Trout Lake Wind and Solar Energy Pre-Feasibility Analysis

Prepared for

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

By

Jean-Paul Pinard, P. Eng., PhD.
703 Wheeler St., Whitehorse, Yukon Y1A 2P6
Tel. (867) 393-2977; Email jpp@northwestel.net,
And
John F. Maissan, P. Eng., Leading Edge Projects Inc.
219 Falcon Drive, Whitehorse, Yukon Y1A 0A2
Tel. (867) 668-3535; Fax (867) 668-3533; Email john@leprojects.com

March 28, 2012

Executive Summary

This study provides a preliminary assessment of wind and solar energy potential in the community of Trout Lake.

The Trout Lake community has about 95 inhabitants and is located on the south end of the lake bearing the same name. Trout Lake is located about 430 km southwest of Yellowknife and is accessible by air and by winter road only. The average power use in the community was 62 kilowatts (kW) and the 2013 annual energy requirement is forecast to be 542 megawatt-hours (MWh).

The ten-year (2001-2010) average wind speed at the airport was measured to be 2.5 m/s at a height of 10 m above ground, which is considered to be very low for wind energy potential in the community. The mean solar energy potential according to NASA is 2.9 kWh/m^2/day (daily insolation), which is considered to be good for solar electricity production.

For a potential wind energy project scenario a 35 kW project based on one Wenvor 30 turbine is estimated to cost $15,200 per kW whereas a 55 kW project based on one Endurance E-3120 turbine would cost about $19,136 per kW. The two wind project options would produce power at a levelized cost of about S7.603 and $5.122 per kWh, respectively.

For a potential solar energy project in a net metering home system the installed cost is estimated to be from $10,000 per kW (for a fixed solar array) to $12,500 per kW (dual axis tracking). In a utility scale scenario (32 kW) the installed cost is estimated to be $8,000 per kW for a fixed solar array. The fixed array configuration recommended is to change the tilt angle twice a year: 45° in the summer and 90° for the winter months, this avoids extra maintenance with winter snow clearing. For an off-grid summer camp a solar system (including battery bank and power equipment) will be expected to cost from $25,000 to $27,500 per kW installed.

For the solar energy and home based net metering application there is a small cost advantage to using single axis trackers ($0.76 per kWh) compared to fixed arrays ($0.80 per kWh). For utility scale systems the cost of solar energy is estimated to be $0.64 per kWh. The cost of energy from grid connected photovoltaic systems is substantially cheaper than wind energy but still significantly more expensive than the marginal cost of diesel generation at $0.392 per kWh.

The diesel fuel savings and the greenhouse gas emissions reduction from a fixed array solar energy system in Trout Lake is expected to be 343 litres and 1,030 kg of CO2 equivalent per kW installed respectively. From a one axis array configuration the fuel savings and greenhouse emissions reduction goes up to 440 litres and 1,319 kg of CO2 equivalent per kW installed respectively.

If Trout Lake is considering alternative energy developments, the use of PV energy generation would be a far more attractive option than wind energy. PV systems can be scaled to a community's needs and the equipment is far easier to transport, install, and operate than wind systems. Should Trout Lake wish to pursue either a PV or a wind energy project, a significant level of subsidies would be required to make the project cost-effective compared to continued diesel generation.

Introduction

The cost of diesel fuel to serve northern remote communities continues to rise as world supplies become scarce. The need for developing renewable energy is becoming more urgent as communities struggle with rising energy costs. Over the past several years, the authors (JP Pinard, P.Eng., Ph.D. and John Maissan, P.Eng.) have been retained by the Aurora Research Institute (ARI) to conduct pre-feasibility studies for wind energy generation in many diesel-served communities in the NWT. All of these studies are found at the ARI website (http://www.nwtresearch.com, search for "wind energy"). With the decreasing costs of solar technology it has become apparent that solar energy is becoming more attractive for remote communities in the North. In this study, the economic potential for both wind and solar energy is assessed for their viability in Trout Lake.

The community of Trout Lake has about 95 people and is located on the south end of the lake bearing the same name. Trout Lake is located about 430 km southwest of Yellowknife (see Figure 1) and is accessible by air and by winter road only. The average power use in the community was 62 kilowatts (kW) and the 2013 annual energy requirement forecast is 542 megawatt-hours (MWh). The community power plant has three diesel generators, one has 97 kW of power capacity and two have 150 kW, owned and operated by Northland Utilities Limited (NUL, subsidiary of ATCO).The marginal cost of producing electricity from diesel (fuel and variable maintenance only) is estimated at $0.392/kWh.

No previous wind or solar resource studies (that the authors are aware of) have been done for Trout Lake. The Arctic Energy Alliance has however produced a summary of the wind and solar potential for the community. In their online report (resource section at www.aea.nt.ca) it is stated that the average wind speed is considered low at 2.9 m/s (height was not noted); however the average solar insolation (radiation) is 2.9 kWh/m^2/day which is considered to provide high solar energy potential for the community.

The purpose of this study is to examine and compare the economics of wind and solar energy development to diesel-generated electricity in Trout Lake. In this study solar and wind climate data is collected, analysed and used to model potential energy output of select wind turbine models and photovoltaic (PV) array configurations. The economic analysis looks at the costs of building and operating a wind or a solar project in the hamlet. Greenhouse gas emission reductions from these renewable energy forms are estimated. An outline of next steps is given regarding the pursuit of wind or solar energy integration in the hamlet.

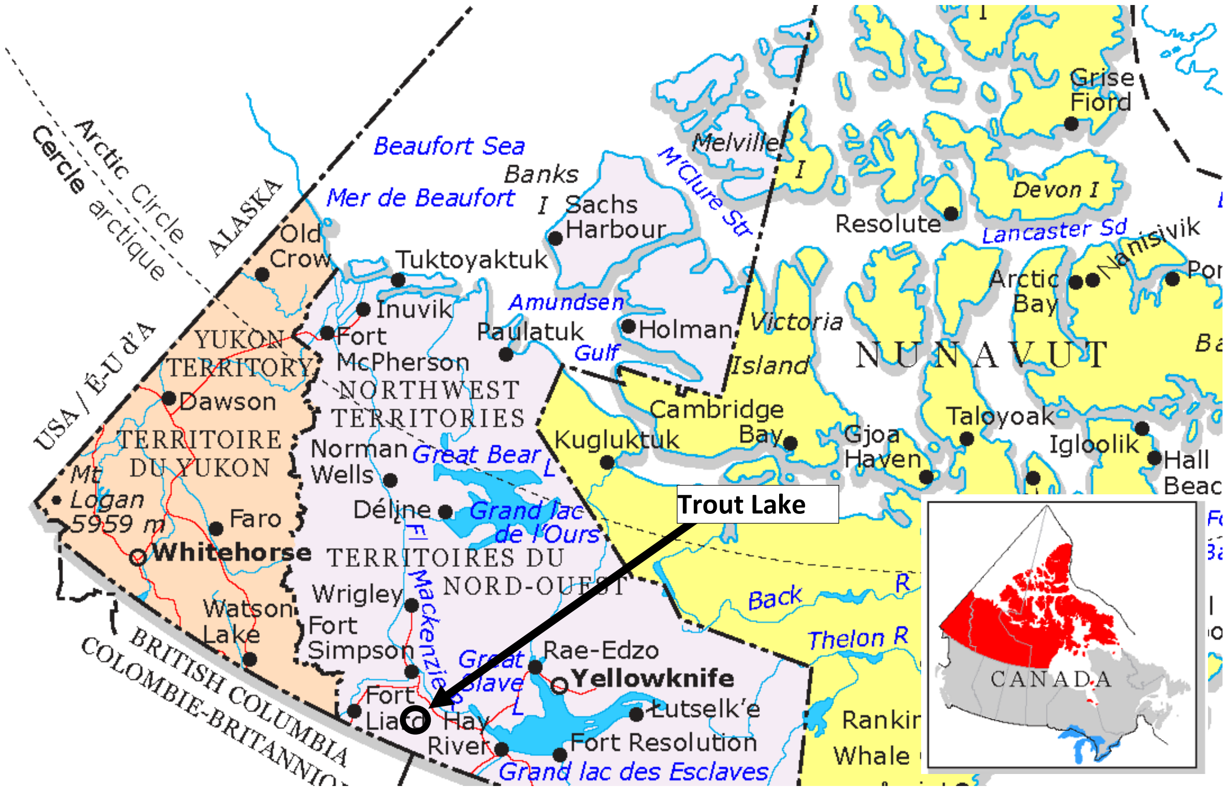

Figure 1: Trout Lake is located in the southwest NWT, about 430 km southwest of Yellowknife.

Wind Climate Assessment

To estimate the wind energy potential in Trout Lake wind speed measurements are required. The wind data used for the wind analysis was extracted from Environment Canada's (EC) climate data, which is available online at their website (www.climate.weatheroffice.ec.gc.ca). According to EC there is a climate (weather) station at the Trout Lake airport (see area map of Figure 5). The data from this station contain hourly measurements of wind speed and direction, temperature, pressure, humidity, and other parameters (solar measurements are not included in these data sets). The wind measurements at this station appear to be made at 10 m above ground level (AGL) which is the standard height for airport weather measurements in Canada.

Wind Speed

Wind data was collected from the website for the 10-year period 2001 to 2010. The 10-year mean wind speed from this set is 2.49 m/s from a height of 10 m AGL at a surface elevation of 498 m ASL. Figure 2 shows the monthly average wind speeds (at 10 m AGL) at the airport. On average the monthly wind speed reaches a minimum of about 2 m/s in December to February and a maximum of 2.8 m/s in September. An analysis of the time series shows no significant trend in the average annual wind speed over the ten-year period.

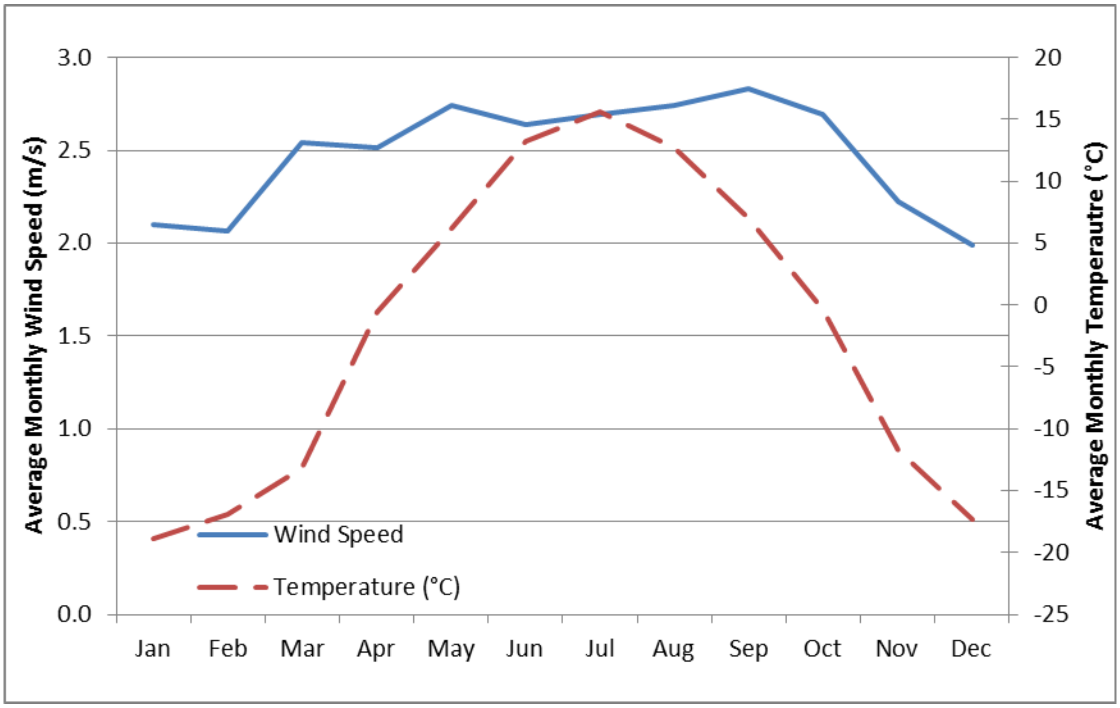

Figure 2: Monthly average wind speed and monthly average temperature at the Trout Lake Airport climate station. The average values are based on ten years (2001-2010) of measurements.

Wind Direction

Wind direction must also be taken into account when considering a wind energy project location. A wind rose provides an indication of the dominant wind direction of the area and is very useful for planning the location of a wind project to ensure its maximum capture of wind energy. In Figure 3, the wind rose for Trout Lake has a solid shaded area that represents the relative wind energy by direction. The wind energy by direction is calculated as the frequency of occurrence of the wind in a given direction sector multiplied by the cube of the mean wind speed in the same direction. The given wind energy in each direction is a fraction of the total energy for all directions. According to the wind rose, the wind energy at Trout Lake comes from two dominant directions: the southwest and the north. Therefore, a wind energy project built in the community should have good exposure mainly to the southwest and the north if possible.

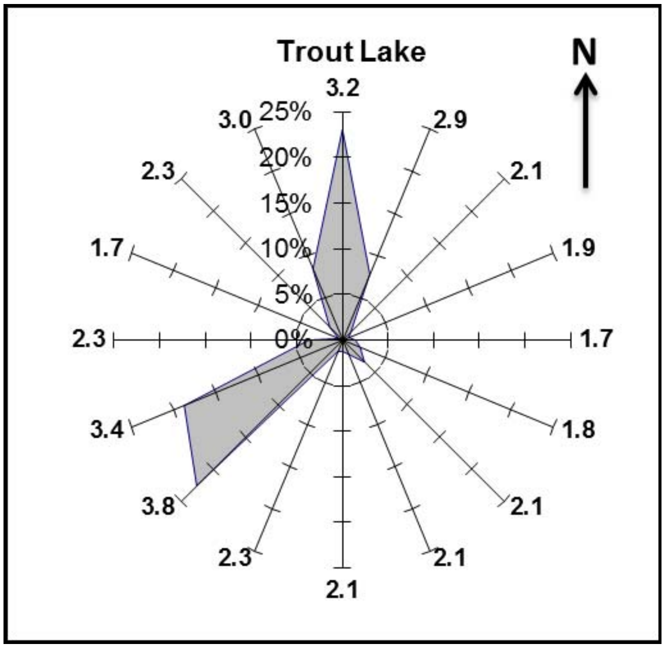

Figure 3: Wind rose showing the wind energy by direction for Trout Lake. The numbers at the end of each axis indicate the average wind speed for that direction. This rose shows that the dominant wind directions are from the north and the southwest.

Vertical Projection of Wind Speed

The wind speed measured at 10 m AGL needs to be projected to higher levels to estimate the mean wind speed for wind turbines with taller towers. The wind turbines used for this analysis are at a 30-m height (Wenvor 30) and at a 42.7-m height (Endurance E-3120), and are described later.

Turbulent air flow over rough surfaces tends to generate a vertical profile of horizontal winds that are fairly well predictable. The wind speed profile near the ground is dependent on neutral well mixed air conditions and the roughness of the ground surface. This vertical profile can be defined by the natural log law equation (see Stull, 2000):

$$u_2 = u_1 \frac{\ln(z_2/z_o)}{\ln(z_1/z_o)}$$

Where u_1 is the known wind speed at z_1 (typically at 10 m AGL), and is projected to u_2 at the height z_2. The surface roughness is defined by z_o which as a rule of thumb is 1/10 the height of the grass, brush, or ground undulations surrounding the site where the measurements are made. This equation is considered most accurate up to approximately 100 m above the surface. The surface roughness z_o can be categorised by the type and size of vegetation as well as the hilliness of the ground itself.

In Trout Lake the climate station is near the air field terminal about 100 m east of the airstrip centreline in an open field. There are trees at about 100 m away to the north and southwest and they are estimated to be about 10-12 m tall. At the climate station site, with the forest nearby, the surface roughness is estimated to be about z_o = 0.1 m, which is typical of level grass fields with few trees (Stull, 2000). Using this surface roughness value and the equation above we calculate the wind speed at 40 m, for example, to be 3.25 m/s (see Figure 4).

In the next stage of analysis, the information from the wind rose and the EC wind speed data are used to run a wind flow model that calculates and visualizes where the best wind sites might be for the Trout Lake area.

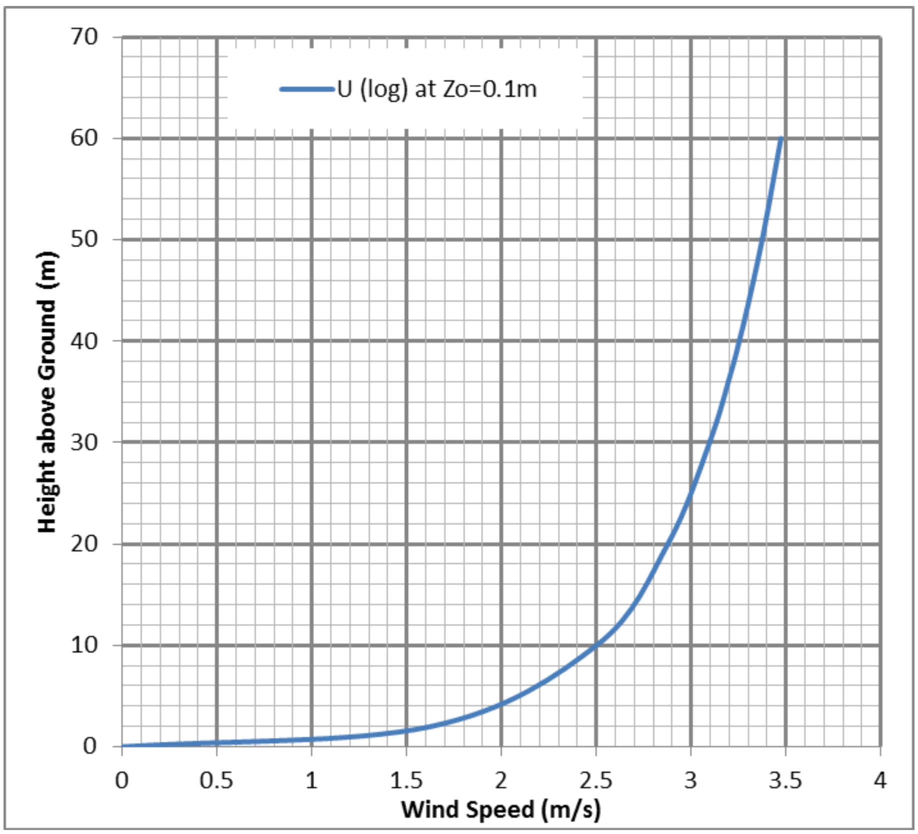

Figure 4: Vertical profile of horizontal wind speed estimated at the Trout Lake airport climate station.

Site Selection through Wind Flow Modelling

Since we only have one location that has been measured for wind speed we need other tools to help estimate the mean wind speed at other locations. To achieve this we use a numerical wind modelling tool called MS-Micro. Originally based on the boundary-layer wind field theories of Jackson and Hunt (1975), it was modified and made into a useable computer wind modelling tool by Walmsley et al. (1986).

MS-Micro was run for the Trout Lake area using a data elevation model from the Municipal and Community Affairs (MACA) website. The surface roughness values were estimated with lakes being z_o = 0.0001 m (open water and snow-covered ice surface), forested areas being z_o = 0.2 m, and the cleared open ground surfaces z_o = 0.01 m. The model domain has an area that is 4 km square centred at a point shown (as a large grey dot) in Figure 5. The model's surface resolution is approximately 31 m horizontally (128 by 128 grid points), whereas the model grid for wind calculations is approximately 16 m (grid of 256 by 256).

The winds that are applied in the model simulation are normalised, arbitrary wind speeds, and six main wind directions are applied to the model: those being 0, 23, 225, 248, 270, and 338 degrees for the six main wind directions measured by the wind monitoring station (Figure 3). The model is run six times (for each direction) and the resulting wind speed output are blended into a single output using a scaling based on the wind energy rose information of the wind monitoring station. The blended output is a normalised wind output whose contours are scaled up and calibrated to the estimated wind speed at 40 m AGL of 3.25 m/s at the airport climate station. The results of the MS-Micro modelling are shown in Figure 5.

The land in the immediate area around the Trout Lake community is relatively flat and so, as the model shows, the wind speeds do not vary significantly from the airport climate station reference point. A suggested site for a wind installation is shown in Figure 5. This site is suggested for its exposure to both the southwesterly and northerly winds. But the model predicts only a marginal improvement in the wind speeds, 3.28 m/s at 40 m AGL here compared to 3.25 m/s at the airport.

For the purpose of modelling the wind energy production at 30 and 42.7 m AGL (the heights of the two turbines used in this analysis) at the proposed wind turbine site, we will use similar vertical projections as at the airport site. At this site we will use a surface roughness of z_o = 0.0001 m to represent the smoothness of the water surface upwind of the proposed site. The new estimated wind speed for the proposed site is then 3.21 m/s at 30 m AGL and is 3.30 m/s at 42.7 m AGL. These two numbers are used to scale the wind data set used to estimate the energy production through the HOMER Energy model, which is described later in this report.

Figure 5: Mean wind speed contours based on the numerical model MS-Micro. The wind speeds are modelled at 40 m AGL. The contour interval is 0.01 m/s. The model domain covered an area that is 4 km^2 for this analysis, centred at the point indicated by the large grey dot.

Solar Climate Assessment

The information for the solar radiation in this study comes from NASA's Surface Meteorology and Solar Energy (SSE) website (eosweb.larc.nasa.gov/sse/). This site is a renewable energy resource centre that keeps a database of compiled solar, wind and other meteorological data for the purpose of evaluating the renewable energy potential at most locations around the world. This is also the same website from which solar, wind and other meteorological data is officially used for input into the RETScreen and HOMER Energy models (both described later). The database at SSE is a combination of meteorological observations and numerical modeling that provides an estimate of such things as solar radiation for locations that are lacking in measurements, such as is the case at Trout Lake.

Solar Insolation at Trout Lake

From the SSE website solar radiation data was extracted for the Trout Lake area and it is compared with actual measurements that were made in the past at other nearby locations such as Fort Smith, shown in Figure 6 below. These average insolation values represent the monthly average daily solar radiation onto a horizontal plane at the Earth's surface. Typically solar radiation is measured with the sensor pointing straight up on top of a flat horizontal (leveled) plane. The measurement is given in the form of energy (kWh) per unit area (m^2) per day. Solar photovoltaic panels are typically not set up on a horizontal plane but rather at an angle that is as close to perpendicular to the sun as possible. Different photovoltaic (PV) array configurations exist to address this and will be discussed later in this study.

The three nearest locations where there was solar radiation data that was collected in the past are Fort Smith and Norman Wells in the NWT and Fort Nelson in BC. Both Fort Smith and Fort Nelson collected data from 1971 to 1988, and Norman Wells collected data from 1967 to 1987. In Figure 6 we can see that the solar radiation estimated by SSE for Trout Lake is similar to that of Fort Nelson, BC and not very different from Fort Smith. With respect to latitude, Trout Lake is only 40 km north of Fort Smith and 170 km north of Fort Nelson. Norman Wells is about 550 km north of Trout Lake, and shows slightly more insolation in the summer and less in the winter compared to other three communities to the south. The average annual insolation for Forth Smith and Norman Wells were 3.01 and 2.66 kWh/m^2/day respectively. The average annual insolation for Trout Lake was estimated to be 2.90 kWh/m^2/day.

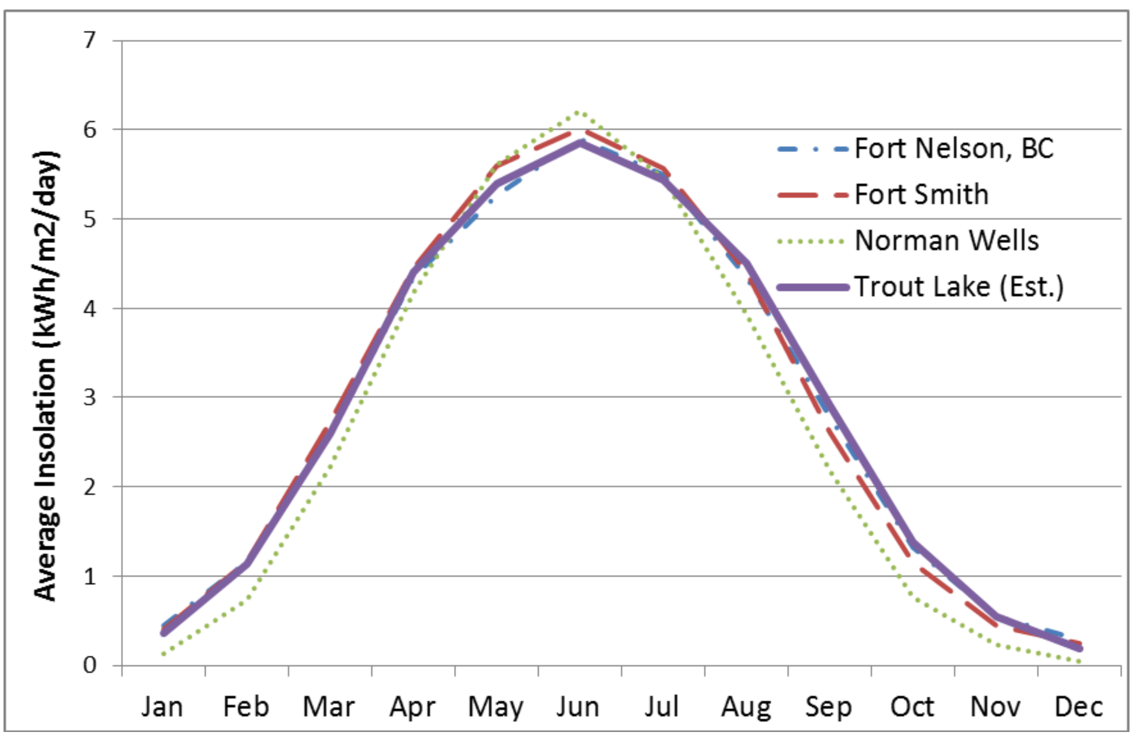

Figure 6: Monthly average insolation, or solar radiation, on a horizontal surface measured at Fort Nelson, Fort Smith, and Norman Wells, and estimated at Trout Lake. All were acquired from the SSE website.

Site Selection for Solar Systems

Within the community of Trout Lake, the insolation values are likely similar anywhere that there is an open area without obstructions such as trees and buildings to shade the solar installation. Ideally the solar PV installation would be next to the power grid. If a home PV installation is being considered, it would be best placed on a south-facing roof or on the ground if there is clear exposure to the sun. For a utility scale fixed array installation, the best location is close to a powerline in a large field exposed to the south. If a tracking system is selected then the area must be exposed to the east, south, and west.

Community Power Requirements and Costs

The community of Trout Lake has its electricity requirements supplied by a Northland Utilities (NWT) Ltd. (NUL, subsidiary of ATCO) diesel power plant consisting of three generators: one 97 kW and two 150 kW generators, for a total capacity of 397 kW. Residual heat recovered from the plant is used to heat the town garage. The most recent NUL General Rate Application (GRA) indicates that the fuel efficiency of the diesel plant is 3.29 kWh per litre.

The 2011-2013 GRA forecast power requirement in the community for 2013 is 542 MWh. This represents an average diesel plant load of about 62 kW and a peak load of about 124 kW. The authors estimated that the minimum plant load is in the order of 35 kW. Relevant excerpts from the NUL GRA documents are attached as Appendix 1. With the diesel plant fuel efficiency provided above and the expected annual electrical energy produced from diesel this represents about 164,742 litres of diesel fuel that will be consumed for electricity production in the community.

In modelling the integration of wind and solar energy with the Trout Lake diesel plant the authors assume that the minimum allowable load of the smallest diesel generator is 30% (typical) of the generator's capacity. For the 97 kW generator at the Trout Lake diesel plant this sets the minimum load at 29 kW. If a community's load drops below this level it simply means that the generator is producing at a lower efficiency level and power quality may become more difficult to control. When adding a renewable energy source to the overall system, on occasions when the community load will be so low (say down to 35 kW in the summer) and the renewable energy production will be high (say 30 kW), then the diesel generator will produce at less than 30% capacity (5 kW in this example). The plant operator will likely wish to cut back on the renewable energy source to keep the diesel generator operating at above 30% load to keep the efficiency up. To cut back on the renewable energy system one must use power controllers that either dump the excess electric from the wind or solar system to outdoor heaters or store the excess electric for later use. The storage can take the form of heat, say, in hot water tanks or in batteries which adds another level of complexity to the whole system. The storage of renewable energy has a future in diesel communities like Trout Lake; however, it is beyond the scope of this study, which is simply to compare the economics of wind to solar energy production. The sizing of the renewable energy systems in this study are meant to be optimized so that little storage or power stabilizing technology are required, thus keeping the renewable energy system integration relatively simple.

For this prefeasibility study, a wind project size of 35 to 55 kW was selected. This represents a low to medium penetration level project with a single wind turbine, and is probably as large as is practical as a first step. A larger project provides economies of scale that a smaller one does not. This study did not examine a higher penetration project as the authors feel that more experience with simpler wind-diesel projects in NWT is required before more technically complicated high penetration systems are taken on.

This study also examines solar PV opportunities in one generic seasonal (April to September) off-grid application (e.g. a camp) involving a 1 kW array, and in two grid connected applications. The grid connected options are a 5 kW net metering arrangement by a residential consumer and a 32 kW utility owned project. Unlike wind turbines, PV arrays can be sized in small increments (of about 200W) and projects can easily be expanded. As well, the transport and installation of PV equipment is simple compared to wind turbines. The operation of PV systems is also relatively simple, but the integration of significant PV capacity, that is, greater than 32 kW, with a diesel plant may be as challenging as significant wind capacity due to a requirement for electrical power stabilizing equipment.

For the purposes of this study it has been assumed that the NUL diesel power plant would save diesel fuel at a rate of 1 litre per 3.29 kWh displaced. This diesel plant would produce variable (or incremental) electrical energy at a levelized cost of $0.392 per kWh over 20 years with diesel fuel at starting $1.00 per litre and increasing with general inflation (2% in model). These costs include only fuel and $0.03 per kWh variable operation and maintenance (O&M) costs. The economic model assumes that the cost of capital is 7.5%.

Wind Power Project

Developer – Operator

For the purpose of this report it was assumed that a wind project would be a low to medium penetration project with a single wind turbine and displace a reasonable amount of diesel consumption without compromising the quality of the electric grid. A larger wind project would require a more complex power and energy control system. A larger project would also create an opportunity to utilise excess wind energy for space heating and eventually other applications (such as local transportation), which would add greater benefits to the community at large. This high level of diesel displacement has however, not been implemented to any great extent in Canada. High penetration systems are being used in Alaska and Australia and could be considered as a future possibility for a project in this community.

For this report it is also assumed that if a wind project were to be developed in Trout Lake it would be done by a developer with wind project experience in the NWT. There is no allowance in the project cost estimates for overcoming a learning curve for inexperienced developers/operators. If a project were to be developed by an inexperienced firm the capital costs would almost certainly be higher. In the opinion of the authors, the project would ideally be developed by or in partnership with the current electrical power supplier (owner of the diesel power plant) in order to make the best use of existing experience, expertise, and infrastructure in the remote communities. As well, the integration of the wind and diesel plants (including power purchase agreement issues) would then be relatively seamless and some overhead costs avoided.

Wind Turbines

Two wind turbine models of appropriate size (capacity) were selected for consideration at Trout Lake based on Trout Lake's low electrical load. These are the Wenvor 30 (35 kW capacity with a 10m rotor diameter) which is not really suited to a low wind speed but is one of the few turbines of this size available and the Endurance E-3120 (55 kW with a 19.2 m rotor) which is better suited to low wind speeds. Neither turbine is presently available with an option for operation down to -40°C so a small allowance for low temperature operation (e.g. low temperature lubrication) was included in the pricing.

Energy Production

The annual energy production from each of the selected wind turbines is calculated using the HOMER model. HOMER was developed by the National Renewable Energy Laboratory of the US Government and is now distributed and supported by HOMER Energy (www.homerenergy.com). HOMER is a power system analysis and optimization model. The energy model uses published wind turbine power curves, diesel plant production specifications, and one-year hourly time series measurements of both wind speed and community power load to model the energy output of various power generators. Two project configurations were examined: first one Wenvor 30 (35kW), and second one E-3120 turbine (55 kW).

The inputs for the HOMER model consist of the three diesel generators described earlier, the wind system and a typical community load data set scaled to Trout Lake's load profile. The wind resource data used as input for the HOMER is a one-year data set synthesized from the ten-year data set from the climate station measurements at the Trout Lake airport. This wind data was then adjusted for the proposed wind turbine site from the MS-Micro wind flow model resulting in a prediction of an average annual wind speed of 3.21 m/s at the Wenvor 30m hub height and 3.30 m/s at the E-3120 42.7m hub height.

The energy produced by each of the selected turbines is based on the published power curves, less 5% to adjust for a turbine availability of 95%. An additional 10% of the production is then subtracted to account for losses (turbulence losses, array losses, mechanical losses, cold and icing performance losses, transformer losses, and transmission line losses) to arrive at the net energy production available to displace diesel energy. Net generation is the HOMER calculated ideal generation less availability and other losses (total deduction of 15% from the ideal generation). Appendix 2 presents a table of energy production from the two project configurations with the two wind turbine models described. The net energy produced by each turbine is also shown in Table 2. The net surplus is assumed to be dumped and not utilized (load stability controllers are factored into the costs). Often there is an adjustment for increased production at higher air densities due to cold temperatures which, in this case, would likely be 5% or a bit higher. However, to be conservative no air density adjustments were made in this study.

The calculations indicate that the net energy generation at the annual average wind speed at the turbine hub height represents a capacity factor of about 2.7% for the Wenvor 30 and 5.5% for E-3120. Although both have very low capacity factors due to the low wind speeds, the Endurance E-3120 turbine has a higher capacity factor than the Wenvor 30 because of its relatively larger rotor diameter (designed for low to moderate wind climates).

The energy calculations in Appendix 2 also indicate that one Wenvor 30 (30 kW) and one Endurance E-3210 (55 kW) will produce 236 and 457 kWh per kW installed respectively (divide diesel energy displaced by total power capacity or the wind turbines).

Capital Costs

The estimated capital costs for the two single turbine projects are presented in Appendix 3 and are summarized below:

1. A 35 kW project based on one Wenvor 30 turbine was estimated to cost about $517,000 or $15,200 per kW;
2. A 55 kW project based on one E-3120 turbine was estimated to cost about $1,052,500 or $19,136 per kW;

The power line required to connect wind project to the community's power system is very modest as the proposed project site is immediately adjacent to the community. Other major cost items besides the purchase of the turbines and towers are the foundation design and the associated geotechnical work at about $80,000 to $120,000, and the mobilization and demobilization of a crane at about $75,000 for the E-3120 turbine. Crane costs could be higher if the turbine installation does not coincide with the winter road being open.

The capital costs of a wind project are a major energy cost driver, so it is critical for any developer to pay considerable attention to all capital cost components. Larger projects provide economies of scale that reduce costs per unit of installed capacity but for this very small community no real economies of scale exist.

Operating and Maintenance Costs

The annual operating and maintenance cost for a project of one turbine was estimated to be about $10,000 for the Wenvor and $20,000 for the E-3120. This cost is based on the simple requirements to keep a project running and does not include costs that may be associated with establishing and running a corporation for the wind project only. The effective assumption is that the wind project is owned and operated by an appropriate existing organization involved in other similar activities (e.g. An independent power producer that owns several renewable energy projects and Trout Lake is one of their projects). The operating and maintenance cost is intended to include all overhead, insurance, lease, and tax costs as well as the actual maintenance costs. This is equivalent to about $0.64 (E-3120) to $1.21 (Wenvor 30) per kWh, which is quite high because of the relatively low energy production from the wind turbines in the low wind speed regime.

For the economic analysis (presented in the following subsection) the cost of capital was assumed to be 7.5%, which represents a regulated utility. Incorporated in the cost of capital is a return on equity which would be earned by the project owners and is separate and distinct from the annual operating and maintenance costs. The authors believe that funding assistance would likely be necessary to interest a wind project developer and this would increase the effective return on equity or reduce the cost of debt. A project developer would need to calculate the economics of a project based on their own circumstances.

Cost of Wind Energy and Economic Analyses

The levelized cost of wind energy over a 20 year project life was calculated to compare the cost of wind generated electricity to the cost of diesel generation. Appendix 4 presents the economic model outputs of the levelized cost of wind energy for the two project variations and Appendix 5 presents the economic model outputs for continued diesel generation. The variables and assumptions used in the economic model include the project capital cost, its capacity in kW, its annual diesel displacing energy production, the useful life of a wind project (20 years), the cost of capital (7.5%), the general inflation rate (2%), and the annual operating costs. The model calculates the levelized cost of energy over the life of the projects.

For continued diesel generation, the assumptions include a variable operating and maintenance cost of $0.03 per kWh, a plant efficiency of 3.29 kWh per litre, and diesel fuel is assumed to inflate at 2% per year, the same as general inflation. Also the authors based the diesel fuel pricing of $1.00 per litre on NUL's GRA ($0.803 per litre) plus a factor representing the present higher fuel costs. $1.00 per litre was considered to be reasonable and consistent with fuel costs assumed for other communities for which prefeasibility studies are also being completed at this time (Deline $1.35, Jean Marie River $1.15, Wha Ti $1.25, and Ft. Providence $1.05). Table 1 summarizes the results of the economic modelling.

Table 1: Twenty-year levelized cost of energy for wind projects and continued diesel generation.

Project Configuration	20 year Levelized Cost of Energy ($ per kWh)
One Wenvor 30 turbine	$7.603
One Endurance E-3120 turbine	$5.122
Diesel generation, $1.00 per litre	$0.392

The economic analyses summarized in the table above indicate that although there is some variation in the levelized cost of energy for different wind project options, which is largely a function of the energy capture due to variation in swept area per unit capacity, wind energy is between ten and twenty times as expensive as continued diesel generation. Even with a very modest cost power line, neither wind project configuration was close to diesel generated power in cost. All of the capital costs and a portion of the O&M costs would need to be subsidized to make a wind project cost competitive with diesel generation.

Of the two turbines considered, the Endurance E-3120 with its large rotor would generate the most cost effective wind energy and thus the lower cost electrical energy. However, the very low wind resource in Trout Lake would prevent a wind energy development from being economically feasible.

It is possible that with an experienced wind project development industry based on other projects in the Northwest Territories a more cost effective project could be installed in Trout Lake but this would still not produce cost effective energy. Other renewable energy options for Trout Lake should be considered.

Greenhouse Gas Reductions

Table 2 outlines the diesel fuel and greenhouse gas (GHG) reductions that would be achieved by the two wind projects examined in Trout Lake. The calculations are based on a diesel plant efficiency of 3.29 kWh per litre, and GHG emissions of 3.0 kg carbon dioxide (CO_2) equivalent per litre of diesel fuel consumed.

Table 2: Annual energy productions, fuel savings and GHG reductions from a wind project of 35 or 55 kW in Trout Lake.

Project Configuration	Diesel Electricity Displaced (kWh)	Diesel Fuel Saved (litres)	GHG Reductions (kg CO_2 equivalent)
One Wenvor 30 (30 kW)	8,248	2,507	7,521
One Endurance E-3120 (50kW)	24,273	7,378	22,133

Wind Power Conclusions

1. Wind power is not a realistic alternative for diesel power generation in Trout Lake.
2. There is a potential wind project site adjacent to the community of Trout Lake.
3. Based on local airport weather data and computer modelling, the wind speed at 30 and 42.7 m AGL is projected to be 3.21 and 3.30 m/s, respectively.
4. Capital costs for a project of 35 kW (Wenvor 30) and 55 kW (Endurance E-3120) would be $532,000 and $1,052,500, respectively.
5. The wind projects would produce power at a levelized cost of about S7.603 and $5.122 per kWh respectively.
6. The Endurance E-3120 with its large swept area per kW of capacity would produce lower cost energy. The Wenvor with its relatively smaller swept area per kW of capacity would produce higher cost energy.
7. A 55 kW E-3120 turbine project would displace 7,378 litres of diesel fuel per year and reduce GHG emissions by 22,133 kg of CO_2 equivalent per year.

Solar PV Project

Project Owners

Three different solar PV applications were considered in this study, and in each case the ownership was different. The first application was a small remote camp using a 1 kW PV array. In this case the camp owner was assumed to own the PV project. The second application was a net metering (i.e. grid connected) installation of a 5 kW PV array, assumed to be owned by a private residential power consumer. The residential consumer was assumed to be acting individually as opposed to being part of a larger project involving many homes. The third application was a 32 kW grid connected project owned and operated by the utility owning the diesel plant. An independent power producer with other business interests (since one small project would probably not justify a stand-alone business) is also a possibility but would involve somewhat more equipment and overhead costs (metering facility, contractual arrangements with the utility, etc.).

PV Equipment

For the 1 kW off-grid and the 5 kW net metering grid connected applications, complete system kits were selected for use in this study. These costs were found to be up to 20% higher than individually sourced components that could be assembled by an owner with appropriate skills and some professional advice. However, the complete kit approach was considered to be a good first approximation on systems and costs. The off-grid kit would include everything – PV modules, fixed array mounting system, charge controller, battery bank, sine wave inverter, power panel/centre, and all required cabling.

The 5 kW net metering kit includes PV modules, micro-inverters, fixed array mounting system, and all cabling (no batteries). Typical PV module sizes are 170 to 230 Watts. For both the off-grid and the net metering applications retail single and dual axis tracking systems were also considered (see Figure 7). The costs of such tracking systems were added to the cost of the kits described.

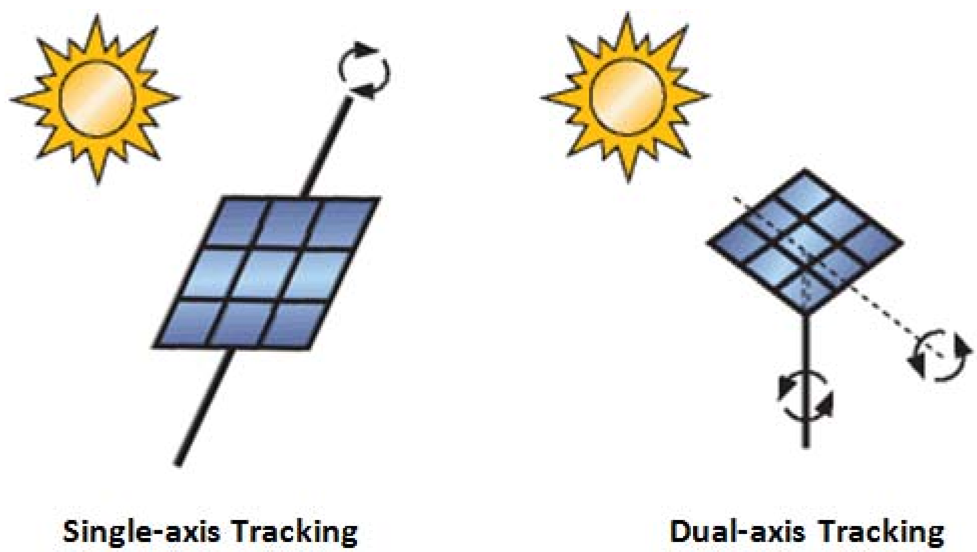

Figure 7: Two most common tracking modes for a solar system with dynamic tracking. A single-axis tracker tracks the sun by rotating around an axis located in the plane of the collector. The axis can have any orientation but in the northern latitudes it is usually pointing south with a tilt that is nearly parallel to the earth's axis. The dual-axis tracker always positions the array surface normal to the beam of the sun by rotating about two axes. Source: www.RETScreen.net.

The utility scale PV costing was based on updated detailed wholesale costing lists for 50kW (or greater, based on concurrent work done in Whati and Deline, see ARI website for reports). However, because the minimum load in the hamlet is about 35 kW (usually between midnight and 6 am) the size of a utility scale solar project is limited to about 32 kW (based on HOMER Energy model runs). A 32kW project could likely be done at the same unit costs as for a 50 kW system and that would make no difference to the economics of PV, but if unit costs did go higher, then the economics would be less favourable than shown. It is assumed that the utility was experienced in PV projects and closely involved in the subject project. Foundation requirements are uncertain and may contribute to higher costs than projected in this study.

The pricing for PV modules at a wholesale level is very competitive at the moment; some reports indicate that costs have decreased to nearly $1.00 per watt of capacity (compared to a retail cost of about $10/watt in 1990s).

Energy Production

For off grid camp and the net metering home applications energy production from three different PV array configurations are considered: first a fixed array that is tilted at about 45° (from the ground) from April to September and at 90° from October through March; secondly a single axis tracker set at a tilt of 55°; and thirdly a dual axis tracker. For the utility scale system only the fixed array configuration was considered but with the same 45° and 90° for summer and winter. The fixed and single axis tracker configurations are assumed to be facing south. The tilt angles that are chosen for each configuration are the most optimum angles that maximize the annual solar energy production in the Trout Lake area. The reason for choosing to tilt the fixed array to 90° in the winter months is to avoid snow build up and subsequent maintenance cost associated with snow clearing requirements. A solar array at any angle less than 90° will often build up with snow and prevent the solar array from producing electricity after a snow fall in the winter. Another advantage to tilting the array to 90° in the winter is the added effect of snow reflectance from the ground to the array, which will improve the performance of the system.

If one chooses to use a fixed array at a permanent angle (the optimum angle would be at 50° for Trout Lake's latitude) then the expected losses due to snow cover will be about 12% (based on work done by Wohlgemuth, 2007) depending on snow fall and weather conditions. It should also be noted that a fixed array configuration set permanently at 50° will produce about 3% less energy than a fixed array adjusted seasonally as indicated above. The total losses will likely amount to 15% if one chooses to use a permanently fixed array system as opposed to one that is adjusted seasonally with the 45° tilt in the summer and 90° tilt in the winter.

The above PV array configurations are analysed for their theoretical performances through the use of the RETScreen Clean Energy Project Analysis Software. RETScreen (Microsoft Excel - based) is a decision support tool developed and supported by the CanmetENERGY research centre of Natural Resources Canada (NRCan). The software is free-of-charge and is used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). More information on the software can be found at www.retscreen.net.

For the utility scale solar system the HOMER Energy model (also used for the wind energy modeling) was used to identify the maximum size a solar system can be without producing excess energy and thus requiring grid power stability equipment or storage. This situation will occur during the summer when the community load is smallest and the solar production is greatest.

Using the SSE insolation data (for Trout Lake) and RETScreen's modelling capability, the monthly and annual energy production of each configuration at various tilt angles were evaluated. RETScreen's solar modelling tool takes into account such factors as ground (snow) reflectance, inverter efficiency, solar cell types and sizes to calculate monthly energy production from these difference array configurations.

The RETScreen energy production calculations are based on an array of generic PV modules with total power capacity of 1 kW (7 m2 area), with an efficiency of 14.4%, a temperature coefficient of 0.40%/°C, and a nominal operating cell temperature of 45°C. Losses of 10% from inverter inefficiency (90% efficiency assumed) and 15% from miscellaneous sources (including module ageing) were assumed in the RETScreen model. The model also included additional losses of 10% for snow shading for the grid connected home and utility systems on trackers; snow shading losses do not apply to the fixed array scenarios, which assume a 90-degree tilt for the winter. Losses are an additional 20% for the off-grid system which uses a charge controller (about 5%) and a battery bank (about 15%).

The result of the RETScreen solar array configuration performance evaluation for Trout Lake are summarised in Figure 8. Projections of the net energy production per kW of array capacity (after losses) at Trout Lake's latitude are outlined in Table 3.

As Table 3 shows, a one kW system on a fixed array will produce about 1130 kWh per year. The total energy production for a 5 kW home based system on a roof using the fixed system will translate into 5650 kWh per year. A utility scale 32 kW fixed array system in Trout Lake will produce 36,160 kWh per year without producing significant excess electricity.

Figure 8 illustrates how a tracking system will have an advantage over a fixed south-facing configuration. Because the tracker allows the solar array to face the sun from morning through afternoon, it captures about 40% more solar energy, mostly during the summertime. Despite the advantage, the tracking system can be compromised if there is snow build up, shading by buildings, trees, or neighbouring solar tracking arrays. For all configurations the advantage of snow reflectance is seen for the months of March to May.

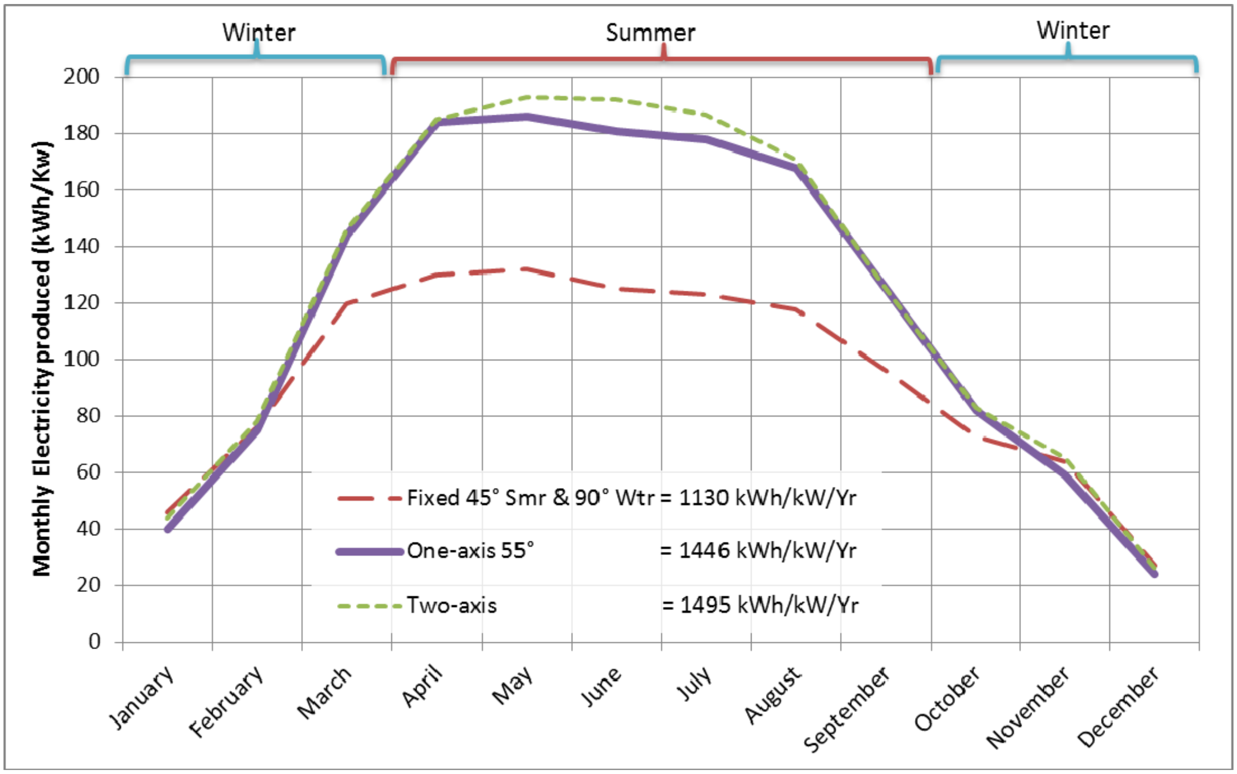

Figure 8: Monthly electricity produced from each type of solar array configuration for Trout Lake, based on RETScreen analysis. Smr = Summer (April to September); Wtr = Winter (October to March).

Table 3: Projected net energy production in Trout Lake. Smr = Summer (April to September); Wtr = Winter (October to March).

System description	Use	Added losses (B = battery, S = snow)	Net annual energy Capacity in kWh / kW	
Off grid camp				
Fixed array: 45°	April – Sept.	B: 20%	579	
1 axis tracker: 55°	April – Sept.	B: 20%, S: 10%	818	
2 axis tracker	April – Sept.	B: 20%, S: 10%	842	
Net metering home (on grid)			**1 kW**	**5 kW**
Fixed array: 45° Smr & 90° Wtr	All year		1,130	5,650
1 axis tracker: 55°	All year	S: 10%	1,446	7,230
2 axis track	All year	S: 10%	1,495	7,475
Utility (32 kW)			**1 kW**	**32 kW**
Fixed array: 45° Smr & 90° Wtr	All year		1,130	36,160

Capital and Operating Costs

Capital costs for the off-grid camp and net metering home applications were based on retail kit costs available on the open market. The authors estimate that knowledgeable owners could buy components and assemble their own systems (with professional advice as required) for about 20% lower capital cost, however, for the purposes of this report the retail kit cost was considered to be a good first approximation. Costs for solar tracking systems for the off-grid and net metering home application were taken from retail web site price listings and were simply added to the kit cost.

Capital costs for utility scale PV systems were based on various existing cost breakdowns available and indicated that in southern Canada these projects would probably cost about $6,500 per kW at present. With increased shipping costs and higher installation costs in the north $8,000 per kW was considered to be a reasonable estimate for a fixed array adjusted twice per year. Given the limitation to a modest size capacity of a utility scale system it would be practical to keep it as simple as possible (fixed array, ground mounted and self ballasted if possible, and adjusted twice per year) rather than getting into the complexity of tracker systems and their more stringent foundation requirements.

In all cases operating and maintenance costs were estimated at $25 per kW of capacity per year for the PV system and where trackers were used an additional $25 per year per kW of capacity was applied. A summary of the operating and capital costs appears in Table 4 below. These costs are probably low for an off-grid battery based system but the alternative of a gas or diesel generator would also involve significant maintenance so these were considered to be off-setting costs.

Table 4: Capital and operating costs of PV systems

System description	Capital cost $ per kW	O&M cost $ per kW per year
Off grid camp (1 kW battery based)		
Fixed array	$25,000	$25
1 axis tracker	$27,000	$50
2 axis tracker	$27,500	$50
Net metering home (5 kW grid connected)		
Fixed array	$10,000	$25
1 axis tracker	$12,000	$50
2 axis track	$12,500	$50
Utility (32 kW)		
Fixed array	$8,000	$25

Cost of PV Energy and Economic Analysis

The levelized cost of energy (LCOE) for PV was examined on the basis of a 25 year project life using an economic model that assumed that the cost of capital was 7.5% and that the inflation rate was 2% per year. As well a modified simple payback was calculated. This consisted of offsetting the O&M cost on the basis of kWh at the applicable marginal rate and then using the savings on the remainder to pay off the capital. The resulting costs and payback are shown in Table 5.

For the off-grid camp two fuel efficiencies were considered, 2 kWh per litre and 1 kWh per litre, which corresponds roughly to a small diesel generator reasonably well loaded and a Honda 6,500 watt generator with the inverter loaded at about 50%, respectively.

For net metering homes, three PV energy value cases were considered: (1) the subsidized Yellowknife rate of $0.232 per kWh, (2) the unsubsidized community rate of $0.8928 per kWh, and (3) the incremental diesel savings of $0.392 per kWh. Note that the diesel saving of $0.392 per kWh is a 20 year levelized cost also used in wind project analyses. The 25 year levelized cost would be a bit higher but using the same value as in the wind generation option avoids confusion.

For the utility scale project, only the diesel saving of $0.392 per kWh was considered.

For off-grid camps, the 25 year LCOE ranged from $2.91 per kWh with the dual axis tracker to $3.81 per kWh with the fixed array. This compares to $1.22 to $2.43 per kWh from small generators, depending on fuel efficiencies. The simple payback after O&M expenses ranges from about 14 to 37 years, depending on the fuel efficiency of the generator and whether a tracker is used on the PV array. A dual axis tracker and the less fuel efficient generator results in the fastest payback, while the fixed array and more efficient generator results in the longer payback.

Table 5: Summary of PV energy cost and payback ranges

System description	LCOE $/kWh	LCOE* diesel $/kWh	Community rate	Yellowknife rate	Simple payback after maintenance years
Off-grid camp					
Fixed array	$3.81	$1.22 to $2.43			18 to 37
Array on tracker	$2.91 to $2.95	$1.22 to $2.43			14 to 28
Net metering home					
Fixed array	$0.80	$0.392	$0.8928	$0.232	10 to 42
Array on tracker	$0.76 to $0.77	$0.392	$0.8928	$0.232	10 to 42
Utility					
Fixed array	$0.64	$0.392			19
* the LCOE for camp diesel is over 25 years, for other applications over 20 years					

For PV arrays on grid connected homes, the 25 year LCOE ranges from $0.76 per kWh for a single axis tracker to $0.77 per kWh for a dual axis tracker, and $0.80 per kWh for a fixed array (with tilt adjusted twice per year). The modified simple payback at the unsubsidized community rate is about 10 years, at the LCOE diesel cost is 23 to 24 years, and at the subsidized (in Trout Lake) Yellowknife rate is about 42 years.

For Utility scale projects, the LCOE of PV energy was $0.64 per kWh for the fixed array configuration. (Of interest to the utility or IPP: the LCOE was also calculated for single and dual axis trackers for the same utility scale PV array (sized reduced to 20 kW to avoid power instability) and the cost was found to be $0.64 and $0.65 per kWh respectively. So there is no significant advantage to using trackers for utility scale PV arrays.). The modified simple paybacks were about 19 years.

From a net-metering perspective the single axis tracker offers a small advantage in term of cost per kWh over the other two options.

GHG Reductions

GHG reductions are directly proportional to the diesel energy displaced. For this reason off-grid applications (where the alternatives are small diesel or gas generators, which have poor efficiencies compared to utility generators) offer the greatest GHG reductions per unit of capacity. The GHG reductions at seasonal off-grid camps using a single axis tracker would range from 1,227 (409 litres diesel saved) to 2,454 (818 litres of gasoline saved) kg of CO_2 equivalent per year per installed kW of capacity. A dual axis tracker would be marginally better and a fixed array would save 22% to 25% less.

The GHG reductions resulting from three scales of solar systems connected to the grid are shown in Table 6. Net metering and utility scale projects all displace fuel at utility power plant fuel efficiencies, which in the case of Trout Lake is 3.29 kWh per litre. These systems would save 1,030 kg of CO_2 equivalent per kW of installed capacity per year when fixed (with tilt adjusted twice per year), 1319 kg of CO_2 equivalent per year on a single axis tracker, and 1363 kg of CO_2 equivalent per year on a dual axis tracker. This assumes all of the installed capacity displaces diesel fuel. Larger projects in which some of the PV energy is surplus to system needs would result in lower GHG reductions.

Table 6: Annual energy productions, fuel savings and GHG reductions from grid-connected solar project scales of 1, 5, or 30 kW in Trout Lake. The two configurations are fixed frame configuration with 45° tilt in summer and 90° in the winter and a single axis tracker.

Project Configuration	Diesel Electricity Displaced (kWh)		Diesel Fuel Saved (litres)		GHG Reductions (kg CO_2 equivalent)	
	fixed	One axis	fixed	One axis	fixed	One axis
Grid-connected – 1 kW	1,130	1,446	343	440	1,030	1,319
Grid-connected – 5 kW	5,650	7,230	1,717	2,198	5,152	6,593
Grid-connected – 32 kW	36,160	-	10,991	-	32,973	-

PV Project Conclusions

1. PV systems can be utilized in a variety of applications and scaled in size to meet requirements.
2. Complete PV systems of about 1 kW of capacity for off-grid applications are likely to cost in the order of $25,000 to $27,500 per kW of installed capacity depending on whether a fixed array or trackers are used.

3. Home size net metering (grid connected) PV systems are likely to cost in the order of $10,000 to $12,500 per kW of installed capacity for fixed and tracker mounted systems respectively and corresponding utility scale projects would likely cost in the order of $8,000 per kW of installed capacity for fixed array systems.
4. The cost of energy from grid connected PV systems at $0.64 to $0.80 per kWh is substantially cheaper than energy from wind energy projects in Trout Lake (lowest cost $5.122 per kWh) but still significantly more expensive than the marginal cost of diesel generation at $0.392 per kWh.
5. For small grid connected systems there is a small cost advantage to using single axis trackers compared to dual axis or fixed arrays. For utilities scale systems fixed arrays are about as cost effective as tracked systems and probably more practical for small projects.
6. It is possible that capital costs for grid connected systems could be reduced with larger scale projects or a larger number of projects, but at present it would appear that the resulting energy would still be more costly than diesel generation.

Next Steps

1. If Trout Lake is considering alternative energy developments, the use of PV energy generation would be a far more attractive option than wind energy. PV systems can be scaled to a community's needs and the equipment is far easier to transport, install, and operate than wind systems.
2. If a wind energy development were to be considered seriously for Trout Lake, a wind monitoring mast should be installed at the proposed project site. Following confirmation of the wind resource, a detailed feasibility study could be carried out. Particular attention would be required to minimize capital costs and identify any available support programs.
3. Should Trout Lake wish to pursue either a PV or a wind energy project, a significant level of subsidies would be required to make the project cost-effective compared to continued diesel generation.
4. If a utility or independent power producer were to pursue a larger scale solar project (larger than 32 kW) then some further feasibility work with energy and economic modelling would be recommended to further optimize solar system integration with the diesel plant.

Reference

Jackson, P. S., and J. C. R. Hunt, 1975. **Turbulent wind flow over a low hill**.Quart. J. R. Meteor. Soc., 101:929–955.

Stull, R.B., 2000. **Meteorology for Scientists and Engineers**, Second Edition.Published by Brooks/Cole.

Walmsley, J., P. Taylor, and T. Keith, 1986. **A simple model of neutrally stratified boundary-layer flow over complex terrain with surface roughness modulations (MS3DJH/3R)**. Boundary-Layer Meteorology, 36:157–186.

Wohlgemuth, D., 2007. **Solar Photovoltaics in the NWT, Jean Marie River Band Office, System Overview**. Summary paper for the Arctic Energy Alliance.

Appendix 1

NORTHLAND UTILITIES (NWT) LIMITED
An ***ATCO*** Company

April 21, 2011

Northwest Territories
Public Utilities Board
203 – 62 Woodland Drive
Box 4211
Hay River, NWT, X0E 1G1

To: Mr. Joe Acorn
Board Chairman

Dear Sir:

Re: Northland Utilities (NWT) Limited 2011-2013 General Rate Application

Northland Utilities (NWT) Limited ("Northland") has attached its Phase I General Rate Application for the 2011-2013 test period.

This application includes:

- Determination of the 2011–2013 revenue requirement included in Sections 1 to 11
- Interim Refundable Rate Riders in Section 12, and
- 2010 Deferral Application and Interim Refundable Rate Riders in Section 13

Other items included in Northland's Annual Filing are included and referenced in Section 14.

Northland anticipates that it will be filing a Phase II Rate Application by June 30, 2011. Included in the Application will be an updated Cost of Service Study, Rate Design, and Terms and Conditions. To support the implementation of the Government of the Northwest Territories (GNWT) Electricity Review, Northland will be following the Revised Electricity Rate Policy Guidelines for the preparation of its Phase II Application including the design of class rates on a thermal and hydro zoned basis. If the Board believes Northland's proposed Phase II approach is not aligned with the Revised Guidelines, Northland respectfully requests the Board's guidance relating to zonal rates.

Northland Utilities (NWT) Limited
2011 - 2013 General Rate Application
Diesel Generation and Fuel Summary
($000s)

Line No.	Description	Cross Ref.	Actual 2009	Actual 2010	Test Period 2011	Test Period 2012	Test Period 2013
1	**Total NWT**						
2	Fuel Expenses - Summary						
3	Hay River		$ 917	$ 229	$ 308	$ 306	$ 308
4	Fort Providence		645	690	756	769	877
5	Wekweeti		210	177	181	181	181
6	Trout Lake		102	115	125	129	132
7	Dory Point/Kakisa		105	104	106	107	-
8	Total Fuel expenses ($000s)	S.1.1 L.8	$ 1,979	$ 1,315	$ 1,476	$ 1,492	$ 1,498
9	Diesel Generation - Summary						
10	Hay River		4,421	1,159	1,362	1,370	1,377
11	Fort Providence		3,322	3,327	3,238	3,296	3,769
12	Wekweeti		635	641	658	658	658
13	Trout Lake		485	493	516	529	542
14	Dory Point/Kakisa		495	422	400	406	-
15	Total Diesel Generation (in MW.h)	S.3.2 L.7	9,358	6,042	6,174	6,259	6,347
16	**Hay River System**						
17	Sales MW.h		30,914	30,211	30,632	30,796	30,970
18	Station Service %		2.5%	3.3%	2.8%	2.8%	2.8%
19	Station Service		762	989	855	859	864
20			31,676	31,200	31,487	31,656	31,834
21	Line Losses %		9.1%	8.2%	8.4%	8.4%	8.4%
22	Line Losses		2,817	2,471	2,573	2,587	2,601
23	Total Required		34,493	33,671	34,060	34,243	34,435
24	Less Purchase Power (MW.H)	S.3.2 L.8	(30,072)	(32,512)	(32,698)	(32,873)	(33,058)
25	Diesel generation (MW.h)	Note 1	4,421	1,159	1,362	1,370	1,377
26	Fuel heat rate (KW.h per litre)		3.37	3.57	3.52	3.56	3.56
27	Litres of fuel (000s)		1,312	325	387	384	387
28	Average cost (cents per litre)		69.91	70.57	79.58	79.58	79.58
29	Fuel expenses ($000s)		$ 917	$ 229	$ 308	$ 306	$ 308

30 **Note 1:** Hay River generation for 2011, 2012 & 2013 forecast to be 4% of system demand.

Northland Utilities (NWT) Limited
2011 - 2013 General Rate Application
Diesel Generation and Fuel Summary
($000s)

Line No.	Description	Cross Ref.	Actual 2009	Actual 2010	Test Period 2011	Test Period 2012	Test Period 2013
31	**Fort Providence**						
32	Sales MW.h		2,991	2,986	2,942	2,995	3,380
33	Station Service %		1.8%	2.0%	1.7%	1.7%	1.7%
34	Station Service		54	59	49	50	56
35			3,044	3,045	2,991	3,044	3,436
36	Line Losses %		9.3%	9.4%	8.4%	8.4%	9.9%
37	Line Losses		278	282	247	252	334
38	Total Generation Required		3,322	3,327	3,238	3,296	3,769
39	Fuel heat rate (KW.h per litre)		3.61	3.64	3.63	3.63	3.64
40	Litres of fuel (000s)		921	914	892	908	1,035
41	Average cost (cents per litre)		70.04	75.49	84.69	84.69	84.69
42	Fuel expenses ($000s)		$ 645	$ 690	$ 756	$ 769	$ 877
43	**Wekweeti**						
44	Sales MW.h		588	593	608	608	608
45	Station Service %		3.8%	4.4%	3.7%	3.7%	3.7%
46	Station Service		22	26	22	22	22
47			610	619	631	631	631
48	Line Losses %		4.2%	3.7%	4.4%	4.4%	4.4%
49	Line Losses		25	22	27	27	27
50	Total Generation Required		635	641	658	658	658
51	Fuel heat rate (KW.h per litre)		3.45	3.49	3.47	3.47	3.47
52	Litres of fuel (000s)		184	184	190	190	190
53	Average cost (cents per litre)		113.94	96.41	95.58	95.58	95.58
54	Fuel expenses ($000s)		$ 210	$ 177	$ 181	$ 181	$ 181

Northland Utilities (NWT) Limited
2011 - 2013 General Rate Application
Diesel Generation and Fuel Summary
($000s)

Line No.	Description	Cross Ref.	Actual 2009	Actual 2010	Test Period 2011	Test Period 2012	Test Period 2013
55	**Trout Lake**						
56	Sales MW.h		431	440	447	459	470
57	Station Service %		5.6%	5.6%	5.4%	5.4%	5.4%
58	Station Service		24	25	24	25	25
59			455	465	471	483	495
60	Line Losses %		6.9%	6.4%	10.0%	10.0%	10.0%
61	Line Losses		30	28	45	46	47
62	Total Generation Required		485	493	516	529	542
63	Fuel heat rate (KW.h per litre)		3.30	3.38	3.29	3.29	3.29
64	Litres of fuel (000s)		147	146	157	161	165
65	Average cost (cents per litre)		69.43	78.94	80.03	80.03	80.03
66	Fuel expenses ($000s)		$ 102	$ 115	$ 125	$ 129	$ 132
67	**Dory Point/Kakisa**						
68	Sales MW.h		441	376	357	363	-
69	Station Service %		2.9%	5.3%	3.7%	3.7%	-
70	Station Service		13	20	13	14	-
71			454	396	371	376	-
72	Line Losses %		9.3%	6.9%	8.3%	8.3%	-
73	Line Losses		41	26	30	30	-
74	Total Generation Required		495	422	400	406	-
75	Fuel heat rate (KW.h per litre)		3.17	3.05	3.12	3.12	-
76	Litres of fuel (000s)		156	138	128	130	-
77	Average cost (cents per litre)		67.22	75.12	82.38	82.38	-
78	Fuel expenses ($000s)		$ 105	$ 104	$ 106	$ 107	$ -

NORTHLAND UTILITIES (NWT) LIMITED
An ATCO Company

Effective: 2009-02-01
Supersedes: 2006-07-01

RATE SCHEDULE 14-8/14-6
RESIDENTIAL SERVICE

Available

- In Fort Providence, Northwest Territories.

Applicable

- For single-phase electric service at secondary voltage through a single meter.
- For normal use by a single and separate household.
- Not applicable to any commercial or industrial use.

Rates

- The charge for service in any one billing month is the sum of the Customer Charge, Supply Charge and Fuel Charge, determined for each individual Point of Service.

Component	Charge
Customer Charge	$22.24 / month
Supply Charge	22.39 ¢ / kW.h
Fuel Charge	21.74 ¢ / kW.h

44.13

- The minimum monthly charge is the Customer Charge.

Options and Riders

Price Adjustments – the following price adjustments (riders) may apply:

- Fuel Clause Adjustment Rider (Rider A)
- Multiple Residence Service (Rider C)
- Temporary Refund/Surcharge Rider (Rider E)
- Interim Rate Rider (Rider K)
- Pension and OPEB Refund Rider (Rider Q)
- Rate Adjustment Rider (Rider R)

NORTHLAND UTILITIES (NWT) LIMITED
An ATCO Company

Effective: 2009-02-01
Supersedes: 2006-07-01

RATE SCHEDULE 15-8/15-6
RESIDENTIAL SERVICE

Available

- In Trout Lake, Northwest Territories.

Applicable

- For single-phase electric service at secondary voltage through a single meter.
- For normal use by a single and separate household.
- Not applicable to any commercial or industrial use.

Rates

- The charge for service in any one billing month is the sum of the Customer Charge, Supply Charge and Fuel Charge, determined for each individual Point of Service.

Component	Charge
Customer Charge	$22.24 / month
Supply Charge	63.82 ¢ / kW.h
Fuel Charge	25.46 ¢ / kW.h

89.28

- The minimum monthly charge is the Customer Charge.

Options and Riders

Price Adjustments – the following price adjustments (riders) may apply:

- Fuel Clause Adjustment Rider (Rider A)
- Multiple Residence Service (Rider C)
- Temporary Refund/Surcharge Rider (Rider E)
- Interim Rate Rider (Rider K)
- Pension and OPEB Refund Rider (Rider Q)
- Rate Adjustment Rider (Rider R)

NORTHLAND UTILITIES (NWT) LIMITED
An ***ATCO*** Company

RIDERS

Rider A	Fuel Clause Adjustment Rider
Rider C	Multiple Residence Service
Rider D	Un-metered Flat Rate General Service
Rider E	Temporary Refund/Surcharge Rider
Rider F	NTPC Shortfall Rider
Rider G	Optional Annual Minimum Charge
Rider I	Diesel Generation Rider
Rider K	Interim Rate Rider
Rider R	Rate Adjustment Rider
Rider Q	Pension and OPEB Refund Rider
Franchise Tax	
Territorial Support	

The Terms and Conditions of Service for Northland Utilities (NWT) Limited have the approval of the Public Utilities Board of the Northwest Territories. They form part of this rate schedule and apply to the Company and every Customer supplied with electric service by the Company. Copies of the Terms and Conditions are available for reference in the offices of Northland Utilities (NWT) Limited during normal business hours, and can be accessed at www.northlandutilities.com

RATE SCHEDULE 24-8
GENERAL SERVICE

Available

- In Fort Providence, Northwest Territories.

Applicable

- To any use of electric energy consistent with safe and adequate service to all customers of the Company, except as more favourable options may apply.

Rates

- The charge for service in any one billing month is the sum of the Demand Charge, Supply Charge and Fuel Charge, determined for each individual Point of Service.

Component	Charge	For the first 200 kW.h per kW of billing demand	In excess of 200 kW.h per kW of billing demand
Demand Charge	$5.83 / kW		
Supply Charge		16.56 ¢ / kW.h	11.72 ¢ / kW.h
Fuel Charge		21.74 ¢ / kW.h	21.74 ¢ / kW.h
		38.30	33.46

- **Billing demand** may be estimated or measured and will be the greater of the following:

  (a) highest metered demand during the billing period;
  (b) the estimated demand;
  (c) contract demand;
  (d) 5 kilowatts

... Continued on next page

RATE SCHEDULE 24-8 (continued)

- **Deficient Power Factor** - Where a customer's power factor is found to be below 80 percent, the Company may require such customers to install corrective equipment.
- Special arrangements must be made for supply to loads over 50 kW in this area.

Options and Riders

Price Adjustments – the following price adjustments (riders) may apply:

- Fuel Clause Adjustment Rider (Rider A)
- Unmetered Flat Rate General Service (Rider D)
- Temporary Refund/Surcharge Rider (Rider E)
- Optional Annual Minimum Charge (Rider G)
- Interim Rate Rider (Rider K)
- Pension and OPEB Refund Rider (Rider Q)
- Rate Adjustment Rider (Rider R)

RATE SCHEDULE 25-8
GENERAL SERVICE

Available

- In Trout Lake, Northwest Territories.

Applicable

- To any use of electric energy consistent with safe and adequate service to all customers of the Company, except as more favourable options may apply.

Rates

- The charge for service in any one billing month is the sum of the Demand Charge, Supply Charge and Fuel Charge, determined for each individual Point of Service.

Component	Charge	For the first 200 kW.h per kW of billing demand	In excess of 200 kW.h per kW of billing demand
Demand Charge	$6.24 / kW		
Supply Charge		53.95 ¢ / kW.h	37.02 ¢ / kW.h
Fuel Charge		25.46 ¢ / kW.h	25.46 ¢ / kW.h
		79.41	62.48

- **Billing demand** may be estimated or measured and will be the greater of the following:

  (a) highest metered demand during the billing period;
  (b) the estimated demand;
  (c) contract demand;
  (d) 5 kilowatts

... Continued on next page

RATE SCHEDULE 25-8 (continued)

- **Deficient Power Factor** - Where a customer's power factor is found to be below 80 percent, the Company may require such customers to install corrective equipment.
- Special arrangements must be made for supply to loads over 50 kW in this area.

Options and Riders

Price Adjustments – the following price adjustments (riders) may apply:

- Fuel Clause Adjustment Rider (Rider A)
- Unmetered Flat Rate General Service (Rider D)
- Temporary Refund/Surcharge Rider (Rider E)
- Optional Annual Minimum Charge (Rider G)
- Interim Rate Rider (Rider K)
- Pension and OPEB Refund Rider (Rider Q)
- Rate Adjustment Rider (Rider R)

Appendix 2

Trout Lake wind project calculation of net diesel displaced from HOMER model output									
Minimum diesel plant load 29 kW (30% of 97kW smallest generator) 2.93 m/s at 10 m AGL									
		Losses from generation				Reductions in surplus			
Project configuration	HOMER generation kWh	Availability 95%	Electrical & other 10%	Net generation	HOMER surplus energy kWh	Availability	Electrical & other losses	Net surplus	Diesel displaced kWh
One Wenvor 30 kW	9,703	485	970	8,248	196	0	196	0	8,248
One Endurance E3120	31,221	1,561	3,122	26,538	2,517	0	252	2,265	24,273
Notes:									
Tower Heights		The tallest available tower is used for the selected wind turbines							
Wenvor 30 kW		The Wenvor is on a 30 m tall tower at which the mean wind speed is estimated to be 3.2 m/s							
Endurance E3120		The Endurance is on a 42.7 m tall tower at which the mean wind speed is estimated to be 3.3 m/s							
Assumptions in reductions of surplus									
Wenvor 30 kW		The very small amount of surplus energy would be consumed by electrical & other losses							
Endurance E3120		One tenth of losses are systematic like electrical that occur during high output reducing surplus differentially							

Appendix 3

Trout Lake Wind Project Capital, O&M, and Energy Cost Summary

Site close to power line

Cost category	low penetration 1 Wenvor 30	medium penetration 1 E-3120 50kW turbine
Project design and Management		
project design	$15,000	$20,000
environmental assessment & permitting	$10,000	$15,000
project management	$10,000	$20,000
Site Preparation		
road construction ($50,000 per km) 100m + 100/turbine	$5,000	$5,000
site & crane pad construction $10,000 per turbine	$2,000	$10,000
powerline construction ($150,000 per km), 100m + 100/turbine	$15,000	$15,000
Wind Equipment Purchase		
wind turbines including towers & Supervisory control system	$120,000	$250,000
transformers	$10,000	$25,000
shipping to Hay River	$15,000	$30,000
shipping Hay River to Trout Lake	$5,000	$10,000
wind dispatch or secondary load controller	$0	$30,000
Installation		
geotehnical & foundation design	$50,000	$70,000
foundations	$30,000	$50,000
equipment rental	$30,000	$30,000
crane mob and de-mob	$0	$75,000
crane site work	$0	$15,000
control buildings	$0	$10,000
utility interconnection	$45,000	$45,000
labour - assembly & supervision	$20,000	$40,000
commissioning (simple, dispatch, & sec load)	$5,000	$20,000
travel and accommodation	$20,000	$30,000
Diesel Plant Modifications		
radio / high speed communications	$10,000	$30,000
Control system modifications	$10,000	$10,000
other plant modifications	$10,000	$20,000
Other		
initial spare parts	$3,000	$5,000
Insurance	$10,000	$15,000
other overhead costs (contracts etc.)	$20,000	$30,000
Subtotal construction	**$470,000**	**$925,000**
Contingency 10%	$47,000	$92,500
TOTAL CONSTRUCTION	**$517,000**	**$1,017,500**
Owners Costs		
staff training	$15,000	$35,000
Subtotal owners costs	**$15,000**	**$35,000**
TOTAL PROJECT COST	**$532,000**	**$1,052,500**
Installed capacity kW	35	55
Installed cost per kW	**$15,200**	**$19,136**
Annual O&M costs ($10,000 or $20,000)	$10,000	$20,000
Total annual costs	$10,000	$20,000
Annual total wind energy kWh at hub height	9,703	31,221
Annual diesel energy displaced	8,248	24,273
Levelized cost of energy (LCOE) 20 year life $ per kWh	$7.603	$5.122

Leading Edge Projects Generation LCOE Economic Model											
Project: Trout Lake 1 Endurance E-3120 wind turbine - medium penetration, $20k O&M											
Capital cost	$1,052,500	$17,733/kW	Capacity	55	kW	Fixed O&M	$20,000	per year	Discount rate	5.39%	
Cost of capital	7.50%	Debt & equity	Annual Energy	24,273	kWh	Variable O&M	$0.00	per kWh			
Inflation	2.00%	per year	Project life	20	Years	Capacity factor					
Year	**Capital**	**Cost of Cap**	**Depreciation**	**Fixed O&M**	**Variable O&M**	**Total Ann cost**	**Ann energy**	**Cost per kWh**	**Discounted cost**	**Discounted energy**	**Discounted cost per kWh**
1	$1,052,500	$78,938	$52,625	$20,000	$0	$151,563	24,273	$6.244	$151,563	24,273	$6.244
2	$999,875	$74,991	$52,625	$20,400	$0	$148,016	24,273	$6.098	$140,443	23,031	$6.098
3	$947,250	$71,044	$52,625	$20,808	$0	$144,477	24,273	$5.952	$130,071	21,853	$5.952
4	$894,625	$67,097	$52,625	$21,224	$0	$140,946	24,273	$5.807	$120,400	20,735	$5.807
5	$842,000	$63,150	$52,625	$21,649	$0	$137,424	24,273	$5.662	$111,385	19,674	$5.662
6	$789,375	$59,203	$52,625	$22,082	$0	$133,910	24,273	$5.517	$102,984	18,667	$5.517
7	$736,750	$55,256	$52,625	$22,523	$0	$130,404	24,273	$5.372	$95,157	17,712	$5.372
8	$684,125	$51,309	$52,625	$22,974	$0	$126,908	24,273	$5.228	$87,868	16,806	$5.228
9	$631,500	$47,363	$52,625	$23,433	$0	$123,421	24,273	$5.085	$81,081	15,946	$5.085
10	$578,875	$43,416	$52,625	$23,902	$0	$119,942	24,273	$4.941	$74,765	15,130	$4.941
11	$526,250	$39,469	$52,625	$24,380	$0	$116,474	24,273	$4.798	$68,888	14,356	$4.798
12	$473,625	$35,522	$52,625	$24,867	$0	$113,014	24,273	$4.656	$63,422	13,622	$4.656
13	$421,000	$31,575	$52,625	$25,365	$0	$109,565	24,273	$4.514	$58,341	12,925	$4.514
14	$368,375	$27,628	$52,625	$25,872	$0	$106,125	24,273	$4.372	$53,618	12,264	$4.372
15	$315,750	$23,681	$52,625	$26,390	$0	$102,696	24,273	$4.231	$49,231	11,636	$4.231
16	$263,125	$19,734	$52,625	$26,917	$0	$99,277	24,273	$4.090	$45,157	11,041	$4.090
17	$210,500	$15,788	$52,625	$27,456	$0	$95,868	24,273	$3.950	$41,375	10,476	$3.950
18	$157,875	$11,841	$52,625	$28,005	$0	$92,470	24,273	$3.810	$37,867	9,940	$3.810
19	$105,250	$7,894	$52,625	$28,565	$0	$89,084	24,273	$3.670	$34,614	9,431	$3.670
20	$52,625	$3,947	$52,625	$29,136	$0	$85,708	24,273	$3.531	$31,598	8,949	$3.531
									$1,579,830	308,467	$5.122
Real levelized cost of energy, $ per kWh					**$5.122**						

Appendix 4

Leading Edge Projects Generation LCOE Economic Model

Project: Trout Lake 1 Wenvor 30 wind turbine - low penetration, $10k O&M

Capital cost	$532,000	$17,733/kW	Capacity	30	kW	Fixed O&M	$10,000	per year	Discount rate	5.39%	
Cost of capital	7.50%	Debt & equity	Annual Energy	8,248	kWh	Variable O&M	$0.00	per kWh			
Inflation	2.00%	per year	Project life	20	Years	Capacity factor					

Year	Capital	Cost of Cap	Depreciation	Fixed O&M	Variable O&M	Total Ann cost	Ann energy	Cost per kWh	Discounted cost	Discounted energy	Discounted cost per kWh
1	$532,000	$39,900	$26,600	$10,000	$0	$76,500	8,248	$9.275	$76,500	8,248	$9.275
2	$505,400	$37,905	$26,600	$10,200	$0	$74,705	8,248	$9.057	$70,883	7,826	$9.057
3	$478,800	$35,910	$26,600	$10,404	$0	$72,914	8,248	$8.840	$65,644	7,426	$8.840
4	$452,200	$33,915	$26,600	$10,612	$0	$71,127	8,248	$8.624	$60,759	7,046	$8.624
5	$425,600	$31,920	$26,600	$10,824	$0	$69,344	8,248	$8.407	$56,205	6,685	$8.407
6	$399,000	$29,925	$26,600	$11,041	$0	$67,566	8,248	$8.192	$51,962	6,343	$8.192
7	$372,400	$27,930	$26,600	$11,262	$0	$65,792	8,248	$7.977	$48,009	6,019	$7.977
8	$345,800	$25,935	$26,600	$11,487	$0	$64,022	8,248	$7.762	$44,327	5,711	$7.762
9	$319,200	$23,940	$26,600	$11,717	$0	$62,257	8,248	$7.548	$40,900	5,419	$7.548
10	$292,600	$21,945	$26,600	$11,951	$0	$60,496	8,248	$7.335	$37,710	5,141	$7.335
11	$266,000	$19,950	$26,600	$12,190	$0	$58,740	8,248	$7.122	$34,742	4,878	$7.122
12	$239,400	$17,955	$26,600	$12,434	$0	$56,989	8,248	$6.909	$31,981	4,629	$6.909
13	$212,800	$15,960	$26,600	$12,682	$0	$55,242	8,248	$6.698	$29,415	4,392	$6.698
14	$186,200	$13,965	$26,600	$12,936	$0	$53,501	8,248	$6.487	$27,031	4,167	$6.487
15	$159,600	$11,970	$26,600	$13,195	$0	$51,765	8,248	$6.276	$24,815	3,954	$6.276
16	$133,000	$9,975	$26,600	$13,459	$0	$50,034	8,248	$6.066	$22,758	3,752	$6.066
17	$106,400	$7,980	$26,600	$13,728	$0	$48,308	8,248	$5.857	$20,849	3,560	$5.857
18	$79,800	$5,985	$26,600	$14,002	$0	$46,587	8,248	$5.648	$19,078	3,378	$5.648
19	$53,200	$3,990	$26,600	$14,282	$0	$44,872	8,248	$5.440	$17,435	3,205	$5.440
20	$26,600	$1,995	$26,600	$14,568	$0	$43,163	8,248	$5.233	$15,913	3,041	$5.233
									$796,916	104,817	$7.603
Real levelized cost of energy, $ per kWh					**$7.603**						

Appendix 5

Leading Edge Projects Generation LCOE Economic Model

Project: Trout Lake incremental diesel generation, 3.29 kWh per litre, fuel at $1.00 per litre, fuel inflation at 2% per year, variable O&M $0.03 per kWh

Capital cost	$0		Capacity		kW	Fixed O&M	$3,000	per year	Discount rate	5.39%	
Cost of capital	7.50%	Debt & equity	Annual Energy	100,000	kWh	Fuel	$0.304	per kWh			
Inflation	2.00%	per year	Project life	20	Years	Capacity factor			Fuel inflation	2.00%	

Year	Capital	Cost of Cap	Depreciation	Fixed O&M	Variable O&M	Total Ann cost	Ann energy	Cost per kWh	Discounted cost	Discounted energy	Discounted cost per kWh
1	$0	$0	$0	$3,000	$30,400	$33,400	100,000	$0.334	$33,400	100,000	$0.334
2	$0	$0	$0	$3,060	$31,008	$34,068	100,000	$0.341	$32,325	94,884	$0.341
3	$0	$0	$0	$3,121	$31,628	$34,749	100,000	$0.347	$31,285	90,029	$0.347
4	$0	$0	$0	$3,184	$32,261	$35,444	100,000	$0.354	$30,278	85,423	$0.354
5	$0	$0	$0	$3,247	$32,906	$36,153	100,000	$0.362	$29,303	81,053	$0.362
6	$0	$0	$0	$3,312	$33,564	$36,876	100,000	$0.369	$28,360	76,906	$0.369
7	$0	$0	$0	$3,378	$34,235	$37,614	100,000	$0.376	$27,447	72,971	$0.376
8	$0	$0	$0	$3,446	$34,920	$38,366	100,000	$0.384	$26,564	69,238	$0.384
9	$0	$0	$0	$3,515	$35,618	$39,133	100,000	$0.391	$25,709	65,695	$0.391
10	$0	$0	$0	$3,585	$36,331	$39,916	100,000	$0.399	$24,881	62,334	$0.399
11	$0	$0	$0	$3,657	$37,057	$40,714	100,000	$0.407	$24,080	59,145	$0.407
12	$0	$0	$0	$3,730	$37,799	$41,529	100,000	$0.415	$23,305	56,119	$0.415
13	$0	$0	$0	$3,805	$38,555	$42,359	100,000	$0.424	$22,555	53,248	$0.424
14	$0	$0	$0	$3,881	$39,326	$43,206	100,000	$0.432	$21,829	50,523	$0.432
15	$0	$0	$0	$3,958	$40,112	$44,071	100,000	$0.441	$21,127	47,938	$0.441
16	$0	$0	$0	$4,038	$40,914	$44,952	100,000	$0.450	$20,447	45,486	$0.450
17	$0	$0	$0	$4,118	$41,733	$45,851	100,000	$0.459	$19,789	43,159	$0.459
18	$0	$0	$0	$4,201	$42,567	$46,768	100,000	$0.468	$19,152	40,950	$0.468
19	$0	$0	$0	$4,285	$43,419	$47,703	100,000	$0.477	$18,535	38,855	$0.477
20	$0	$0	$0	$4,370	$44,287	$48,657	100,000	$0.487	$17,939	36,867	$0.487
									$498,310	1,270,823	$0.392
Real levelized cost of energy					**$0.392**						