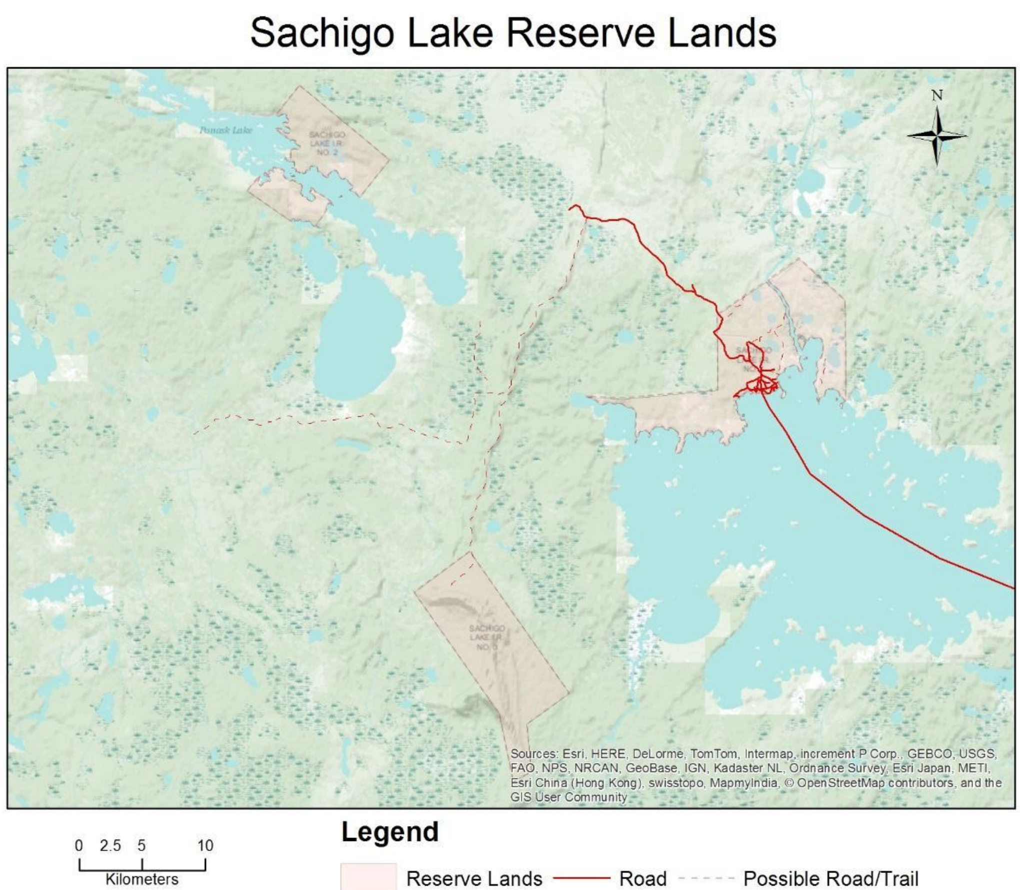


FIGURE 3: SACHIGO LAKE'S THREE PARCELS
SOURCE: P. ROBITAILLE, 2014

Sachigo Lake's three parcels of Indian reserve land are spread apart by many kilometres and lack all-weather roads between the parcels (as shown in Figure 3), which increases the difficulty of harvesting firewood from reserve land for heating residential homes. Traditional activities that are an important part of Aboriginal culture and community food and economic security, including hunting, trapping, and harvesting forest products, require access to all three parcels, which is difficult and expensive for local residents since they generally require vehicles to access them. Four-wheel drive trucks, all-terrain vehicles, and snow machines all require fuel and maintenance, which increases not only the costs for residents but also increases pollution levels and environmental impacts. Sachigo Lake has access to their own reserve lands for harvesting biomass and may be able to access the surrounding provincial Crown land in between the parcels of reserve land for biomass if there were changes to policy in Ontario's Far North Act. Currently, harvesting is limited to heating for community use and is not for export.

1.4.2 Lac Seul First Nation

The community of Lac Seul, officially known as Lac Seul 28 Indian Reserve, is a primarily Ojibway road access community 319 km northwest of Thunder Bay and 40 km northwest of Sioux Lookout. The total registered population of Lac Seul as of 2013 was 2,936 people with an on-reserve population of 762 spread amongst the main community of Frenchman's Head and the two smaller satellite communities of Kejick Bay and Whitefish Bay (AANDC, 2013). Lac Seul is an adherent to Treaty 3 and is a member of the Independent First Nations Alliance (IFNA) tribal council and of Nishnawbe-Aski Nation (IFNA, 2015; NAN, 2015). The members of the Independent First Nations Alliance are Kitchenuhmaykoosib Inninuwug, Lac Seul, Muskrat Dam Lake, Pikangikum, and Whitesand (AANDC, 2015). The total reserve area of Lac Seul is 26,821.5

ha (AANDC, 2015). A map of northwestern Ontario with Lac Seul and its location relative to Thunder Bay highlighted with a blue arrow is shown in Figure 4. The communities within the black lines are off grid, illustrating that Lac Seul is below this and on the grid.

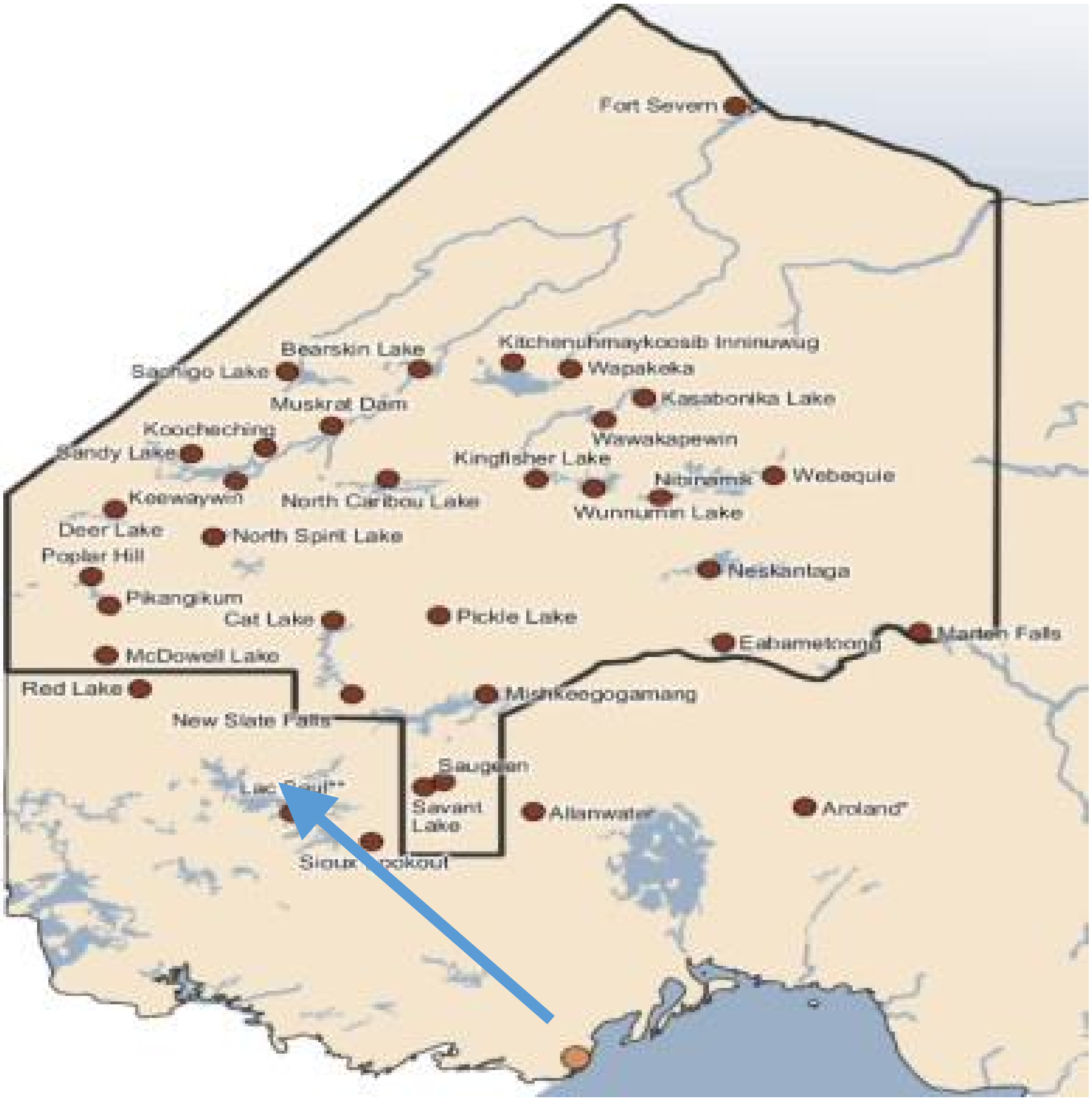


Figure 4: Location of Lac Seul in Ontario
Source: MapSource 2014

The three communities of Lac Seul are connected by all-weather roads (see Figure 5). Many health and government services can be accessed only in the nearby community of Sioux Lookout. Electricity is provided by Hydro One. There are no natural gas lines into the community as shown in the Union Gas, the only supplier of natural gas in northern Ontario, service area map in Figure 6.

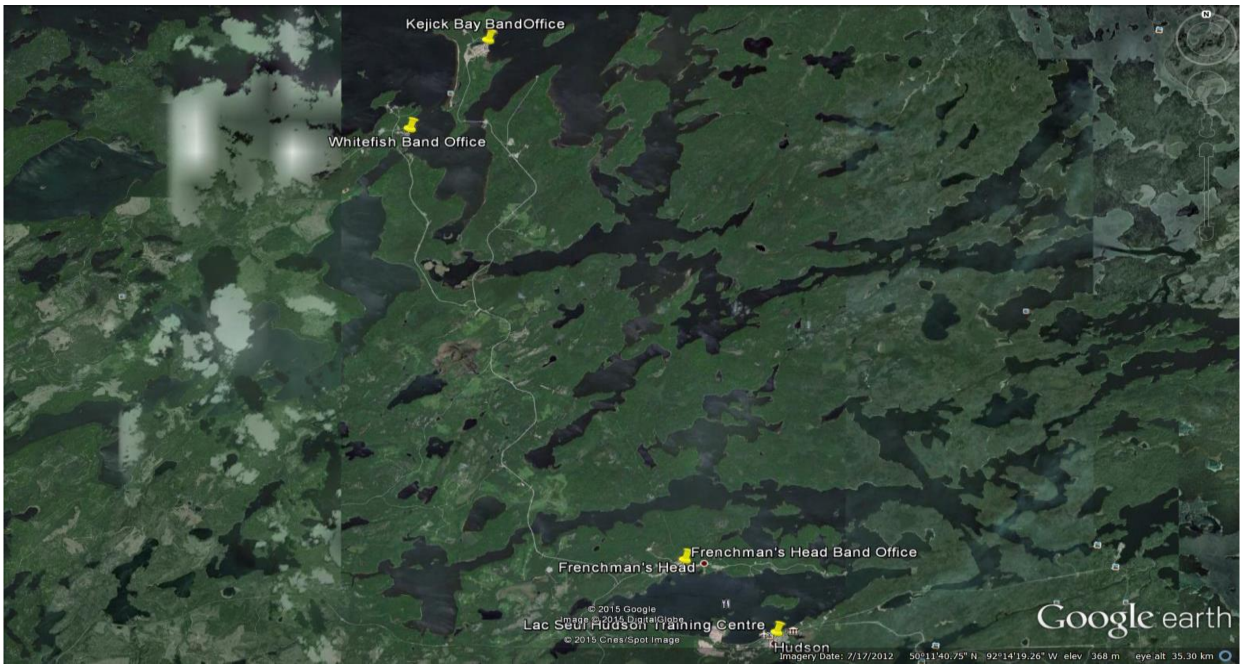


FIGURE 5: LAC SEUL'S THREE COMMUNITIES
SOURCE: GOOGLE EARTH 2015

FIGURE 6:UNION GAS SUPPLY MAP (ONTARIO)
SOURCE: IESO 2014

Lac Seul has forestry operations on its reserve land and on the surrounding Lac Seul Crown Forest, which is managed by the Band[2]owned Obishokakaang Resources Corporation. The Sustainable Forest License (SFL) for the Lac Seul Forest was surrendered by the previous holder because of bankruptcy, likely as a result of the 2008 worldwide economic slowdown. A portion of that forest was awarded to Lac Seul First Nation as a special Enhanced Forest Resource License (EFRL) with a five-year renewable term as a test case for community-based forestry. Trees harvested from this forest go to the McKenzie sawmill with the rest sold as chips, primarily for pulp. Many local residents have experience working in the local forestry

[2] A "Band" is defined by the federal Indian Act, 1876 as: "a body of **Indians** … for whose use and benefit in common, lands, the legal title to which is vested in Her Majesty, have been set apart." (http://laws-lois.justice.gc.ca/eng/acts/i-5/page-1.html)

industry and have certifications for operating equipment used in industrial forestry. The local labour force is skilled and frequently under-employed, which bodes well for the possibility of using forest biomass for community scale district heating.

1.5 Energy Resources, Use, and Costs

Sachigo Lake and Lac Seul use electricity as their primary heat source. Lac Seul is on the provincial grid and pays the rates set by the Ontario Energy Board (OEB) and administered by Hydro One. The electricity rates in Ontario rise every May and November. The rates paid by Lac Seul as of April 2014 were time-of-use rates at $0.086 kW/h off-peak, $0.114 kW/h mid-peak and $0.14 kW/h on-peak. Hydro One Remote Communities Inc. supplies electricity to Sachigo Lake at the air-access community residential rate of $0.086 kW/h and the Standard “A” rate of $0.88 kW/h for larger buildings and users.

The community of Sachigo Lake had a community energy report prepared for them by the Pembina Institute in 2011 that was a snapshot of energy use in 2009; the year at that point had the most recent and complete records of energy use and costs. The report showed community energy use by fuel, cost, and distribution within the community (see Table 1). Information from this report was used in this thesis and augmented with information and community records provided directly by community members, including information from Hydro One Remote Communities Inc.

Larger buildings that used the most amounts of energy in the community had records of energy use and costs; residential use was estimated by using total residential load figures and dividing by the total number of residences. The community obtains all of its electricity from the Hydro One Remote Communities Inc. diesel generators, minus a small amount from the school and health clinic back-up generators, which simplified tracking the total supply. The energy loads in Lac Seul were estimated based on examination of heating units in the larger buildings and a sample of anonymous residential loads since complete energy use records were not available to the research team. It was assumed that energy use in Lac Seul would be similar to energy use in Sachigo Lake.

Sachigo Lake non-residential community infrastructure buildings had a significant energy load that used a combination of fuel oil (diesel for heating), electricity at the residential rate for smaller buildings, and electricity at the Standard A rate for larger buildings. Diesel fuel used for space heating had an average price of $ 0.97 per litre over the year (2009) according to the baseline study. Electricity used in these buildings was for a combination of back-up baseboard heating, electrical boilers and other electrical loads that included lights, computers and common appliances. A summary of the energy costs and total greenhouse gas emissions (CO_2 equivalent) for community buildings is displayed in Table 1.

TABLE 1: SACHIGO LAKE NON-RESIDENTIAL BUILDING ENERGY COSTS, 2009

Building	Fuel Oil (diesel) Cost	Electricity Cost	Standard A Electricity Cost	Total Energy Cost	Total GHG Emissions (tCO_2 eq.)
Arena	$5,743	$2,125	-	$7,868	39
Martin McKay School	$45,164	-	$163,262	$208,426	245
Nursing Station	$9,700	-	$100,310	$110,010	36
Band Office	$5,867	-	$29,162	$35,030	17
Teacherages	$10,870	$2,607	-	$13,478	96
Water Treatment Plant	$16,281	-	$100,448	$116,729	66
Total (non-residential buildings)	**$179,402**	**$40,108**	**$529,882**	**$749,391**	**1,384**

Source: Pembina Institute 2011

The cost of Standard A electricity ($0.88 kWh) alone for non-residential community buildings was $529,882, which was 71% of total energy costs and is highlighted in blue. Martin McKay School, the Nursing Station, and the Water Treatment Plant are highlighted in yellow and represented 58% of the total energy costs of non-residential community buildings at $435,165. Total annual energy costs were broken down into three sectors: community buildings, residential buildings, and transportation. Electricity and fuel oil (diesel) were used in community buildings for heating and electrical loads where electricity and firewood were used in residential buildings. Firewood costs were estimated by the community at $260 per cord based on sales to some community members (usually elderly members) and costs incurred to harvest firewood from the local forest. There was very little record-keeping by community members to verify exact costs of firewood harvesting so the community estimates and the figure calculated by the Pembina Institute based on those estimates were used. Chainsaws, trucks, snow machines, and all terrain vehicles used by community members to harvest firewood all require fuel, oil, and maintenance which each contribute to the cost of harvesting firewood. The average energy cost per sector is displayed in Figure 7.

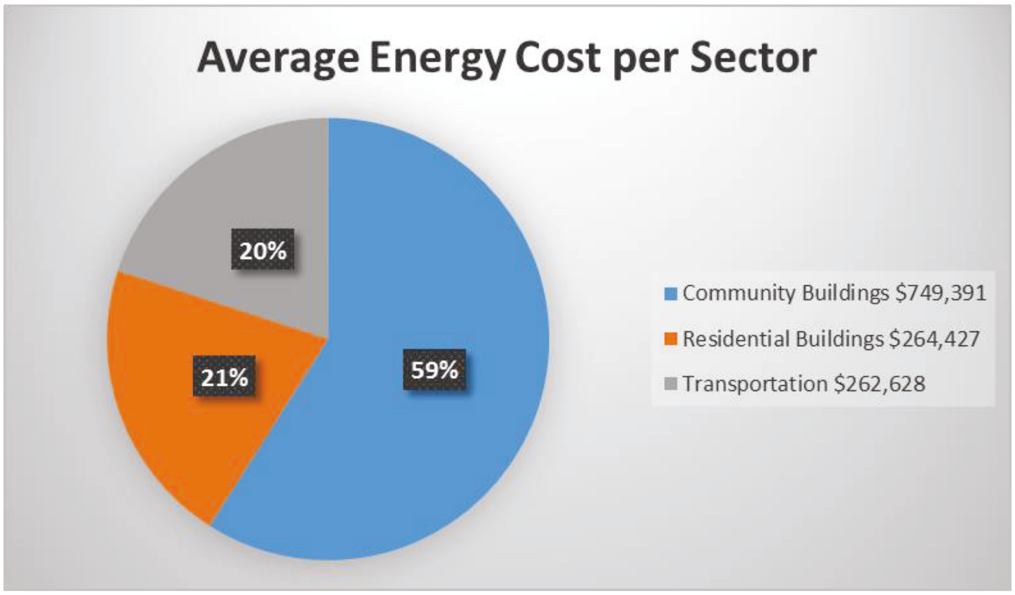


Figure 7: Sachigo Lake Annual Energy Cost per Sector
Source: Pembina Institute 2011

The major energy sources that were used in Sachigo Lake were: electricity (from diesel powered generators), diesel for transport, diesel for heating fuel oil, gasoline for vehicles, and firewood for home heating. Standard A-priced electricity and residential rate-priced electricity are each put into their own category because of the large price difference between them. The average energy cost by energy or fuel source is displayed in Figure 8.

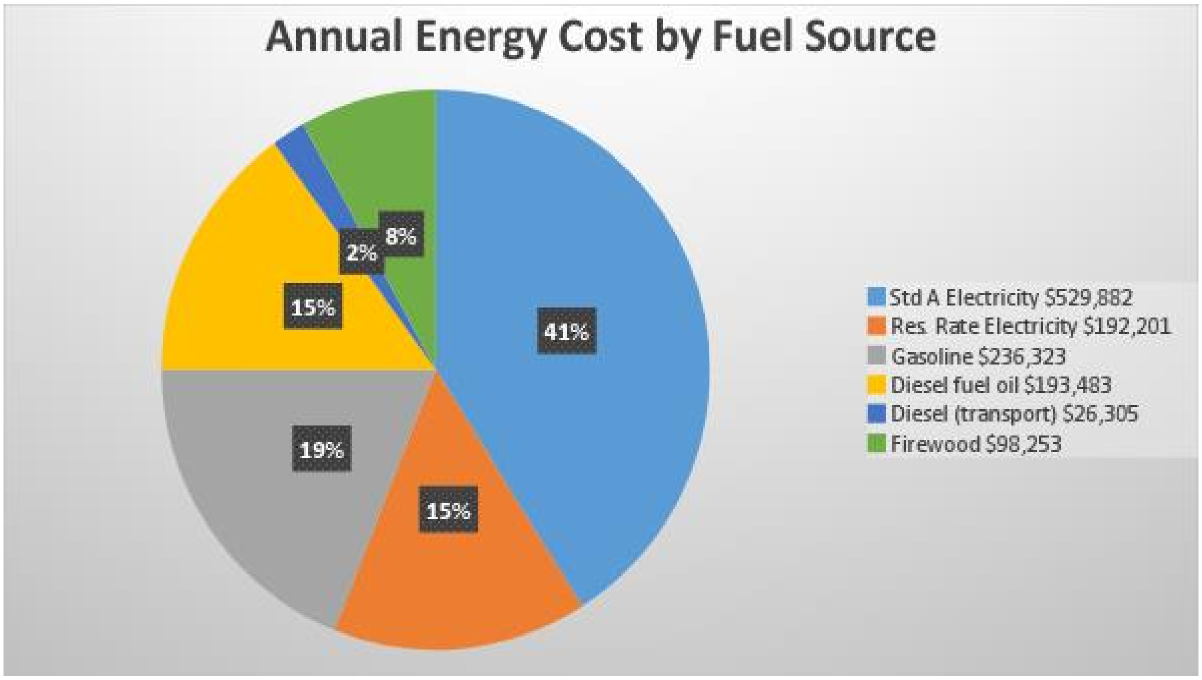


FIGURE 8: SACHIGO LAKE ANNUAL ENERGY COST BY FUEL SOURCE
Source: Sachigo Lake 2011

The diesel generating facility in Sachigo Lake is located at the community airport and is owned and operated by HORCI. Detailed records are kept of fuel use, fuel costs, and electricity production at the generating facility. The cost of diesel fuel to run the community generators is a major part of the total electricity cost for the community. An overview of the generator performance, total electricity production, and fuel costs comparison for the years of 2007, 2008, and 2009 are shown in Table 2. The years displayed are the last years with the most detailed information that was available to the research team and incorporates additional information that was collected and analyzed by the research team and by the Pembina Institute for the community report for the same period.

TABLE 2: SACHIGO LAKE GENERATOR PERFORMANCE 2007-2009

Year	2007	2008	2009
Total Fuel Use (litres)	848,612	868,704	867,679
Total Fuel Cost ($)	$1,099,369	$1,373,050	$1,062,246
Average Fuel Cost per Litre ($)	$1.30	$1.58	$1.22
Electricity Generated (kWh)	2,874,000	3,034,500	2,992,500
Average Efficiency (kWh / litre)	3.39	3.49	3.45
Average efficiency (litres / kWh)	0.295	0.286	0.290
Average Cost of Generation ($/kWh)	$0.38	$0.45	$0.35

Source: HORCI, 2011

Table 2, which presents total fuel use and the amount of electricity generated, shows that these did not vary significantly from year to year, but the cost of fuel per litre increased in 2008. This increased the total fuel cost and the average cost of power generated. Small increases in electricity demand could be attributed to colder weather, which leads to higher heating demands and construction of newer buildings and infrastructure. Gasoline and diesel use in the transportation sector represented 20% of energy costs and were not part of the investigation and analysis except to highlight fuel usage and show a future research possibility. Transportation fuels must be brought in by air transport or over the ice roads. Hybrid vehicle and electric vehicle technology are possibilities that can be looked at in the future for vehicles that do not travel long distances and can be recharged by locally sourced renewable energy.

1.6 Historical Challenges

First Nations communities faced many challenges in the past due to their remote location and the influx Europeans that settled land which Indigenous peoples traditionally occupied. Many First Nations communities were forced off their traditional lands and into reserves as part of treaty negotiations with Canada. The settler-colonials wanted to enable settlement and resource development of the land by immigrants from Europe and elsewhere. Aboriginal peoples were “given” separate reserves, which nonetheless remained under the “care” of the Crown or federal government. As part of their treaty rights, Aboriginal peoples were supposed to have access to the land for fishing, hunting, trapping, and other traditional activities.

Treaties were negotiated between the British Crown and Indigenous nations with the intent of delivering mutual benefits (AANDC, 2015) Treaties were legally binding agreements that covered the ceding of First Nations’ title to certain lands, payment of goods and cash, creation of reserves, protection of fishing, hunting and harvesting rights and promises of schools, clothing and farming supplies (Government of Ontario, 2017). Treaty rights are protected by subsection 35(1) of the *Constitution Act*, 1982. The federal government of Canada tried to keep each First Nations geographically and politically separate with specific marked territories (Stark, 2012). Lac Seul First Nation became a signatory to Treaty 3 in 1873 and Sachigo Lake First Nation became an adherent to Treaty 9 in 1929/1930 (AANDC, 2008).

The legacy of colonialism and racism has left First Nations communities throughout Canada facing significant challenges. Treaties promised respectful partnerships, but Indigenous peoples were targeted by colonial policies designed to exploit, assimilate and eradicate them (Government of Ontario, 2017). Treaties in some cases had First Nations surrender the land they traditionally occupied in exchange for small reserves (AANDC, 2008). Forced off land they traditionally occupied and onto reserves, many members of First Nations migrated to cities and left remote communities in Northern Ontario, which now find themselves with high rates of unemployment. Members of First Nations that stayed on the reserves set aside for their nation are known as on-reserve where members of the same nation that live elsewhere are know as off-reserve (StatsCan, 2006). Statistics Canada does not currently have unemployment figures for on-reserve populations due to their apparent difficulty collecting data from remote communities (Government of Canada, 2017c), but one can compare the Canadian average in 2014 at 5.7% for non-Aboriginal people with the 10% for Aboriginal people living off-reserve (Government of Canada, 2017c). Windigo First Nations Council has performed surveys in some of their communities and found unemployment in Sachigo Lake First Nation to be 25% in 1998/1999 and at 35% in 2010 (Windigo First Nations Council, 2011).

There is also a substantial income disparity between these communities and the rest of Canada; people living on First Nation reserves usually have substantially lower incomes (Pendakur & Pendakur, 2011). The average hourly wage for Aboriginal workers working off-reserve was $26 per hour compared to $27.41 per hour for the non-Aboriginal population based on Statistics Canada data as of August 2017 (Government of Canada, 2017d). There are also differences in educational outcomes, which can impact employment. Statistics Canada reports that 52% of Aboriginal people in the 25-64 age group had a college diploma, university degree, or certificate from a trade school, whereas the percentage of non-Aboriginal people in the same age group was 65% (Government of Canada, 2016).

Some social problems in First Nations communities were caused by families being fractured by having their children sent to residential schools. Approximately 150,000 children were separated from their families and communities to attend residential schools (AANDC, 2008). These communities are still living with the terrible legacy of residential schooling when children were forcibly removed from their families in the federal government's attempt to "assimilate" Aboriginal peoples (TRC, 2015). Cases of physical and sexual assault were claimed against employees and staff of these schools with many claims from victims still being decided by the federal government (AANDC, 2008). The last residential school closed just over 20 years ago, in 1996, and the profound impacts of the resulting loss of language and culture has been well documented (Harrison, 2009). Currently, these communities also face profoundly inequitable education funding. Education is under provincial jurisdiction in Canada, whereas First Nations communities are funded federally and a complex federal/provincial funding formula results, on average, in one third less money for schools and students in these communities (Windigo, 2011).

1.7 Project Methodology

This section begins with the energy information that was collected from, and on behalf of the two communities for analysis and which organizations provided it. The next section describes how that information was used to calculate the size of biomass district heating loads for cost analysis. The following section outlines the methods and tools used to collect and analyse biomass volumes in the forests surrounding both communities. The next section outlines how solar and wind resources were initially analysed and which sources were used and how the follow-up solar analysis was done and which tools and software were used. Lastly, a description of how the fieldwork was done is described and how the project information was stored.

The volume and cost of fossil fuels (primarily diesel) used and the electricity consumed to heat each community annually was assessed using information provided by the communities, Hydro One, Hydro One Remote Communities Inc., and Watay Power, which is operated by the Windigo Tribal Council to help manage Sachigo Lake First Nation and the other Windigo communities in northern Ontario. Individual buildings were inspected by the research team and heating units were photographed with the energy rating tag showing and recorded to determine the maximum heating load for each building. An energy map was produced that showed where and how much energy was required to heat buildings in each community. Large heat clusters of buildings that were in close proximity to each other were identified. Energy loads and distances between buildings were mapped to produce the cost estimates of constructing a biomass district heating unit with the appropriate biomass units and the piping lengths required for each heating scenario. The heat load information for local buildings was collected by all members of the research team and analysis was done by the industrial partner in the project, BioThermic Energies, which had installation cost information on the biomass units that they install.

The forestry field work, heat data collection and solar field data collection for each of the two communities was limited to ten days each in total due to budget constraints. Detailed planning preparations and organization were needed to ensure that the volume and quality of data would be adequate for a pre-feasibility study that would be useful for the communities. Potential solar sites for both communities were identified on Google Earth™ before going into the field to speed up site selection. As well, provincial land cover imagery was used to identify different forest types in the remote community and create GIS forest stand maps in advance. The stand types from the provincial land cover imagery were matched to the corresponding forest stand types used in the forest resource inventory maps for the forest operations of the road access community and are based on provincial standards set by the Ontario Ministry of Natural Resources and Forestry (OMNRF). The forest was stratified into five stand types and sampled with three replicates from each stand type in both communities. The inventories were used to calculate available forest biomass volume and were combined with the thermal values collected from samples of each tree species from each site, and used to calculate total heat potential of the available biomass volume per hectare.

Forest resources were assessed by examining the Forest Management Plan 2011-2021 for the Lac Seul Forest. Sachigo Lake is located outside of the provincial Area of the Undertaking (AOU)[3] where forest operations are conducted; Sachigo Lake has no forest management plan or forest inventory. An initial forest resource inventory was conducted by the research team to get a snapshot of forest composition, size, and age, which allowed the development of an initial estimate of forest biomass volume and heat potential. Tree samples were brought back to the Lakehead University Wood Science Testing Facility to test the thermal values of the different species of trees to compare with published values and to estimate the heating potential from the community forests and surrounding Crown land. The forest resource inventory in Sachigo Lake was duplicated by the research team in Lac Seul to compare the results of each community as well as with the inventory done for the current Lac Seul Forest Management Plan to compare the thermal values with published values.

[3] The AOU is the Crown land base approved under the Environmental Assessment Act, 1990 for forest management activities (OMNRF, 2014). https://www.ontario.ca/page/forest-management-planning

Wind and solar power potential were evaluated as a possible complement to biomass district heating. The non-heating electrical energy loads for both communities are estimated to be 20% of the total energy load based on Natural Resources Canada's 2010 Energy Efficiency Trends report (NRCAN, 2010). This is a significant portion of the total electrical load. If the load could be wholly or partially supplied by solar or wind power or a combination of both, it would represent a significant reduction in ongoing energy costs for both communities and a reduction in the diesel emissions in the remote air-access community.

The initial assessment of the wind and solar potential was done at Lakehead University before the fieldwork portion of the project began using multiple publicly available resources (Natural Resources Canada wind maps, Natural Resources Canada solar maps and Ontario Renewable Energy maps) to determine if the wind and solar potential was high enough to warrant further analysis in the communities. Wind resources for both communities were shown to be in the marginal to marginal/acceptable borderline range. Solar resources for both communities were shown to be in the mid to high range based on the public solar energy potential maps. The publicly accessed information was followed up with actual site images from the two communities and a measurement of average annual and monthly sun hours per day was calculated with an industry standard Solar Pathfinder™ at multiple sites in both communities. The solar site information was collected from seven sites in Sachigo Lake and fourteen sites in Lac Seul, seven of which were from the main community, Frenchman's Head and the remaining seven from the two smaller satellite communities, Kejick Bay and Whitefish. This site information was then fed into the PV Suite™ software, which comes as part of the Solar Pathfinder™ analysis package. Cost savings analysis was done with the PV Suite™ software using the site information and comparing scenarios of two different sizes of solar array at the two different electricity rates charged in each of the two communities.

Solar analysis RETScreen software is available free from the Natural Resources Canada website. RETScreen is a renewable energy evaluation software package that contains weather and site information for many Canadian communities; the software is used to calculate theoretical solar photovoltaic, solar thermal, wind, biomass and hydropower potential for a potential renewable energy project. Solar analysis using RETScreen gives an estimate of the solar potential and financial viability of a solar project at a potential site, but does not take local obstructions like buildings or trees into account since no actual and current local images are used in the analysis. An initial analysis using RETScreen was useful when images from potential sites were unavailable or as an initial decision tool to narrow down the best potential sites before visiting a remote community, which can only be accessed by expensive air transport. The research team went to both communities to collect forestry and heat data and site images for use in a commercially available solar analysis tool (Solar Pathfinder™) that was used for a pre-feasibility analysis after using the RETScreen analysis.

The Pathfinder™ solar analysis tool uses a series of sun-path diagrams that chart the sun hours of each month specific to a certain latitude range. The sun-path diagrams specific to the latitude ranges of each of the two communities were included with the unit. The Pathfinder unit fits in a small weather resistant case that allowed easy transport to each potential site and set up in minutes. Digital cameras were used to capture the images used in the Pathfinder™ analysis and also for the forestry site images required for the forest inventory and biomass volume analysis. The digital images were stored on a laptop in addition to an extra rugged-duty back-up hard-drive which was provided by Confederation College.

The information collected before and during the fieldwork portion of the project was sorted and organized for analysis by all research team members at Confederation College and Lakehead University after the fieldwork was done. Community heating maps were prepared at the college for BioThermic™ in order to make biomass district heating cost projections which were then used to calculate long-term payback using RETScreen for each heating scenario. Forest inventory data were analysed at the Lakehead University Wood Science Testing Facility to calculate biomass availability volumes in each community. Solar data that was collected in each community was then processed with the Solar Pathfinder™ and P.V. Suite™ software to calculate average sun-hours and savings for each solar power scenario, which was then used to calculate project payback times.

2 BIOMASS DISTRICT HEATING WITH FOREST BIOMASS

This section begins with definitions of what biomass is, advantages and disadvantages of biomass energy, how it is used for energy, and potential sources of forest biomass. Section 2.1 outlines how biomass availability was calculated for Sachigo Lake and Lac Seul using forest inventories. Section 2.2 outlines the calculations of costs of biomass district heating projects in both communities which were used to calculate long-term payback times.

Bioenergy is energy derived from living and recently living plant matter, which is referred to collectively as biomass (Boyle, 2012). Biomass on earth is an enormous store of chemical energy created and continuously replenished through photosynthesis, which takes carbon dioxide from the air to make living material, releasing oxygen in the process (Morris & Scurlock, 2012). Biofuels, which includes biomass, currently make up about 1% of the current primary energy supply in Ontario (IESO, 2017). In some jurisdictions, biomass contributes to district heating systems. However, in Ontario, district heating is not listed as part of the primary energy supply in 2017 by the IESO. In contrast, district heating in Sweden accounts for over 10% of the primary energy supply and 14% of the final energy use (Truong & Gustavsson, 2014). Space heating and hot water demand are supplied by district heating in 92% of Swedish multi-family residential buildings (Aberg, 2013). Biomass fuels represented 46% of the district heating supply in Sweden in 2014 (Werner, 2017).

An advantage to using biomass for heat energy in remote communities in the boreal forest is that the source of energy is typically close to the community. Another advantage is that energy can be created locally instead of paying an outside organization for that energy and keeping the energy created under the communities control. Biomass derived energy also has disadvantages compared to other energy sources. Biomass energy harvest is complex, feedstock must be grown (which can take decades) then harvested, cut or chipped or ground, then dried and stored. Forest lands must be set aside and managed for biomass harvesting while balancing ecological, environmental, social and cultural objectives which can conflict with each other. Biomass fuel quality is also dependent on species of trees or shrubs that are available and drying method when using forest biomass.

The cost of biomass energy is also typically higher than many energy sources currently in use. Levelized Cost of Energy (LCOE) combines capital costs, operation and maintenance costs and fuel costs and is used by investors, researchers and governments to compare different technologies, fuels and expected power plant life (Narbel et al, 2014). The levelized cost of biomass energy as of 2016 was $96.1 per MWh (USEIA, 2017). In comparison, conventional natural gas derived energy cost $58.1 per MWh, solar photovoltaic energy cost $84.7 per MWh and onshore wind cost $64.5 per MWh (USEIA,2017).

The province of Ontario has a population of 13.6 million people and has 107.6 million hectares of land, of which 71 million hectares is forested with approximately 85 billion trees (HRSDC, 2014, OMNR, 2014). Sweden has a population of 9.7 million people with 27.5 million hectares of forested land, which is a little more than a third of Ontario (Statistics Sweden, 2015). Sweden has less forested land and potential biomass supply than Ontario, but uses much more biomass for district heating and as part of its energy supply. Over 90% of human and goods transport in Sweden is over their extensive public and private road network, which covers the majority of the country (SNRA, 2015). The road network in northern Ontario only extends north of highway 11 in narrow corridors to Red Lake, Sioux Lookout and Pickle Lake (see Figure 2).

There are many types of biomass that can be burned to create heat including trees, shrubs, agricultural wastes, biofuels, peat, and clean wood construction waste (no nails, screws, paint or chemically treated products). Biomass burners that can burn logs, wood chips, wood pellets, or a combination of forest fuel types are currently available in Ontario (Froling, 2017). The communities of Lac Seul and Sachigo Lake are situated in the boreal forest in northwestern Ontario with reserve lands under the control of the federal government through Indigenous and Northern Affairs Canada under the Indian Act, 1876, and provincial Crown land surrounding reserve lands under the control of the Government of Ontario. The boreal forest is a circumpolar forest in the northern hemisphere covering 1.9 billion hectares across many countries and comprising 14% of the earth’s land and 33% of the earth’s forest (NRCAN, 2015). As stated in section 1.7, Sachigo Lake is north of where commercial forestry operations take place and has no forest resource inventory and trees re-generate naturally. Lac Seul has forestry operations in both the reserve forest and the Lac Seul Forest, a Crown forest management unit and uses both natural and artificial re-generation. Biomass that can be harvested or collected with conventional equipment within 100-150 km or less from the community infrastructure is the focus of this research.

Trucks and harvesting equipment need maintenance and use fuel, which become ongoing costs. Keeping the harvest radius small also reduces the complexity of harvest operations and the time required to harvest a given volume of biomass. The research team observed the remains of small trees and shrubs from thinning under electrical wires in both communities, which were discarded into ditches away from the roads. Sachigo Lake has a number of seasonal four-wheel drive trails between the three reserve parcels, two of which had the remains of trees and shrubs in a 1 to 1.5 metre wide corridor at least 10 km long that were cleared away from edges of the trails and piled in place. Biomass from these regular clearing operations could possibly be incorporated into and planned for in a total biomass harvest plan to reduce the harvest levels from the surrounding forests.

Biomass district heating systems are typically hydronic systems that use a boiler to burn biomass which heats a liquid (usually water or an anti-freeze solution) that is piped through a heat exchange unit to be used to heat water or for space heating (BERC, 2010). Piping can be buried between buildings during new installations or during retro-fit situations and is a major cost of a district heating project. Large buildings with high heating loads spaced close together reduces the length of piping required as well as total cost per unit of heat. Small residential heating loads in a spread-out subdivision increases the length of piping required and the cost per unit of heat. The ideal location for a biomass district heating plant is thus close to the centre of a community, near the largest heat loads and close to electrical lines.

Imagery collected for the solar power portion of the project was either in front of or next to large buildings or open areas with a good southerly exposure to capture sun energy, in close proximity to the electrical lines. The majority of these locations were chosen because they were near the centre of the community and could also be potential district heating plant locations. Solar thermal power is an option that works similarly to biomass district heating, where a liquid is heated by sun energy and piped to a heat exchanger to heat water or for space heating. Many biomass heaters have control systems that will maximise heat capture from solar thermal collectors to increase system efficiency and are located on the return (cold) line as a pre-heating system to reduce biomass fuel use for a given amount of heat production (Froling, 2017). Solar thermal collectors located on the same site as a biomass district heating plant will have minimal extra piping costs since the piping is kept short. Advantages to this system are fewer emissions, since less biomass is burned, and lower fuel costs since sunshine is a free fuel and biomass fuel must be harvested.

2.1 Forest Biomass Availability

The study area for both communities consisted of Federal Reserve land, three separate parcels in Sachigo Lake, and provincial Crown land surrounding these parcels. Lac Seul had a study area of 178,630 hectares of forested land that was approximately 150 km road distance from the main community of Frenchman's Head. Sachigo Lake had a study area of 75,175 hectares, which represented three separate parcels and Crown land between these parcels. Lac Seul had a much larger study area because it has all-weather roads that can support trucks and harvesting equipment throughout the area whereas Sachigo Lake had mostly four-wheel drive trails between its parcels outside the main community.

The Forest Resource Inventory (FRI) procedures used to analyze data related to biomass were based on the Wood Science Software Application (WS App) developed by the Lakehead University Wood Science Testing Facility (LUWSTF). The software was loaded onto a weather resistant tablet that was used in the field to collect forest inventory data. The WS App is consistent with the OMNRF Strategic Forest Management Model (SFMM) (Seymour, 2016). The WS App also records wood density and heat potential following American Society for Testing and Materials (ASTM) Standards (Seymour, 2016).

The GIS data used for the forest inventory was the Provincial Land Cover imagery for both communities and additionally, GIS data for Lac Seul provided by the Buchanan Group. Sachigo Lake is outside the Area of Undertaking (AOU) where current commercial forestry operations exist and does not have a forest resource inventory. Using the GIS data available for both communities, five forest cover types for the study area were delineated:

- Softwood
- Hardwood
- Mixedwood
- Treed Wetland
- Disturbed Forest

Following Ontario Forest Inventory GIS polygon size limitations, forest stands less than 8 hectares in size were eliminated. Forest stands greater than 1 km from roads and waterways were also eliminated in order to meet study budget and time restrictions.

Field collection sites were chosen randomly with 2 FRI lines per forest type on both Crown and Reserve lands for both communities. A modified FRI Calibration Plot procedure was used to assess species composition, volume, and forest stand age. The results for biomass volume were broken down into three categories:

1. Total Biomass, which represented all woody biomass growing within the forest stands.
2. Available Biomass, which is all woody biomass not used for wind breaks, buffers, animal habitat, firewood, cultural lands, or other cultural purposes.

3. Annual Available Biomass, which represents the amount of Available Biomass that can be harvested annually in a sustainable manner without adversely affecting forest health or other community use.

Wood density and heat potential were also assessed from samples collected in both communities from both Crown and Reserve land, which were then tested in the laboratory from each forest type.

The results of the study were for pre-feasibility analysis only and were limited by the lack of detailed forest inventory GIS data for Sachigo Lake. Forest inventories are typically assessed by ecosite type rather than the five forest types used, which reflected the limits of the Provincial Land Cover GIS imagery that was available for Sachigo Lake. Sampling intensity was smaller than current FRI Calibration Plot procedures due to budget and time restrictions. The intent of the study was to present a possible energy option to the participating communities while providing as much relevant information as possible at little cost to the communities before these communities pay for a full feasibility study should they wish to proceed with a project.

2.1.1 Forest Inventory of Sachigo Lake

Sachigo Lake has three parcels of Reserve land (see Figure 3) with Crown land in between them. The Crown land contained 69,611 hectares of forest that the community currently uses for their traditional activities. The majority of the community infrastructure is in Reserve parcel 1 and has 2,266 hectares of forest. Reserve parcel 2 is southwest of the main community along a ridgeline and has 1,898 hectares of forest. Reserve parcel 3 is located west of the main community at Ponask Lake and has 867 hectares of forest. Sachigo Lake is in a forest fire-prone area, making fire prevention and risk reduction through retention of wind firm buffers around lakes a key forest health management criterion for the study.

The species composition of the Crown land surrounding and in between Sachigo Lakes Reserve parcels is 53.01% jack pine (*Pinus banksiana*), 24.98% white birch (*Betula papyrifera*), 15.03% trembling aspen (*Populus tremuloides*), and 6.98% black spruce (*Picea mariana*). The species composition of Sachigo Lakes' Reserve lands is 40.6% trembling aspen, 23.2% black spruce, 22.1% white birch, and 14.0% jack pine. The jack pine in the Crown land portion appeared to be of fire origin, which was confirmed by community members and fire records. Sachigo Lake had less jack pine in its Reserve parcels because of fire suppression efforts near the community infrastructure. There was a large wide corridor of mature trembling aspen along the length of one side of the airport runway that is not currently used by the community that has an all-weather road leading to it from the community that could also be possibly be managed for biomass harvesting.

Total Biomass for Sachigo Lake was 5,704,209 m^3, which included Reserve lands and Crown lands. Reserve lands have 7% of the total biomass (401,026 m^3), whereas the Crown lands have 5,303,181 m^3 of total biomass. Available Biomass is calculated by subtracting 30% from total biomass to account for forest buffer retention areas that also include flood control and water quality control areas. The available biomass for the Crown forest is 3,712,227 m^3 and the available biomass for the Reserve forest is 280,719 m^3. The boundaries of the Reserve forest are within the community infrastructure and are included for illustrative purposes only. Future infrastructure development and possible green space buffers will have to be taken into account should a biomass harvesting plan be implemented.

Annual available biomass in the Crown land portion of Sachigo Lake is calculated by dividing the available biomass by a 120 year rotation age, adjusting for the 30-60 year fire cycle and a 35% loss of biomass due to mortality. The annual available biomass for the Crown land portion of Sachigo Lake is 30,935 m^3, which does not take into account firewood harvesting or other traditional activities. The annual available biomass for parcel 1 of Reserve land (which is the main community with the majority of the infrastructure) is 1,209.62 m^3, for parcel 2 of Reserve land is 1,114.38 m^3, and for parcel 3 (located at Ponask Lake) is 15.33 m^3. There are currently no formal records of the amount of community forest use or of trees taken for firewood.

2.1.2 Forest Inventory of Lac Seul

Lac Seul is located within the Lac Seul Forest (LSF), which has commercial forestry operations outlined in the LSF Management Plan and is part of Sustainable Forest License #542455. Lac Seul may be able to access logging residuals from Crown land operations and underutilized tree species from their Reserve lands and Crown lands in a biomass harvesting plan. The total forest area within 150 km of Frenchman's Head is 178,630 hectares, of which 18,438 hectares is Reserve land and 160,192 hectares is Crown land. Total Biomass for Lac Seul study area is 23,707,073 m^3 of which 2,898,916 m^3 is from the Reserve land, and 20,808,157 m^3 is from Crown land.

The species composition of The Lac Seul Crown Forest studied is 46.5% jack pine, 36.5% black spruce, and 8.2% balsam fir (*Abies balsamea*). The remaining 9.8% are trembling aspen, white birch, eastern larch (*Larix laricina*), alder (*Alnus* s.p.p.), eastern white cedar (*Thuja occidentalis*), white pine (*Pinus strobus*), and red pine (*Pinus resinosa*). The species composition for the Lac Seul Reserve forest is 80.8% jack pine, 4.96% white birch, 4.82% balsam fir, 3.81% trembling aspen, and 2.95% black spruce, with the remaining 2.66% being alder and other shrub species.

The available biomass from the Lac Seul Crown Forest studied is calculated as 20% of the volume of the three commercial species: jack pine, black spruce, and balsam fir, which is 18,977,039 m^3 minus 50% stem recovery for further processing, 13% for breakage and waste decay, and 17% to meet environmental services equalling 3,795,407.8 m^3. The available biomass for the remaining under-utilized species is 1,831,118 m^3 minus 13% for breakage and waste decay, and 17% for environmental services making the total available biomass of 5,077,190 m^3.

Calculating the available biomass on Lac Seul Reserve lands is not straightforward since much of the forest occurs in areas where there are community buildings and homes. Reserve lands are also used for hunting, fishing, and other traditional activities. There are no formal records of tree harvest levels for firewood and other economic opportunities on Reserve lands. Lac Seul's management priorities for the Reserve forest are unknown so the research team assumed 70% of the Reserve forest would be set aside for forest health and environmental services including wind buffers, flood control, and areas critical to water quality. The available biomass for the Reserve portion is 857,644 m^3.

The annual available biomass is calculated by dividing the available biomass by a 90-year harvest rotation. Annual available biomass for the Crown forest is 56,413 m^3, which does not take into account logging residues that are currently converted into chips as part of regular harvesting operations. Annual available biomass in the Reserve forest is 9,529.4 m^3. Additional biomass might be obtained from residues produced in the nearby MacKenzie Sawmill located across the lake from Frenchman's Head.

2.2 Costs and Long-term Payback

Financial analysis was done using RETscreen. A series of assumptions were made that were common to every analysis done in this section and plugged into the drop-down menus provided in the software, which were:

- A minimum 30-year project life
- 6% financing with 4% debt interest + 2% inflation
- 100% financing for every scenario

Scenarios with shorter payback times were run with 30 or 40% grants to display situations when there is an immediate positive cumulative cash flow. Biomass district heating installation costs were provided by BioThermic™ Inc., which installs Froling™ biomass heating units.

2.2.1 Lac Seul

Lac Seul is made up of three distinct communities with significant distances between them. The heating loads of each of the three communities in Lac Seul is considered individually because of these distances. While biomass can be collected for the whole community and distributed to each of the three satellite communities as needed, each community would require their own biomass district heating plant and heat distribution network. The total heating load for the three communities is approximately 8.8 MW, which would require between 5,700 and 15,700m³ of biomass annually. An initial forest inventory analysis that was done early in the project determined that Lac Seul has an annual allowable biomass harvest volume of approximately 65,900 m³, which would require legal access for harvesting on both Crown land and reserve land.

2.2.1.1 Frenchman's Head

The total heating load for Frenchman's Head is 4.6 MW and a cluster of larger high heat demand and closely-spaced buildings in the centre of the community have a heating load of 1.5 MW. Heat load maps and cost analysis were prepared for these two scenarios. The full community heating map is displayed in Figure 9, and the high heat cluster is shown in Figure 10.

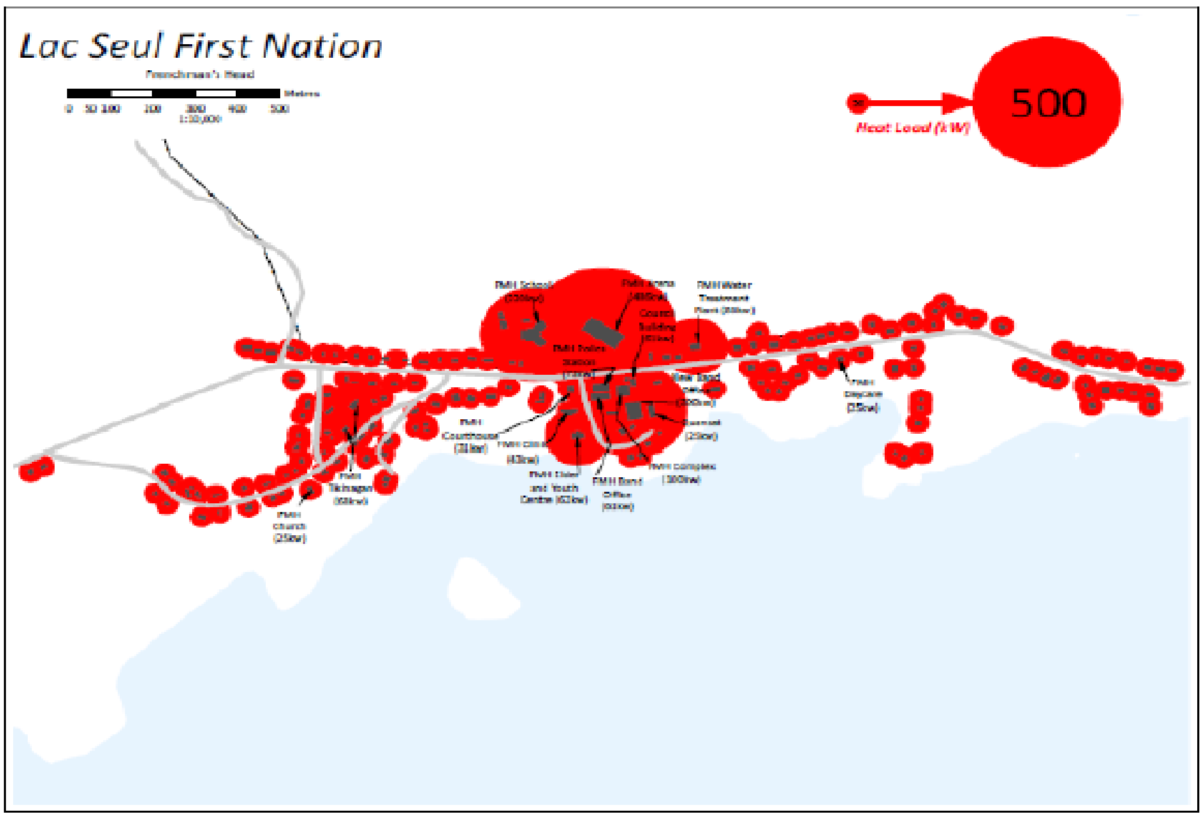


FIGURE 9: HEAT DISTRIBUTION FOR FRENCHMAN'S HEAD, LAC SEUL FIRST NATION
SOURCE: ROBITAILLE, P. (2015)

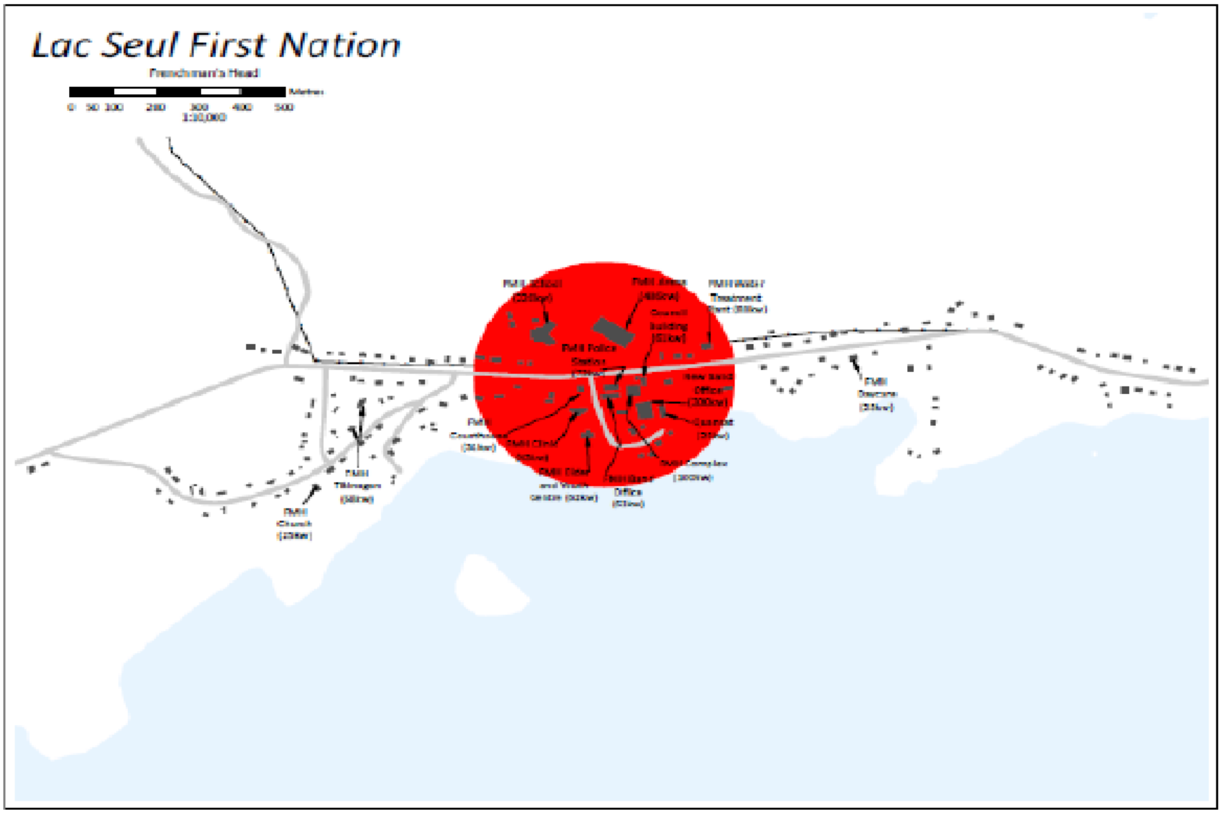
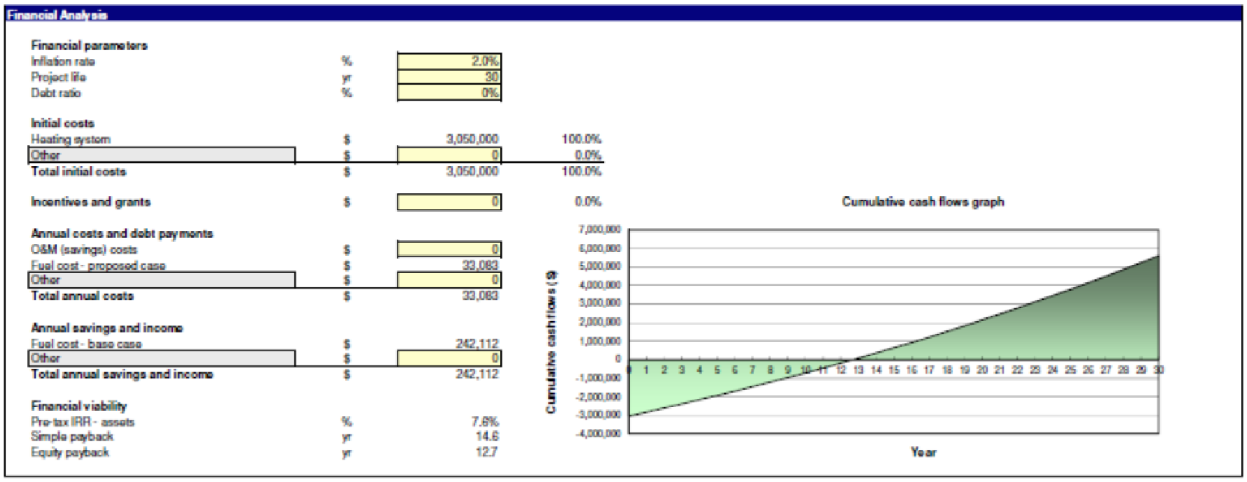


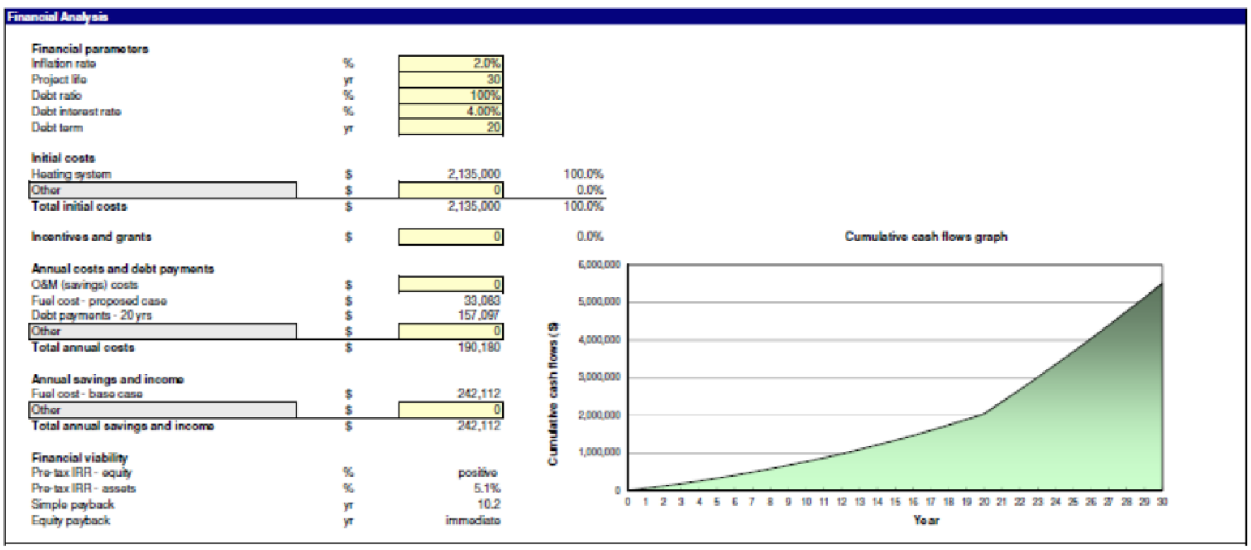
Figure 10: Frenchman's Head High Heat Cluster, Lac Seul First Nation
Source: Robitaille, P. (2015)

Construction costs for the complete community district heating scenario for Frenchman's Head are estimated to be $13.2 million with no return on investment for 24 years (BioThermic, 2015). Construction costs for the high heat demand community cluster district heat scenario in Frenchman's Head are estimated to cost $3.05 million with a payback period estimated to be 15 years. If Lac Seul is able to obtain a grant for 30% of the construction costs, the fuel savings would outweigh the debt repayments immediately. A RETscreen financial analysis for the high heat cluster district heat scenario for Frenchman's Head at 100% financing is shown in Figure 11. A RETscreen financial analysis for the same project, but with a 30% grant for construction costs showing immediate positive cash flows, is shown in Figure 12.



Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	0%	
Initial costs			
Heating system	$	3,050,000	100.0%
Other	$	0	0.0%
Total initial costs	$	3,050,000	100.0%
Incentives and grants	$	0	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	33,083	
Other	$	0	
Total annual costs	$	33,083	
Annual savings and income			
Fuel cost - base case	$	242,112	
Other	$	0	
Total annual savings and income	$	242,112	
Financial viability			
Pre-tax IRR - assets	%	7.8%	
Simple payback	yr	14.6	
Equity payback	yr	12.7	

FIGURE 11: RETSCREEN ANALYSIS, HIGH HEAT CLUSTER;FRENCHMAN'S HEAD
SOURCE: BIOTHERMIC™ INC. (2015)



Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	100%	
Debt interest rate	%	4.00%	
Debt term	yr	20	
Initial costs			
Heating system	$	2,135,000	100.0%
Other	$	0	0.0%
Total initial costs	$	2,135,000	100.0%
Incentives and grants	$	0	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	33,083	
Debt payments - 20 yrs	$	157,097	
Other	$	0	
Total annual costs	$	190,180	
Annual savings and income			
Fuel cost - base case	$	242,112	
Other	$	0	
Total annual savings and income	$	242,112	
Financial viability			
Pre-tax IRR - equity	%	positive	
Pre-tax IRR - assets	%	5.1%	
Simple payback	yr	10.2	
Equity payback	yr	immediate	

FIGURE 12: RETSCREEN ANALYSIS, HIGH HEAT CLUSTER WITH 30% GRANT
Source: BioThermic™ Inc. (2015)

2.2.1.2 Kejick Bay

The total heating load for Kejick Bay is 2.9 MW and the heating load for a cluster of closely spaced high heat demand buildings in the community is 0.5 MW. Heat load maps were prepared for these two scenarios. The full community heating map is displayed in Figure 13, and the high heat cluster is shown in Figure 14.

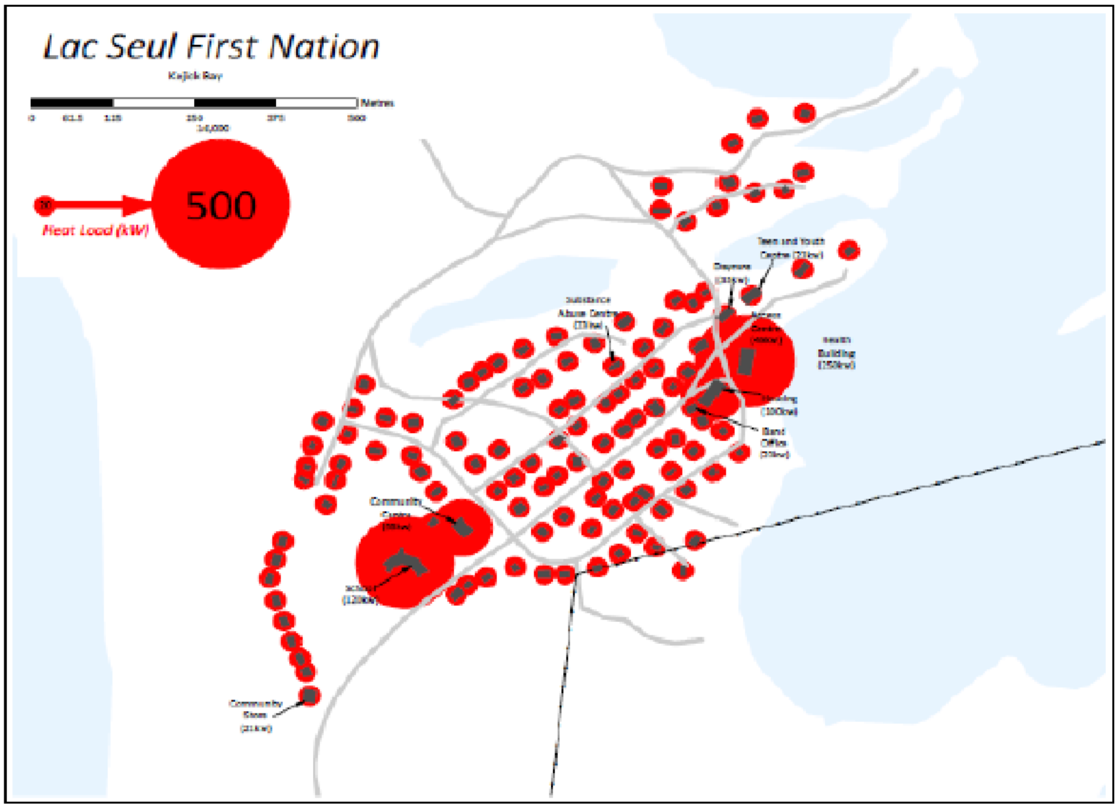


FIGURE 13: KEJICK BAY FULL HEATING MAP
SOURCE: ROBITAILLE, P. (2015)

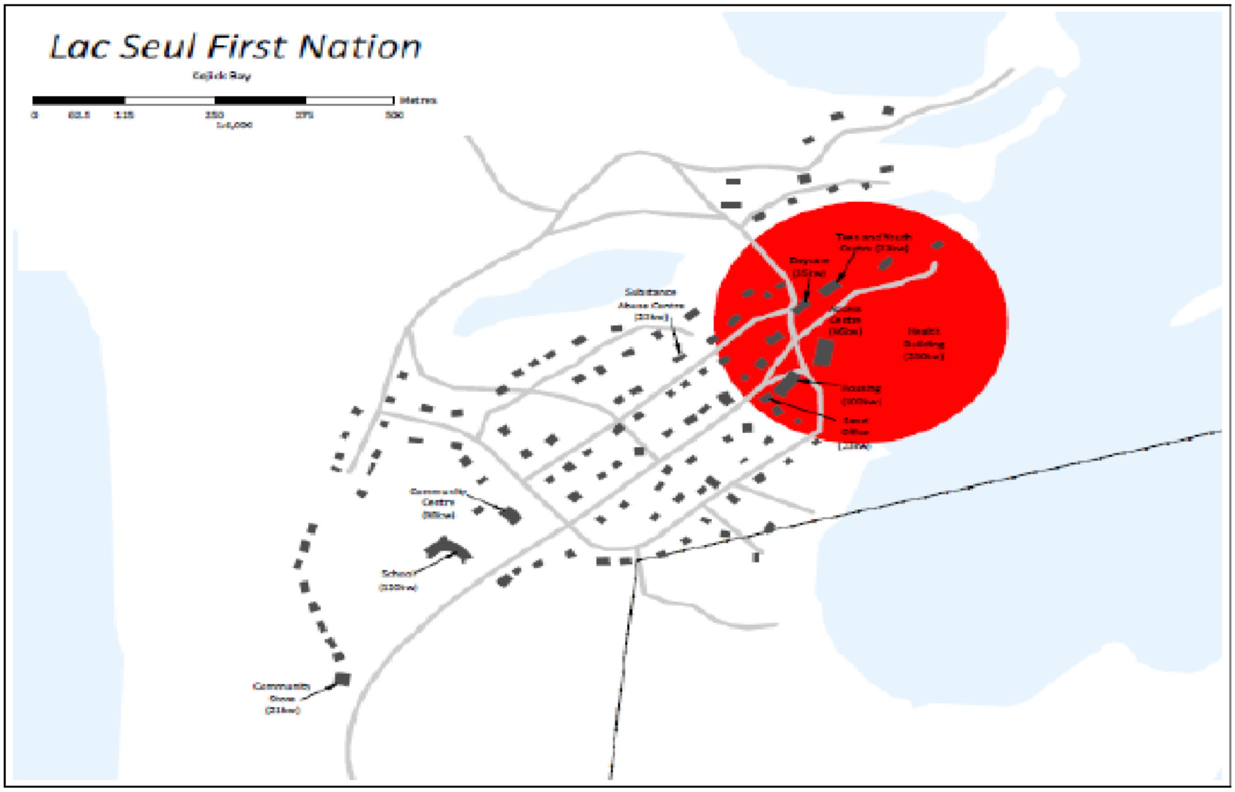
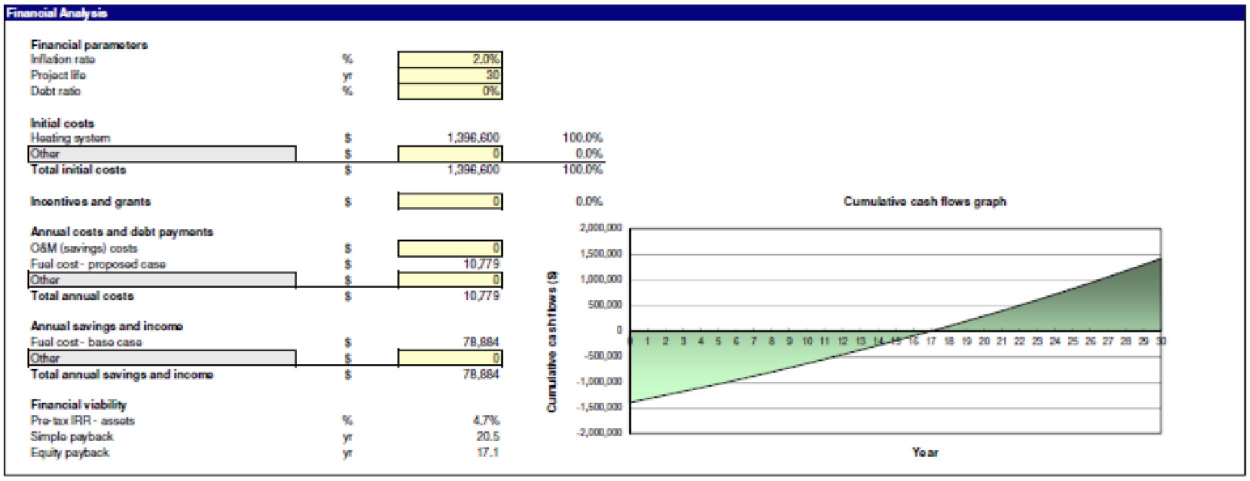


FIGURE 14: KEJICK BAY HIGH HEAT CLUSTER
SOURCE: ROBITAILLE, P. (2015)

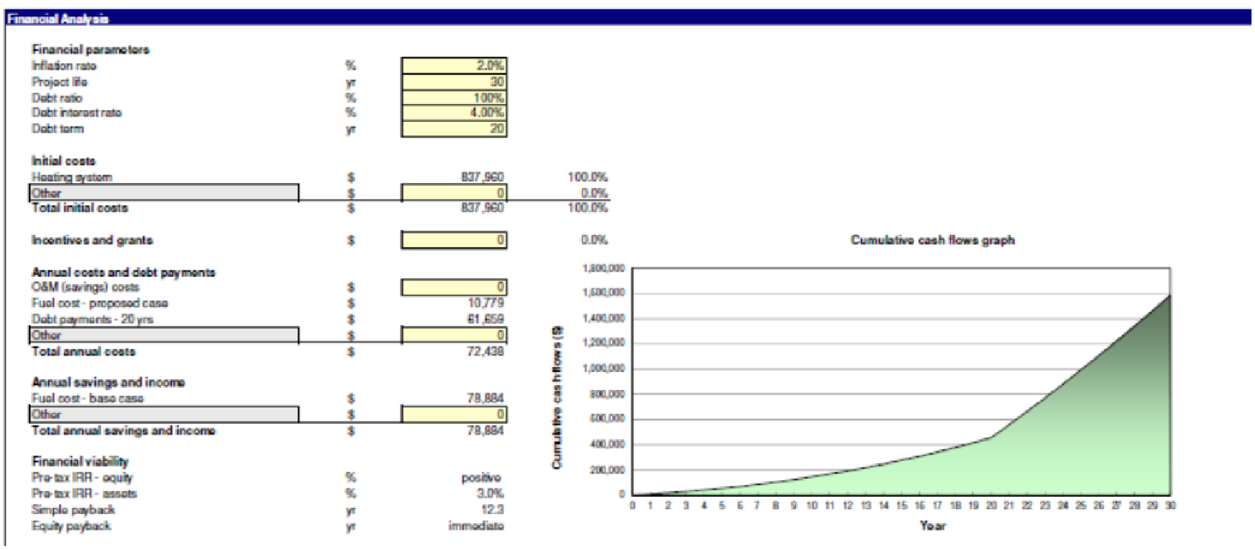
The buildings in Kejick Bay were spread out except for some larger, high heat demand buildings in a cluster at the lake shoreline. The construction costs of the district heat cluster scenario are estimated to be $1.4 million with a payback time of under 17 years at 100% financing. A financial analysis of this district heat cluster in Kejick Bay was done using RETscreen shown in Figure 15. A RETscreen financial analysis was done for the same scenario except with a grant for 40% of construction costs with the rest financed and showing an immediate positive cash flow as shown in Figure 16.



Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	0%	
Initial costs			
Heating system	$	1,396,600	100.0%
Other	$	0	0.0%
Total initial costs	$	1,396,600	100.0%
Incentives and grants	$	0	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	10,779	
Other	$	0	
Total annual costs	$	10,779	
Annual savings and income			
Fuel cost - base case	$	78,884	
Other	$	0	
Total annual savings and income	$	78,884	
Financial viability			
Pre-tax IRR - assets	%	4.7%	
Simple payback	yr	20.5	
Equity payback	yr	17.1	

FIGURE 15: RETSCREEN ANALYSIS, HIGH HEAT CLUSTER; KEJICK BAY
SOURCE: BIOTHERMIC™ INC. (2015)



Financial Analysis

Financial parameters			
Inflation rate	%	2.0%	
Project life	yr	30	
Debt ratio	%	100%	
Debt interest rate	%	4.00%	
Debt term	yr	20	
Initial costs			
Heating system	$	837,960	100.0%
Other	$	0	0.0%
Total initial costs	$	837,960	100.0%
Incentives and grants	$	0	0.0%
Annual costs and debt payments			
O&M (savings) costs	$	0	
Fuel cost - proposed case	$	10,779	
Debt payments - 20 yrs	$	61,659	
Other	$	0	
Total annual costs	$	72,438	
Annual savings and income			
Fuel cost - base case	$	78,884	
Other	$	0	
Total annual savings and income	$	78,884	
Financial viability			
Pre-tax IRR - equity	%	positive	
Pre-tax IRR - assets	%	3.0%	
Simple payback	yr	12.3	
Equity payback	yr	immediate	

FIGURE 16: RETSCREEN ANALYSIS, HIGH HEAT CLUSTER WITH 40% GRANT
Source: BioThermic™ Inc. (2015)

2.2.1.3 Whitefish Bay

Whitefish Bay has a unique layout with some homes across a narrow lake channel away from the main community (see Figure 17). The homes on the south side of the channel were excluded from the total heating load (for logistical reasons and difficulty of construction), which is estimated to be 1 MW.

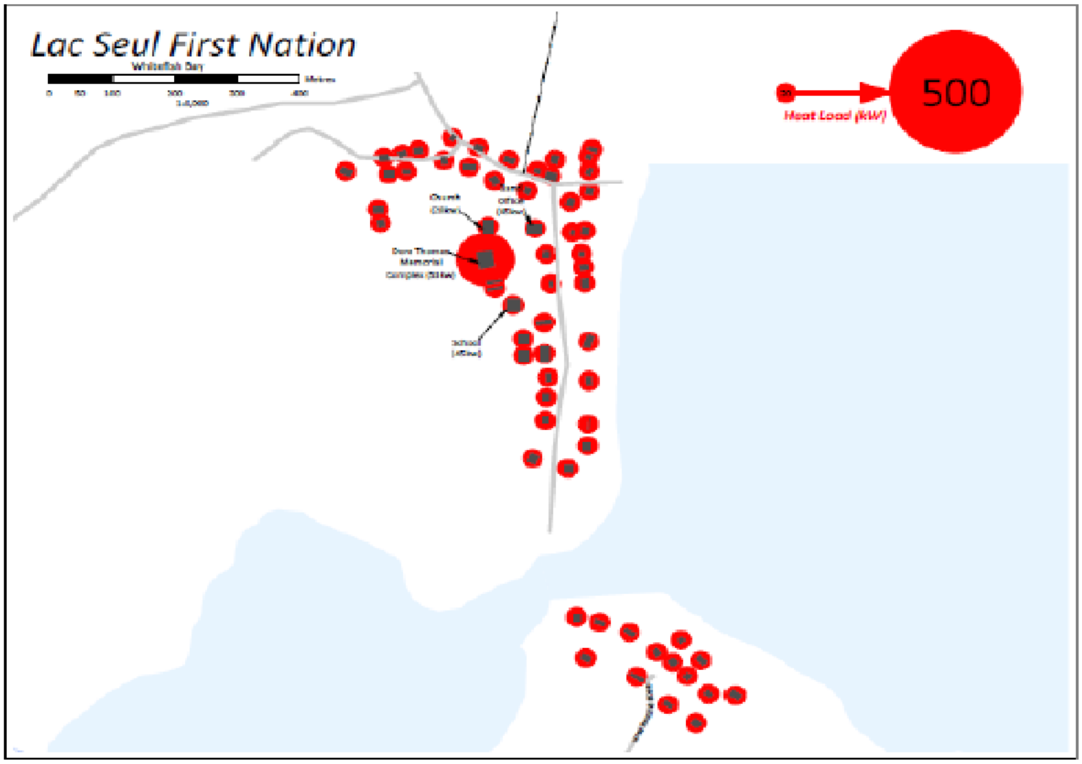


FIGURE 17: WHITEFISH BAY FULL HEAT DISTRIBUTION MAP
SOURCE: ROBITAILLE, P. (2015)

Construction costs for district heating in Whitefish Bay are estimated to be $3.12 million with a payback of 18 years at 100% financing using RETscreen financial analysis (see Figure 18). The same scenario with a grant for 40% of the construction costs with the rest financed shows an immediate positive cash flow using RETscreen as shown in Figure 19.

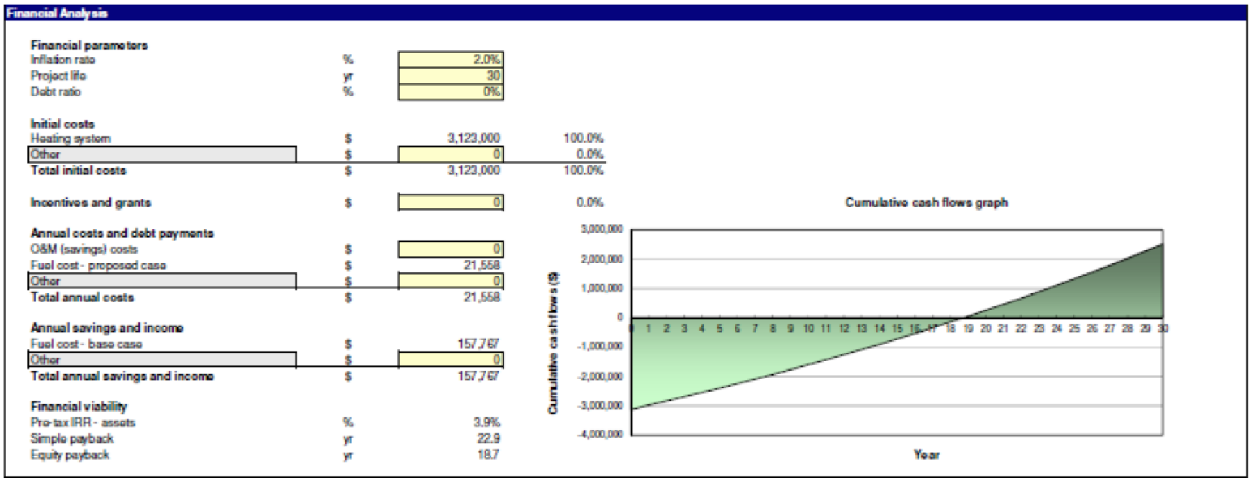


FIGURE 18: RETSCREEN ANALYSIS, WHITEFISH BAY DISTRICT HEAT PROJECT
SOURCE: BIOTHERMIC™ INC. (2015)

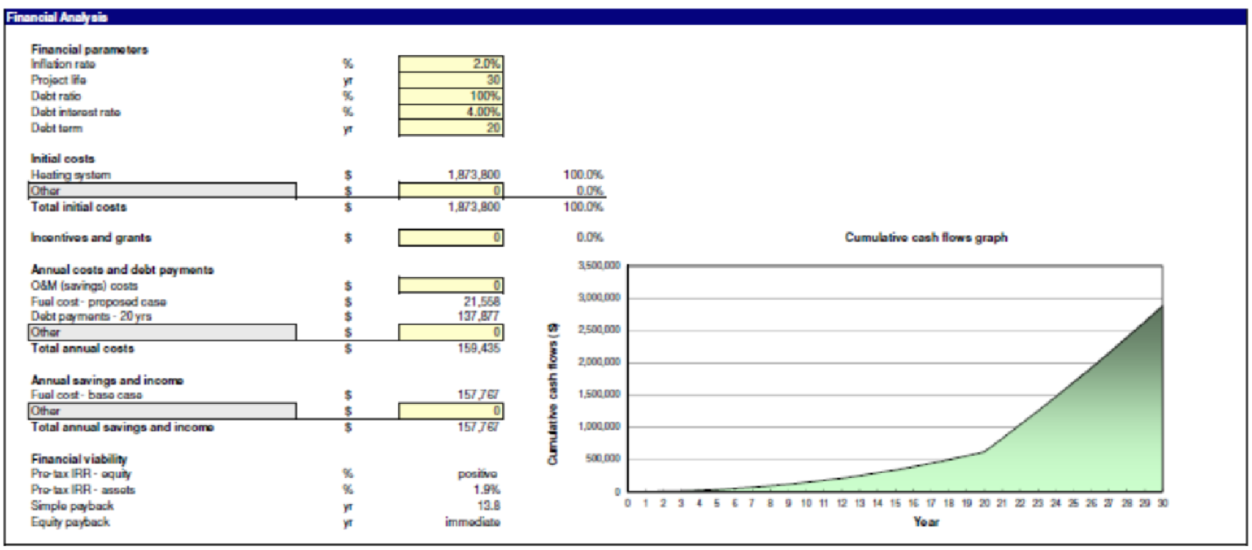


FIGURE 19: RETSCREEN ANALYSIS, WHITEFISH BAY HEAT PROJECT WITH 40% GRANT
Source: BioThermic™ Inc. (2015)

2.2.2 Sachigo Lake

The total heating load for the entire community of Sachigo Lake is estimated to be 5.3 MW, which requires between 4,800 12,800 m³ of biomass annually. The airport is not included in the estimate, since it is several kilometres north of the main community. A heating load map and costing scenario was done for the whole community as shown in Figure 20 and also for a cluster of closely spaced high heating load buildings, which had a heating load of 1.5 MW as shown in Figure 21.

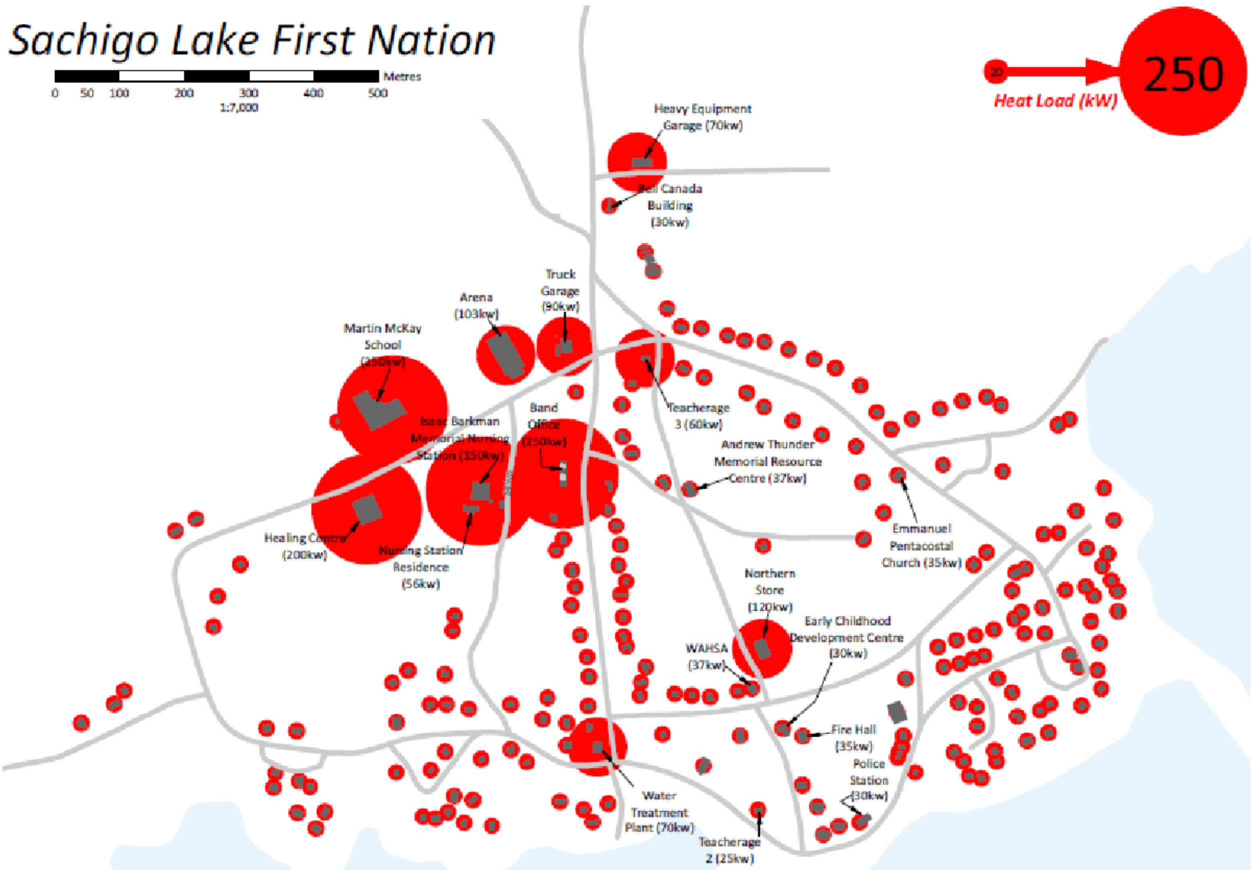


FIGURE 20: FULL COMMUNITY HEAT MAP FOR SACHIGO LAKE
SOURCE: ROBITAILLE, P. (2015)

Complete construction costs for district heating in the entire community scenario are estimated to be $18.4 million with a payback time of over 24 years. The long payback time indicates that the research team considers this scenario to not be financially feasible at this time.

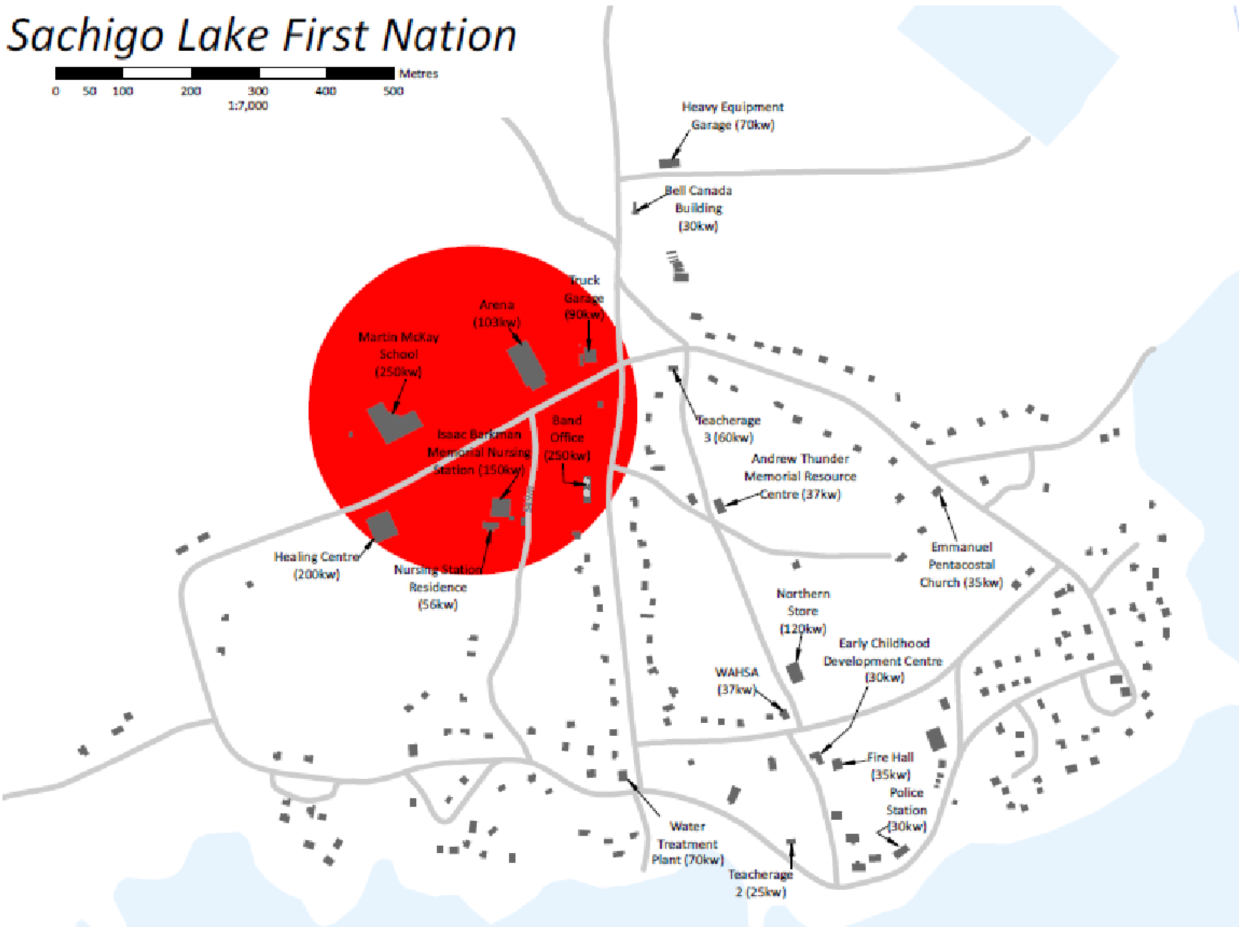


FIGURE 21: HIGH HEAT CLUSTER FOR SACHIGO LAKE
Source: Robitaille, P. (2015)

The high heat demand building cluster scenario has a total construction cost of $3.12 million at 100% financing with a payback time of under 15 years and a cumulative cash flow of over $1,000,000 by the 19th year using RETscreen analysis as shown in Figure 22. The same RETscreen financial analysis for this scenario was done, except with a grant for 30% of construction costs and the rest financed, which shows an immediate positive cumulative cash flow (Figure 23).

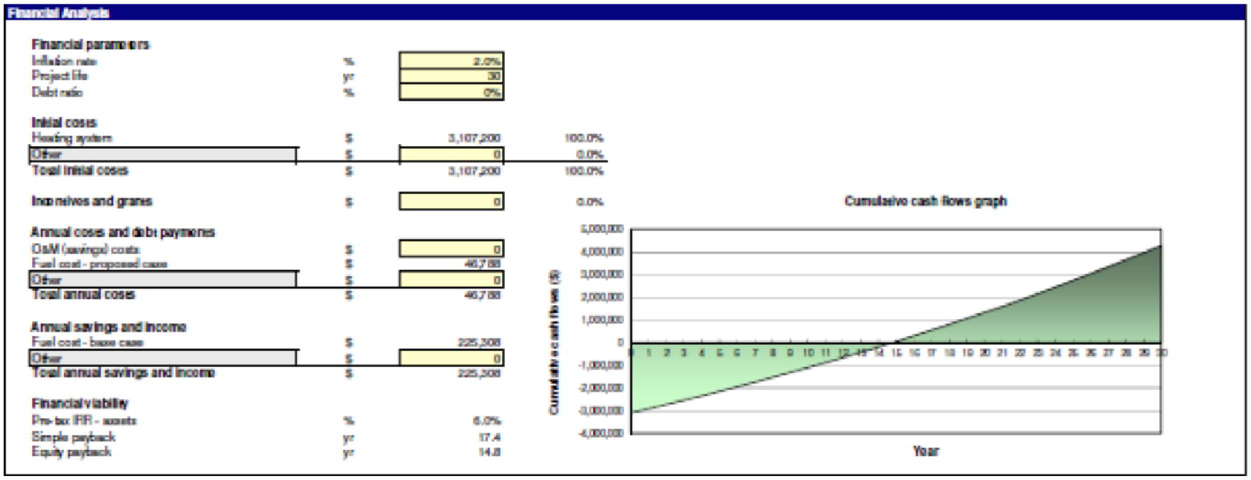


FIGURE 22: RETSCREEN ANALYSIS OF SACHIGO LAKE HIGH HEAT CLUSTER
SOURCE: BIOTHERMIC™ INC. (2015)

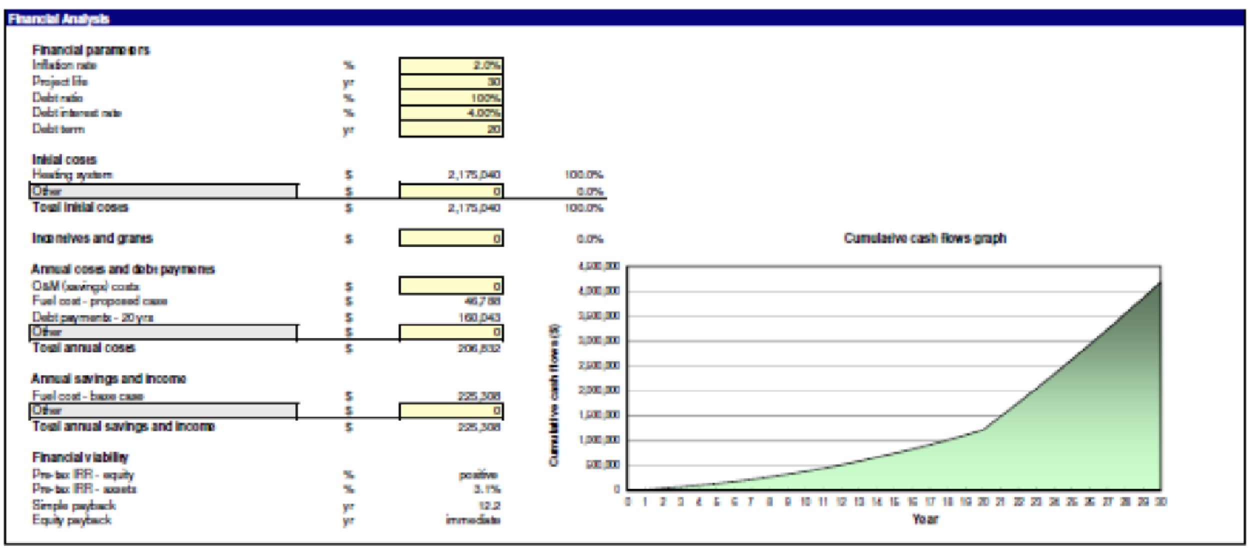


FIGURE 23: RETSCREEN ANALYSIS, SACHIGO LAKE HEAT PROJECT WITH 30% GRANT
SOURCE: BIOTHERMIC™ INC. (2015)

The layout of each community and its buildings influenced the cost and long-term payback period of each project scenario. Scenarios where there were closely spaced clusters of larger high-heat demand buildings had the shortest payback period in each community including Whitefish Bay, where homes across the lake were excluded from district heat hookup. Biomass district heat technology is financially feasible where the layout of the community allows for short piping distances and space is set aside for a biomass storage building and the heating plant. Future community infrastructure planning would be needed to allow space for renewable energy technologies to be placed within communities to reduce cost and complexity of potential projects.

3 EVALUATION OF SOLAR AND WIND RESOURCES

This chapter begins with a listing of the different tools and databases available that were used to evaluate wind and solar power resources using the internet. Section 3.1 examines how wind power works, its advantages and disadvantages and wind statistics for Sachigo Lake and Lac Seul. Section 3.2 examines how solar power works, its advantages and disadvantages and solar resources available in Sachigo Lake and Lac Suel. The chapter ends with justification of eliminating wind power as an energy option for Sachigo Lake and Lac Seul and concentrating on solar power for these communities so the research team could meet time and budget restraints for the project.

There are public, free access resources in Ontario that allow individuals and businesses to evaluate local solar and wind resources from online tools. These tools were used by the researchers and remote First Nation communities can use these resources and educate themselves about renewable energy resources available in their communities. For example, Natural Resources Canada has solar maps for the entire country that display the possible solar resources for an area using a colour-coded scale that is based on latitude, elevation, and average historical weather (www.nrcan.gc.ca/18366). EcoSmart Solar is a non-profit organization that has online maps with colour-coded scales for solar resources specific to each province that can be printed out easily (https://ecosmartsun.com/canadian-solar-maps-province/). The Environment Canada Wind Energy Atlas has maps displaying the estimated average wind speeds in metres per second at 50 metres height for the entire country (http://www.windatlas.ca/maps-en.php?field=EU&height=50&season=ANU). The Ontario

Renewable Energy Atlas has an interactive map system with wind data, hydro data, solar data and other resources on different layers of GIS maps for the entire province that can be printed with different colour-coded layers turned on or off (http://www.gisapplication.lrc.gov.on.ca/REA/Renewable.html?site=REA&viewer=REA&locale=en-US).

The solar and wind data for Sachigo Lake and Lac Seul were collected from these resources as a first step to determining what each community had for potential renewable energy resources. This initial evaluation of wind and solar resources determined whether there were sufficient resources to do a follow-up analysis for more detailed information. What follows is a summary of this data.

3.1 Wind Power

Wind power is a form of solar energy that is created by the uneven heating of the earth's surface and the earth's rotation that creates temperature differentials and wind currents. Rock, soil, vegetation, and water bodies all absorb heat from the sun at different rates during sunlight hours and radiate that heat outward at different rates when the sun is not shining (Cheremisinoff, 1978). Surface topography, like hills, mountains, and escarpments that are near large water bodies, can funnel wind in predictable patterns that can be harnessed by wind turbines (Burroughs et al., 1996). Air currents in coastal areas are also predictable and can also be harvested by wind turbines since water heats faster and retains heat longer than land warming the air above it resulting in warm air moving towards cooler air (Taylor, 2012).

Wind power has been used for thousands of years to power water vessels through the use of sails and for hundreds of years using windmills to harness mechanical power to mill grain and pump water (Narbel et al, 2014, Boyle et al, 2012). The first windmills for grinding grain and pumping water were used between the 7th and 9th century of the common era in Asia and started to appear in Europe in the 12th century (Nelson, 2009). The first practical electrical wind turbine was built in 1887 by Professor James Blyth in Glasgow, Scotland, had cloth sails, and was 10 metres high (Taylor, 2012). This early wind turbine only created enough electricity to power ten 25-watt light bulbs but was proof of concept of the technology.

Modern day electrical wind turbines have metal or composite blades and create electricity by converting the mechanical energy of the wind from the spinning blade through a gearbox that powers a generator. Wind generators can be found in sizes that range from a one-metre turbine producing 100 peak watts to hundred metre and larger turbines producing between two and seven megawatts, which is enough electricity to power up to 3,000 homes. The average Canadian residential household electricity consumption in 2010 was 11,879 kWh per year and would require a wind generator with a 5 kW generating capacity to power it assuming there is adequate wind energy available (OMAFRA, 2010).

Global wind energy use has increased by 24% per year since 1990 (IEA, 2017). Wind-generated electricity met almost 4% of global electricity demand in 2015 and is expected to double between 2014 and 2021 (IEA, 2017). Wind-generated electricity costs in the U.S. in 2015 were one sixth of what they were in 1980 (AWEA, 2017). Onshore wind power costs are expected to fall 47% and offshore wind power costs are expected to fall 71% globally by 2040 (BNEF, 2017). Wind energy installed generation capacity in Ontario in 2016 was 4,213 MW, which was 11% of total supply (IESO, 2017).

Wind turbines do not create emissions while harvesting wind for electrical energy but do have emissions associated with them during their manufacture and installation. Winds are intermittent making energy from wind intermittent since energy cannot be stored with a wind turbine. Small communities with only one or two energy sources would need a battery system to store excess energy or another generation source to send power to the electricity grid when there is minimal or no wind, which increases the cost and complexity. As stated in section 2, the average cost of onshore wind energy is $64.5 per MWh (USEIA, 2017). These costs include capital, operational and fuel costs, but since there is no fuel cost to wind energy, capital costs and operational costs are higher. Higher capital costs for a small community means more money needs to be raised upfront or financed.

Wind turbines have large towers that must shipped and assembled and require a cleared flat space to install them. Wind turbines can also kill birds and bats, especially if they are placed on a migratory route. Many small communities have small airports near the community and large wind towers can be a hazard, especially in poor weather with smaller aircraft that do not have radar.

Wind energy is very site-specific and can change with elevation, proximity to water bodies, and terrain. Wind maps will give general information over large areas but can underestimate wind speeds in small specific areas. The most accurate way to measure wind speeds in a specific area is to use a wind anemometer at a fixed height over multiple years. Small wind data logger kits with weatherproof containers and USB ports to export information are available for a few hundred dollars each and are easy to use (Scientific Sales, 2017).

Promising sites for wind energy use can be studied as part of a long-term project for a community

3.1.1 Wind Potential for Sachigo Lake

The Environment Canada Wind Energy Atlas displays different average wind speeds for an area as different colours on a map with provincial boundaries lightly highlighted, but little information is available for specific locations. In Figure 24, the approximate area of interest is encircled. A Google Earth map was used side by side as a reference to locate the area of interest, which in this case is Sachigo Lake shown in Figure 24.

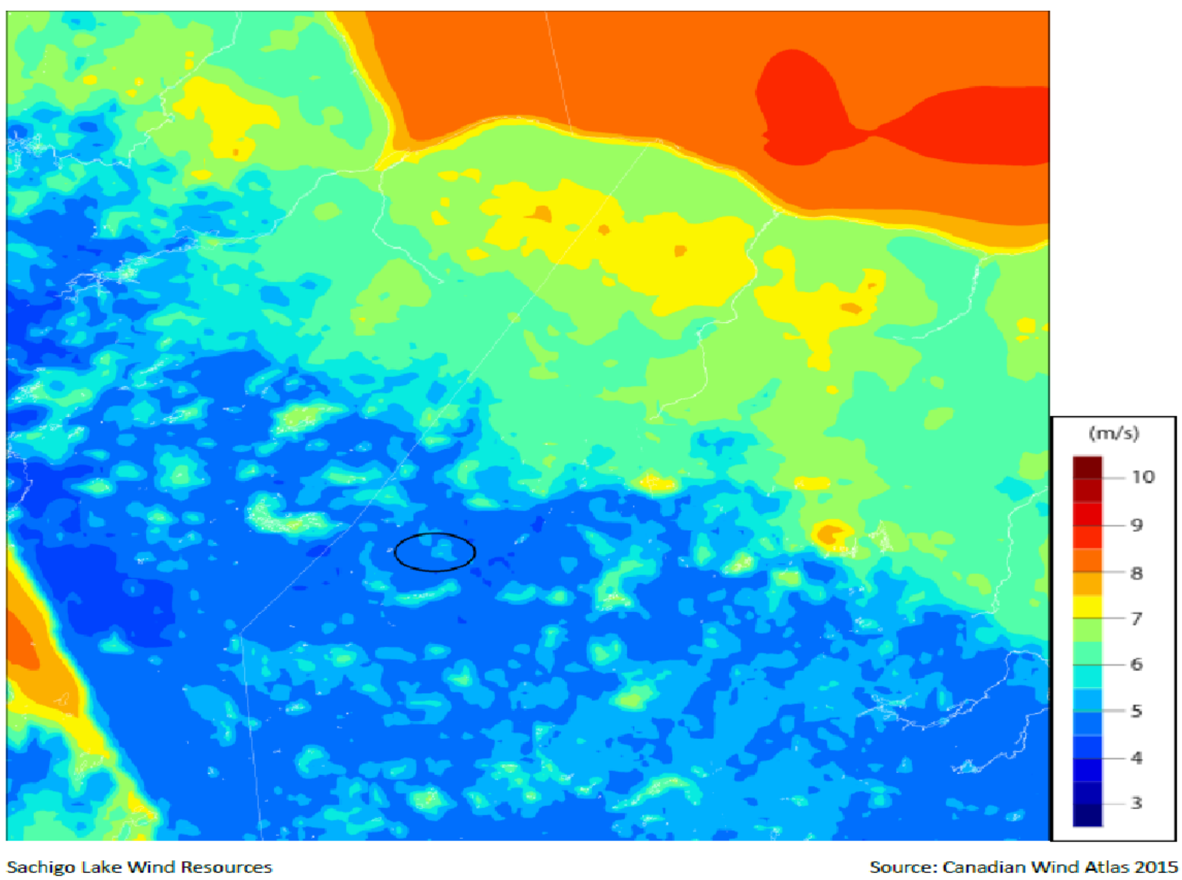


FIGURE 24: SACHIGO LAKE AVERAGE WIND SPEEDS
SOURCE: CANADIAN WIND ATLAS, 2015

The provincial Ontario Renewable Energy Atlas can zoom into pre-set regional areas within Ontario. The wind energy layer colour can be turned on or off for reference and laid over the map using different colours to represent different wind speed classes (Figure 25). The Ontario Renewable Energy Atlas shows that an average wind speed of six m/s is the threshold between marginal and acceptable wind resources for a viable wind project in Ontario, using a colour-coded scale that can be overlaid on its maps. A zoomed-in depiction of that scale is shown in Figure 26.

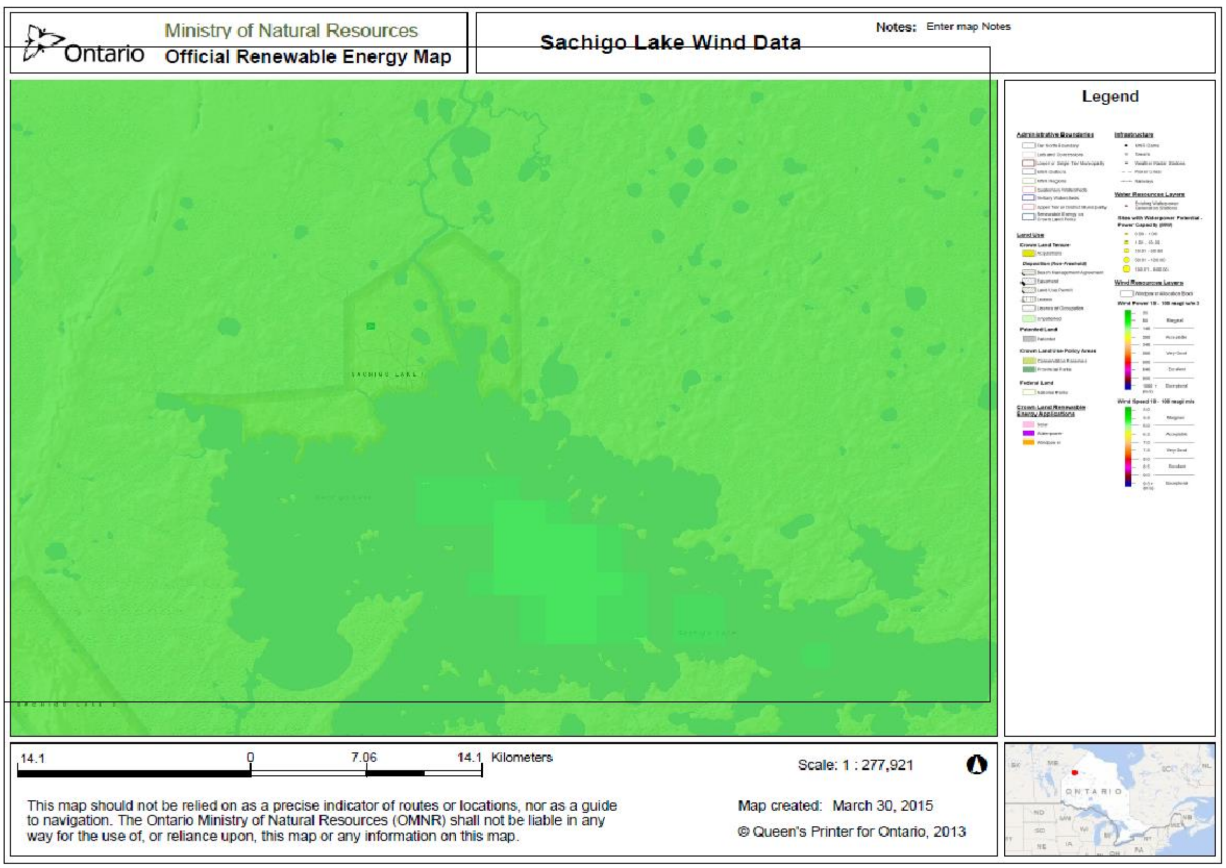


FIGURE 25: WIND SPEED MAP OF SACHIGO LAKE
SOURCE: ONTARIO RENEWABLE ENERGY ATLAS, 2015

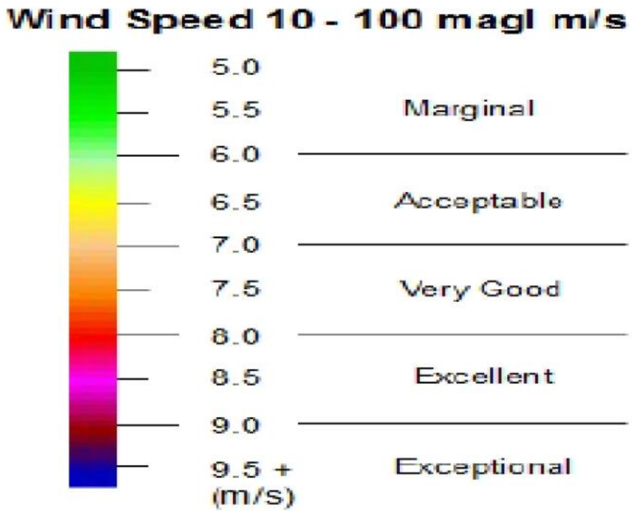


Figure 26: Wind Speed Viability Code. Source: Ontario Renewable Energy Atlas, 2015

The Environment Canada Wind Energy Atlas also has tables that show numerical values for average wind speed and average wind energy for Sachigo Lake (at a 50 m height Sachigo Lake's latitude and longitude) (see Table 3). Average annual wind speed values are the simplest and easiest way to understand measures of wind resources and are the typical starting point for evaluating whether a site is suitable for a wind energy project. Wind energy figures are used to calculate the ideal size and style of windmill and the surface area of its blades that will harness the most energy for a particular project and are most relevant once a project is already in the planning stages.

TABLE 3: SACHIGO LAKE WIND SPEED AND WIND ENERGY NUMERICAL VALUES

Numerical Values at 50m

Latitude = 53.911, longitude = -92.172

Period	Mean Wind Speed	Mean Wind Energy	Weibull shape parameter (k)	Weibull scale parameter (A)
Annual	5.27 m/s	129.25 W/m2	2.17	5.95 m/s
Winter (DJF)	5.70 m/s	155.00 W/m2	2.31	6.43 m/s
Spring (MAM)	5.01 m/s	113.13 W/m2	2.13	5.66 m/s
Summer (JJA)	4.79 m/s	95.06 W/m2	2.22	5.41 m/s
Fall (SON)	5.87 m/s	173.00 W/m2	2.25	6.62 m/s

Source: Environment Canada Wind Energy Atlas.

Annual wind resources for Sachigo Lake are on an average at 5.27 m/s according to Environment Canada data and Ontario Renewable Energy Atlas data.

3.1.2 Wind Potential for Lac Seul

The wind resources areas of Lac Seul are shown in Figure 27; with the area of interest circled on an Environment Canada Wind Energy Atlas map with the colour-coded wind speed scale in m/s.

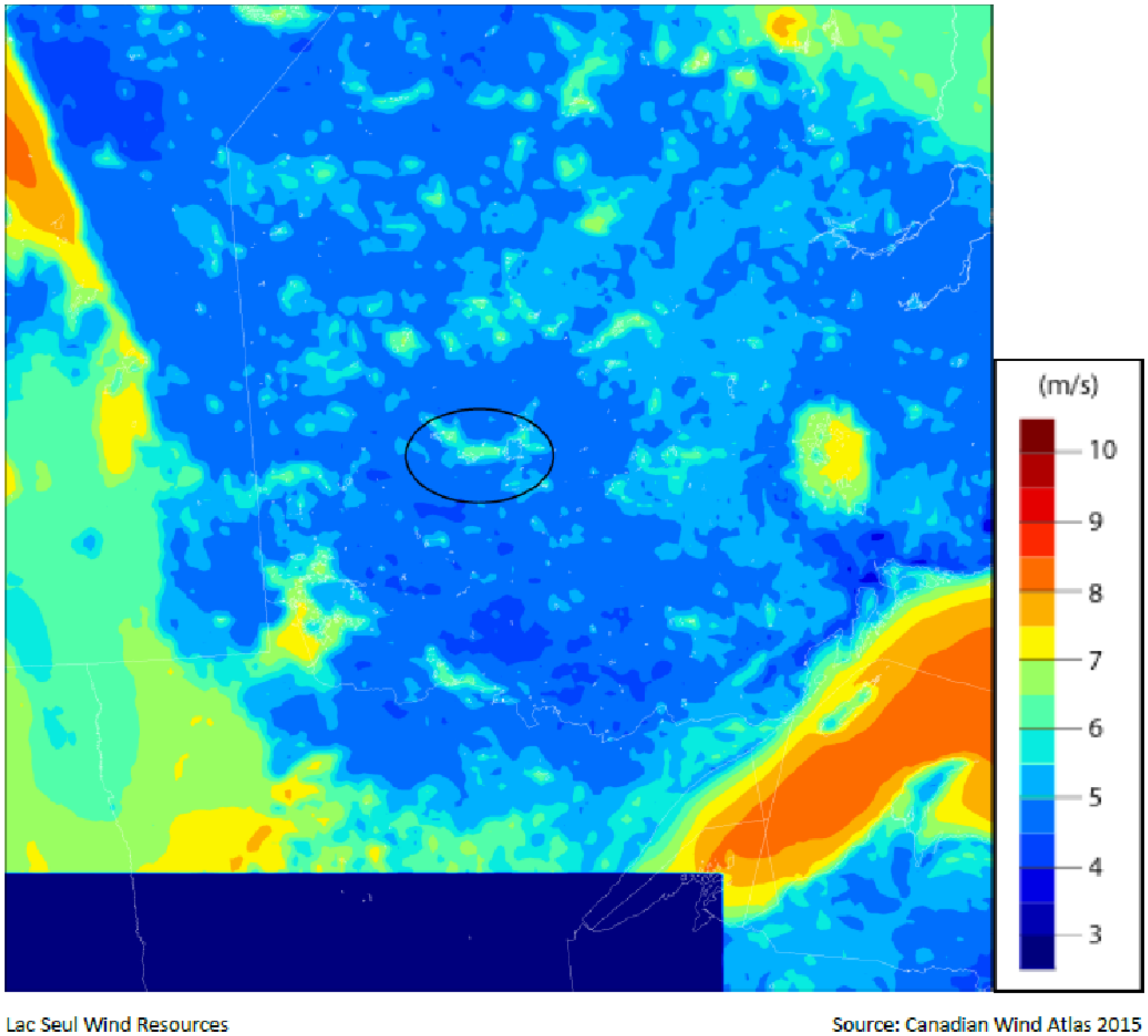


FIGURE 27: LAC SEUL AVERAGE WIND SPEEDS
SOURCE: CANADIAN WIND ATLAS, 2015

The Ontario Renewable Energy Atlas with the colour-coded wind speed layer turned on and overlaid onto the region of Lac Seul is shown in Figure 28. A zoomed-in depiction of the wind speed scale is shown in Figure 29.

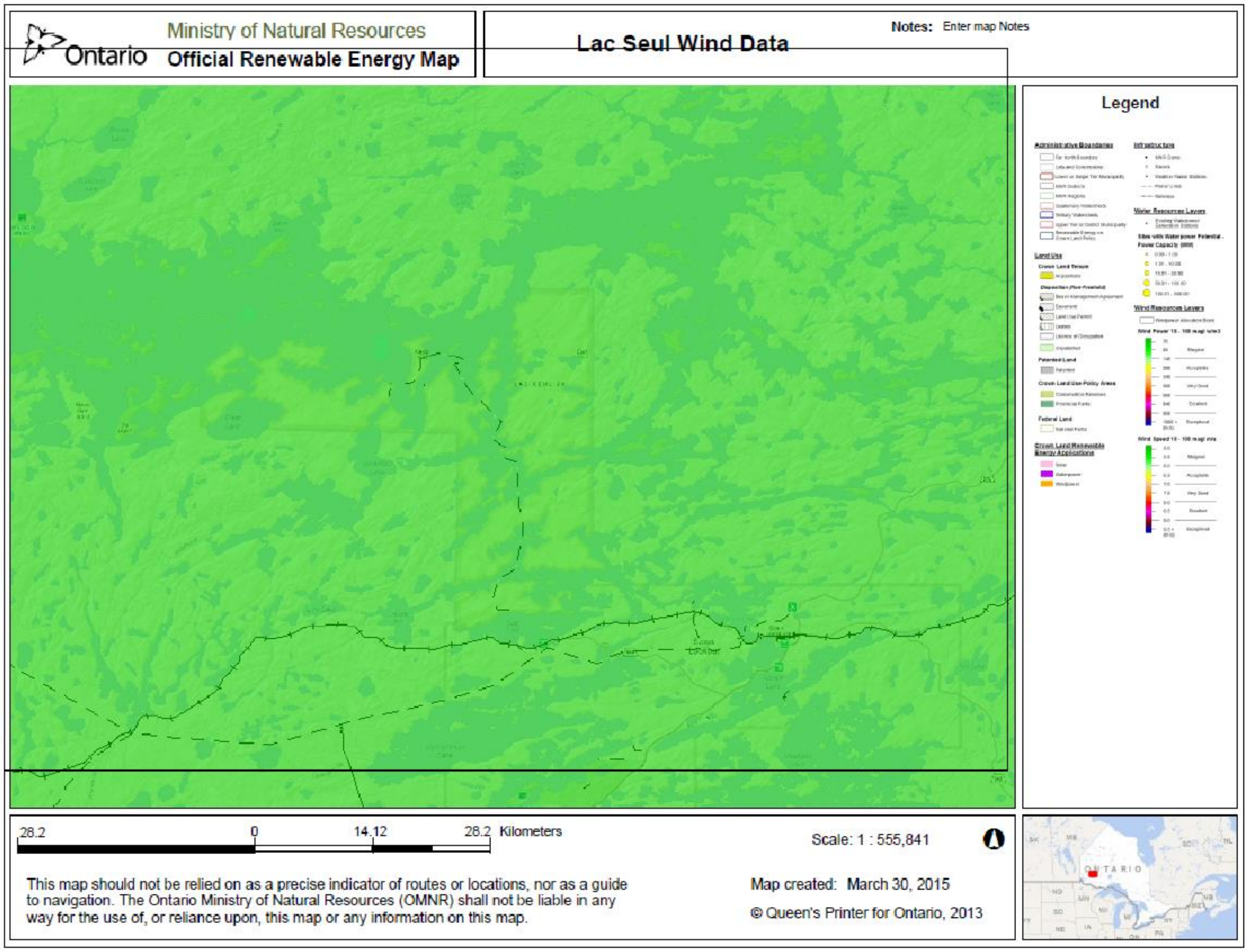


Figure 28: Wind Speed Map of Lac Seul
Source: Ontario Renewable Energy Atlas, 2015

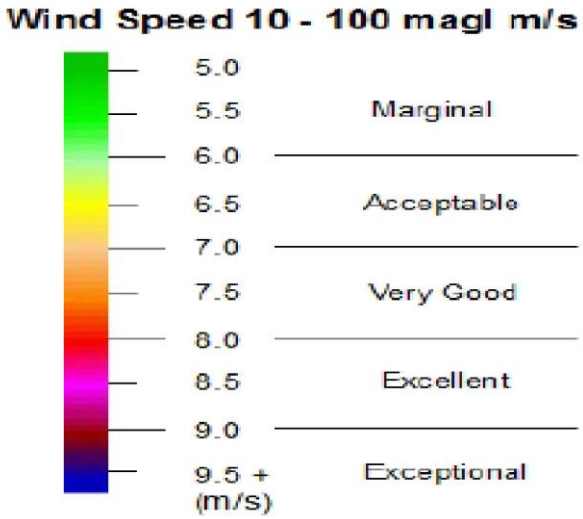


Figure 29: Wind Speed Viability Threshold
Source: Ontario Renewable Energy Atlas, 2015

Table 4 shows the Environment Canada Wind Energy Atlas with the numerical values for average wind speed and average wind energy for Lac Seul at 50 m height.

Table 4: Lac Seul Wind Speed and Energy Numerical Values

Numerical Values at 50m

Latitude = 50.133, longitude = -92.235

Period	Mean Wind Speed	Mean Wind Energy	Weibull shape parameter (k)	Weibull scale parameter (A)
Annual	4.91 m/s	105.00 W/m2	2.16	5.54 m/s
Winter (DJF)	5.29 m/s	125.00 W/m2	2.30	5.98 m/s
Spring (MAM)	4.66 m/s	92.13 W/m2	2.11	5.27 m/s
Summer (JJA)	4.26 m/s	66.19 W/m2	2.25	4.81 m/s
Fall (SON)	5.21 m/s	122.63 W/m2	2.22	5.88 m/s

Source: Environment Canada Wind Energy Atlas

The annual wind resources for Lac Seul are on an average at 4.91 m/s according to the Environment Canada and Ontario Renewable Energy Atlas data. The threshold between acceptable and marginal wind resources is a wind speed of 6 m/s.

3.2 Solar Power

Solar power is defined as power derived from the heat or light of the sun. The sun creates large amounts of energy, some of which hits the earth and is absorbed or radiated back out into space (Everett, 2012). The use of solar passive heating dates back over 2000 years to ancient Greece and Rome where courtyards were built from stone facing south to capture heat from the winter sun after de-forestation and clearing land for agriculture led to a shortage of wood for building materials and for heating (Butti and Perlin, 1980). Two types of solar power that can be harnessed for electrical or heat energy that are suitable for small communities were examined, solar photovoltaic power and solar thermal power, which includes active solar hydronic heat and passive solar air heat.

3.2.1 Solar Photovoltaic Power

Photovoltaic panels capture light photons and convert them directly into electrical energy. The first modern semi-conductor photovoltaic solar cell was developed in the Bell labs in 1953 using technology developed a few years earlier when the first modern semi-conductor transistor was developed (Chapin et al., 1954). This technology can be mounted on the ground or onto the roof of a building. Solar cells require only light as fuel, have no moving parts and can be built durable enough for harsh environments. Solar cells were used to charge batteries which powered a small satellite name Vanguard 1 in 1958 that demonstrated the use of solar technology, which is now common in spacecraft, satellites and space stations. Worldwide solar photovoltaic electricity generation has grown by 45.5% per year since 1990 (IEA, 2017).

Solar photovoltaic power was not listed as part of the electricity generation supply in Ontario in 2004 (IESO, 2017). Solar power made up 0.0185 TWh of the electricity supply in Ontario in 2014 (less than 1%), 0.25 TWh of the electricity supply in 2015 (less than 1%) and 0.46 TWh of the electricity supply in 2016 (about 1%) (IESO, 2017). Solar power electricity supply in Ontario increased by almost 25 times between 2014 and 2016.

The costs of solar photovoltaic installations, which includes solar panels, power control components, mounting hardware and installation labour, have dropped 60% worldwide since 2010 (Scientific American, 2016), (IEA, 2017). Solar photovoltaic panels cost was $77 per watt in 1977 and fell to $0.64 per watt in 2015, a 99% price drop (BNEF, 2017). Solar photovoltaic worldwide installed capacity is expected to triple between 2014 and 2021 (IEA, 2017).

Solar photovoltaic power is intermittent and can be used to offset diesel-derived electricity but cannot be stored without a battery system, which increases costs and complexity. The number of daylight hours at a specific latitude can be calculated accurately but cannot predict foggy, rainy or snowy weather that will reduce the amount of sunlight solar photovoltaic panels will harvest. Northern communities that receive high snowfall must take into consideration and budget for the need to clear snow from panels mounted on rooftops to maintain sunlight harvest and the safety of workers clearing the snow. The average cost of solar photovoltaic energy is $84.7 per MWh, which includes capital cost, maintenance costs and fuel costs (USEIA, 2017). Solar photovoltaic panels do not have fuel costs since they harvest sunlight and have no moving parts which should make maintenance costs minimal, which increases the capital costs and the money and financing needed up front by a small community to install a project.

3.2.2 Solar Thermal Power

There are two types of commonly used solar thermal heat: 1) hydronic heating that is generated by panels filled with liquid that capture heat from the sun which is then pumped into hydronic heating systems for domestic hot water or space heating and 2) solar air heaters that have multi-layered dark-coloured tubes that heat air for use in a passive or forced air heating system. Solar thermal liquid heating panels can be used to pre-heat liquid on the return line of a hydronic biomass district heating system. The second type of solar thermal heating—solar air heaters—can be used as an air pre-heating system to increase the efficiency of forced air systems or to augment another heat source or reduce fuel use. These systems are simple and durable and there are models small enough that can be retrofitted into an existing home or larger models into buildings through existing heating ductwork to pre-heat incoming air. Global solar thermal energy use has grown by 11.4% per year since 1990 (IEA, 2017).

3.3 Solar Potential for Sachigo Lake and Lac Seul

Natural Resources Canada publishes solar potential interactive online maps for all regions of Canada, organized by province. The interactive maps show provincial boundaries and provincial capitals but little other location information. The areas of both communities are outlined with a blue-shaded box and labelled. A map of northwestern Ontario, within which both Lac Seul and Sachigo Lake are located, is shown in Figure 30, with colour-coded solar potential and the accompanying scale.

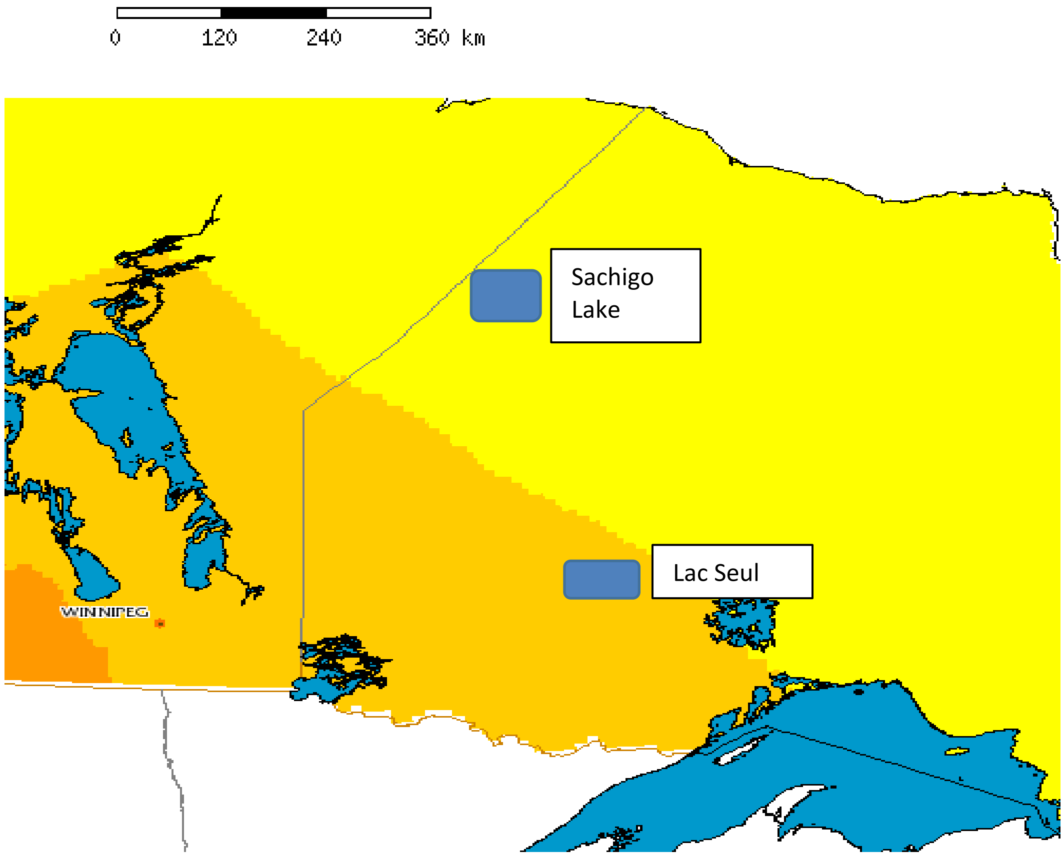


FIGURE 30: SOLAR POTENTIAL OF NORTH-WESTERN ONTARIO
SOURCE: NRCAN 2015
Legend: Photovoltaic potential (kWh/kW) South-facing, tilt=latitude Annual

- 0 - 500 kWh/kW
- 500 - 600
- 600 - 700
- 700 - 800
- 800 - 900
- 900 - 1000
- 1000 - 1100
- 1100 - 1200
- 1200 - 1300
- 1300 - 1400
- 1400

EcoSmart Solar publishes maps of solar potential in Ontario for homeowners and solar installation contractors. These maps offer more local detail than the Natural Resources Canada maps (see Figures 31 and 32). The areas of interest have been outlined and labelled.

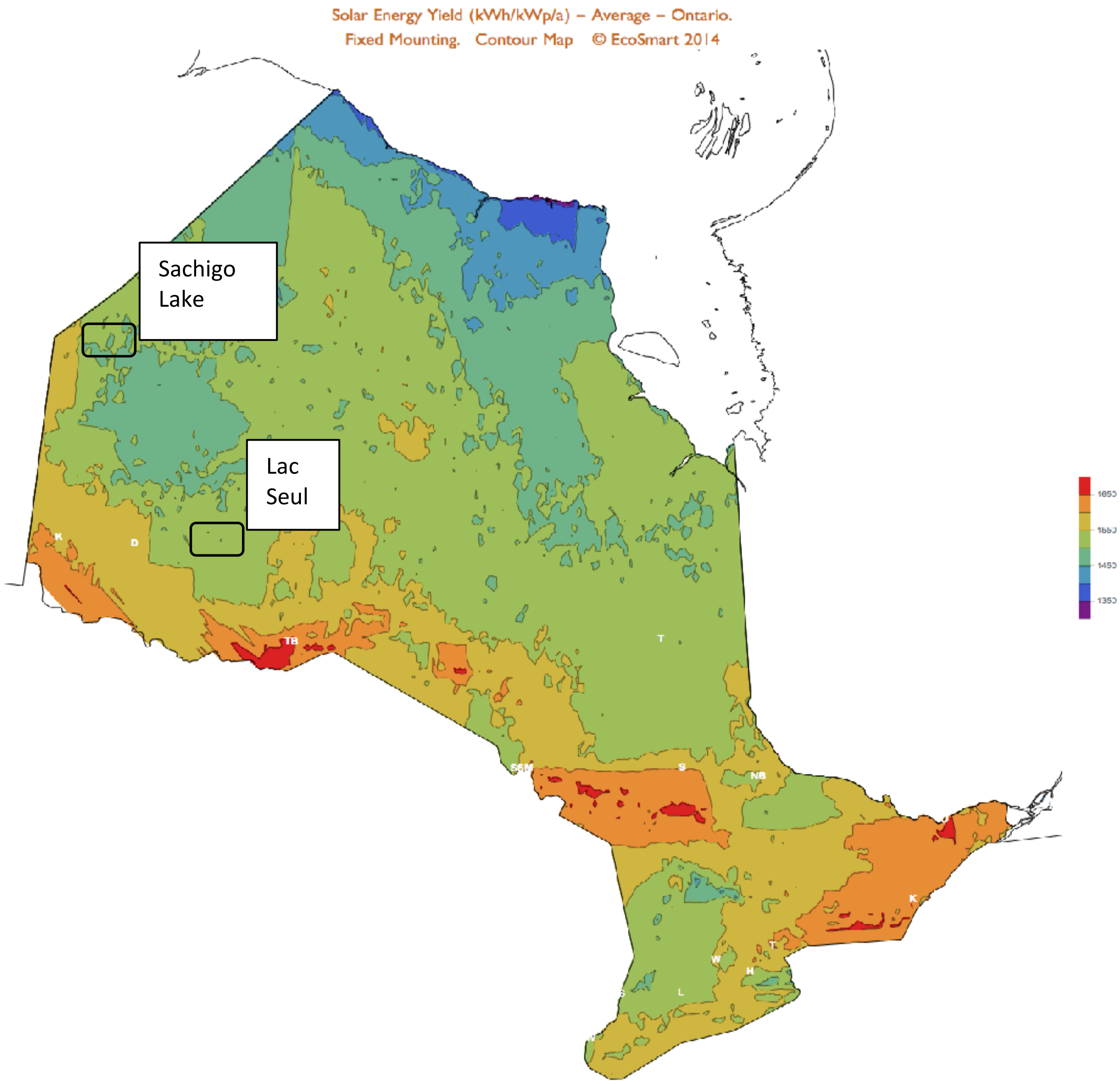


FIGURE 31: SOLAR ENERGY YIELD IN ONTARIO (KWH/KW)
SOURCE: ECOSOLAR, 2014

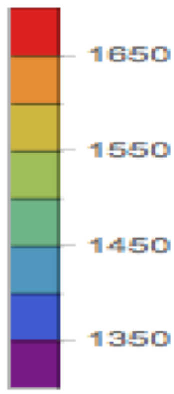


FIGURE 32: SOLAR YIELD SCALE ENLARGEMENT
SOURCE: ECOSOLAR, 2014

The renewable energy evaluation tools provided by the Canadian federal government, Ontario provincial government and renewable energy websites that were used to make the initial evaluation of solar and wind resources in Sachigo Lake and Lac Seul were easy to use and access from the internet. Wind resources for Sachigo Lake and Lac Seul fell below six metres per second, which is considered the threshold between marginal and viable according to Natural Resources Canada and the Ontario Renewable Energy Atlas. Solar resources for Sachigo Lake and Lac Seul were in the mid to high range from the Natural Resources Canada solar maps and the EcoSmart solar maps. The research team decided not to recommend wind power for follow-up analysis and to perform follow-up analysis of solar resources in both communities based on this initial evaluation.

4 SOLAR POWER ANALYSIS

This section begins with a description of how the solar power analysis was planned, followed by section 4.1 which describes the methodology and tools used. Section 4.2 examines the physical layout of each community including tree cover which had the potential to shade buildings that solar panels could be mounted on. Section 4.3 describes how solar site data were gathered, which included daily, monthly and annual average sun hours. Section 4.4 used information from the previous section to analyse savings expected when using solar power to replace electricity at present costs. Section 4.5 evaluates the 25-year solar power potential of each community using information from the previous sections. The final section, 4.6, uses information from the entire section to calculate potential project long-term payback for both communities and sums up the results.

Analysing the solar power potential of each community required analysis at every stage of the research project. Available resources were examined to determine the quality of solar resources for each community before the fieldwork was scheduled. Available images of community infrastructure and layout were also examined at this time. Images from potential solar sites of community infrastructure and solar obstructions from both communities were collected during the fieldwork portion of the project. Solar savings and payback analysis were done after the fieldwork portion of the project using all the information and images collected.

4.1 Solar Methodology

The next step after the preliminary analysis of publicly available solar maps as reported above was to examine publicly available road, tourist, fishing and hunting maps and Google Earth imagery to see the layout of each community. Because the fieldwork data collection for the entire project was limited to ten days in each community, including the forest resource inventory and solar data, it meant there was limited time for the solar analysis portion of the project. Thus, pre-scouting possible solar sites before fieldwork began was done in order to save time and speed up the site selection process once the research team arrived in each community.

Paper maps and electronic maps of infrastructure were later supplied by each community and it was found that these did not contain enough details on the surrounding area and forests or on the community infrastructure. GIS files were then accessed through the Lakehead University Scholar's Geoportal spatial database. It was found that while these images were good resolution, the layers were complex to work with and the forest cover layer did not have enough details on the size of trees present within community infrastructure boundaries. Larger trees will shade out possible solar sites. In the end, Google Earth was used because of the clear images and the ease of manipulation. The community infrastructure-forestland interface shows up clearly on Google Earth images of the communities, and forests and trees show up in their actual colours and not in chosen layer colours common to GIS maps. Trees sizes could be estimated by the shadows cast, keeping in mind that trees close to buildings obstruct sunlight and reduce the amount of solar energy reaching a building.

The final site decisions were made after visually inspecting each area from the ground. About two-thirds of the potential sites were eliminated because of obstructions that reduced solar exposure but were not visible on maps or Google Earth™. There were three criteria that determined whether a site was suitable for a detailed solar analysis:

1. Close proximity to electrical power lines.

2. Good southerly exposure with minimal obstructions (i.e., trees, buildings).
3. Large buildings with large roof surfaces

The first criterion was deemed to be the most important since there were many possible sites with southerly exposure but limited electrical infrastructure. Long distances between a solar array and electrical lines increase the voltage losses, costs and complexity of a project. The third criterion was considered optional in areas with large open spaces with southerly exposure, since some solar arrays can be positioned on ground mounts. Officials from one of the communities also asked that we look at one site that was not part of the community infrastructure but was used by some community members; this request was accommodated.

4.2 Community Analysis

The layout of each community is different, which had an impact on the results. Sachigo Lake is a single, closely-spaced community with the majority of its infrastructure in a small geographic area at the north end of the community, whereas Lac Seul is made up of three different smaller communities spread along the shoreline of its lake many kilometres from each other.

The community of Sachigo Lake is oval-shaped with a series of east-west roads running parallel to the shoreline of its lake, bisected by the north-south road that leads to the airport which lies to the north of the community. This is where the diesel generator power plant is located. The layout of the community of Sachigo Lake with the sites where solar data were collected are marked in yellow in Figure 33.

FIGURE 33: SACHIGO LAKE SOLAR SITES OVERVIEW
Source: Google Earth 2015

Lac Seul First Nation is made up of the three communities of Frenchman's Head, Kejick Bay, and Whitefish. The small community of Hudson is also nearby across the lake. While not officially part of Lac Seul First Nation, it has a building that houses a training centre that is used by the community and the office of Obishikokaang Resources Corp. that manages forestry operations for the Lac Seul Forest.

It was decided that solar data would be collected on each of the three communities as well as on the Hudson training centre/forestry building to supply the community with data on multiple solar options should they choose to pursue one or more solar projects in the future. Figure 34 provides an overview image that shows the spread-out nature of the three communities within Lac Seul First Nation and the nearby town of Hudson; sites where solar data were collected are in yellow.

FIGURE 34: LAC SEUL'S THREE COMMUNITIES AND HUDSON
Source: Google Earth 2015

The community of Frenchman’s Head is built around a main road along an east-to-west axis that runs parallel to the north shoreline of the lake, giving most buildings a good southerly exposure. The arena, school, band office, Elder centre, nursing station, and the water treatment plant are all located in a cluster either on or just off the main east-west road at what is considered the centre of the community. The Frenchman’s Head Lac Seul Resort is located a few kilometres east on the same road, ending on a point on the lake facing southwest. It was included as a study site at the communities’ request because it is used by some community members.

The east-west road through Frenchman's Head is on a gentle south-facing slope above the shoreline and has good southerly exposure with the only obstructions being a few buildings and a few trees on the south side. Figure 35 provides an overview of Frenchman's Head, showing the cluster of infrastructure and the proximity of the east-west road to the shoreline. It also shows the location of Hudson on the south shoreline of the lake where solar data were collected at the front of training centre/forestry building.

FIGURE 35: FRENCHMAN'S HEAD WITH HUDSON ON SOUTH SHORE
Source: Google Earth 2015

The community of Kejick Bay is isolated from the other Lac Seul communities with a single road into the community from Frenchman's Head and a single road out of the community travelling north. It is laid out on a narrow strip of land on the shoreline of the lake with a north-south road leading into the community and the majority of buildings built on a pair of inlets on the west side of the peninsula. The health centre and the band office face southeast and are near the shoreline of the bay. The school and the community centre are inland from the bay and also face southeast. The electrical transmission lines in Kejick Bay are smaller, lower voltage single phase lines and not the larger three phase lines that are present on the west end of Frenchman's Head; this limits the size of a possible solar project that can be accommodated. An overview of Kejick Bay is shown in Figure 36.

FIGURE 36: OVERVIEW OF KEJICK BAY
Source: Google Earth, 2015

The community of Whitefish is the smallest of Lac Seul's communities. It is built on two isthmuses protruding out into the lake with a short north-south causeway joining them and with the majority of the buildings on the north isthmus. Both are on the western shoreline of the lake. Whitefish is a small community with a limited choice of solar sites as it only had two large buildings with lots with southeast exposure facing the open lake. The electrical lines in

Whitefish are smaller single-phase lines and not the higher capacity three-phase lines that go into Frenchman's Head. The lower capacity lines will restrict the size of a possible photovoltaic solar project and its long-term financial viability. The sites chosen were the best that could be seen and were both located on the north side of the community. An overview of Whitefish with the tested sites marked in yellow is shown in Figure 37.

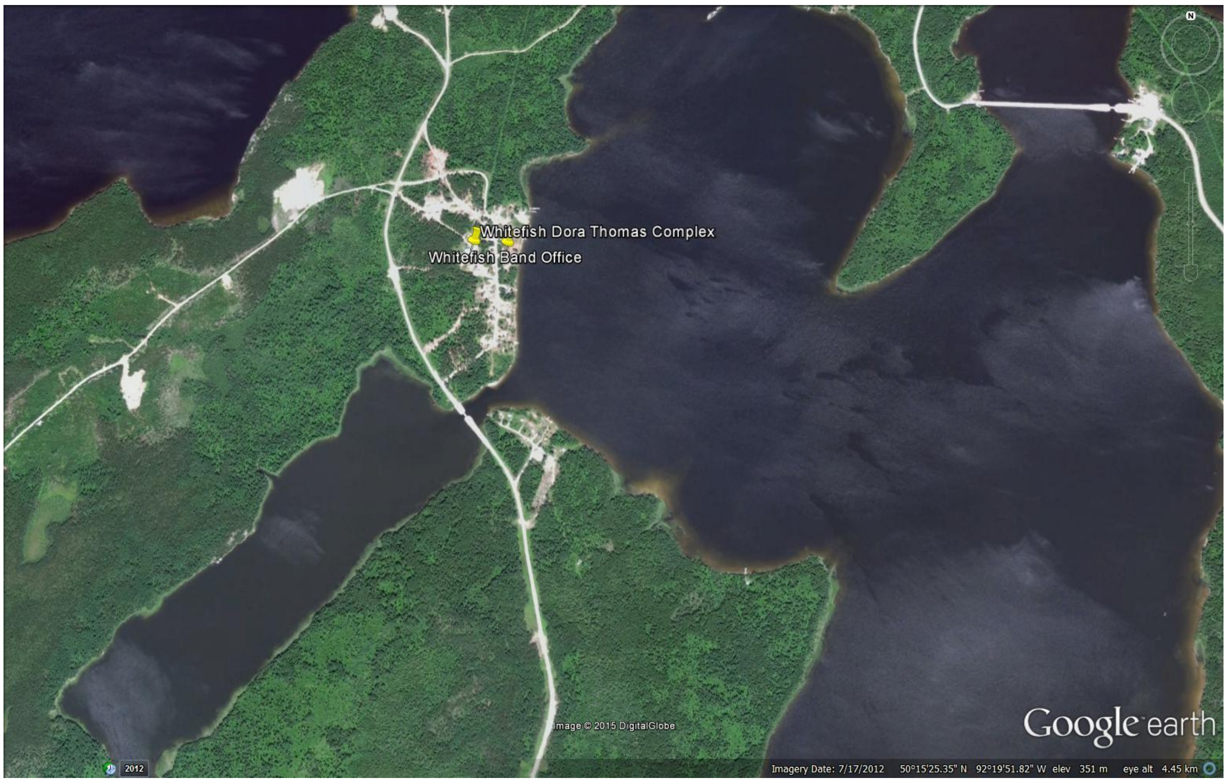


FIGURE 37: OVERVIEW OF WHITEFISH BAY
Source: Google Earth 2015

4.3 Solar Analysis

The Solar Pathfinder™ with the associated P.V. Studio™ software calculated total daily, monthly and annual sun hours for each site. The software allowed for the creation of an individual report for each test site. The three types of analysis and reports that can be created are:

1. Ecological: general daily, monthly, and annual sun hours at chosen site.
2. PV (photovoltaic solar): Monthly and annual savings using a chosen number and model of a manufacturers' photovoltaic panels in a solar array (from a drop-down menu).
3. Solar Thermal: Monthly and annual savings using a chosen number and model of a manufacturers' solar thermal collectors in a solar array (from a drop-down menu).

The ecological report was done for all solar sites as it contains all the basic solar and site information needed for basic financial analysis. The PV and solar thermal reports use the information from the ecological reports to calculate projections for specific makes and models of solar panels and solar thermal collectors for a proposed project. Panel choices programmed into the PV analysis software were in a drop-down menu. I selected the Canadian Solar™ CS6X-300M 300-watt panel because it is a popular model made in Canada, designed for harsh conditions, and available from multiple Ontario solar distributors and installers (Solar trader.ca, 2015; Gooffthegrid.ca, 2015). There are other panels in the same size class that will give similar results and can be substituted at a later time as an additional option into the software if desired.

The Solar Pathfinder™, with its wide-angled and highly reflective dome, is designed to capture images using a digital camera, which is focused at a right angle above and parallel to the dome, of site obstructions that could shade each potential site. Images were taken at ground level only for safety reasons, which means that sites that were evaluated at large buildings with the intention of solar panels being mounted on their roofs will have lower annual sun hours compared to images captured from the height of the roofline. Actual sun hours will be higher for these buildings and can be recalculated with new images from a Pathfinder™ at roof height by the community should they wish to have more accurate sun hour measurements as part of a fuller feasibility study.

The Solar Pathfinder™ was placed at what was determined to be the centre point of a south-facing potential solar array using a forester's measuring tape in cleared areas along the east-west axis with the aid of a hand-held forester's compass. Sites with buildings used the south-facing side with the Pathfinder™ placed at approximately the middle point of the east-west axis of the roof even where the entrance was on a different side as long as there was a large roof space where solar panels could be mounted. The compass in the centre of the Pathfinder™ was aligned to due south since North America is in the northern hemisphere and receives southerly sun exposure, with correction for magnetic declination and levelled using the level bubble in the centre of the face. A clear digital image was taken with a camera from 30-40 centimetres away as parallel to the dome bottom plate as possible with the reflections of the obstructions as clear as possible on the face of the dome and on the Sunpath™ diagram underneath the dome. A sample image that was taken with the Pathfinder set up correctly is shown in Figure 38.

FIGURE 38: PATHFINDER™ IMAGE ON SUNPATH™ DIAGRAM

The data captured by the Solar Pathfinder™ were used to generate an ecological site report that included the monthly and annual percentage of unshaded sun exposure at 180° south azimuth. Correction for magnetic declination is done by rotating the outer ring the appropriate number of degrees west in the case of the two communities studied. The ideal panel tilt angle, which equals the latitude angle of the site, is the default angle programmed into the software. The data on monthly and annual actual full unshaded sun hours is produced from the image captured on the Solar Pathfinder™ reflective dome, which shows obstructions as shaded areas, and the known sun exposure at the given latitude, which is displayed on the latitude-specific Sunpath™ diagram (see Figure 39).

The site with the highest number of annual sun hours and average daily sun hours is considered the site with the best solar resources with the potential to produce the most solar power. The monthly level of sun hours is also important since there is a higher variance of sun hours between summer months and winter months at higher latitudes. For example, several readings of “zero” monthly direct sun hours were recorded at two different sites because of the low winter sun and forest obstructions. Monthly variance in power production is also an important factor when planning the integration of a solar project as intermittent electricity production into the local grid can be an issue.

The ideal panel tilt angle is the same as the site latitude angle in order to maximise the amount of daily sunlight captured by panels; it is the right angle to the sun at noon on June 21, which is the day of the year with the longest daylight. The least amount of daylight occurs on December 21 when the northern hemisphere is seasonally tilted away from the sun and causes the sun to appear lower in the sky. Increasing the panel tilt angle by 10° to 15º above latitude is a common practice to increase winter sun harvest but this lowers the summer sun harvest and slightly lowers the overall annual sun harvest. Increasing the panel tilt angle is nonetheless helpful in reducing the seasonal variance in sun harvest when there is an issue of integrating intermittent solar power into a sensitive grid environment.

The Sunpath™ diagrams have the sun hours for each day and month at a specific latitude pre-plotted onto them and allow for the subtraction of hours where reflection of obstructions are visible. Sachigo Lake First Nation is located at north 53.87º latitude so the 54º-56º range Sunpath™ diagram was used. Lac Seul First Nation is located at north 50.12º so the 49º-51º range Sunpath™ diagram was used. The image was then loaded into the PV Studio™

software and cropped and centred with a tracing of the obstruction reflections entered with a computer mouse. The software then made the sun-hours calculation automatically once the tracing image was saved in the software. The original image with the tracing and a second image showing just the tracing over a Sunpath™ diagram was produced and included for each site report, as shown in Figure 39.

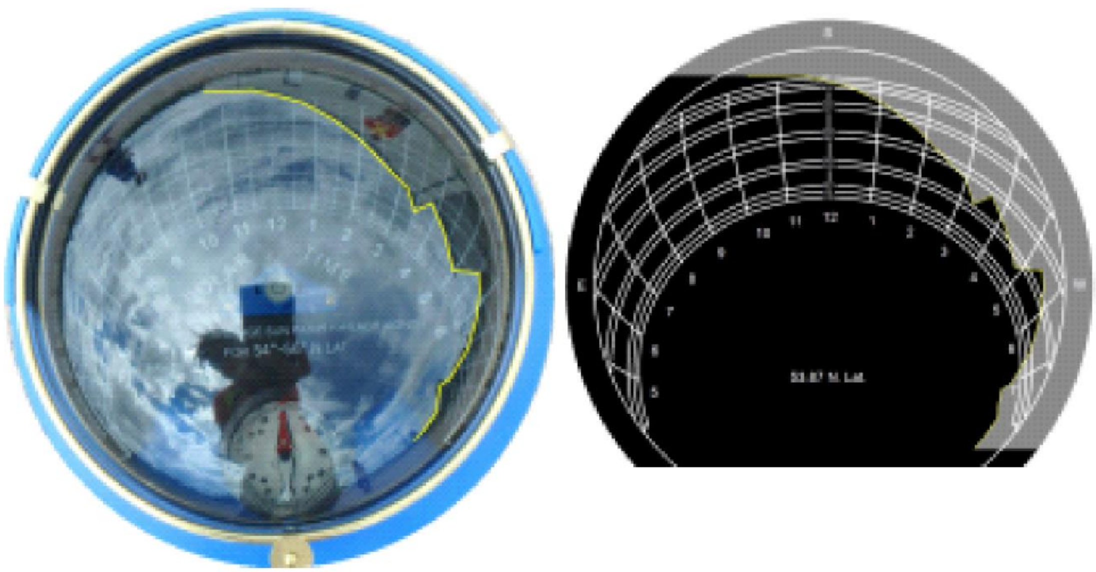


FIGURE 39: PATHFINDER™ OBSTRUCTION TRACING OVER SUNPATH™ DIAGRAM

The data outputs from the Solar Pathfinder™ ecological reports were then entered into the accompanying PV Suite™ software, which created four-page reports for each site and included all the site information and sun hours analysis as well as the financial savings analysis for each solar power scenario and which were used to create the tables included. The results and reports were separated by community since Sachigo Lake First Nation and Lac Seul First Nation are located at different latitudes and have different electricity providers and rates. Each community was given a copy of their community's report.

Information that was recorded and contained on the first page of all reports was:

- Site location name
- Report date
- Magnetic declination
- Latitude and longitude (the software rounds to 2 decimal places)
- Closest weather station
- Distance from nearest weather station
- Type of report: Ecological, photovoltaic, or solar thermal
- Array type: fixed or adjustable angle
- Ideal panel tilt angle
- Ideal panel orientation or azimuth

4.3.1 Sachigo Lake Site Data

The initial site selection for collecting solar data was 20 sites, which was narrowed down to the seven sites listed after the research team arrived in the community and visually examined the sites. Large trees and buildings that shaded other buildings eliminated many sites as did the lack of electrical transmission lines and southerly exposure.

The following is a summary of information on Sachigo Lake that was common to all of that community's sites.

- Report date: 28/01/2015
- Magnetic declination: -2d 39m
- Latitude and Longitude: 53.89º / -92.19º

- Closest weather station: Winnipeg Int'l. MB, Elevation 239 metres, (49.900/-97.233)
- Distance from weather station: 563 kilometres
- Report type: Ecological
- Array type: Fixed angle
- Ideal tilt angle: 53.89º

Ideal azimuth: 180.00º

Sachigo Lake had seven sites where data were collected:

- The airport
- The community arena
- The community garage
- The front of the motel (attached to the band office)
- The rear area of the motel
- The nursing station
- The front of the school (lined up with the centre of the roofline)
- The west side of the school

Multiple images were taken from the motel and the school areas because they were large areas that appeared to have different levels of visible obstructions (i.e., treeline and buildings) that could be compared.

A comparison of the monthly and annual total unshaded sun hours at the various sites in Sachigo Lake is shown in Table 5.

Table 5: Monthly and Annual Measured Sun Hours in Sachigo Lake

Sachigo Lake	Total Corrected Average Daily Sun Hours (53.89° Latitude & tilt angle)												Annual
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
Airport	2.93	4.24	5.48	5.53	5.70	5.60	5.73	5.68	4.57	3.63	2.45	2.36	**4.49**
Arena	1.57	2.63	4.11	5.26	5.66	5.56	5.70	5.51	3.69	2.72	1.56	1.19	**3.76**
Garage	0.00	0.00	3.26	5.45	5.62	5.58	5.69	5.63	4.01	0.00	0.00	0.00	**2.94**
Motel Front	2.07	3.09	4.21	4.59	5.19	5.40	5.44	4.86	3.26	2.44	1.64	1.53	**3.64**
Motel Rear	1.69	3.32	5.28	6.47	6.01	5.52	5.54	4.51	3.06	1.74	1.29	1.24	**3.81**
Nurse Station	0.00	3.92	5.21	5.46	5.66	5.55	5.69	5.63	4.30	3.36	1.20	0.00	**3.83**
School Front	2.46	3.59	4.95	5.08	5.29	5.23	5.29	5.23	4.09	3.04	1.89	1.44	**3.97**
School west	2.87	4.18	5.36	5.38	5.58	5.51	5.64	5.53	4.47	3.61	2.30	2.05	**4.37**

4.3.2 Lac Seul Site Data

Site data for Lac Seul was broken into two groups: the main community of Frenchman's Head which had the most infrastructure where seven sites were analyzed; and the smaller communities where seven sites were analyzed in total—Kejick Bay with four sites, Whitefish with two sites, and one site at the Hudson Training Centre building in the nearby community of Hudson. The number of sites analyzed in the smaller communities was based on the size of the communities, the size of the area, and available potential sites with good southerly sun exposure.

The following is a summary of information common to all the Lac Seul sites.

- Report date: 28/01/2015
- Magnetic declination: -1d 33m
- Latitude and Longitude: 50.12º / -92.21º
- Closest weather station: Thunder Bay, ON, Elevation: 199 metres, (48.367/-89.317)

- Distance from weather station: 287 kilometres
- Report type: Ecological
- Array type: Fixed angle
- Ideal tilt angle: 50.12º
- Ideal azimuth: 180.00º

The seven sites at Frenchman's Head from which solar data were collected were:

- The community arena
- The band office
- The elder centre
- The police station
- The school front lined up with the centre of the roofline
- The water treatment plant
- The Lac Seul Resort

The seven remaining sites in the satellite communities of Lac Seul from which solar data were collected were:

- Kejick Bay band office
- Kejick Bay community complex
- Kejick Bay health centre
- Kejick Bay School
- Whitefish Bay office
- Whitefish Bay community complex
- Hudson Training Centre

A comparison of the monthly and annual total unshaded sun hours at locations in Frenchman's Head is shown in Table 6.

Table 6: Monthly and Annual Measured Sun Hours for Frenchman's Head

Lac Seul	Total Corrected Average Daily Sun Hours (50.12° Latitude & tilt angle)											Annual
Frenchman's Head	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Avg.
Arena	3.23	4.49	5.77	5.44	5.52	5.36	5.58	5.04	4.54	3.26	2.55	2.44	**4.43**
Band Office	2.93	4.07	5.38	5.40	5.43	5.25	5.48	4.98	4.20	2.91	2.25	1.80	**4.17**
Elder Centre	3.69	4.45	5.47	5.38	5.33	5.15	5.33	4.95	4.38	3.20	2.77	2.67	**4.40**
Lac Seul Resort	2.87	4.29	5.47	5.15	5.12	4.96	5.09	4.71	4.37	3.09	2.29	2.11	**4.13**
Police Station	3.37	4.03	4.87	5.20	5.51	5.36	5.58	4.86	4.00	2.90	2.59	2.63	**4.24**
School Fr.	3.13	4.30	5.65	5.31	5.49	5.36	5.56	4.90	4.48	3.10	2.48	2.33	**4.34**
Water treatment	3.40	4.58	5.84	5.54	5.55	5.39	5.63	5.08	4.58	3.30	2.68	2.34	**4.49**

A comparison of monthly and annual total unshaded sun hours for the Lac Seul satellite communities of Kejick Bay, Whitefish, and the Hudson Training Centre is shown in Table 7.

Table 7: Monthly and Annual Measured Sun Hours for Lac Seul Satellite Communities

Lac Seul	Total Corrected Average Daily Sun Hours (50.12° Latitude & tilt angle)											Annual
Kejick+Whitefish	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
Kejick Band Office	3.57	4.49	5.24	4.76	4.70	4.61	4.67	4.33	4.08	3.19	2.82	2.61	**4.09**
Kejick Complex	2.88	3.38	4.48	4.79	5.02	4.84	5.01	4.45	3.68	2.58	2.20	2.29	**3.80**
Kejick Health Ctr.	3.01	4.42	5.43	5.36	5.51	5.36	5.59	4.98	4.35	3.21	2.54	2.28	**4.34**
Kejick School	3.34	4.59	5.75	5.31	5.41	5.28	5.46	4.94	4.49	3.29	2.65	2.58	**4.43**
Whitefish Office	0.08	0.53	4.52	4.87	5.04	4.92	5.08	4.46	3.87	0.71	0.17	0.00	**2.85**
Whitefish Complex	2.06	3.80	4.89	4.95	5.20	4.96	5.17	4.62	3.85	2.92	2.04	1.34	**3.82**
Hudson Training Ctr.*	2.40	4.05	5.55	5.15	5.33	5.23	5.38	4.78	4.43	3.15	1.89	1.68	**4.08**

4.4 Savings Analysis

The savings analysis used data from the ecological reports and inputs of the cost of electricity in each community to calculate projected savings based on the model of solar panel and the number of panels deployed. The variables were input into the P.V. Suite™ software which created a set of tables that contained expected monthly and annual power output, and monthly and annual expected savings. Both communities were analysed with 15 kW and 24 kW arrays since smaller single-phase electrical lines are 25 kW or less and were present in each community. The diesel generator plant at the Sachigo Lake airport had higher capacity three-phase electrical lines, which became single-phase lines in the residential areas. The higher electricity rates paid in Sachigo Lake led to higher savings so extra scenarios were created with 30 kW, 60 kW, 120 kW and 240 kW arrays.

Sachigo Lake's and Lac Seul's electrical systems are governed by two different bodies and pay significantly different rates so the analysis had to be done separately for each community. Sachigo Lake pays the Hydro One Remote Communities Inc. (HORCI) air-access residential rate of $0.086 kW/h and the Standard "A" rate of $0.88 kW/h for larger users. The two sites analysed that had the best solar resources in Sachigo Lake were the airport and the west side of the school. The airport is also where the diesel power plant is located, making the transmission line very short from the solar site. The school has a back-up generator and a solar array could supply excess solar power to the local grid during the summer months when solar production is high and school loads are at a minimum.

4.4.1 Sachigo Lake Savings Analysis

The analysis for the Sachigo airport compares four possible solar arrays and the actual calculated monthly and annual power output for 30 kW, 60 kW, 120 kW and 240 kW arrays at the residential rate of $0.086 kW/h (see Table 8), and the Standard "A" rate of $0.88 kW/h (see Table 9) and the possible calculated savings for each project.

Table 8: Sachigo Lake Airport Solar Power Potential and Savings at $0.086 kW/h

Sachigo Airport	Hydro One Remote Communities Solar savings at Residential Rate ($0.086 kWh)												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
30kW-Actual AC (kWh)*	1,780.18	3,346.12	4,807.77	5,186.00	4,608.60	3,957.80	3,954.46	3,323.68	2,259.15	1,501.38	1,196.02	1,253.70	37,174.86 kWh
60kW-Actual AC (kWh)*	3,562.06	6,691.29	9,616.10	10,373.00	9,218.20	7,912.20	7,909.92	6,653.04	4,517.20	3.002.76	2,388.55	2,508.41	74,352.92 kWh
120kW-Actual AC (kWh)*	7,123.51	13,384.54	19,233.24	20,743.00	18,437.80	15,825.00	15,817.83	13,304.40	9,038.27	6,003.89	4,779.06	5,016.02	148,706.56 kWh
240kW-Actual AC (kWh)*	14,245.74	26,769.12	38,463.87	41,487.00	36,876.60	31,652.00	31,633.66	26,606.47	18,074.54	12,007.41	9,558.16	10,030.29	297,404.88 kWh
30kW-Solar Savings	$153.10	$287.77	$413.47	$446.00	$396.34	$340.37	$340.08	$285.84	$194.29	$129.12	$102.96	$107.82	$3,197.04
60kW-Solar Savings	$306.34	$575.45	$826.98	$892.08	$792.77	$680.47	$680.25	$572.16	$388.48	$258.24	$205.42	$215.72	$6,394.35
120kW-Solar Savings	$612.62	$1,151.07	$1,654.06	$1,783.90	$1,585.65	$1,360.95	$1,360.33	$1,144.18	$777.29	$516.33	$411.00	$431.38	$12,788.76
240kW-Solar Savings	$1,225.13	$2,302.14	$3,307.89	$3,567.88	$3,171.39	$2,722.07	$2,720.49	$2,288.16	$1,554.41	$1,032.64	$822.00	$862.61	$25,576.82

It is assumed that a 30 kW array is comprised of 100-300 watt panels, a 60 kW array of 200-300 watt panels, a 120 kW array of 400-300 watt panels, and a 240 kW array of 800-300 watt panels. The panel model used was Canadian Solar CS6X-300M (300 watt) for all scenarios.

Table 9: Sachigo Lake Airport Solar Potential Savings Standard "A" Rate $0.88 kW/h

Sachigo Airport	Hydro One Remote Communities Solar savings at Standard "A" Rate ($0.88 kWh)												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
30kW-Actual AC (kWh)*	1,780.18	3,346.12	4,807.77	5,186.00	4,608.60	3,957.80	3,954.46	3,323.68	2,259.15	1,501.38	1,196.02	1,253.70	**37,174.86 kWh**
60kW-Actual AC (kWh)*	3,562.06	6,691.29	9,616.10	10,373.00	9,218.20	7,912.20	7,909.92	6,653.04	4,517.20	3.002.76	2,388.55	2,508.41	**74,352.92 kWh**
120kW-Actual AC (kWh)*	7,123.51	13,384.54	19,233.24	20,743.00	18,437.80	15,825.00	15,817.83	13,304.40	9,038.27	6,003.89	4,779.06	5,016.02	**148,706.56 kWh**
240kW-Actual AC (kWh)*	14,245.74	26,769.12	38,463.87	41,487.00	36,876.60	31,652.00	31,633.66	26,606.47	18,074.54	12,007.41	9,558.16	10,030.29	**297,404.88 kWh**
30kW-Solar Savings	$1,566.56	$2,944.59	$4,230.84	$4,563.68	$4,055.57	$3,482.86	$3,479.92	$2,924.84	$1,988.06	$1,321.21	$1,052.50	$1,103.26	**$32,713.88**
60kW-Solar Savings	$3,134.62	$5,888.34	$8,462.16	$9,128.24	$8,112.02	$6,962.91	$6,960.73	$5,854.67	$3,975.14	$2,642.43	$2,101.92	$2,207.40	**$65,430.57**
120kW-Solar Savings	$6,268.69	$11,778.39	$16,925.25	$18,253.84	$16,225.26	$13,926.00	$13,919.69	$11,707.87	$7,953.68	$5,283.43	$4,205.57	$4,414.10	**$130,861.77**
240kW-Solar Savings	$12,536.25	$23,556.83	$33,848.21	$36,508.56	$32,451.41	$27,853.76	$27,837.62	$23,413.70	$15,905.60	$10,566.52	$8,411.18	$8,826.66	**$261,716.30**

The analysis for the Sachigo Lake School compared four possible solar arrays of 30 kW, 60 kW, 120 kW, and 240 kW (the same size arrays as that of the airport analysis), with the calculated actual monthly and annual power output at the Standard "A" rate of $0.88 kW/h to generate the calculated savings of each size project. Large power users like the school pay the higher Standard "A" rate that is charged by Hydro One Remote Communities Inc. as a way of recovering some of the true cost of diesel-derived electricity which includes the costs of shipping the diesel by air and over the winter ice roads. The solar energy potential and cost savings for the school are compared in Table 10.

Table 10: Solar Potential and Energy Savings at Sachigo Lake School

Sachigo School	Hydro one Remote Communities Solar savings at Standard "A" Rate ($0.88 kWh)												
West	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
30kW-Actual AC (kWh)	1,753.89	3,312.55	4,749.68	5,095.77	4,550.23	3,928.89	3,938.83	3,278.64	2,248.11	1,498.55	1,153.41	1,086.93	36,595.49 kWh
60kW-Actual AC (kWh)	3,507.69	6,624.30	9,501.13	10,190.85	9,099.47	7,855.87	7,879.32	6,560.47	4,496.05	2,997.11	2,305.47	2,173.31	73,191.03 kWh
120kW-Actual AC (kWh)	7,016.48	13,248.45	19,340.00	20,743.00	18,202.00	15,715.22	15,757.02	13,122.76	8,993.36	5,991.59	4,612.28	4,347.96	146,389.28 kWh
240kW-Actual AC (kWh)	14,033.90	26,497.01	38,003.88	40,759.33	36,401.79	31,428.45	31,514.60	26,240.70	17,985.72	11,984.81	9,225.57	8,696.33	292,772.08 kWh
30kW-Solar Savings	$1,543.43	$2,915.05	$4,179.72	$4,484.28	$4,004.21	$3,457.42	$3,466.17	$2,885.21	$1,978.33	$1,318.73	$1,015.00	$956.50	$32,204.03
60kW-Solar Savings	$3,086.77	$5,829.38	$8,361.00	$8,967.95	$8,007.53	$6,913.17	$6,933.80	$5,773.21	$3,956.52	$2,637.46	$2,028.81	$1,912.51	$64,408.11
120kW-Solar Savings	$6,174.50	$11,658.64	$16,723.03	$17,933.26	$16,017.76	$13,829.40	$13,866.18	$11,548.03	$7,914.16	$5,272.60	$4,058.81	$3,826.21	$128,822.57
240kW-Solar Savings	$12,349.83	$23,317.37	$33,443.42	$35,868.21	$32,033.58	$27,657.03	$27,732.85	$23,091.81	$15,827.43	$10,546.63	$8,118.50	$7,652.77	$257, 639.43

A final analysis was done for the Sachigo airport with two different-sized arrays of 15 kW and 24 kW at the Hydro One Remotes residential rate of $0.86 kW/h and the Standard “A” rate of $0.88 kW/h. The smaller, modest-sized arrays can be used on lower capacity single-phase electrical lines that are common in small remote communities. The same-sized arrays were analysed with the different on-grid Hydro One off-peak and on-peak rates in Lac Seul for comparison to see how the different rates in on-grid, drive-to communities compare to off-grid, fly-in communities and how that affects the total possible savings. The comparison of Sachigo airport at 15 kW and 24 kW at the two different rates charged to the community by Hydro One Remote Communities Inc. is shown in Table 11.

Table 11: Sachigo Lake Airport 15 kW and 24 kW Solar Array Comparison

	Hydro One Remote Communities Residential rate $0.086/kWh												
Sachigo airport	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)*	890.44	1,672.56	2,402.86	2,592.00	2,305.00	1,978.80	1,976.00	1,663.68	1,130.96	750.88	596.24	627.19	**18,586.61**
Actual AC kWh (24kW)*	1,424.68	2,675.12	3,847.92	4,151.00	3,688.60	3,165.80	3,163.46	2,658.68	1,807.00	1,200.50	954.41	1,00.27	**29,740.44**
											Difference		**11,153.83**
PV Solar Savings (15kW)	$76.58	$143.84	$206.65	$222.91	$198.23	$170.18	$169.94	$143.08	$97.27	$64.58	$51.28	$53.94	**$1,598.45**
PV Solar Savings (24kW)	$122.52	$230.06	$330.92	$356.99	$317.22	$272.26	$272.06	$228.65	$155.40	$103.24	$82.08	$86.28	**$2,557.68**
											Difference		**$929.23**
	*15kW is 50-300 watt panels. *24kW is 80-300 watt panels												
	Hydro One Remote Communities Standard "A" rate $0.88/kWh												
Sachigo airport	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	890.44	1,672.56	2,402.86	2,592.00	2,305.00	1,978.80	1,976.00	1,663.68	1,130.96	750.88	596.24	627.19	**18,586.61**
Actual AC kWh (24kW)	1,424.68	2,675.12	3,847.92	4,151.00	3,688.60	3,165.80	3,163.46	2,658.68	1,807.00	1,200.50	954.41	1,00.27	**29,740.44**
											Difference		**11,153.83**
PV Solar Savings (15kW)	$783.59	$1,471.85	$2,114.52	$2,280.96	$2,028.40	$1,741.34	$1,738.88	$1,464.04	$995.24	$660.77	$524.70	$551.92	**$16,356.22**
PV Solar Savings (24kW)	$1,253.72	$2,354.10	$3,386.17	$3,652.88	$3,245.97	$2,785.90	$2,783.84	$2,339.64	$1,590.16	$1,056.44	$839.88	$882.88	**$26, 171.59**
											Difference		**$9,815.37**

4.4.2 Lac Seul Savings Analysis

The area where the main infrastructure cluster and larger buildings in Frenchman's Head were had higher capacity three-phase electrical lines that become single-phase lines as they moved to the smaller buildings and residential areas. Whitefish Bay and Kejick Bay had single-phase electrical lines. The analysis for the communities within Lac Seul was based on a comparison of 15 kW and 24 kW arrays at the Hydro One residential base rate of $0.086 kW/h and the peak time rate of $0.14 kW/h. An analysis from the best solar site in each of the three communities that makes up Lac Seul was done (see tables 12, 13, and 14). The arena had the best solar resources in Frenchman's Head and was used for the 15 kW and 24 kW scenario (see Table 12).

Table 12: Solar Production and Cost Savings of Two Arrays Frenchman's Head Arena.

Lac Seul: Frenchman's	Hydro One Residential off-Peak Rate $0.086 kWh												
Head Arena	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	1,318.34	1,593.47	2,162.60	1,926.65	1,942.50	1,789.04	1,891.41	1,728.01	1,554.79	1,201.51	925.16	995.67	**19,029.12**
Actual AC kWh (24kW)	2,111.28	2,551.53	3,460.80	3,082.31	3,107.49	2,863.04	3,029.31	2,763.68	2,487.69	1,923.19	1,480.46	1,593.40	**30,454.19**
											Difference		**11,425.07**
PV Solar Savings (15kW)	$113.38	$137.04	$185.98	$165.69	$167.05	$153.86	$162.66	$148.61	$133.71	$103.33	$79.56	$85.63	**$1,636.50**
PV Solar Savings (24kW)	$181.57	$219.43	$297.63	$265.08	$267.24	$246.22	$260.52	$237.68	$213.94	$165.39	$127.32	$137.03	**$2,619.06**
											Difference		**$982.56**

Lac Seul: Frenchman's	Hydro One Residential Peak Rate $0.14 kWh												
Head Arena	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	1,318.34	1,593.47	2,162.60	1,926.65	1,942.50	1,789.04	1,891.41	1,728.01	1,554.79	1,201.51	925.16	995.67	**19,029.12**
Actual AC kWh (24kW)	2,111.28	2,551.53	3,460.80	3,082.31	3,107.49	2,863.04	3,029.31	2,763.68	2,487.69	1,923.19	1,480.46	1,593.40	**30,454.19**
											Difference		**11,425.07**
PV Solar Savings (15kW)	$184.57	$223.09	$302.76	$269.73	$271.95	$250.47	$264.80	$241.92	$217.67	$168.21	$129.52	$139.39	**$2,664.08**
PV Solar Savings (24kW)	$295.58	$357.21	$484.51	$431.52	$435.05	$400.83	$424.10	$386.92	$348.28	$269.25	$207.26	$223.08	**$4,263.59**
											Difference		**1,599.51**

The Kejick Bay School had the best solar resources in the smaller community of Kejick Bay and was used for the 15 kW and 24 kW scenario. The calculated energy production and savings comparison between the Hydro One residential off-peak rate of $0.086 kW/h and the on-peak rate of $0.14 kW/h are shown in Table 13.

***Table 13: Solar Production and Energy Savings of Two Arrays at Kejick Bay School*.**

Lac Seul: Kejick School	**Hydro One Residential off-Peak Rate $0.086 kWh**												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	1,364.79	1,632.86	2,154.00	1,880.63	1,895.35	1,762.12	1,846.45	1,688.92	1,541.10	1,217.77	964.78	1,051.95	**19,000.71**
Actual AC kWh (24kW)	2,186.07	2,614.92	3,448.00	3,005.48	3,035.06	2,815.68	2,956.92	2,700.74	2,463.88	1,947.78	1,544.50	1,683.12	**30,402.14**
											Difference		**11,401.43**
PV Solar Savings (15kW)	$117.37	$140.43	$185.24	$161.73	$163.00	$151.54	$158.79	$145.24	$132.53	$104.73	$82.79	$90.47	**$1,634.06**
PV Solar Savings (24kW)	$188.00	$224.88	$296.53	$258.47	$261.01	$242.15	$254.29	$232.26	$211.89	$167.51	$132.83	$144.75	**$2,614.58**
											Difference		**$980.52**
Lac Seul: Kejick School	**Hydro One Residential Peak Rate $0.14 kWh**												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kWh)	1,364.79	1,632.86	2,154.00	1,880.63	1,895.35	1,762.12	1,846.45	1,688.92	1,541.10	1,217.77	964.78	1,051.95	**19,000.71**
Actual AC kWh (24kW)	2,186.07	2,614.92	3,448.00	3,005.48	3,035.06	2,815.68	2,956.92	2,700.74	2,463.88	1,947.78	1,544.50	1,683.12	**30,402.14**
											Difference		**11,401.43**
PV Solar Savings (15kW)	$191.07	$228.60	$301.56	$263.29	$265.35	$246.70	$258.50	$236.45	$215.75	$170.49	$135.07	$147.27	**$2,660.10**
PV Solar Savings (24kW)	$306.05	$366.09	$482.72	$420.77	$424.91	$394.19	$413.97	$378.10	$344.94	$272.69	$216.23	$235.64	**$4,256.30**
											Difference		**1,596.20**

The Whitefish Bay Community Complex building had the best solar resources in the smallest Lac Seul community of Whitefish Bay and was used for the 15 kW and 24 kW scenarios. The actual solar power production and savings comparison between the Hydro One residential on-peak rate of $0.14 kW/h and the off-peak rate of $0.086 kW/h at the Whitefish Bay Community Complex building are shown in Table 14.

Table 14: Solar Power Production, Cost Savings Two Arrays Whitefish Bay Complex.

Lac Seul: Whitefish	Hydro One Residential off-Peak Rate $0.086 kWh												
Complex	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	845.22	1,348.88	1,821.03	1,759.13	1,849.72	1,679.00	1,773.00	1,592.03	1,323.48	1,077.62	735.97	548.88	16,353.97
Actual AC kWh (24kW)	1,354.23	2,159.64	2,913.99	2,811.56	2,962.55	2,684.00	2,840.00	2,546.60	2,116.56	1,723.00	1,179.25	879.05	26,170.43
											Difference		9,816.46
PV Solar Savings (15kW)	$72.69	$116.00	$156.61	$151.29	$159.08	$144.39	$152.48	$136.91	$113.82	$92.68	$63.29	$47.20	$1,406.44
PV Solar Savings (24kW)	$116.46	$185.73	$250.60	$241.79	$254.78	$230.82	$244.24	$219.01	$182.02	$148.18	$101.42	$75.60	$2,250.66
											Difference		$844.22
Lac Seul: Whitefish	Hydro One Residential Peak Rate $0.14 kWh												
Complex	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Actual AC kWh (15kW)	845.22	1,348.88	1,821.03	1,759.13	1,849.72	1,679.00	1,773.00	1,592.03	1,323.48	1,077.62	735.97	548.88	16,353.97
Actual AC kWh (24kW)	1,354.23	2,159.64	2,913.99	2,811.56	2,962.55	2,684.00	2,840.00	2,546.60	2,116.56	1,723.00	1,179.25	879.05	26,170.43
											Difference		9,816.46
PV Solar Savings (15kW)	$118.33	$188.84	$254.94	$246.28	$258.96	$235.06	$248.22	$222.88	$185.29	$150.87	$103.04	$76.84	$2,289.56
PV Solar Savings (24kW)	$189.59	$302.35	$407.96	$393.62	$414.76	$375.76	$397.60	$356.52	$296.32	$241.22	$165.09	$123.07	$3,663.86
											Difference		1,374.30

4.5 Twenty Year Solar Power Potential

Natural Resources Canada produces tables for many communities across the country, including Lac Seul and Sachigo Lake, that can calculate how much energy a solar project will produce over its lifetime. The tables assume a 20-year operational life for a solar project although many solar panels have at least a 25-year warranty and have been known to last 30 to 40 years. The four most common panel tilt angles used in commercial solar projects are listed; tilt = 90°, tilt = latitude, tilt = latitude + 15° and tilt = latitude - 15°. The tables are useful for a community that is planning to finance a project over 20 years as they give an approximate power output and revenue or savings potential over that period, which can then be evaluated by a bank or finance or grant agency. The solar potential is an estimate of how many AC kW/h might be generated over the lifetime of a typical grid-connected solar array per DC rated kilowatts in a system without batteries (NRCAN, 2014).

4.5.1 Sachigo Lake Twenty Year Solar Power Potential

The total lifetime estimate of solar potential kW/h for Sachigo Lake with a south facing array where the panel tilt angles are: tilt = latitude, tilt = 90º, tilt = latitude +15° and tilt = latitude-15° is shown in Table 15.

Table 15: Total Lifetime Solar Potential for Sachigo Lake.

Sachigo Lake: -92.16E, 53.88N				
PV potential (kWh/kW)				
	South-facing vertical (tilt=90°)	South-facing, tilt=latitude	South-facing, tilt=lat+15°	South-facing, tilt=lat-15°
January	82	76	82	66
February	100	99	104	89
March	129	142	141	134
April	106	140	130	142
May	82	126	111	136
June	68	112	96	123
July	72	116	100	127
August	73	107	96	113
September	61	79	74	80
October	53	59	59	57
November	51	49	52	44
December	62	57	62	49
Annual	**939**	**1163**	**1107**	**1162**

Source: Natural Resources Canada, 2015

The two most common types of arrays installed in the mid-latitude northern hemisphere are where the panel angle is at tilt=latitude and tilt=latitude+15°. The total lifetime kW/h solar potential of a project in Sachigo Lake can be calculated by multiplying the potential (kWh/kW) by the size of a solar array (in kW). The two sizes of solar array that were used for analysis for both Sachigo Lake and Lac Seul were 15 kW and 24 kW. The two most commonly installed arrays, tilt=latitude and tilt=latitude+15°, were analysed at 15 kW and 24 kW for both communities. The total potential lifetime power for 15 kW and 24 kW arrays at the two most commonly installed angles for Sachigo Lake is shown in Table 16. Additional scenarios were done for Sachigo Lake since the initial results showed much higher savings potential because of the higher electricity rates charged by HORCI for air-access diesel-generated electricity.

Table 16: Total Lifetime Power Potential for Two Solar Arrays in Sachigo Lake.

Sachigo Lake: -92.16E, 53.88N						
PV potential (kWh/kW)						
	South-facing, tilt=latitude	**15 kW**	**24 kW**	**South-facing, tilt=lat+15°**	**15 kW**	**24 kW**
January	76	1140	1824	82	1230	1968
February	99	1485	2376	104	1560	2496
March	142	2130	3408	141	2115	3384
April	140	2100	3360	130	1950	3120
May	126	1890	3024	111	1665	2664
June	112	1680	2688	96	1440	2304
July	116	1740	2784	100	1500	2400
August	107	1605	2568	96	1440	2304
September	79	1185	1896	74	1110	1776
October	59	885	1416	59	885	1416
November	49	735	1176	52	780	1248
December	57	855	1368	62	930	1488
Annual	1163	17430	27888	1107	16605	26568

Source: Natural Resources Canada, 2015

4.5.2 Lac Seul Twenty-Year Solar Power Potential

The total potential lifetime power production for 15 kW and 24 kW solar arrays at the two most commonly installed panel angles of tilt = latitude and tilt = latitude + 15° for Lac Seul is shown in Table 17.

Table 17: Total Lifetime Solar Power Potential for Two Arrays at Lac Seul.

Lac Seul: -91.90E, 50.10N						
PV potential (kWh/kW)						
	South-facing, tilt=latitude	**15 kW**	**24 kW**	**South-facing, tilt=lat+15°**	**15 kW**	**24 kW**
January	90	1350	2160	90	1350	2160
February	97	1455	2328	102	1530	2448
March	116	1740	2784	132	1980	3168
April	97	1455	2328	127	1905	3048
May	75	1125	1800	111	1665	2664
June	62	930	1488	96	1440	2304
July	68	1020	1632	105	1575	2520
August	72	1080	1728	102	1530	2448
September	67	1005	1608	84	1260	2016
October	65	975	1560	74	1110	1776
November	59	885	1416	61	915	1464
December	72	1080	1728	72	1080	1728
Annual	**940**	**14100**	**22560**	**1156**	**17340**	**27744**

Source: Natural Resources Canada, 2015

4.6 Long-term Payback

Calculating the long-term payback requires knowing the cost of a project, the savings expected per year (or income per year for a grid-connected project), the electricity rate paid in the project area, the size of the solar array in kW, the financing rate, the expected inflation rate, and the percentage of the project cost to be financed. For variables where there is no direct information, a series of assumptions were made; where there were multiple sources for the cost of a solar array, the highest cost was used to produce a conservative estimate. Analysis from previous calculations and tables produced with the PV Suite™ software were used for some of the variables.

A modest 24 kW array size was used for calculations since some areas in both communities studied only had lower capacity single phase electrical lines which are usually 25 kW (IESO, 2015). Many buildings in the study areas also had limited roof space for a solar array. The price per watt of a small-to-modest sized project will drop slightly with size but not substantially. The most common-sized array installed in Ontario is 10 kW, which is the maximum sized array for a FIT (feed in tariff)-qualified residential project, and is the size of array with the most pricing information and sources.

Prices for solar installations in Lac Seul or Sachigo Lake were unavailable to the research team but were available for Thunder Bay and the surrounding area. Costs were calculated first on the assumption that the cost would be equal to installations in the Thunder Bay and northern Ontario area and then up to twice that price due to increases in shipping distance and labour costs. Technicians performing an install in remote areas need to be housed and fed while in a community which increases costs. The two scenarios that were used, then, are the standard highest install cost and an install at double the cost to compare the payback times at the highest and lowest projected cost. It was assumed that a 24 kw array will cost 2.4 times that of a 10 kW array. Installation prices ranged from $10,000 to $40,000 for a 10 kW array, so the highest price was used, which gives a price of $96,000 for a 24 kW array with the double price scenario being $192,000, which is assumed to account for higher shipping and labour costs in a remote community.

As noted above, the electricity rates paid in the communities are different because the electricity is delivered by two different divisions of Hydro One. To remind readers, Lac Seul is a road access community that is on the provincial electricity grid where the publicly owned OPG generates the electricity and the IESO is responsible for delivering electricity and Hydro One is responsible for billing and customer service. The rates charged by Hydro One at the time data were collected and reports and presentations were made to the communities (as of April 2015) were $0.086/kWh for residential customers and $0.14/kWh peak rate. The peak rate is a time of use rate that is generally paid by customers, who operate 24 hours a day like water treatment plants, police buildings, and schools, which need to be heated all winter. In Sachigo Lake, electricity is generated and delivered by HORCI, a subsidiary of the IESO. The rates charged by HORCI were $0.086/kWh for residential customers and the Standard “A” rate of $0.88/kWh for larger users and buildings (as of April 2015). The high Standard “A” rate is the utility’s way of attempting to recoup the true cost of generating electricity with expensive, imported diesel fuel.

As described earlier, a community energy map was prepared for Sachigo Lake and showed that the breakdown of electricity use is roughly 50% residential use and 50% commercial building use. Energy statistics for Lac Seul were unavailable, but it was assumed that the energy use breakdown was similar. Annual savings for a 24 kW array at the different electricity rates for each community were calculated previously with the PV Suite™ software and were used in a 50/50 breakdown, where half the savings at the residential rates in each community were used and added to half at the Standard “A” rate for Sachigo Lake and half at the peak rate for Lac Seul to reflect the 50-50 electricity usage. Doing so enabled the breakdown of cost savings to better reflect actual savings to be expected since there were two different rates charged.

The financing cost of 6% was used, with 4% representing the expected bank rate and 2% annual inflation. This is the same rate that was used in the cost calculations for the biomass plant project prepared by Biothermic, the industrial partner for the project. A financing rate of 100% was used as a highest cost scenario, which was also used in the biomass project cost calculations prepared by Biothermic.

The formula used to calculate compound interest for the total cost of the loan is: Total loan cost= P(1+R/100)^T, where P= principal, R= interest rate, and T= time in years. The payback period in years is total cost divided by the annual savings. The long-term payback period is calculated and shown in Table 18.

24 kW array installation costs and long-term payback at 6% rate and 100% financing					
Sachigo	Costs	Annual savings at \$0.086/kWh × 0.5	Annual savings at \$0.88/kWh × 0.5	Annual savings	Years payback
Standard install	\$96,000	\$1,278.84	\$13,085.80	\$14,364.64	6.7
Install at 6%	\$307,885	\$1,278.84	\$13,085.80	\$14,364.64	21.4
Install × 2	\$192,000	\$1,278.84	\$13,085.80	\$14,364.64	13.4
Install × 2 at 6%	\$615,770	\$1,278.84	\$13,085.80	\$14,364.64	42.9
Lac Seul	Costs	Annual savings at \$0.086/kWh × 0.5	Annual savings at \$0.14/kWh × 0.5		Years payback
Standard Install	\$96,000	\$1,309.53	\$2,131.80	\$3,441.33	27.9
Install at 6%	\$307,885	\$1,309.53	\$2,131.80	\$3,441.33	89.5
Install × 2	\$192,000	\$1,309.53	\$2,131.80	\$3,441.33	55.8
Install × 2 at 6%	\$615,770	\$1,309.53	\$2,131.80	\$3,441.33	179

Table 18: Projected Long-term Payback Scenarios for Two Communities

Financing costs dramatically increase the total cost of a project, which increases the payback time. The more capital a community is able to put into the upfront cost of a project without having to borrow, the lower the borrowing costs and the shorter the payback time. The total savings do not change since the power output is the same and the savings at the output of each solar array do not change.

Sachigo Lake pays much higher electricity rates, which leads to higher annual savings and shorter payback times. The savings for a community is dependent on the installation costs, the financing rate, the financing cost, the average annual sun hours (which translates to annual energy produced), and the electricity rate paid. The financing rate and the financing cost for the next scenario are the same as the previous scenario at 100% and 6% respectively. The assumed installation costs for each scenario are the same as in the previous scenarios, where actual installation costs are unknown but the cost of installation near Thunder Bay is known. Thunder Bay is located in northwestern Ontario and is the closest centre to the communities studied where multiple solar distributors are located and prices could be compared. A second cost of twice the Thunder Bay cost is included to account for higher shipping and installation costs because of the remote nature of the communities studied. The highest average annual sun hours are also the same at both communities, with the Sachigo Lake airport having 4.49 hours per day and the average annual sun hours at the Lac Seul water treatment plant at 4.49 hours per day. The most significant variable, then, was the electricity rate paid by each community.

The residential rate is the same in both communities at $0.086/kWh with the peak rate in Lac Seul at $0.14/kWh and the Standard “A” rate in Sachigo at a $0.88/kWh. The Standard “A” rate is ten times the residential rate and had the highest impact on the annual savings and consequently the long-term payback time. An extra set of scenarios for Sachigo Lake for larger solar arrays were thus done since that community pays much higher rates and has higher calculated potential annual cost savings leading to shorter payback times.

The same assumptions for financing rate, financing costs, installation cost scenarios (Thunder Bay install costs and twice cost) apply. The four sizes of array used were 30 kW, 60 kW, 120 kW and 240 kW. The first set of scenarios applies to the Sachigo airport site, which had the highest average annual sun hours per day at 4.49 and the west side of the community school at 4.37 hours per day. The airport site was next to the diesel generator site and has ample room for a ground mount solar array. The west side of the school has a large open space for a ground mount solar array that could be combined with solar panels on the roof of the school.

The cost savings for the airport site were based on a combination of the cost savings at the residential rate of $0.086/kWh and the Standard "A" rate of $0.88/kWh in a 50/50 split as in the previous scenario. The cost savings for the west side of the school site were based on the Standard "A" rate only, since the school pays the Standard "A" rate for its electricity. The maximum installation cost of a 10kW array in the Thunder Bay area is $40,000 and it is assumed that the price ratio of the 30 kW, 60 kW, 120 kW, and 240 kW arrays are the same at $120,000, $240,000, $480,000, and $960,000 respectively. The long-term payback for the large array scenarios for the Sachigo airport site are shown in Table 19.

Table 19: Large Array Payback Scenarios for Sachigo Airport.

Sachigo Airport install costs and payback period at 6% rate and 100% financing					
30 kW	Costs	Annual savings at \$0.086/kWh × 0.5	Annual savings at \$0.88/kWh × 0.5	Total annual savings	Years payback
Standard install	\$120,000	\$1,598.52	\$16,356.94	\$17,955.46	6.7
Install at 6%	\$384,856.26	\$1,598.52	\$16,356.94	\$17,955.46	21.4
Install × 2	\$240,000	\$1,598.52	\$16,356.94	\$17,955.46	13.4
Install × 2 at 6%	\$769,712.51	\$1,598.52	\$16,356.94	\$17,955.46	42.9
60 kW					
Standard install	\$240,000	\$3,197.18	\$32,715.29	\$35,912.47	6.7
Install at 6%	\$769,712.51	\$3,197.18	\$32,715.29	\$35,912.47	21.4
Install × 2	\$480,000	\$3,197.18	\$32,715.29	\$35,912.47	13.4
Install × 2 at 6%	\$1,539,425.08	\$3,197.18	\$32,715.29	\$35,912.47	42.9
120 kW					
Standard install	\$480,000	\$6,394.38	\$65,430.89	\$71,825.27	6.7
Install at 6%	\$1,539,425.08	\$6,394.38	\$65,430.89	\$71,825.27	21.4
Install × 2	\$960,000	\$6,394.38	\$65,430.89	\$71,825.27	13.4
Install × 2 at 6%	\$3,078,850.05	\$6,394.38	\$65,430.89	\$71,825.27	42.9
240 kW					
Standard install	\$960,000	\$12,788.41	\$130,858.15	\$143,646.56	6.7
Install at 6%	\$3,078,850.05	\$12,788.41	\$130,858.15	\$143,646.56	21.4
Install × 2	\$1,920,000	\$12,788.41	\$130,858.15	\$143,646.56	13.4
Install × 2 at 6%	\$6,157,700.11	\$12,788.41	\$130,858.15	\$143,646.56	42.9

The payback scenarios for the same four large array sizes for the Sachigo Lake School are shown in Table 20.

Table 20: Large Array Payback Scenarios for Sachigo Lake School

Sachigo School install costs and payback period at 6% rate and 100% financing			
30 kW	Costs	Annual savings	Years payback
Standard install	$120,000	$32,204.03	3.7
Install at 6% interest	$384,856.26	$32,204.03	12
Install × 2	$240,000	$32,204.03	7.5
Install × 2 at 6% interest	$769,712.51	$32,204.03	23.9
60 kW			
Standard install	$240,000	$64,408.11	3.7
Install at 6% interest	$769,712.51	$64,408.11	12
Install × 2	$480,000	$64,408.11	7.5
Install × 2 at 6% interest	$1,539,425.08	$64,408.11	23.9
120 kW			
Standard install	$480,000	$128,822.57	3.7
Install at 6% interest	$1,539,425.08	$128,822.57	12
Install × 2	$960,000	$128,822.57	7.5
Install × 2 at 6% interest	$3,078,850.05	$128,822.57	23.9
240 kW			
Standard install	$960,000	$257,639.43	3.7
Install at 6% interest	$3,078,850.05	$257,639.43	12
Install × 2	$1,920,000	$257,639.43	7.5
Install × 2 at 6% interest	$6,157,700.11	$257,639.43	23.9

Annual savings did not change since the cost of electricity is assumed to be the same and the number of panels is the same, making the assumed electrical power production approximately the same every year. The total cost of a project determines the payback times of a project in this case. Financing costs dramatically increase total project costs and payback time. A rise in the rates paid for electricity will also reduce the payback times since it raises total annual costs, which increases total annual savings and yet the installation costs do not change. Electrical rates in Ontario are determined by the Ontario Energy Board and are a cost beyond each community's control, but solar power created within the community would be a cost within the communities' control.

Sachigo Lake pays the high Standard A price for electricity which increased the solar savings and decreased the payback times, which was as low as 3.7 years at the lowest projected install cost for the Sachigo Lake School. The Sachigo Lake airport had a payback time of 6.7 years for the same size solar arrays as the school at the same projected install cost but, had far more space for ground mounted panels with room to expand and is also next to the generating plant. The payback time for a solar project in Lac Seul was projected to be 28 years at the lowest projected install cost, making solar power not viable at current electricity rates. Lac Seul is connected to the Ontario grid and may qualify for the FIT program or the net-metering program, which would increase savings and reduce payback times. Solar installation prices are expected to continue to fall which would increase savings and reduce payback times for solar projects in both communities in the future.

5 DISCUSSION

The discussion section begins by examining some of the lower cost secondary objectives of the project that were discussed with both communities during the presentations made in each community after the project delivered the technical reports to them. Both communities had many questions about how to reduce electricity costs so the research team spent time answering questions for them with an emphasis on inexpensive, simple solutions. This section ends with explanations about how the initial evaluations of solar and wind power were evaluated and why wind power was not considered viable but solar power had follow-up analysis. Section 5.1 outlines the findings for biomass district heating and solar power in Sachigo Lake. Section 5.2 outlines the findings for biomass district heating and solar power in Lac Seul. Section 5.3 compares the results of the project’s findings for both communities. Section 5.4 examines present and proposed renewable energy projects in remote communities in Ontario and how they can be duplicated in Sachigo Lake and Lac Seul. This chapter concludes with future options for renewable energy for both communities.

One of the secondary objectives of the project and a good first step for both communities was to investigate ways of reducing energy usage in both communities inexpensively and without specialised skills or contractors. Energy efficiency upgrades to homes and buildings in both communities including insulation, better windows and doors will permanently reduce energy consumption and lower heating costs and save money in the long term while making buildings more comfortable. Many of these upgrades are lower cost than energy generation projects and can gradually be done over time. It is recommended that both communities also try LED lights in a few homes and buildings as a test to see if the energy saved and light quality are worth the cost of switching over from incandescent or compact fluorescent bulbs. LED lights will provide modest savings over time at a modest cost. Switching to LED light bulbs can also create long-term savings as many manufacturers offer multi-year warranties since many are designed to last thousands of hours. Ordering LED lights in bulk from a distributor may save a community money if the community decides to switch over many homes or buildings in their community at the same time. The research team brought a selection of LED bulbs for both communities to try as a response to questions about them during the fieldwork portion of the project.

The initial evaluation of renewable energy resources for Lac Seul and Sachigo Lake was done with publicly available information from the Ontario provincial government, the Canadian federal government and non-profit renewable energy association websites. This first step allowed the research team to narrow the research focus to solar power and eliminate wind power.

The published wind speed values for both Sachigo Lake and Lac Seul fell below 6 m/s, which is considered the threshold between marginal and viable wind resources listed in the Ontario Renewable Energy Atlas and the Canadian Wind Atlas. Higher values might be obtained along lakeshores if measured over at least an entire year or preferably over multiple years with a wind anemometer kit at a suitable height (50 metres is the standard height used in the Canadian Wind Atlas). Further analysis of potential wind power in both Lac Seul and Sachigo Lake were not pursued by the research team based on the average speeds listed for these resources.

The solar resources from all three of these sources (see section 3) were in the mid to high range, which justified follow-up analysis. The research team had limited time and budget, much of which was dedicated to investigating biomass district heating. An initial investigation was done to determine if there was another renewable energy option that could be analysed and used to offset the non-heating electrical loads in both communities. Residential non-heating loads make up to 20% of total average energy use in Canadian households, which could be supplied by solar power as a complement to biomass district heating. Small remote communities can use publicly available resources to make an initial evaluation of potential renewable energy resources in their communities as a starting point. Smaller communities can then narrow their focus to the best renewable energy options before using financial resources to pay for feasibility studies.

5.1 Sachigo Lake

Sachigo Lake has ample forest resources in their reserve lands and in surrounding provincial Crown lands. There is currently no forest inventory in Sachigo Lake and no formal records of forest product harvest for firewood or for building materials processed by the small bandsaw mill in the community. There are also currently no specific forest areas set aside for firewood harvesting. Families harvest from areas they are familiar with and access them with vehicles they currently operate, whether four-wheel drive vehicles or snow machines in winter. Harvesting for biomass in Sachigo Lake would require harvesting equipment, training and infrastructure as well as a detailed forest inventory and harvesting plan. Firewood harvesting could possibly be incorporated into a forest inventory and harvest plan and set up as a community-owned business. Clearing brush from roads and trails and from under electrical lines could also be planned for in a harvest plan to reduce the amount of biomass needed from the surrounding forest.

Individuals from Sachigo Lake currently harvest firewood from both reserve land and Crown land for use in residential homes. Harvesting firewood from Crown land is currently permitted for individual use by members of Indigenous communities, on land they traditionally occupied as re-affirmed by the Supreme Court of Canada decision R. v. Sappier; R. v. Gray, 2006. It is not clear, however, whether this right extends to members of Indigenous communities harvesting wood for biomass district heating that is strictly for community use. Approval from the federal government and the Ontario provincial government would be required before implementing a biomass harvesting plan. A comprehensive forest inventory would be required to calculate actual available biomass from both reserve and Crown land.

Total biomass calculations for Sachigo Lake's reserve lands included trees and large shrubs found near homes within the residential community infrastructure. It is not known how many of these trees and shrubs would be excluded from harvesting. A community forest-use plan prepared with community input would clarify how much biomass is available within the community and how much would be set aside for windbreaks, flood control or aesthetics.

The cluster of closely spaced high heat demand community buildings in Sachigo Lake had a total maximum heating load of 1.5 MW and a final installation cost of $2.08 per watt of heat. A 1.5 MW heating system could be made up of three 500 kW units, or other sized multiple units, which could respond to different heating loads by taking one or more units on or off line depending on weather and heating demand. The calculations assumed that every building used the maximum rated heating load at the same time. Actual heat usage would likely be lower and would need to be tracked over the different seasons to give a more realistic seasonal average heat load.

The electrical generator plant in Sachigo Lake is rated for a total output of 1 MW. Electrical heat is the most common form of primary heating in Sachigo Lake. The band office and hotel currently use fuel oil for heating with electrical baseboard supplemental heating. Fuel oil, outdoor wood furnace and propane heating are used on some smaller buildings. The potential biomass heating unit size for the high heat cluster scenario would likely be lower than the 1.5 MW used given that the generator for the entire community is 1 MW.

Biomass district heating plants can be located where solar resources are high to take advantage solar thermal pre-heating or a photovoltaic array to provide electricity to the biomass plant. The west side of the school had the second highest solar resources in Sachigo Lake at an annual average of 4.37 hours per day and large spaces to allow for construction of a biomass plant and/or solar array. This site also had a wooded area behind the school that could be partially cleared to make more room for a plant.

Ongoing costs for biomass district heating units are the electricity that is needed to power the pumps, the fuel-feed mechanisms, the control systems and harvesting the biomass fuel. The local electricity grid can be used to power these systems but the heating units will shut down when the grid fails. A back-up diesel generator is used at the Sachigo Lake school when the grid fails to ensure heating systems keep students in safe temperatures during the winter months. A back-up generator for a biomass district heating plant would ensure that heat flows to all buildings when the main electricity grid fails.

A solar photovoltaic array with an appropriate-sized battery is a cleaner option that could also provide power to a biomass plant. The solar array should be sized large enough to power the plant during daylight hours and charge a battery bank that would power the plant during the night. Electricity consumption figures for biomass district heating plants were not available to the research team and would be needed in order to correctly size a back-up generator or solar photovoltaic array with battery back-up.

Separate or stand-alone solar thermal hydronic heating systems create no emissions but the control systems and pumps require an electricity source that may have emissions. Solar thermal collectors can be incorporated into a biomass district heating system and used to pre-heat the liquid medium on the return line (cold line) of the system as a way of reducing the amount of biomass needed to create the same amount of heat energy. The use of solar pre-heating can also reduce emissions from diesel generators used in Sachigo Lake and many other fly-in, remote communities that currently use electricity for heating. Many biomass burners can control a certain amount of solar thermal collectors with their own control and pump systems. When used this way, solar thermal does not require separate pumps, control systems or separate electricity supplies and only requires solar thermal collector assemblies and minimal piping to connect to the main biomass heating system. The total heat rating of biomass burner systems that control solar thermal collectors does not increase when maximising solar thermal heat, but decreases the amount of biomass fuel needed to create that heat.

The airport site in Sachigo Lake had the highest solar resources in the community and would be an ideal site for a solar photovoltaic array since the diesel generators are also located there. A 30 kW solar array costs about $120 000 to install in the Thunder Bay area and could possibly cost twice that amount because of high shipping and transportation into Sachigo Lake. The price per watt was \$4.00 at the Thunder Bay installation price and \$8.00 per watt at double that price. The 30 kW array could be added to in the future because of solar PV's modular nature. The 60 kW, 120 kW and 240 kW arrays produced similar payback period and price per watt results.

The diesel generators for Sachigo Lake are rated at 1 MW (1000 kW) for the entire community but actual electricity use varies during the year. The highest heat demand and total electricity demand is in winter with the lowest heat demand and electricity demand in summer. The smallest of the three generators, rated at 250 kW, was observed by the research team during a tour of the generator plant as the only generator operating in July. Longer daylight hours during summer days also reduce the need for interior lighting. Solar resources are highest in summer, when heat and electricity demands are lowest so even a modest-sized solar photovoltaic array should noticeably reduce diesel fuel use and emissions from the generator plant at that time of year. A 240 kW solar photovoltaic array, which was one of the scenarios analysed, could potentially power the entire community in the summer during daylight hours.

A battery bank could be sized to store electricity from a 240 kW photovoltaic array and power the entire community after the daylight hours during the summer months. Many utility grid-scale batteries are modular and can be added to over time as energy needs change or budgets allow. The Tesla™ Power Pack batteries have been deployed in grid-sized configurations in California, Ta'u Samoa and Kaua'i (Tesla Canada, 2017).

Sachigo Lake is not connected to the Ontario electricity grid and does not qualify for the provincial FIT program or the net metering program that pays the community for excess electricity generated by solar, wind, hydro or biofuel. HORCI maintains the diesel-powered electricity generating plant in Sachigo Lake. The community would require technical advice and co-operation from HORCI. to incorporate a solar photovoltaic electricity array into its electricity supply.

5.2 Lac Seul

Biomass district heating units have the potential to offset large heating loads that currently use electricity, whether from Hydro One in Lac Seul or diesel generator produced from HORCI in Sachigo Lake. In both cases an outside distributor is paid by the community with money leaving the community. Harvesting biomass locally to produce energy requires local workers to maintain the heating plant and to harvest the biomass. The workers could potentially spend a portion of their wages earned within the community purchasing goods and services produced locally, thus keeping money recirculating in the local economy.

The total heating load for all three of Lac Seul's communities is well within the calculated annual available biomass. Each of the three communities in Lac Seul would need separate biomass district heating units because of the distances between the communities, but the biomass can be harvested as a community and distributed to each as needed. Many residents of Lac Seul already work in the forestry industry locally and have training and certifications related to forest harvesting. Obishkakaang Resources Corp. is owned and run by the community of Lac Seul with operations in the Lac Seul Forest. Harvesting equipment should be readily available or easily obtained given these forestry operations.

Possible sources of biomass for Lac Seul that were not considered, but may be available, are residues from current forestry operations already taking place in the Lac Seul Forest and residues from the McKenzie sawmill located across the lake from Lac Seul. If the community is able to obtain biomass from either of these sources, it would reduce the amount of biomass needed to be harvested from the reserve and Crown forests.

The total heating load for the main Lac Seul community of Frenchman's Head is 4.6 MW with a final cost of $2.87 per watt of heat. The cluster of closely-spaced high heat demand buildings in Frenchman's Head has a total heating load of 1.5 MW at a final cost of $2.03 per watt of heat with a shorter payback time. The total heating load for the Lac Seul satellite community of Kejick Bay is 2.9 MW. Many of the buildings were spread out except for a cluster of larger high heat demand community buildings that had a calculated total heat load of 0.5 MW and a final cost of $2.80 per watt with a shorter payback time. The smallest Lac Seul community of Whitefish Bay had a total heat load of 1 MW, which did not include the homes across the narrow lake channel that were deemed too difficult to include because of construction cost and complexity of running piping. The full community biomass district heating system had a payback time of 18 years and a final cost of $3.12 per watt of heat.

The shortest payback times and lowest cost per watt of heat energy in each case was the high heat cluster scenario where buildings were close together. Whitefish Bay had fewer buildings than either Kejick Bay or Frenchman's Head and all the community buildings were closely spaced, with the exception of homes across the narrow lake channel, which were not included. One of the highest costs incurred in a district heating project is installing the piping between the heating plant and the buildings being heated. Shorter piping distances reduce the installation cost of a district heating system and the payback time as well as the cost per watt of heat energy.

The arena in the main Lac Seul community of Frenchman's Head had the second highest solar resources at an annual average of 4.43 hours per day with a very large open space behind the arena. The arena also backs onto a wooded area that could be partially cleared to maintain space for parking since the arena is used for many community events. The arena currently has hydronic heating supplied by two electrically-powered 150 kW boilers. This location might be ideal for a biomass district heating plant since the hydronic piping is already installed in the building and the two boilers are relatively new and could possibly be sold to offset some of the construction costs. This site has ample room for a solar thermal or solar photovoltaic array.

Lac Seul is connected to the Ontario grid and may qualify for the FIT program which pays a premium for renewable electricity projects feeding back into the grid. Net-metering contracts pay less for power sent to the electricity grid but still may help offset the cost of the electrical load in the community. It is recommended that the community make an application for the FIT program and the net-metering program, should the FIT application be rejected and have a thorough feasibility study done on a solar project if either application is accepted.

5.3 Community Comparison

Lac Seul sources its electricity from Hydro One and pays the same residential rate (as of April 2015, when the initial analysis was done) of $0.086/kWh as Sachigo Lake and $0.14/kWh for the peak rate, which is significantly less than the $0.88/kWh HORCI charges Sachigo Lake for large electricity users. The payback times for solar photovoltaic arrays in Lac Seul varied from 28 to 56 years. Delivery and shipping costs of solar components would likely be less expensive to Lac Seul compared to Sachigo Lake since Lac Seul has all-weather roads into the community and is closer to Thunder Bay, the closest large urban centre with a rail, road and water shipping network. Solar photovoltaic installation costs worldwide have fallen an average of 10% per year since 2010 and this trend is expected to continue. Lower installation costs reduce the cost per watt and the payback times of energy projects.

The high heat cluster biomass district heating scenario for Sachigo Lake had an installation cost per watt of heat of $2.08. The solar photovoltaic array for the Sachigo Lake airport had a final cost per watt of $4.00 to $8.00, depending on what the final installation costs are. The Lac Seul high heat cluster biomass district heating scenario for the main community of Frenchman's Head had an installation cost per watt of heat of $2.03. The solar photovoltaic array for Frenchman's Head had a final cost per watt of $4.00 to $8.00 depending on the final installation cost. The cost per watt of energy of biomass district heating in both communities is about half of the price of solar photovoltaic power.

The ongoing costs of both sources of energy are unknown and will impact the final price paid per watt of energy over time. Biomass district heating systems, solar thermal systems and solar photovoltaic systems are designed to last many years. Solar photovoltaic power installations mounted on rooflines or fixed ground mounts have no moving parts, require no fuel and require very little maintenance. Ongoing costs for these systems should be minimal.

Biomass district heating systems require fuel that needs to be harvested and stored and periodic cleaning to remove ash and inspect exhaust piping. These systems also require electricity to operate the fuel feed systems, control systems and pumps. The final price per watt for biomass district heat will likely be higher. The figures calculated in this study were for pre-feasibility only and for illustrative purposes in order to begin discussions with both communities. Detailed feasibility studies for biomass district heating systems with and without solar thermal pre-heating, should be able to calculate a more accurate final cost per watt.

Both Sachigo Lake and Lac Seul have large buildings where a passive or solar wall air heater might lower the heating loads if incorporated into a forced air space heating system. Solar air heaters have passive or active fans to help create air flow and work best as a pre-heating system for forced air furnaces. The Sachigo airport buildings have large open spaces where a solar wall can be installed and retrofitted to augment the electric baseboard heaters. The Lac Seul police station has forced air heaters in the garage area that could benefit from a solar air heater pre-heating the incoming air.

5.4 Renewable Energy in Remote Communities

Renewable energy has been deployed in many communities in Canada and around the world. Canada currently gets 18.1% of it's energy from renewables (NRCAN, 2017). Renewable energy generation grew at a faster rate world-wide than either coal or natural gas in 2016 (IEA, 2017). The focus of this study and report was to examine renewable energy in remote First Nations communities in the boreal forest of northern Ontario. There are renewable energy projects that are currently operating in remote First Nations communities in Ontario as well as projects that have been proposed. HORCI owns and operates generators in 21 remote communities in Ontario which include renewable energy generators in five communities (Karanasios & Parker, 2016). There are hydro-electric stations in Deer Lake and Sultan and two demonstrator wind turbines in Kasabonika Lake First Nation as well as demonstrator wind turbines in Fort Severn and Big Trout Lake (Hydro One, 2012; HORCI, 2012).

There have been twelve community owned solar projects in eleven communities installed between 2013 and 2016 in remote communities in Ontario including Deer Lake, Fort Severn, Kasabonika Lake, Kingfisher, North Caribou Lake, Keewayin, North Spirit Lake, Wawakapewin, Poplar Hill, Muskrat Dam and Weenusk. In each case, the solar arrays are modest sized and range between 10-20 kW except for Deer Lake, which has a larger array with a power output of 152 kW. Each of these communities has diesel generators and the power from these projects is used offset diesel use. Deer Lake had five homes that could not be hooked up to the local electricity grid until the solar photovoltaic was operational since the community had surpassed the capacity of its generator facility (Watay, 2015). Deer Lake received a grant from the federal government for $100,000 and provided the remainder $500,000 towards the cost of the project. The leadership in Deer Lake is also hoping the Hydro One electricity grid eventually connects the off-grid communities in their vicinity so the community can possibly eventually sell electricity to the grid for revenue (Watay, 2015).

A proposed solar project in Fort Severn for a 300 kW solar array with a 300 kW battery system is expected to be operational in 2017 (MNDM, 2015). The Ontario government provided $2.5 million in funding for the project which is to be built and owned by Fort Severn (NOHFC, 2015). There is also a 250 kW proposed solar project in Kasabonika Lake that is waiting approval.

There are currently no biomass energy projects operating in Ontario's remote communities but there is a proposed project to generate electricity from biomass in Whitesand First Nation near Armstrong, Ontario. This project was first proposed in 1992 and finally received approval in 2017 (TBNewsWatch, 2017). The proposed project received $3.8 million from the federal and provincial governments and is expected to employ at least 60 people and offset a significant amount of the diesel used in their current generators (Northern Ontario Business, 2017). Biomass power has potential in Ontario and it is hoped that regulatory bodies will be willing give approvals for biomass projects now that Whitesand First Nation has been given approval for its project.

Solar projects appear to be the most common newly installed renewable energy projects in remote communities in northern Ontario. Solar panels require no fuel, have no moving parts and require minimal maintenance. Federal and provincial governments have provided funding for renewable energy projects and solar projects in particular, which could be a possibility for Sachigo Lake and Lac Seul. Grants that decrease the upfront capital costs of renewable energy projects also reduce financing costs and long-term payback periods. Remote communities in Ontario have also partnered with renewable energy companies like Canadian Solar, Sky Power and Jazz Power to help them develop projects in their communities (CBC, 2014; Northern Ontario Business, 2016).

Sachigo Lake has taken the first step towards developing renewable energy in its community that began with installation of a small solar array on the water treatment plant in their community. Sachigo Lake signed an agreement with Sky Power to develop solar projects in Sachigo Lake and other communities (IESO, 2016; Northern Ontario Business, 2016). Sachigo Lake is hoping to build large-scale projects in many communities including their own in the near future as a result of this partnership (Photon, 2016).

Sachigo Lake and Lac Seul both have adequate biomass resources for biomass district heating projects in their communities. Lac Seul has forestry operations and should have access to equipment and trained personnel needed to harvest trees for biomass. In addition, they may be able to access biomass from the local sawmill and current harvest residues. Lac Seul also has good solar resources in the community but at current electricity rates and solar costs, payback times might exceed the life of a solar project. Accessing government funding or waiting for solar prices to come down, which is the current trend, might make a solar project viable since solar has high capital costs, but no fuel costs and minimal maintenance costs.

Sachigo Lake has no forestry inventory or forestry operations and may require financial and technical assistance to develop a forest inventory and harvest plan to feed a biomass district heating project. Government financial assistance, similar to what Whitesand First Nation received for their biomass energy project, could allow the community to cover the capital costs of a district heating project for the cluster of high heat demand buildings in the centre of the community. Sachigo Lake has good solar resources in the community and has taken the first step towards developing solar energy in their community by signing an agreement with a solar energy company to develop projects in theirs and other communities.

Sachigo Lake and Lac Seul both have sufficient renewable energy resources to pursue projects in their communities. Both communities may be able to access government assistance to help with initial costs and capital costs. Sachigo Lake has partnered with a renewable energy company and is receiving technical assistance from them to develop solar projects. Lac Seul may also be able to enter into an agreement with a renewable energy company to assist them with developing a biomass or solar project in the future. Partnering with academic institutions to research further options in the future may also lead to other opportunities for energy projects.

6 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to evaluate renewable energy resources available to two remote First Nations communities in northern Ontario to replace electricity used for heating. Lac Seul has all-weather roads and is connected to the Ontario electricity grid but is beyond the natural gas network. Sachigo Lake is an air-access community with a limited winter road season that uses diesel generators to create electricity. Both communities are surrounded by the boreal forest where biomass resources are plentiful. Biomass district heating with solar thermal pre-heating can be used in these communities to off-set space heating and domestic hot water heating that make up 80% of Canadian average residential heating loads. The non-heating electrical loads in both communities represented about 20% of total electrical loads, which was an opportunity to evaluate solar and wind power to offset these loads. The specific objective of this research was to compare the cost savings and payback times of solar projects in both communities to complement biomass district heating, with cost comparisons between both solar and biomass energy sources.

One of the secondary objectives of the project and a good first step and lowest cost option for both communities is reducing electricity use through energy efficiency upgrades to reduce energy usage and costs. Insulation and better windows and doors can be retrofitted to many buildings and reduce heating loads. Efficient lighting that use LED's can reduce electricity used for lighting. Replacing older appliances with newer energy efficient ones can also reduce electricity use. Each of these options can be done over time and are likely the least expensive options for reducing energy use. The presentations to both communities ended with a short list of inexpensive upgrades that could be done with minimal specialized skills while considering the information presented to them along with a sample of energy efficient lights that they could try.

The initial evaluation of wind energy resources in both communities ranged from marginal to not viable. It is not recommended that either community pursue a wind energy project at this time. Higher wind speed values might result from measurements collected over a year or multiple years along lakeshores or ridgelines and could be part of a university or college study.

Sachigo Lake does not currently have a forest management plan or forest inventory. A detailed forest inventory for reserve land and surrounding Crown land would produce more accurate biomass availability figures for a biomass district heating project. A community forest use and management plan should be done with community consultation and input to determine location and amount of land that should be set aside for non-harvest use. A detailed tracking of seasonal heat energy consumption within Sachigo Lake's high heat community building cluster is recommended to produce accurate actual seasonal heat energy needs to accurately size a biomass district heating project. A biomass district heating unit within this cluster that is able to control a solar thermal pre-heating array to reduce final biomass fuel use, will help in reducing emissions and harvests from local forests.

The Sachigo Lake generating station is located at the airport and has ample south-facing open space for a ground mounted solar photovoltaic array. Sachigo Lake pays higher electricity rates that translated to higher savings from solar arrays and short payback times. Transmission lines could be kept very short with a solar array next to the generator building. The prices of the solar arrays analysed would be in the hundreds of thousands of dollars where the biomass plant would be in the low millions. A solar photovoltaic array would be a smaller investment than a biomass district heating plant and might be easier to finance and would represent a good first step in replacing diesel-derived electricity. Solar installations are common in southern Ontario, and the financial institutions and insurance companies there have experience with them and can be approached for financing and insurance.

Sachigo Lake has recently partnered with SkyPower, a solar company, and could benefit in the future by including solar power into newer homes and buildings, and possibly retrofitting older ones with solar as well. Colleges and universities can partner with the community to research and assist with future community and energy planning to incorporate solar power and biomass district heating before buildings are built, to simplify incorporating installations into the community infrastructure. Newer buildings can be planned with better materials and technologies to make them more energy efficient with lower energy usage. Colleges and universities can also provide training and education to community members wishing to work in solar and biomass heating. All levels of government can be approached to provide financial incentives to study and implement cleaner and more sustainable energy sources as new technologies develop.

Lac Seul has forestry operations within and near the community. Lac Seul should have access to biomass harvesting equipment and trained personnel locally. Accessing biomass from current forestry operations or biomass from the local sawmill could reduce the ongoing cost of biomass harvesting. It is recommended that the community update their management plan for the community reserve forest to include biomass harvesting for a district heating unit in the main community of Frenchman’s Head, where much of the community infrastructure is located.

The arena in Frenchman's Head already uses hydronic heating and would be the ideal starting point for a biomass district heating plant. The arena also has a large open space for buildings and equipment and has good solar resources. A district heating unit with solar thermal pre-heating is recommended to increase efficiency and reduce fuel use and emissions.

Lac Seul could partner with the local sawmill, forestry operators in the area and other private sector partners to incorporate biomass harvesting into a community energy plan. Colleges and universities can assist Lac Seul with technical advice for implementing a biomass harvesting plan and community infrastructure planning for biomass heat with solar pre-heating. The Ontario government can assist Lac Seul with a FIT application for a possible solar photovoltaic project, while all levels of government can be approached for funding to study and implement new and current renewable energy projects as technology progresses.

It is recommended that both communities incorporate either a back-up generator or solar photovoltaic array with battery to ensure that biomass district heating continues to supply heat should the electricity grid fail during the winter months. Both communities can benefit from a solar and battery powered vaccine fridge to protect medicines during prolonged power outages, similar to models that have been tested by the World Health Organization. It is not recommended that Lac Seul pursue a solar photovoltaic project until installation costs come down. The community should prepare an application for the Feed-in-Tariff (FIT) program that pays a premium for solar electricity, and apply for grants from each level of government to help pay for a detailed feasibility study for possible solar power projects.

It is recommended that both communities pursue government financial and technical assistance for biomass district heating projects and solar projects in the near future. Both communities were very welcoming to the research team and university and college student researchers and it is recommended that the university and college follow up with both communities to gauge their interest in future collaborations.

Finally, it is recommended that both Lac Seul First Nation and Sachigo Lake First Nation educate themselves about renewable energy and its benefits to their communities. This can be done individually or through education programs provided by college, university and trades organizations. Leadership in both communities can challenge their citizens to bring ideas forth on how to reduce energy use (and costs in the process) and pursue renewable energy technologies for the benefit of their communities.

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