Pre-Feasibility Analysis of Wind Energy for Inuvialuit Region in Northwest Territories

Aurora Research Institute

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Aurora Research Institute

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Energy Secretariat
Resources, Wildlife and Economic Development
Government of the Northwest Territories

And

Northwest Territories Power Corporation

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About the Consultants

Jean-Paul Pinard is a mechanical engineering consultant based in the Yukon since 1992. In 1996 he joined the Boreal Alternate Energy Centre to help work on their wind energy assessment program. Jean-Paul acquired community development funding for his first project of wind monitoring by the Alsek Valley, Yukon. Since then Yukon Energy has been hiring Jean-Paul for most of their wind energy assessment work. Jean-Paul has a bachelor's degree from the University of Waterloo (1991), a Master's from University of Alberta (2000), and is working towards a PhD also at University of Alberta on the subject of computer modeling of wind in the mountainous terrains of the North.

Tim Weis is part of the Community Eco-Solutions team at the Pembina Institute for Appropriate Development, working on community energy planning and community-scale renewable energy systems research. Tim is also currently doing his PhD at the Université du Québec à Rimouski in Environmental Science, researching wind-diesel energy systems in autonomous electrical grids in Northern Canadian communities. Tim has a Master’s degree in Mechanical Engineering from the University of Alberta (2002) where he studied rime ice adhesion to wind turbine blades, and a Bachelor degree in Mechanical Engineering from the University of Waterloo (1999) with an option in Environmental Engineering.

Executive Summary

Several wind turbines are currently operating in the Canadian North. However, no wind turbines are currently running in the Northwest Territories. A select few studies have been done in the past examining the feasibility of wind energy in communities of the Northwest Territories and Nunavut. These have been reviewed here. This study is an attempt to further examine the opportunities and to identify barriers for wind energy development. Also, techno-socio-economic analysis is conducted on displacing diesel fuels generation by wind in the four communities.

This project reanalyzes historical summarized data from several sources including NCEP/NCAR Reanalysis Project and the Canadian Climate Normals. We have identified key locations for installing wind monitoring stations in four Inuvialuit communities: Holman, Paulatuk, Sachs Harbour, and Tuktoyaktuk. Wind climate and geography of these coastal communities is taken into consideration.

To understand the current situation and to identify opportunities, site visits were made in February 2003. A public meeting was held in each community to discuss community energy concerns. The visit to each community also included a tour of their diesel power plants, a tour of the surrounding landscape to identify possible sites for wind monitoring stations and ultimate wind turbine deployment, and a meeting with hamlet officials to discuss land use issues. Informal meetings were also held with well-informed members of these communities to discuss local social, technical and economic constraints to the development of a wind energy program. The high cost of electricity was a major concern to the public-at-large. All of the communities expressed a general sense of frustration about the inability to regulate their own fuel and electricity costs.

A meeting was also held with Northwest Territories Municipal and Community Affairs to discuss zoning issues for the possible citing of wind monitoring towers, and the future wind turbines.

Interconnection issues and opportunities for wind energy into the local power grids were discussed with the regional officials of Northwest Territories Power Corporation (NTPC). It became evident that NTPC is open to buying wind energy from an independent power producer rather than developing further wind projects themselves. NTPC would be willing to purchase wind energy at the displaced cost of diesel fuel.

Geographic features of each community, annual electrical consumption and their wind climate are described in this report. Sites are recommended for the purpose of wind monitoring. These would, however, need to be discussed and approved by the community members and with airport officials before final selections are made for wind monitoring tower installations. Most of these sites are on Inuvialuit land and will need to be dealt with accordingly.

There are special considerations for wind turbines in the North, which are described in the report. For example, icing is a major concern in Sachs Harbour; it was evident on the

day's visit to this community. This will require anti-icing technologies such as heated elements on blades to overcome this icing problem.

Much focus and cost reductions have been made with large-scale wind turbine in the global wind energy industry. However, medium-scale turbines are the most appropriate sizes to examine for the Inuvialuit region. This scale of turbine provides many advantages over large turbine such as ease and low cost of installation and redundancy. Since there are only a few manufacturers of medium-scale wind turbines, we need to carefully choose our product and so ensure a close working relation with the manufacturer to help improve and integrate their technology.

RETScreen® software was used here to develop an economic overview of the opportunities for wind energy systems in the four communities. Historical wind speed data collected at airports by Environment Canada was used for this analysis. Two cases were examined for each of the four communities, a low-penetration system and a high-penetration system. For Holman and Paulatuk we have included additional analysis for a predicted higher wind speed on nearby hilltops. Our analysis indicates that wind generated electricity mostly does not appear to be economically viable when compared solely to the displaced cost of diesel fuel. Other factors, including environmental, certainly make it a viable technology.

It is fair to conclude that there can be economic potential for developing wind energy in the four communities of interest, provided sites are carefully selected. Several recommendations are made at the end of the report.

Cost estimates for the proposed wind-monitoring program are attached as an appendix to this report.

Acknowledgements

The authors wish to thank all community members who have helped with information gathering, site visits, and attendance at the meetings. We greatly appreciate NTPC and all of their field staff for helpful discussions and for sharing company data. In particular, we would like to thank Gary Bristow, Mel Pretty and Eleanor Young in Holman; Terry Rafferty and Brian Willows in Inuvik; Manny Kudlak and Bob Elbridge in Sachs Harbour; Francis Ruben and Fred Bennett in Paulatuk; and Daniel Nasogaluak and Rex Cockney in Tuktoyaktuk. We acknowledge the financial assistance, advice and guidance from the Energy Secretariat (ES) of the Government of Northwest Territories and the Northwest Territories Power Corporation. Gerd Sandrock of NTPC and Dennis Bevington of ES suggested valuable editorial changes to this document. Professor Liuchen Chang of the University of New Brunswick accompanied the team for site visits and provided useful advice. Last but not the least, tireless efforts of Pietro de Bastiani of ES are worth mentioning for providing guidance and support.

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a.s.l.	above sea level
a.g.l.	above ground level
CDC	the Climate Diagnostics Center
Isotachs	line of same wind speed value
m	metres = 3.28 feet
m/s	metres per second, 1 km/h = 0.278 m/s
NCEP	the National Center for Environmental Modeling (formerly NMC)
NCAR	the National Center for Atmospheric Research
km	kilometres = 1000 metres
km/h	kilometres per hour

1 Introduction

The costs of energy in remote communities in the Northwest Territories and Nunavut are the highest in Canada. The major reason is the communities' reliance on fossil fuels that must be imported and often stored for a year at a time. The cost of importing and storing fuel is very high, but is also subject to market fluctuations, as the community's entire year's worth of fuel is purchased at a single point in the previous year. This is not only an economic burden but also adds to uncertainty in the ability to forecast costs in order to make long-term economic or development plans. As such, many important local community decisions are in effect influenced by oil prices and oil companies thousands of kilometres away.

The communities of Sachs Harbour, Holman, Paulatuk and Tuktoyaktuk are a part of the Inuvialuit settlement of the Northwest Territories on the Beaufort Sea. All four of these communities are isolated from main electrical and natural gas grids, and currently rely on diesel for their electrical generation. Diesel fuel is not only expensive to import, but is an inefficient method of generating electricity, as only about 30% of the fuel's internal energy ultimately gets converted into electrical energy. Diesel generators are also sources of greenhouse gases, and other local air pollutants, most notably volatile organic compounds (VOC) and particulate matter (PM), both of which are known-precursors to cancer.

Furthermore the government of the Northwest Territories currently subsidizes the first 700 kilowatt-hours (kWh) used monthly by each residential community member to Yellowknife electricity rates (currently $0.17/kWh), after which point community members must pay the full cost for each additional kilowatt-hour. The high electricity costs are therefore also a burden to the territorial government.

It is therefore obvious that minimizing diesel generators for electrical power generation is a long-term goal for these communities, from an economic, environmental and public health point of view. Diesel generators do have a number of advantages however, which has led to their common usage in off-grid applications. These advantages include reliability, modularity and the ability to deal with a well-known and well-understood technology, whose replacement parts are readily available. Short daylight hours and frozen bodies of water make renewables such as photovoltaic or micro-hydro incompatible with the arctic winters. On the other hand, wind energy is particularly suitable for northern climates as cold winter temperatures increase the air density, and therefore increase the power available in the wind when it is needed most.

Wind energy is renewable, emission-free, and is continually dropping in capital cost per installed kilowatt. Wind can provide a sustainable source of electrical power generation from a local natural resource improving communities' self-reliance and sustainability. Wind energy has become the fastest growing source of renewable energy worldwide, with a growth rate of over 25% for the last 15 years. Wind energy's rapid growth, can be attributed not only to the inherent environmental benefits of a low impact renewable energy source, but also to the gradual technological advances since the 1980's

that have made wind energy an economically competitive option in many parts of the world. As countries attempt to ratify the 1997 Kyoto protocol for reductions in greenhouse gas emissions, wind energy development is likely to continue to increase for the foreseeable future. Canada, a signatory to the protocol, has also seen a slow but sustained growth in wind energy development as part of its move towards developing sources of energy with reduced greenhouse gas emissions.

The majority of the development in global wind energy has occurred in the large, utility-scale wind turbines meant for connection to national and international grids. Many social, technical and economic aspects of off-grid communities will differ substantially from grid-connected applications. This being the case, wind energy development opportunities must be examined individually for off-grid communities.

This report identifies key locations for installing monitoring stations for the purpose of measuring the wind energy potential in each of the communities of Holman, Paulatuk, Sachs Harbour, and Tuktoyaktuk. Here we describe the wind climate and geography of Inuvialuit and some of the past studies related to wind energy in the region. We reveal the long-term wind data based on the previous studies, and then we describe and recommend sites that are considered suitable for installing wind monitoring stations. Cost estimates for the proposed wind monitoring program are attached as an appendix to this report. This study is also an attempt to examine the opportunities and identify barriers to overcome for wind energy development. This includes a focus on techno-socio-economic research on the wind energy options in the four communities.

2 Wind Climate of Inuvialuit Communities

2.1 Wind Climate and Geography

To understand the wind climate in the Inuvialuit region we briefly explore some observations and principals on the general circulation patterns in the Polar Regions.

Typically the upper atmospheric air moves from the warmer equatorial regions towards the poles. There the air cools and subsides downward to the surface at the pole and then moves outward away from the pole. This polar surface air moves southward, and because the earth rotates, the air tends to turn right, towards the west. This air movement is generally a north-easterly wind (Ahrens, 1999).

This north-easterly wind pattern is an average climatic condition and changes weekly and seasonally depending on the movement of the surface lows and highs that we are informed about in the news.

The shorelines and land forms further modifies this wind pattern to create a localized wind climate. Land-sea breezes will add to the regional wind by turning the wind towards a right angle onto or away from the shoreline. The land relief (orography) also causes wind deviations. The slope of land can create katabatic (down slope) winds if the air is cooled over a snow surface. The reverse is also true, especially in the summertime when the sun is heating a south-facing slope, causing air to rise and to move up-slope (anabatic).

It seems that from anecdotal evidence, and from observations of local airport wind data that winds are general easterly. Wilson (1974) alludes to this in his study of winds and currents in the Beaufort Sea. According to Wilson there are two types of dynamics that cause wind behaviors in the Beaufort Sea. One is the strong thermal gradients due to the temperature differences between land and sea. This creates onshore or offshore breezes that will add to overlying wind conditions. The other dynamics has to do with land barriers that cause a redirection of wind flows. In the case of an island, the wind tend to flow anti-cyclonical around the island or hill, this means that with our back to the wind and facing an island, the wind will tend to flow around to the left of the island or hill. For a bay the wind may take on a cyclonic flow, or may turn in an anti-clockwise fashion around the bay, with the higher winds to the right of the bay if we have our back to the wind and are facing the bay.

This wind dynamic likely plays an important role in the arctic since we have, for most communities, a combination of both land relief and atmospheric stability. In the arctic the atmosphere is highly stratified, for practically all seasons of the year. It reaches near neutral stratification during the daytime in the summer but is essentially stable on a daily average. This stable stratification means that, near the ground surface, the air tends to be colder and hence denser than in the layers above. Denser air tends to stay low and resist being pushed upwards, over islands or hills. Because of this phenomena land forms that are as high as 50 to 100 metres may be sufficient to cause channelling effects (Janz et al. 1982). This should help us to explain the local wind climates that we observe in each community. More details on wind climate data will be described, but briefly we shall try to connect the major land form to prevail winds in each community.

In Figure 1 we have a relief map that covers the four communities of interest. The darker shades on land surface represent elevations above 300 m a.s.l. Sachs Harbour is at the western point of a triangle of hills that peak to 724 m at the southernmost tip of Banks Island. Any easterly wind would likely flow around the southern tip and flow clockwise around the hills, becoming a south-easterly wind.

Prince Albert Sound is bordered by high ground to the north and south. This will likely cause local winds to flow in either easterly or westerly fashion. Holman is on the north-western side of the mouth of the sound and also on south-western end of hills of the Diamond Jenness Peninsula. Here again we should expect any easterly winds out of the sound to be turning clockwise (or anti-cyclonically) around the peninsula to become a SE wind at Holman.

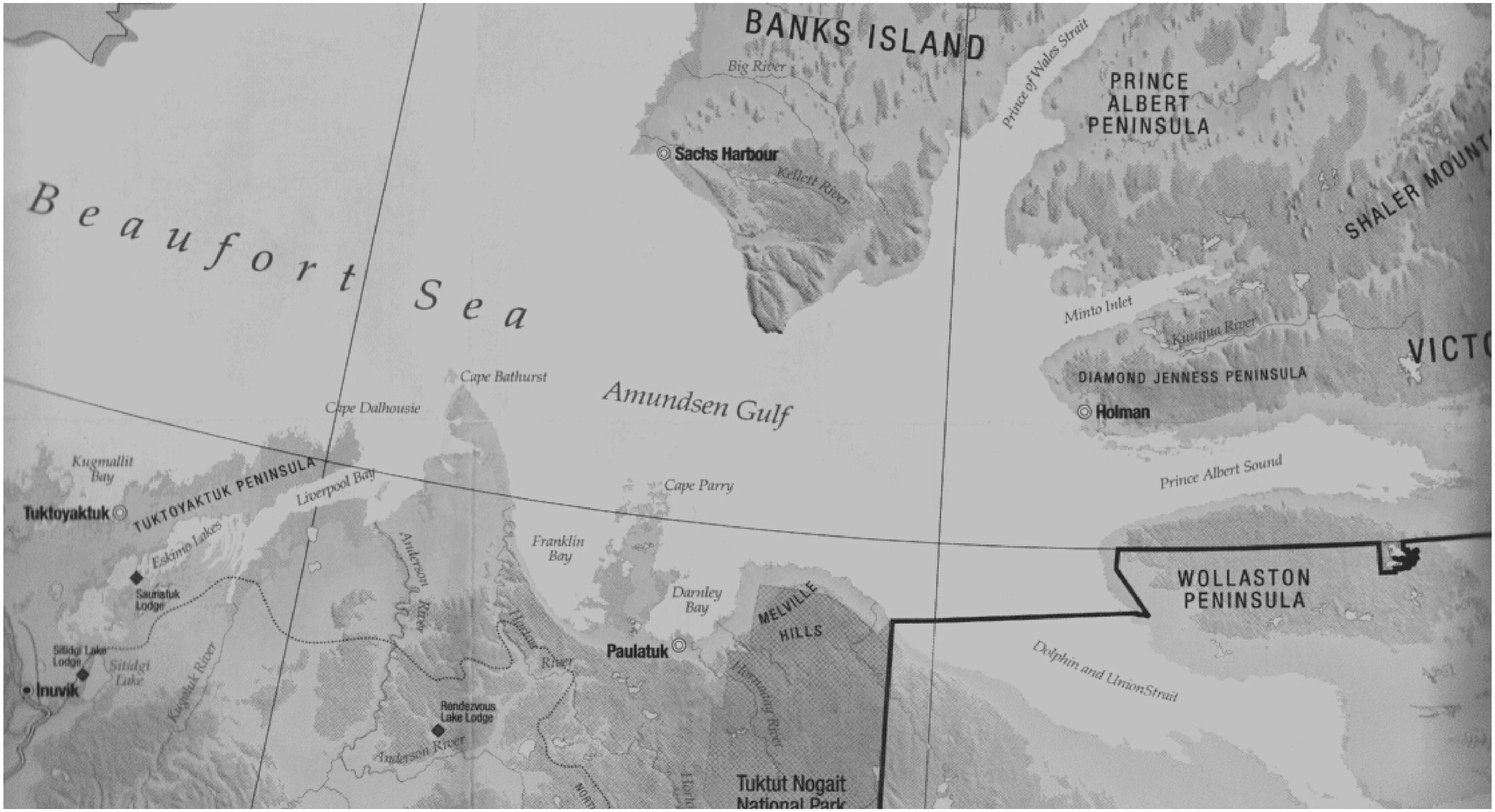

Figure 1 - Relief map of the Amundsen Gulf area of the Inuvialuit Region. The darker shades are of the order of 300 m or higher and have important effects on the local wind patterns in communities.

Paulatuk is situated at the south end of Darnley bay, but also cupped in by the Melville Hills and the hills (Smoking Hills?) of the Horton River. The Melville Hills peak at 874 m a.s.l. about one hundred kilometres east of Paulatuk. There is also the valley of the Hornaday River which flows directly towards Paulatuk from the southeast. We have no wind rose data for Paulatuk, but we suspect that the Hornaday River valley combined with overall easterly winds flowing around Melville Hills likely cause a prevailing south-easterly.

Tuktoyaktuk is surrounded by relatively flat terrain but is open towards the northwest. The easterly winds are slower than the north-westerly ones. This can be explained by the land to the east have higher surface roughness. This land creates more turbulence and slows the wind near the surface, more so than over the ocean to the northwest.

2.2 Previous Assessments of Wind Energy Climate

Several papers have been written on wind energy in the Canada's northern territories. Some of these are listed in the references section. A more extensive bibliography exists in Jagpal et al. (1996), which also includes a list of installed wind turbines in the north.

From the past studies we can conclude that there can be economic potential for developing wind energy in the four communities of interest, but careful siting will be required.

Figure 2 is derived from the NCEP/NCAR Reanalysis Project. This project reanalyzes historical data using computer models and weather input information such as marine surface, airport, weather balloon, and aircraft (military and commercial) data. This figure illustrates the differences in long-term annual mean wind speed between all of the communities.

The isotachs in Figure 2 represent near surface annual mean wind speeds[1]. According to this figure we should expect Sachs Harbour to have the highest mean annual wind speed. The mean wind speed of about 6 m/s at Sachs Harbour according to this figure helps us to confirm that what is found to be a 5.7 m/s (described later) long-term mean annual wind speed measured at 10 m a.g.l. at the airport is very likely.

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[1] Near surface by their definition means at 5 hPa (mbars) above the surface and this surface is, according to the website the surface layer is 80m thick. The wind speed probably represents the average for the surface layer. So the height of this wind speed is perhaps at 40 m a.s.l. The surface is defined as being at 1000 hPa which is sea level.

By dividing the wind speed values at Sachs Harbour into each those of the other communities we would have mean annual wind speeds of at least 90% of that at Sachs Harbour. According to the reanalysis project Holman has the lowest wind speed at 5.45 m/s.

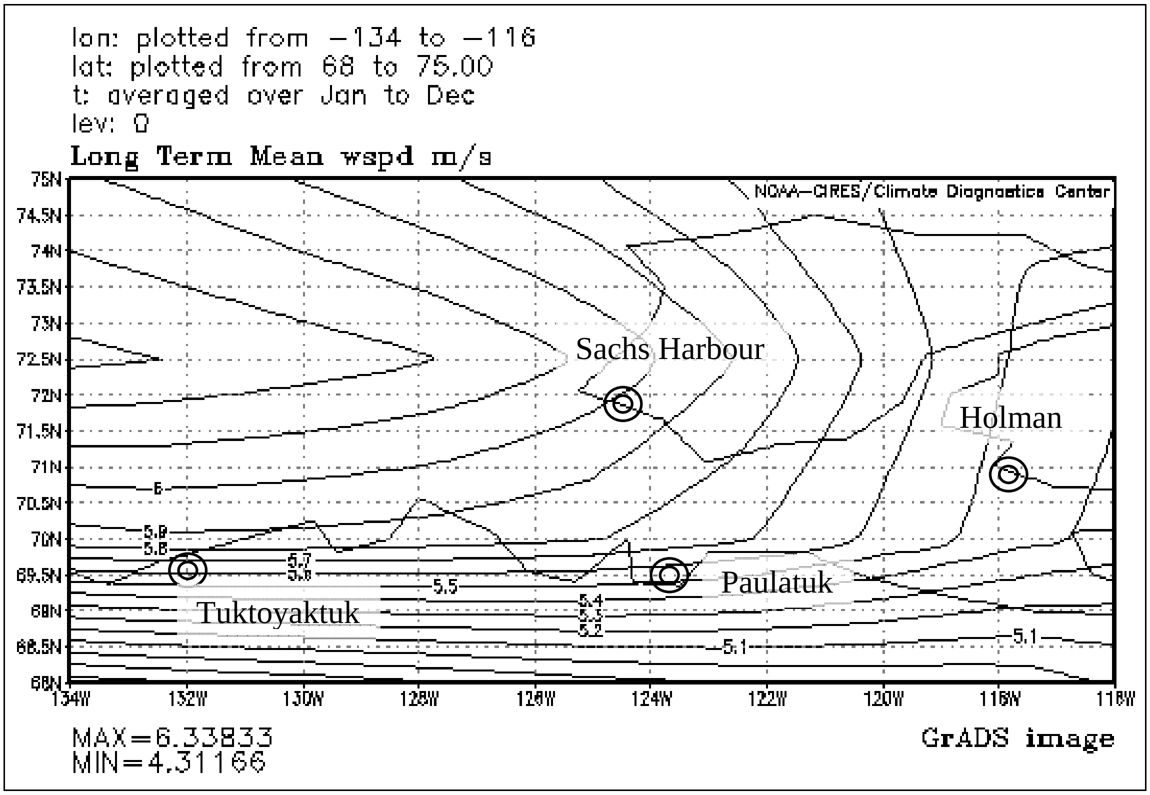

Figure 2 - Isotachs of near surface wind speed in the Inuvialuit region as derived from weather station and NCEP Reanalysis Products Surface Level. Near surface is defined by pressure level and so is vague in terms of actual height above ground. This map should therefore only be used for comparative purposes. (Source: NOAA-CIRES Climate Diagnostics Center website)

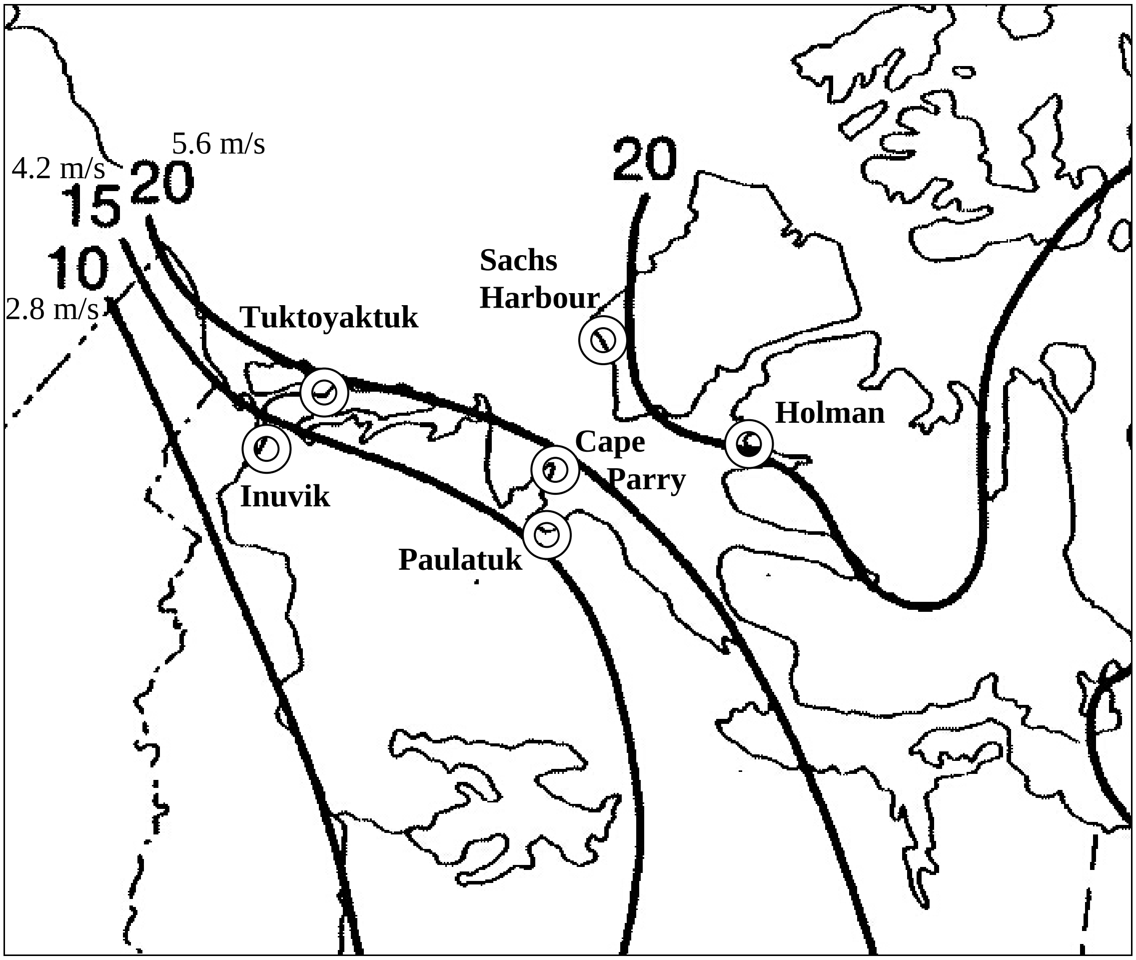

Figure 3 - Mean annual wind speed in km/h at 10 m height for the period 1967 to 1976.

Figure 3 shows an isotach map of annual mean wind speed in the Inuvialuit region by Walmsley and Morris (1992). According this map Sachs Harbour and Holman have mean annual wind speed of around 5.6 m/s at 10 m above ground, which is considered excellent in terms of wind regime. Tuktoyaktuk and Paulatuk, according to this map wound be considered marginal to good with wind speed values of about 5 and 4.4 m/s respectively.

The wind regime as described in Janz et al. (1982) determines Sachs Harbour, Holman, and Paulatuk to have excellent wind regimes and Tuktoyaktuk to have marginal potential. According to Janz et al. all four communities will need careful site selection in order to maximize wind energy capture, but Tuktoyaktuk will need more careful attention than the others.

2.3 Monthly Wind and Temperature Summaries

The long-term mean values of wind speed and temperature data has been compiled from three published sources and is shown in Table 1 below. The data sources are Barkstrom

(2002), Wilson (1969), and Environment Canada's Canadian Climate Normals 1951-1980 (Env. Canada 1982). These data are also shown graphically in Figure 4 and Figure 5. The wind speeds are measured at the standard ten-metre that is typical of most airport stations in Canada. All wind speeds mentioned in this report are referenced to ten-metre height above ground unless otherwise stated.

Table 1: Tabular form of long-term monthly and annual means of temperature and wind speed for the four Inuvialuit communities

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Source
Mean monthly temperature (deg C)														
Holman	-36.7	-34.7	-26.1	-15.3	-5.1	-0.9	11.2	7.7	-3.1	-19.5	-30.6	-33.9	-15.6	NASA
Paulatuk	-29.8	-27.6	-20.6	-10.6	-2.9	2.8	6.7	6.3	-0.3	-14.6	-26.2	-28.6	-12.1	NASA
Sachs Harbour	-25.1	-23.7	-18.6	-10.2	-3.3	0.4	2.6	2.1	-2.4	-12.6	-20.8	-22.6	-11.1	NASA
Tuktoyaktuk	-31.1	-27.9	-20.6	-9.9	-2.6	4.1	6.0	5.2	-0.6	-15.8	-29.1	-29.8	-12.7	NASA
Mean monthly wind speed (m/s) at ten metres above ground														
Holman	4.1	3.5	4.2	5.1	4.6	4.2	3.9	4.0	5.2	5.9	5.2	5.0	**4.6**	ColdClima
Paulatuk	4.7	4.9	4.6	4.5	4.3	4.4	4.0	4.5	4.8	4.6	4.3	4.8	**4.5**	NASA
Sachs Harbour	5.2	5.0	5.2	5.8	5.8	5.8	5.7	5.9	6.5	6.8	5.6	5.6	**5.7**	ClimNorm
Tuktoyaktuk	4.6	4.5	4.1	4.2	5.3	5.0	5.1	5.2	5.2	5.1	4.8	4.8	**4.8**	ClimNorm

	summer	winter	
Holman	4.5	4.6	summer = average from April to September
Paulatuk	4.4	4.7	winter = average from September to March
Sachs Harbour	5.9	5.6	
Tuktoyaktuk	5.0	4.7	

In Figure 4 we can see that Sachs Harbour has the highest mean wind speed of the four communities. It reaches a minimum in February and a maximum in October. Its summer wind speed average is higher than in the winter. This low winter mean could, in part, be due to rime icing conditions affecting the wind speed sensor. This is discussed later.

Holman has similar monthly peaks as Sachs Harbour in terms of the highest and lowest monthly means, but seems to have more monthly variability. This variability is probably due to sheltering of the hills surrounding the Holman wind station for some wind directions.

Paulatuk shows the lowest monthly mean wind speed in July and the highest in Feb. The wind speeds are higher during the winter months than in the summer. Tuktoyaktuk has maximum in May and a minimum in March. The summer average is higher at 5 m/s then the winter at 4.7.

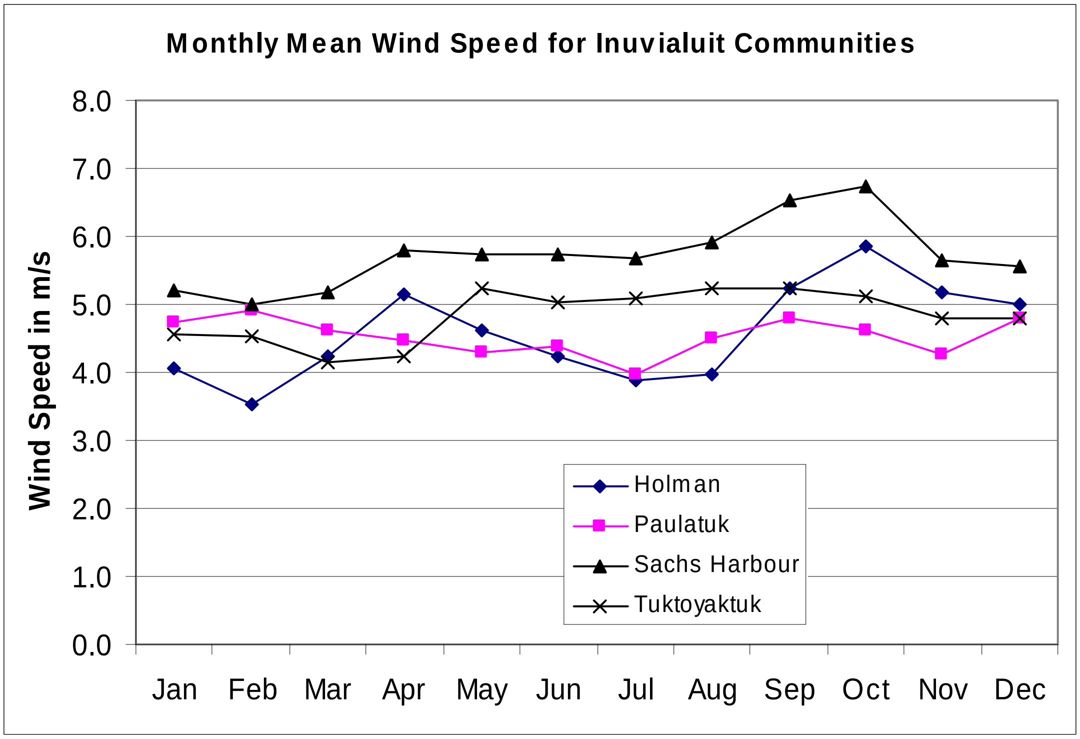

Figure 4 - Describes graphical the variation in monthly mean wind speed for four Inuvialuit communities. Sachs Harbour has the highest average wind speed.

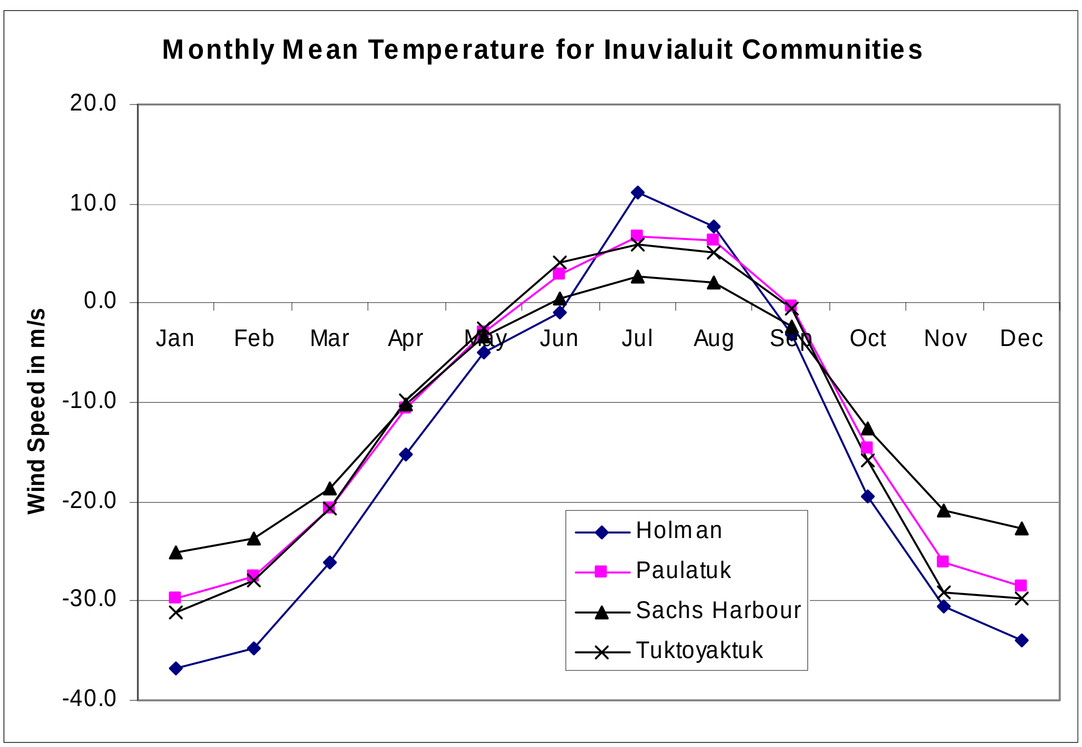

Figure 5 - Variation of long-term mean monthly temperatures for the four Inuvialuit communities.

2.4 Wind Power Classes

The Wind Energy Resource Atlas of the United States (Elliot et al., 1987) adopted a wind power class to help identify areas with different levels of feasibility as wind energy producers. This scheme was originally proposed by Battelle – Pacific Northwest Laboratory (PNL) and is also being adopted by Llinca (2003) for a Quebec Wind Atlas (see Table 2 below). This method uses a Rayleigh wind speed distribution and a standared sea level air density (1.22 kg/m3) to determine wind speed for wind power class limit. This does not take into account that densities in the Inuvialuit regions would be higher during the winter. This is an advantage that we can ignore and therefore allow us to be more conservative with our estimates in this study.

Table 2: Classes of Wind Power density at 10, 30, and 50 m above ground. (Source: Battelle PNL and adapted by Llinca et al. (2003)

	10 m (33 ft)		30 m (100 ft)		50 m (164 ft)	
Wind Power Class	Wind Power Density (W/m^2)	Average Wind Speed (m/s)	Wind Power Density (W/m^2)	Average Wind Speed (m/s)	Wind Power Density (W/m^2)	Average Wind Speed (m/s)
1	≤ 100	≤4.4	≤ 160	≤5.1	≤200	≤5.6
2	≤ 150	≤ 5.1	≤ 240	≤ 6.0	≤ 300	≤ 6.4
3	≤ 200	≤ 5.6	≤ 320	≤ 6.5	≤ 400	≤7.0
4	≤ 250	≤ 6.0	≤ 400	≤ 7.0	≤ 500	≤ 7.5
5	≤ 300	≤6.4	≤480	≤7.5	≤ 600	≤8.0
6	≤ 400	≤7.0	≤ 640	≤ 8.2	≤ 800	≤ 8.8
7	≤ 1000	≤9.4	≤1 600	≤ 11.0	≤2 000	≤ 11.9

According to Elliot and Schwartz (1993) areas designated as class 4 or greater are suitable for wind energy development. Class 3 areas may be suitable for future generation technologies as of 2000 beyond (technology has been improving). Areas classified as 2 are considered marginal and Class 1 are unsuitable for wind development.

In this report we refer to the 10-m above ground level to make comparisons. The projection to 30 m or otherwise are done within the RETScreen analysis shown later. According to wind speed classes defined above, the airport station of Sachs Harbour is a class 4 site and the other three communities are considered class 2. Holman and Paulatuk might be promoted to higher classes if we consider the newer sites considered for wind monitoring. As will be described later Holman could fall into a Class 5 or 6 and Paulatuk a Class 3 at the proposed new sites. Tukutoyaktuk will likely stay at Class 2 at the proposed site. Further discussions are found in section 3.2.

2.5 Weibull Distributions

To calculate wind energy production from wind speed data, it is more accurate to separate the wind data into a speed frequency distribution and to multiply it against the power curve of a wind turbine. If accurate wind data is not available the next best method is to use the known mean wind speed for the site of interest and assume that it has the shape of a certain frequency distribution. The statistical distribution most commonly used for wind speed analysis is known as the Weibull distribution. The exact formula and explanation is found in Walmsley and Morris (1997).

The Weibull distribution has only two parameters required to define its shape and amplitude and can usually be calculated by fitting it to the speed frequency distribution of a known wind data set. The parameters are the amplitude *A*, which is also the mean wind speed, and the shape factor *k*. The shape factor requires a good set of wind data to be defined, but is also found that it can be very similar among communities of a wider region.

We do not have accurate wind data for each community; however, we can assume that the statistical distribution for each community will have a similar shape as some nearby community with a better wind data. Walmsley and Morris (1997) calculate the Weibull shape factor for all of the communities chosen in its study. Four nearby communities with similar geography chosen for this study are Cape Parry, Inuvik, Cambridge Bay, and Resolute. The average of the Weibull distribution for each of those communities is 1.6, this value is used in the RETScreen calculation in section 9.1.

2.6 Wind Energy Roses

Wind energy roses are used to determine the most important direction for wind energy capture. This is done with data that is available for wind speed and direction and rearranged into a rough estimate of wind energy by direction sectors. In equation 5.1 the energy E is calculated on the basis that:

$$E = \tfrac{1}{2} \rho A t U^3 \tag{5.1}$$

with ρ being the air density, A the swept area perpendicular to wind direction, t the time duration of the wind at the speed U, which is the long-term mean wind speed. To create the wind energy rose we reduce equation 5.1 into a simplified form:

$$E_i = t_i U_i^3 \tag{5.2}$$

where the rose is divided into 8 or 16 direction sectors i, t_i is the time fraction that the wind blew in that sector, and U_i is the average wind speed for the sector. The density and area drop out because the density is impossible to calculate with the given data, and the area is a constant value.

Figure 6 shows the wind energy rose for Cape Parry. This figure is shown for Holman, Sachs Harbour, and Tuktoyaktuk inside Figures Figure 8, Figure 11, and Figure 14. We found no published wind speed and direction for Paulatuk at the time of this study.

Cape Parry is centered in between the four communities of interest and provides a good sense of main wind directions. Cape Parry, as seen in Figure 1, reaches into the Amundsen Gulf, on the north end of Parry Peninsula.

The wind rose in Figure 6 shows the shaded form indicating that 40% of the wind energy comes from the east and about 15% from the west. The thick outlined shape indicates that 20 % of the time the wind comes from the east and about 12% of the time it comes from the west. It also shows that some of the time winds come from the north and south but are lighter winds.

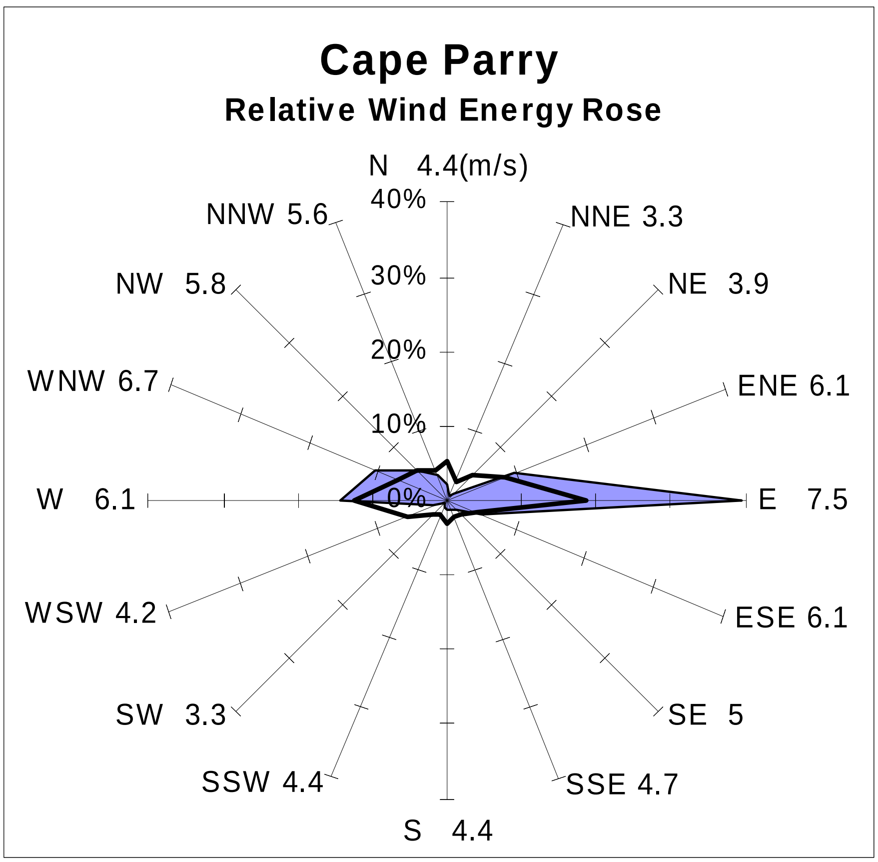

Figure 6 - The wind energy rose for Cape Parry, which is centered in between the four communities of interest. This rose shows the dark shaded form indicating that 40% of the wind energy comes from the east and about 15% from the west. The thick outlined shape indicates the wind direction frequency. The numbers beside the letters (N, NNE, etc.) are the mean wind speed in m/s for that direction sector. The long term mean wind speed for Cape Parry at 10 m above ground is 5.3 m/s.

The numbers beside the letters (N, NNE, etc.) are the mean wind speed in m/s (at 10 m above ground level) for that direction sector. These indicate that the highest mean wind speed by direction is from the east at 7.5 m/s. The second highest is from almost the opposite direction at 6.7 m/s from the WNW. The long term mean wind speed for Cape Parry at 10 m above ground is 5.3 m/s.

Given this information from Cape Parry we would expect that the wind in the surrounding communities would likely follow similar patterns with slight direction and speed due to local geographic features. These are discussed in later sections.

The wind energy roses in Figure 7 represent January and July for Sachs Harbour, Homan and Tuktoyaktuk. The annual wind energy roses are shown later along with locations maps of each community.

Although the annual wind energy rose for Sachs Harbour indicates that the prevailing wind energy direction is from the SE, the January and July roses show the opposite. They are not completely representative of the seasons. Also, it turns out that the sixteen point wind data that this rose is based on comes from human recorded wind data, that is, the wind data is only recorded during day time work hours, not 24 hours a day. Verifying with the data from the 24 recording (not shown in this report) we find that the January wind energy is mostly from the northwest with a major component from the SE. In July the wind energy is generally SE.

The Holman rose shows that 40% of the wind energy is south-easterly winds in January and 55% is easterly in July.

The winds in Tuktoyaktuk tend to be more spread out in many directions. This makes sense as there are no major land forms to direct or funnel the winds. In January about 35% of the wind energy seems to come from the SE and 21% from the west. Whereas, in July about 22% comes from the NW and 22% comes from the NE.

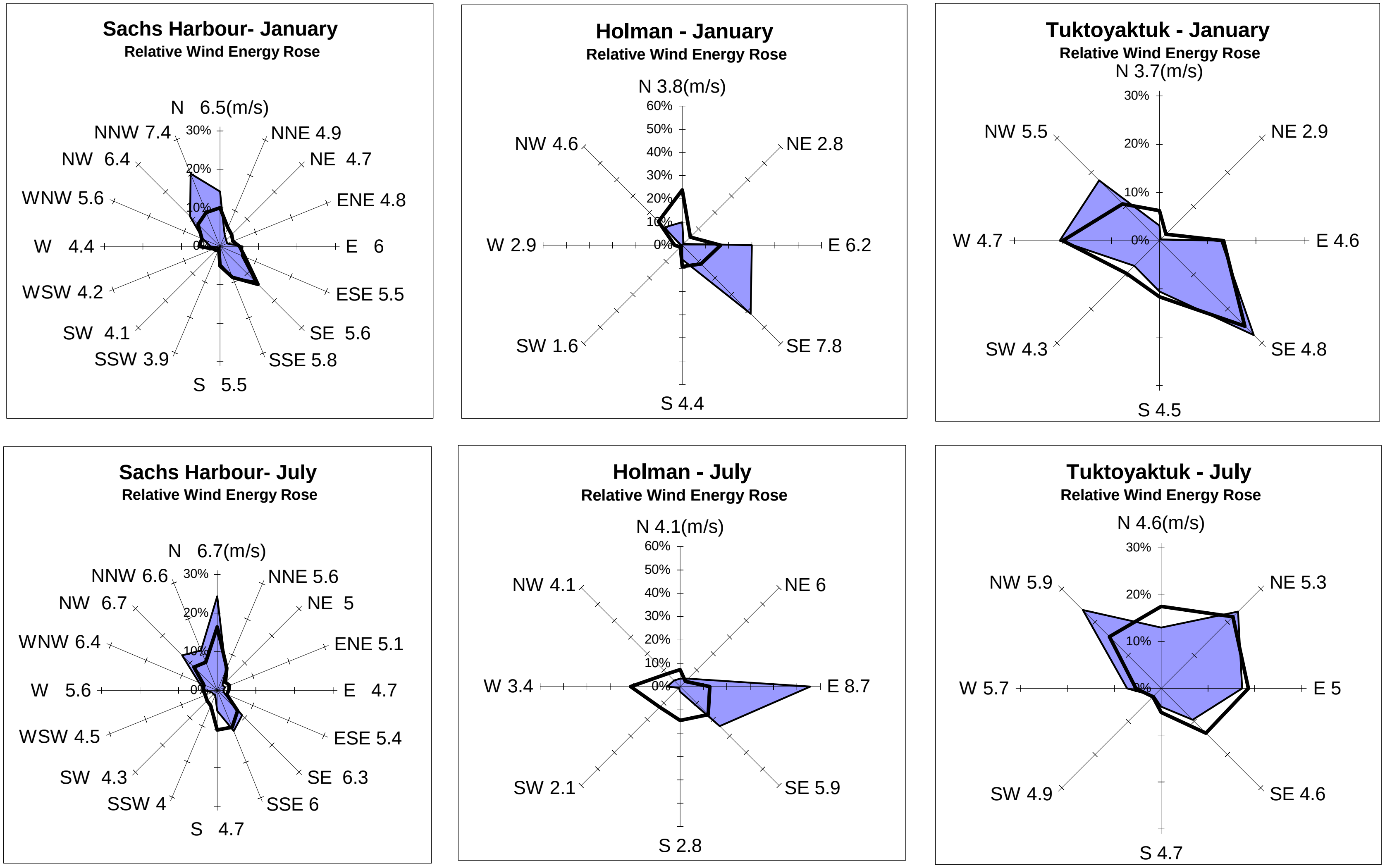

Figure 7 - Wind Energy and frequency roses for January and July for all communities but Paulatuk.

3 Community Descriptions

3.1 Site Visits

In order to get an understanding of the current situation and identify opportunities in Inuvialuit, site visits were made to Tuktoyaktuk, Holman, Sachs Harbour and Paulatuk on February 20-23, 2003. The visits were arranged by the Aurora Research Institute and were made in conjunction with the Energy Secretariat of the Northwest Territories, who were presenting a discussion paper to every community in the Northwest Territories on the development of a Territorial energy strategy.

The visit to each community included:

1) a tour of the diesel power plant,
2) a tour of the surrounding landscape to identify possible sites for wind energy monitoring stations and wind turbine deployment,
3) a public meeting with the Energy Secretariat to discuss community energy concerns,
4) meeting with the local community office to discuss land use issues,
5) informal meetings with community members to discuss local social, technical and economic constraints to the development of a wind energy program.

Meetings were also set up with Northwest Territories Power Corporation (NTPC) in Inuvik to discuss the opportunities for wind energy interconnection into the local NTPC power grids. A meeting was also held with Northwest Territories Municipal and Community Affairs (MACA) to discuss zoning issues for the possible citing of wind monitoring towers, and eventually wind turbines.

3.2 Community Wind Monitoring Sites

The following sections describe each community and their geographic features, the wind climate, and recommended sites to begin wind monitoring. These are the recommended sites and will need to be discussed and approved by the community members before final selections are made for wind monitoring tower installations. Most of these sites are on Inuvialuit land and will need to be dealt with accordingly.

3.2.1 Holman

The community of Holman is located in hilly terrain on Victoria Island, on the southwest shores of the Diamond Jenness Peninsula. It is set at the end of Queens Bay. Immediately to the east of the community is Kings Bay, and further east is a mesa that rises to about 180 m (600 feet) a.s.l. Just southwest of the community is a small hill that rises to about 90 m (300 feet) a.s.l.

According to Env. (1982) there was an airport wind monitoring station in the community at the end of the bay about 180 m west of Kings Bay (see Figure 8). This station recorded predominantly east winds in terms of energy content. There is presently a wind station about 2 km NNE of Holman, where the present airport is located. Published and reliable wind data for this newer station was not apparent during the course of this study.

Based on site visits and knowledge of wind direction, the sites with most exposure to eastern winds would be site #1 and then site #2. We should note here that the first airport location, from which the mean wind speed is identified in section 3, is a relatively sheltered area. The prevailing easterly wind comes from the direction where there is a significant hill. If we consider placing a wind station on hills higher than the airport location we should expect higher mean wind speeds. To determine how much higher the wind speed might be, let us make a simple assumption that the atmosphere is this area is neutral and that there are no hills. If we are to project the wind[2] from a 10-m tower at 9 m a.s.l. to 71 m and 180 m a.s.l. of the hills that we are about to describe below then we should expect an increase in mean wind speed to about 6.0 and 6.8 m/s respectively. These two new sites would be considered Class 5 and 6 respectively according to Elliot and Schwartz (1993). This is a conservative projected estimate, and the wind speeds should be higher for two reasons, the average atmospheric conditions are very stable (sharper increase of wind speed with height), and the airport is sheltered by a hill (reduced wind).

Site #1 is about 180 m high on the top of the bluff on the east side of the community. Its location is about 1.2 km east of the cemetery just north of the community. A power line to this potential site would span about 1.2 to 1.5 km from the road to the water pumping station. Access to this site may be difficult by ATV or snow machine. A wind monitoring tower installation would require either a helicopter or walking up the tower pieces to the top of the hill. The second more likely option would require help from the community members to help bring single tower pieces up the 160-m slope. This could be done in one day with at least one dozen fit individuals. If the wind climate proves to be economically feasible, a road would need to be built to access the site. This would be built into the cost of the turbine installation.

Site #2 is at 71 m a.s.l. and on the middle of the three hills. This site is located about 650 m from the nearest power pole. This site may be considered sacred and out of bounds as we sensed that some community members opposed the idea of a future wind farm there. This will be decided by the community.

[2] This vertical projection assumes a log law profile with a surface roughness of 0.03 m.

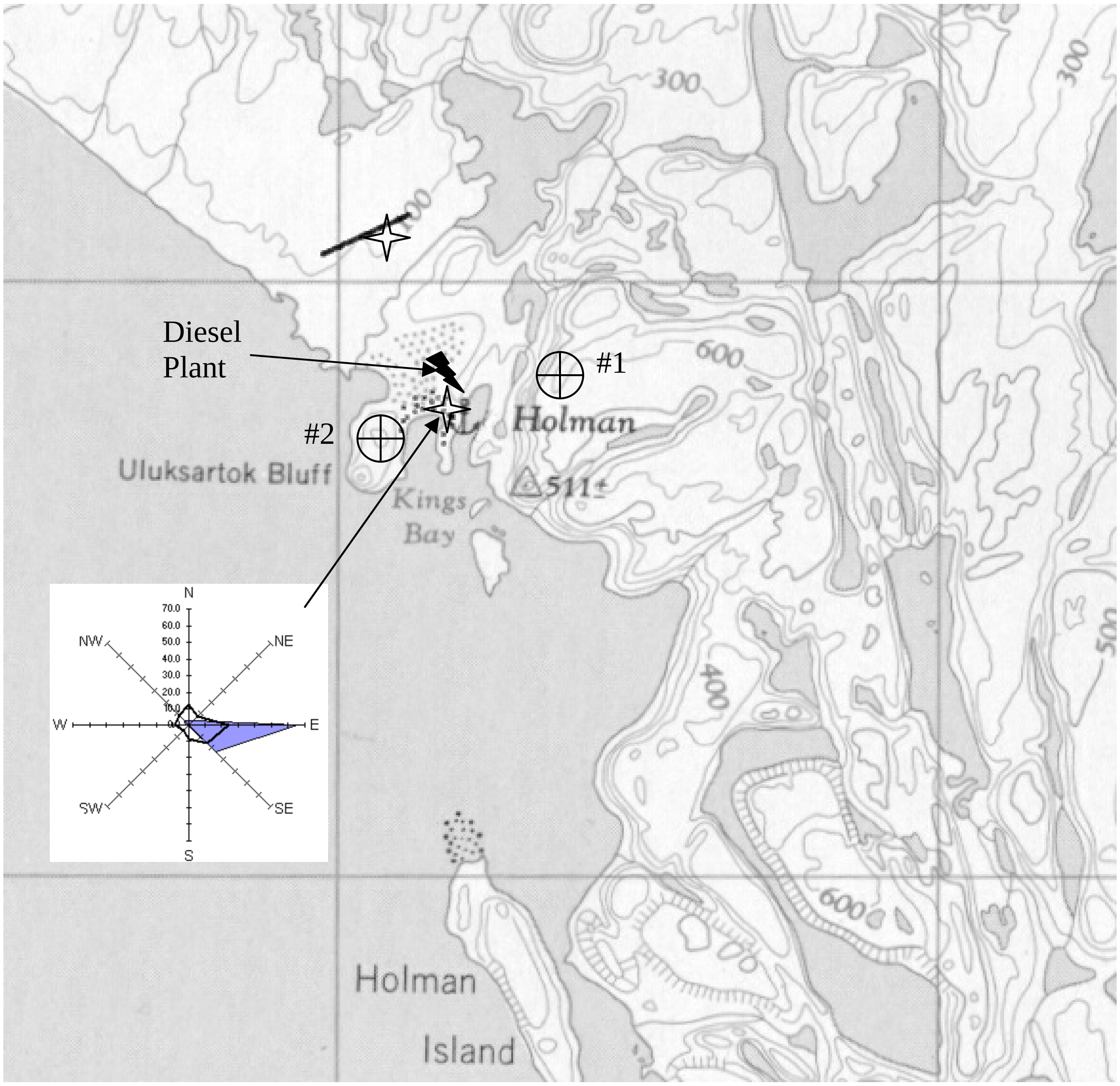

Figure 8 - Map (scale 1:250k) of Holman with recommended sites shown by the circle cross symbols. The four-point star shows the location of the wind monitoring stations. The wind station for which wind data was available in this study is indicated by the wind energy rose in the lower left. The wind energy rose shows that the prevailing wind energy is from the east.

3.2.2 Paulatuk

At the south end of Darnley Bay is the community of Paulatuk. About ten kilometers south of Paulatuk is the edge of the Melville Hills whose northern edge rises to about 300 m a.s.l. and runs east-west. These hills to the south probably have implications on the wind climate in the area. They may likely cause down-slope or katabatic winds. Local knowledge indicates that most winds are from the SE. About 20 km to the SE is the mouth of a SE-NW valley cut by the Hornaday River. Katabatic winds may be channeled down this valley and come out towards Paulatuk.

On the afternoon of February 12th 2003, wind speed measurements with a handheld anemometer were taken at the pump house and then on the hills to the east. The wind was coming from the SE. We found that there were at least 15% higher winds on the hills. Measurement were taken again in the community and found to be slightly less than at the pump house. This leads us to conclude that a good site would be on the hills just west of the pump house. If the annual mean winds are 4.5 m/s as measured by the airport it is possible that with the 15 % increase we might expect 5.2 m/s on the hill top. This would bring Paulatuk into a class 3.

Figure 10 shows the recommended sites for wind monitoring. The preferred site is #1, it is about 30 m a.s.l. and is about 350 m from the nearest power line. Handheld wind speed measurements revealed that winds may be slightly higher at this site then at site #2, which is about 28 m a.s.l. and is about 220 m from the nearest pole.

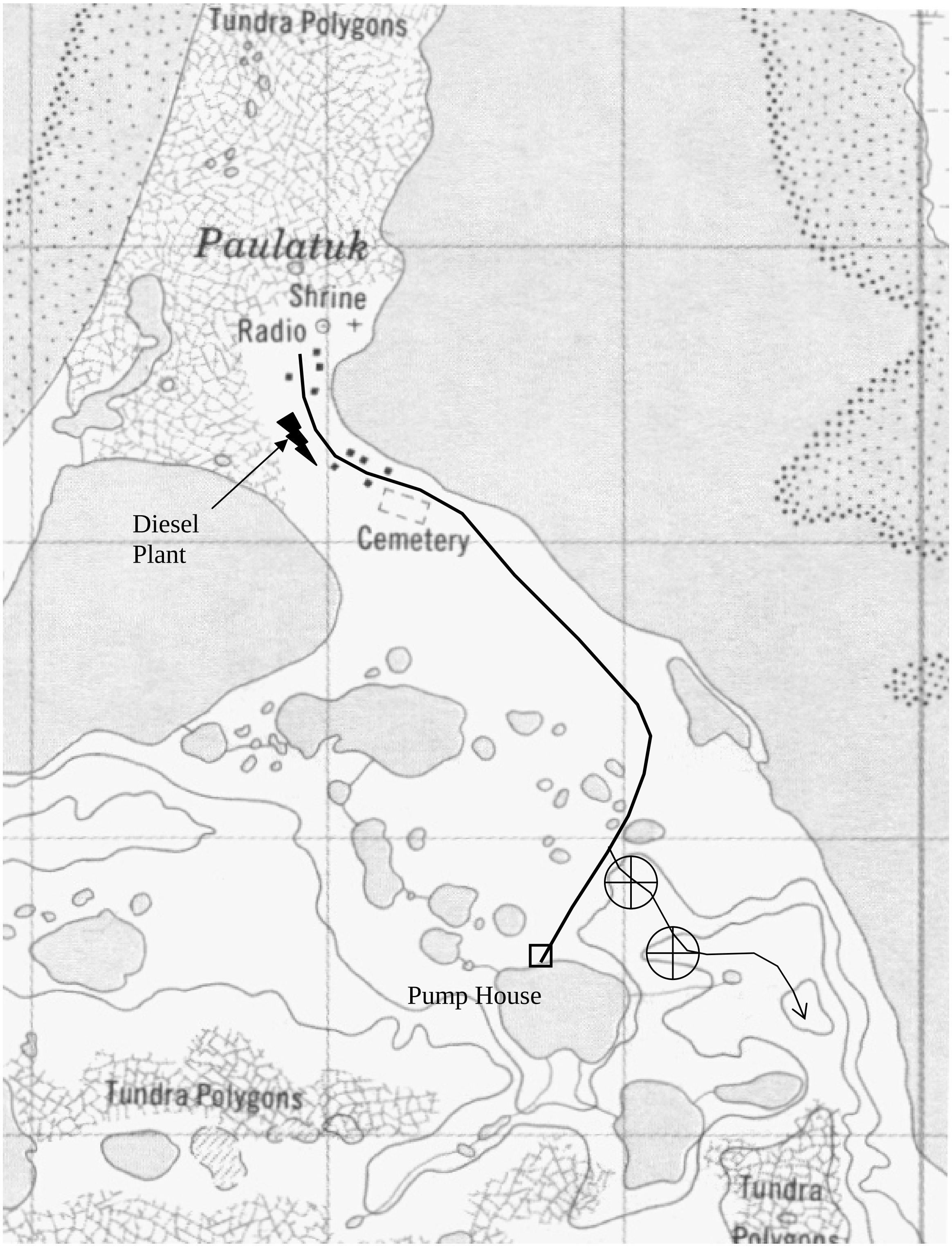

Figure 9 - Map (1:50k) of Paulatuk and the approximate location of the road to the pump house. Note the circle cross indication potential wind monitoring sites. The following figure shows greater details of the hills.

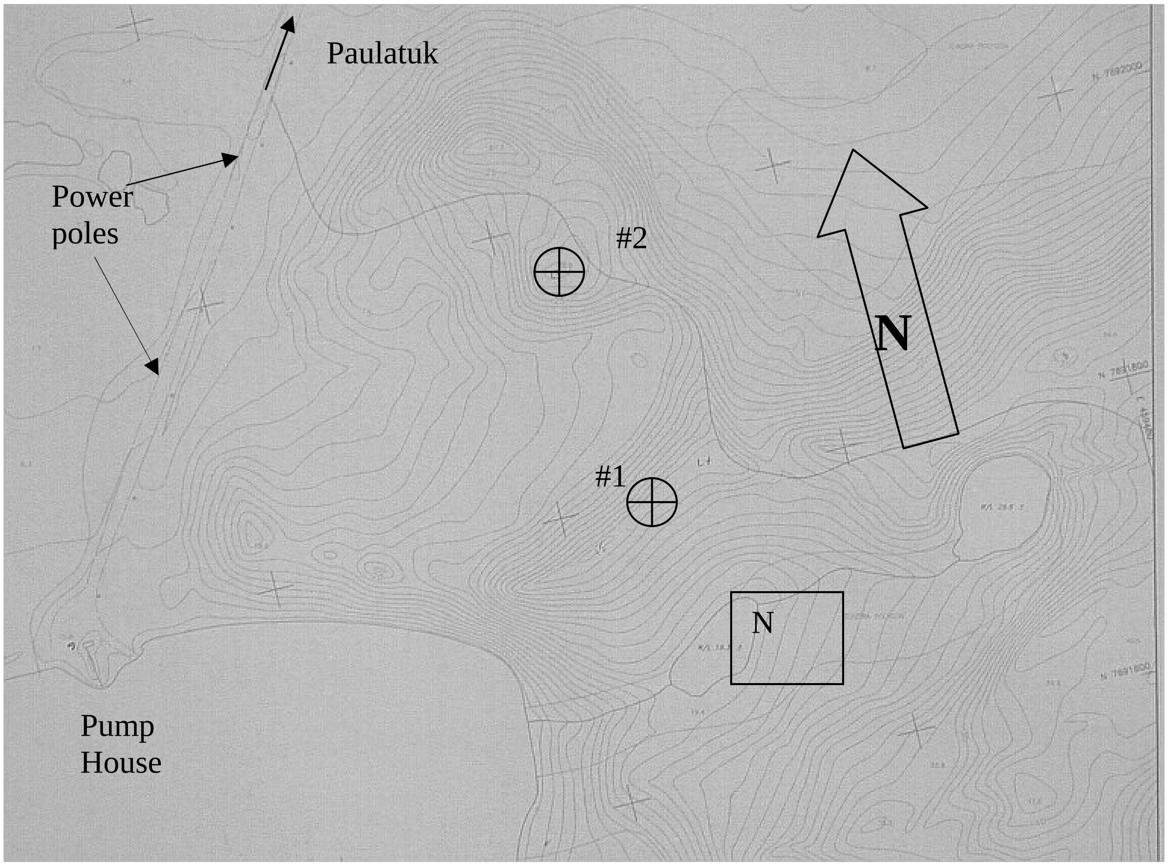

Figure 10 - Map (1:2000) of the hills by the pump house. The recommended sites for wind monitoring are shown by the circle-cross symbol. The preferred site is #1, it is about 30 m a.s.l. and is about 350 m from the nearest power line. Site #2 is about 28 m a.s.l. and is about 220 m from the nearest pole.

3.2.3 Sachs Harbour

The community is located along the shore at the SW corner of Banks Island. The shore is oriented in an east-west fashion and is overlooked by a bank that rises to above 80 m a.s.l. to the north. The top of the bank is less than 1 km from the shoreline and relatively flat with an elevation around 80 m a.s.l. for tens of kilometers to the north. To the south is the ocean and low lying land towards the east. Any locations along the top of the bank is well exposed to the south winds.

From published wind data (CCN, 1982) we find that most of the wind energy is from the SE, that is also the direction of the highest frequency of wind. Reports (Nor'wester, 1988 and Cheriyan, 1995) have recommended sites for installing wind turbines just south of the airport. The final location of the wind turbine was at an elevation of approximately 75 m a.s.l. about 420 m north, uphill of the diesel generator plant. This site is next to existing power poles and is shown in Figure 11 as site #1 with the circle-cross symbol.

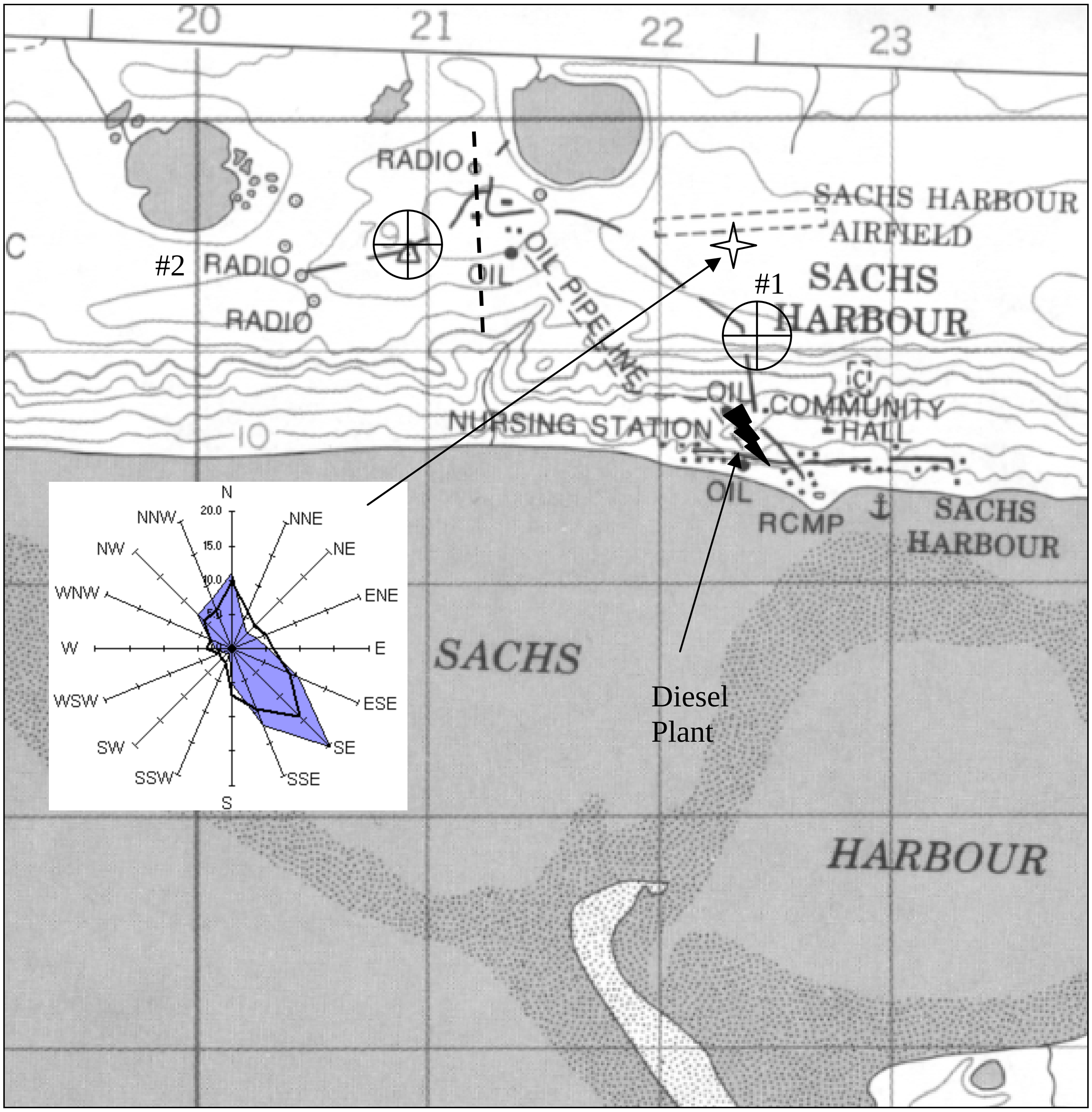

Figure 11 - Map (1:50k) of Sachs Harbour. At the bottom left is a wind energy rose showing the most important direstion of wind energy being from the south. Two sites recommended for wind monitoring are shown by the circle-cross symbols. The four-point star is the site of the airport wind station.

Another site that could be used for building a wind farm is site #2 (see Figure 12). This area is in line with the runway directly to the east. We estimate that a 45-m tall wind turbine would need to be at least 850 m from the end of the runway. This is based on a pilot's knowledge[3] of a rule that there is a required distance of 500 m from the end of the runway plus a 3% gradient rise from there. The distance requirements for a wind turbine at this site will need to be confirmed in writing by the NWT Airport Division before wind monitoring is set up there.

[3] Conversation with Blair Jensen of Ursus Aviation. Need to confirm the rules he provided.

There is apparently an underground power cable running along the road from the Ice Palace to the Antennae. The wind turbines could be fed into this line.

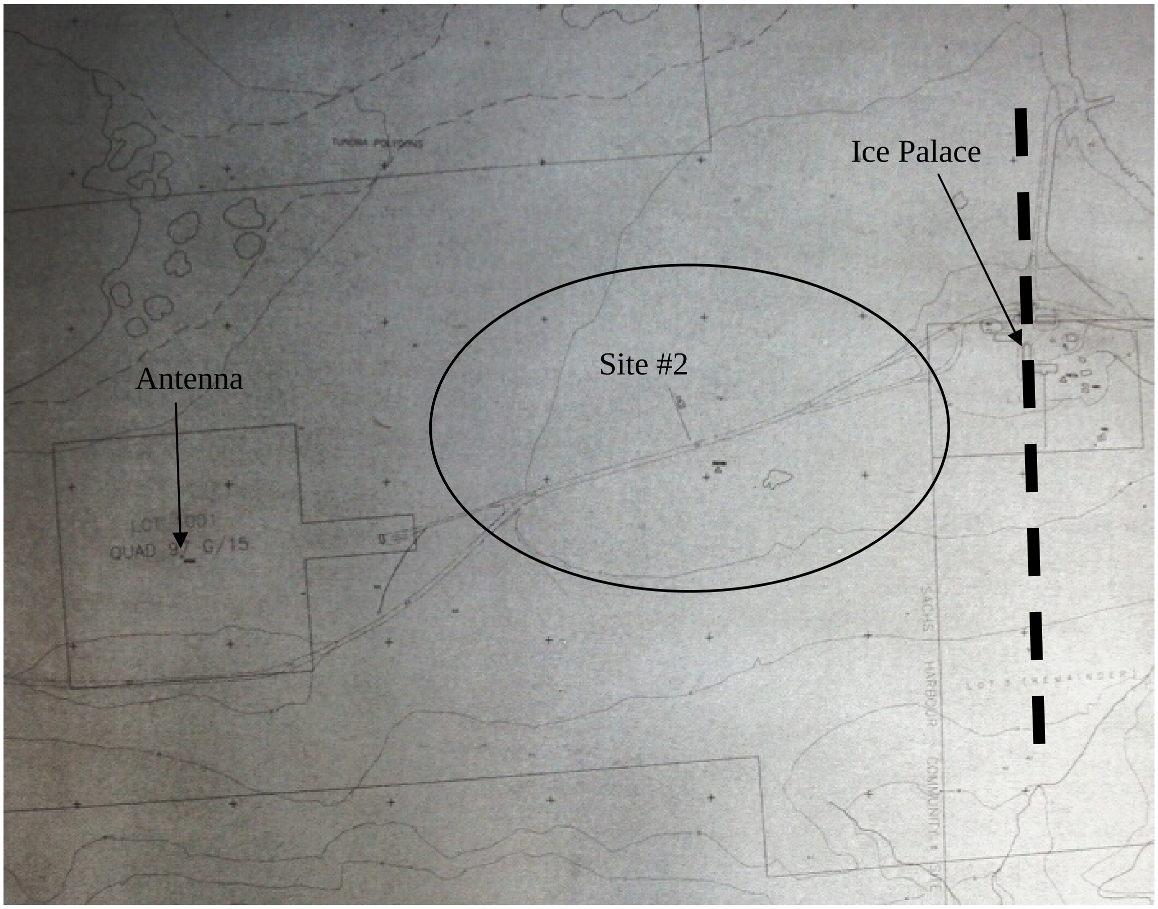

Figure 12 - Site #2 is within the oval, between lot 1001 and the Sachs Harbour community site boundary. The darker dashed line is our calculated approximate limit from airport fly zone. This line is about 850 m from the end of the runway to the right (east).

According to the annual wind energy rose there is about 20% of the wind energy that comes from the north. For this reason site #2 may be more attractive than site #1 because it is more open to the north winds. Site # 1 is obstructed to the north by the air strip that rises another 10 m about 300 m away. Neither one of these proposed sites is expected to have significantly improved wind speeds over the airport station.

Icing is a concern in this community. On the day of the visit[4] to Sachs Harbour there was rime ice on standing objects. Figure 13 shows the ice build-up on the airport wind instruments and on the powers near the site of wind turbine base. The wind sensor had been knocked free of ice earlier that morning. It can be seen in the figure that these sensor still have a significant amount of ice. The power pole shows how rime ice can accumulate

[4] On February 22, 2003

if interrupted. The authors observed approximately 10 cm diameter cores around guy lines. Wind monitoring would require heated instruments and local grid to provide power to the heaters. This raises the cost of wind monitoring in this community but is necessary if we want reliable wind data. This does however raise questions that perhaps the wind speeds are higher than has been measured at the airport. We observed[5] that the cups were often iced over (see Figure 13) and that instruments had to be shaken free of build-up. This will be a concern as wind turbines will require anti-icing technologies such as heated pads on blades to overcome this icing problem.

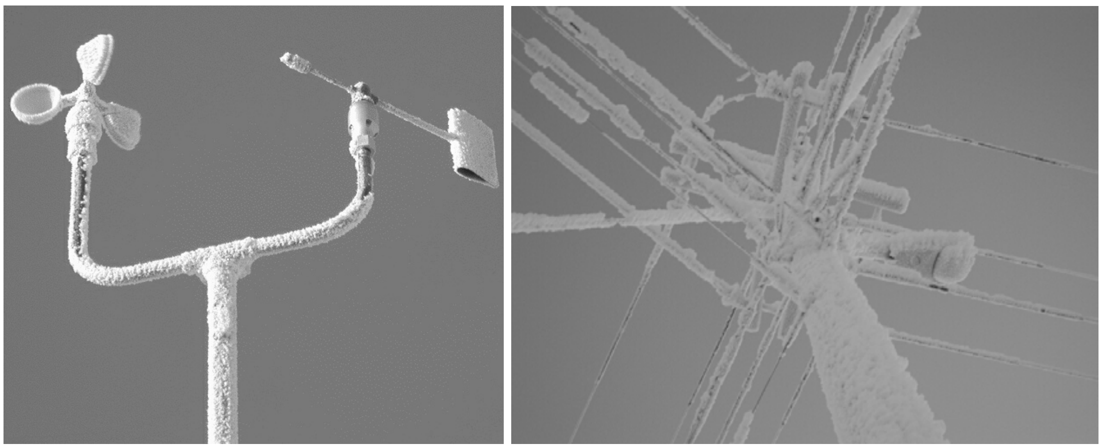

Figure 13 - Shows the severity of icing in Sachs Harbour. The photo on the left was taken around noon on February 22, 2003, the wind instruments were cleared that morning. The power pole on the right better depicts the severity of the icing without any mechanical removal.

3.2.4 Tuktoyaktuk

Tuktoyaktuk is located on the eastern edge of Mackenzie Delta. There is open ocean toward the NW and flat land, save the Pingos, to the east and to the south.

The wind energy rose for Tuktoyaktuk shows two interesting features: The highest wind energy is from the NW, and the most frequent wind direction is from the E, and then SE. When the winds are from the NW they are usually quite strong, but most of the time the wind is from the E and SE.

There are two likely sites that are shown in Figure 14. Site #1 was recommended by the plant maintenance person[6] is in on what used to be a building and is now a flat pad (not sure if cemented or not). Apparently the site belonged to Northern Transportation Co. Ltd. The second site (#2) is on a small hill that is about 12 m a.s.l., it juts out on a small peninsula and is more open to the north-east, east, and south-east winds. At the most this site is about 600 m from the nearest power line. We are not sure who this land belongs to. This will need to be further discussed with the community members. Also, for both of

[5] Conversation with Manny Kudlak, weather observer at the airport, describes removing ice from the cups every morning and changing the cups once a month in the winter.
[6] Conversation with Rex Cockney, NTPC in Tuktoyaktuk.

these sites we would need to have written authority by NWT Airport Division to allow a wind turbine generator.

Because there is not much gain in elevation at the new proposed sites it is not clear that there may be an improvement in the wind regime.

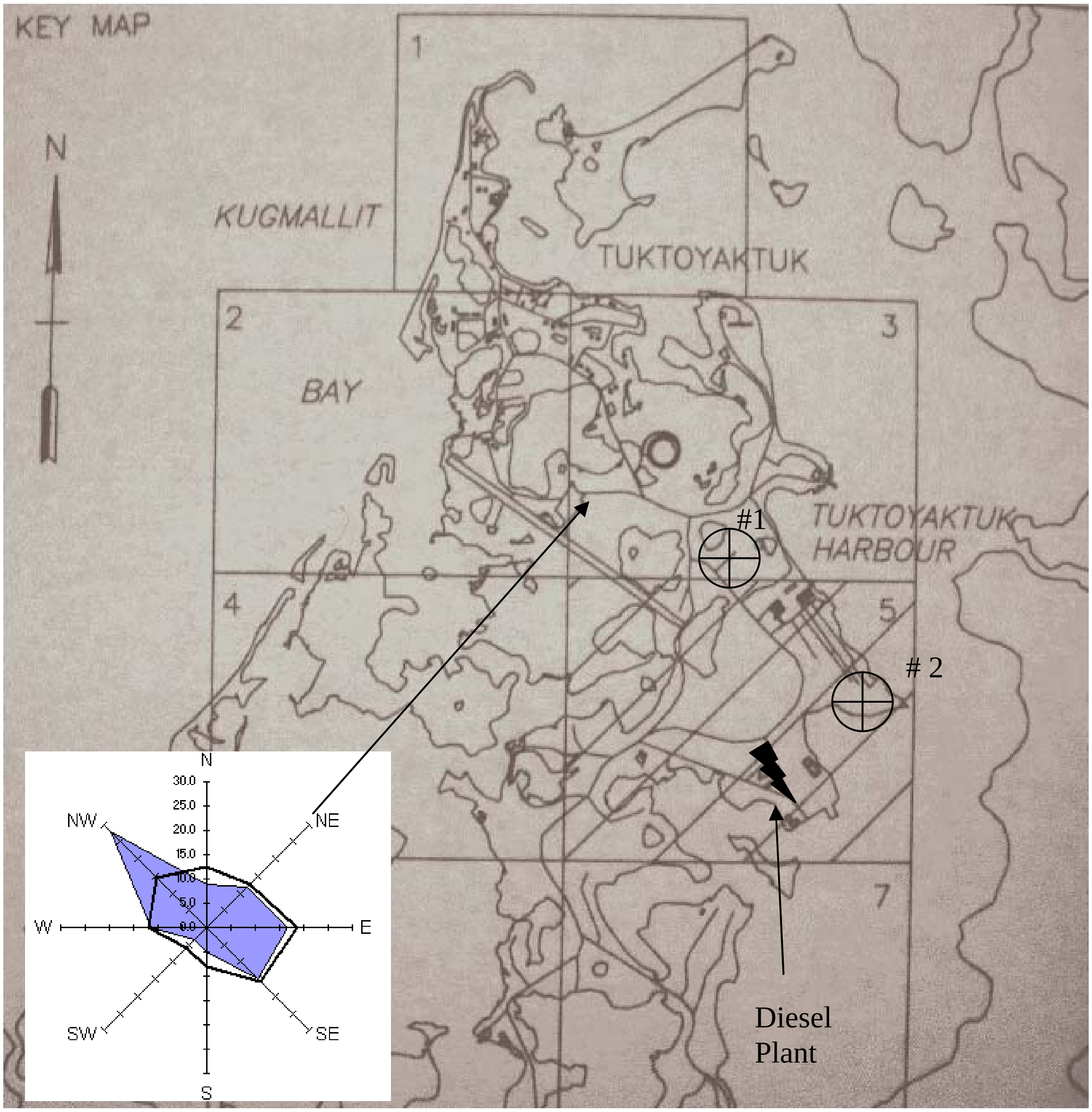

Figure 14 - Map of Tuktoyaktuk. Wind energy rose for the airport station is in the bottom left corner.

4 Community Electricity Concerns and Opportunities

Public meetings with community members revealed that the high cost of electricity is a major concern to all of the Inuvialuit communities. Although residents are subsidized for the first 700 kWh of electricity they consume, industrial and commercial buildings incur the full costs immediately. According to community members, the Icicle Inn, a hotel in Sachs Harbour was forced to close due to energy costs, while 25% of the prices of goods at the local Co-op are due to electricity costs. All of the communities expressed a general sense of frustration about the inability to regulate their own fuel and electricity costs, as they are subjected to the whims of the global oil market.

Environmental protection and long-term sustainability was another common, although secondary concern voiced by all of the communities during the public meetings. Community members expressed their interest in the development of renewable energy resources such as wind energy to help secure long-term local self-sufficiency. Overall energy costs and energy supply reliability were the primary concerns.

Meetings with NTPC revealed that NTPC is open to buying wind energy from a private power producer rather than developing further wind projects themselves. NTPC has indicated that they are willing to purchase wind energy at the displaced cost of diesel fuel. The feasibility of wind energy systems for the Inuvialuit communities therefore depends on the costs of diesel fuel for the specific communities. Table 3 lists the current costs associated with the displacement of diesel fuel for the four communities.

Table 3: Cost of Displaced Diesel Fuel

	Annual Diesel Fuel Expense (C$)	Annual Generation (kWh)	Cost of Displaced Diesel (C$/kWh)
Holman	496,100	2,024,817	0.245
Sachs Harbour	167,600	980,048	0.171
Paulatuk	321,800	1,324,388	0.243
Tuktoyaktuk	721,200	4,318,818	0.167

It is evident in the table above that Holman and Paulatuk have about a 41% higher cost of displaced diesel fuel than either of Sachs Harbour and Tuktoyaktuk. This makes these two communities very attracted for wind-diesel even despite the mediocre wind regimes indicated by the airport stations.

Found in Tables Table 4 to Table 7 are the electrical load, costs and forecasts at the time of this study. These tables describe for each community the population, annual generation, peak load, expected growth and the present power rate. The following are notes for each table: * average rate of all classes, **average rate based on Phase II GRA, *** based on population forecast from the GNWT stats bureau.

Table 4: Annual Electrical Consumption in Holman

HOLMAN Diesel Capacity: 1140 kW

	Population***	Annual Generation (kWh)	Peak Load (kW)	Expected Growth Rate	Power Rate (C$/kWh)
Current (2003/04)	495	2,024,817	495	1.1%	0.71*
3-Year Forecast (2006/07)	504	2,089,668	530	n/a	0.71**

Table 5: Annual Electrical Consumption in Paulatuk

PAULATUK Diesel Capacity: 800 kW

	Population***	Annual Generation (kWh)	Peak Load (kW)	Expected Growth Rate	Power Rate (C$/kWh)
Current (2003/04)	319	1,324,388	270	2.6%	0.79*
3-Year Forecast (2006/07)	327	1,430,523	274	n/a	0.91**

Table 6: Annual Electrical Consumption in Sachs Harbour

SACHS HARBOUR Diesel Capacity: 775 kW

	Population***	Annual Generation (kWh)	Peak Load (kW)	Expected Growth Rate	Power Rate (C$/kWh)
Current (2003/04)	159	980,048	221	0.26%	0.91*
3-Year Forecast (2006/07)	164	987,615	223	n/a	0.93**

Table 7: Annual Electrical Consumption in Tuktoyaktuk

TUKTOYATTUK Diesel Capacity: 3100 kW

	Population***	Annual Generation (kWh)	Peak Load (kW)	Expected Growth Rate	Power Rate (C$/kWh)
Current (2003/04)	1013	4,318,818	843	0.79%	0.59*
3-Year Forecast (2006/07)	1039	4,421,607	861	n/a	0.57**

5 Manufacturers of Medium-Scale Wind Turbines

There are 3 broad categories of wind turbines currently available on today's market; large-scale which are designed to be grid-connected and range in size from 660 kW to 3 MW, medium-scale turbines, appropriate for village and isolated community electrification which typically range from 35 kW to 200 kW and small-scale turbines that are appropriate for individual homes, farms and remote outposts such as communication towers, these range in size from 500 W to 10 kW.

For the current study, medium-scale turbines are the most appropriate class of turbines to examine. The large-scale wind turbine class has been the major focus of the global wind energy industry and has experienced the most technical improvements in recent years, and as such, has seen the most dramatic reduction in costs per installed kW. For these reasons it may be tempting to investigate larges-scale wind turbines for remote community applications. Although the larger communities of Tuktoyaktuk and Holman could possibly support large-scale wind turbines there are several important drawbacks to doing so. Firstly, utility scale wind turbines are massive structures that have rotor diameters of at least 40 m and nacelles weighing several tons. A heavy-duty crane is therefore required to install such machines, which is not only very expensive but is not readily available, even in southern communities. Obtaining a suitable crane was a major difficulty and expense for Yukon Energy's installation of a 660 kW turbine in Whitehorse in 2001.

Furthermore, the multiple turbines that would be required to equal the energy output of a large-scale machine will provide redundancy and power-smoothing effects to the grid. Because the wind is inherently variable the output of wind turbines is also not constant. However, because local turbulence effects are not well spatially correlated, multiple turbines on the same grid are unlikely to experience the same power fluctuations at the same instant. Therefore, it is typically estimated that the effective network flicker will reduce as:

$$\frac{\Delta P}{P} = \frac{1}{\sqrt{n}} \frac{\Delta p}{p}$$

where n is the number of wind turbines, P is the rated power of the wind farm and p is the rated power of the individual wind turbines, ΔP and Δp are the power fluctuations of the entire wind network and an individual turbine respectively.. Multiple turbines will also provide redundancy so that maintenance down-time will be minimized and should repair-work or trouble-shooting be required with an individual turbine, the remaining machines should still be available.

Small-scale wind turbines tend to have the highest cost per kW, as well as the lowest wind energy conversion efficiencies. The remainder of this report will therefore only consider medium-scale machines.

There are only a few medium-scale wind turbines that are currently available. The companies with the longest history that are still manufacturing medium-scale machines are: Atlantic Orient (AOC), Vergnet and Lagerway. Specifications for these three turbines are in Table 8 below:

Table 8: Medium-Sized Wind Turbines Appropriate for Inuvialuit Communities

Manufacturer	**AOC**[7]	**Vergnet**[8]	**Lagerway**
Size (kW)	50	60	80
Blade	3-Blade	2-Blade	2-Blade
Yaw	Downwind Passive	Downwind Passive	Upwind Active
Generator	Induction	Induction	Rectified DC
Speed Control	Stall	Stall	Pitch
Overspeed Control	Tip Brakes	Emergency Pitch	Pitch Control
Rotor Diameter	15 m	15 m	18 m
Cut-In Windspeed	4.6 m/s	5 m/s	3 m/s
Rated Windspeed	12 m/s	15 m/s	15 m/s
Manufactured	USA/Canada	France/Canada	Netherlands

Bergey Windpower, an important small-scale manufacturer is currently developing a 50 kW wind turbine, while PGI, a Canadian company recently announced the development of a 35 kW machine. Given Bergey's long history in the industry, and the possibility that the Canadian-made PGI turbine will have lower capital costs, these two machines may be of interest for future projects. However, given the limited track record of both machines they would not be recommended for remote communities in the immediate future.

Northern Power Systems (NPS) is also developing a 100 kW wind turbine specifically designed for cold climates, which is the only wind turbine in this class to include a gearless generator. The cold climate modifications that include a gearless, direct-drive generator, result in a significantly higher capital cost. One NPS wind turbine is currently operating as a pilot project in Kotzebue, Alaska, alongside their AOC machines. It remains to be seen if the long-term productivity of the NPS wind turbine justifies the increased capital costs.

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[7] See Appendix A.1 for manufacturers details
[8] See Appendix A.2 for manufacturers details

6 Wind Turbine Systems in Northern Canada and the United States

Several studies have been done in the past examining the feasibility of wind-energy in communities in the Northwest Territories and Nunavut. Several wind turbines have also operated and are currently operating in the Canadian North although there are currently no wind turbines running in the Northwest Territories.

The two most recent wind energy projects in the Northwest Territories were 80 kW Lagerway wind turbine installed by Dutch Industries Ltd. in Cambridge Bay, and the 50 kW AOC wind turbine installed by NTPC in 2001 in Sachs Harbour. Two other wind programs that were transferred to Nunavut include Kugluktuk, which had two 80 kW Lagerway turbines installed in 1996, and Rankin Inlet which had a 50 kW AOC installed in 2000. The largest wind-diesel system in the North is in Kotzebue, Alaska. Kotzebue Electric Association expanded their wind energy program in 1999 to install an additional eight wind turbines, to the three that have been operating since 1997. These important recent wind projects in the north are discussed in this chapter.

6.1 Cambridge Bay

A single 80 kW Lagerway wind turbine was installed onto the Cambridge Bay grid by Dutch Industries Ltd. of Regina, Saskatchewan. The turbine was installed in 1994 with a contract to sell power for 8 years to NWT Power Corporation at 0.20 C$/kWh. The turbine operated with an average capacity factor of 20% for the period between September 1994 and August 1998 and supplied NWT Power with approximately 135,000 kWh annually or 2% of its annual total generation (6,750,000 kWh). The avoided fuel costs were estimated to be 0.17 C$/kWh, so that NWT Power in comparison was paying an extra 0.03 C$/kWh to buy the wind energy. 135,000 kWh represents about 39,200 L of displace diesel fuel annually, which displaced about 100 tonnes of CO_{2eq} per year, and 78 kg of particulate matter. The wind turbine collapsed in June 2002, the cause of the accident is unknown, as is whether or not the turbine will be replaced.

6.2 Sachs Harbour

A single 50 kW AOC wind turbine was installed in Sachs Harbour in 1998. The project began as a joint venture between NTPC, GNWT Department of Energy, Mines and Petroleum Resources and Natural Resources Canada, and ended up being an NTPC solo venture, due to an unusual set of financial circumstances from the original project partners. Supplier difficulties delayed the commissioning of the turbine, and grid difficulties occurred due to start-up voltage dips were not regulated until a soft-start connection was established in 2000. The turbine ran for about 6 weeks in the late summer and early fall of 2000, when a tip break broke off a blade and was lost. The brake was replaced in October 2000. Severe icing conditions in Sachs Harbour caused operators to attempt to motor the turbine to get it started. This eventually resulted in a damaged gearbox that needed replacing. The turbine was accidentally dropped and had all three blades destroyed during the gearbox repair in 2001. The project was forecast to cost $230,000 and ended up costing over $450,000 due to the unusual and unfortunate circumstances. The project was abandoned after the turbine was dropped.

6.3 Kugluktuk, Nunavut

Two 80 kW Lagerway turbines were installed in 1997 in Kugluktuk, and were the first turbines owned by NTPC. Of the three locations for the turbines recommended by the supplier, only one was approved by the Hamlet office. Several electrical problems initially occurred with the wind turbines, along with maintenance and after-sales service difficulties, resulted in considerable downtime of the turbines. The purchase and installation of these turbines was $580,000 and resulted in $41,298 in fuel savings in the 24 months that they were operational. In July 2000, one of the turbines fell from its tower after several mounting bolts failed, and the other was hit by lightening earlier in the same month. A $110,500 quote was received to recondition the damaged turbine, but it has not been repaired. The damaged turbine may be sold to Cambridge Bay, which has a more favourable wind resource.

6.4 Rankin Inlet, Nunavut

Rankin Inlet erected a single AOC 50 kW wind turbine in 2000, after the planning and installation began in 1998. Siting difficulties that were encountered include negotiations with Transport Canada, the local community, Arctic Airports and the Government of Nunavut to ensure that the turbine was sufficiently far from the community's airport. Further construction delays were caused when the control building did not make it onto the annual sealift, postponing commissioning by a year.

From November 2000 to December 2001, the turbine produced 80,000 kWh, with 36% availability. The downtime included not only low wind-speeds, but several difficulties encountered with the tip brakes, which were serviced by Island Technologies from PEI. When fully operational, it is expected that this turbine will produce 152,000 kWh annually displacing 41,100 L of diesel for a $24,000 and 119,000 CO_{2eq} annual savings.

6.5 Kotzebue, Alaska

Kotzebue Alaska is a community of approximately 3,000 on the west coast of Alaska. They use approximately 20 million kWh annual, and consume over 5.3 million litres of diesel fuel annual to do so.

In order to reduce the community's reliance on diesel fuel, and to try to reduce energy costs, Kotzebue Electric Association (KEA) installed three AOC 15/50 wind turbines in 1997. The success of these initial turbines prompted the expansion of the program, and another seven AOC wind turbines were installed in 1999.

The ten turbines are expected to produce over 1.2 million kilowatt-hours of electricity annually. Each wind turbine produces enough to meet the electricity needs of about 20 homes.

KEA is in the process of testing the AOC wind turbines, so determine their ability to operate in arctic conditions. This test program has recently been expanded to include the erection of a Northern Power Systems turbine as well. KEA hopes to eventually develop 2-4 megawatts of wind energy capacity, enough to meet the electrical needs of the community's peak load.

The project hopes to demonstrate the feasibility of wind energy systems for remote communities in the arctic, and around the world. On their website, KEA lists the following goals and expected benefits from their wind energy program:

Project Goals

- Testing turbines designed for arctic conditions and making adaptations as necessary.
- Documenting installation, operations and maintenance challenges and expenses to evaluate the real potential for wind energy generation in remote communities that are not interconnected with a large electricity transmission grid.
- Developing a training center to teach wind technician maintenance skills to rural Alaskans.
- Developing remote electronic communications control systems for wind turbines.
- Developing techniques for installation and operation of wind turbines in smaller village conditions.

Expected Benefits

- Lower electricity generation costs for consumer-owned KEA.
- Decreased environmental damage and risks associated with using diesel fuel.
- Decreased reliance on the State of Alaska's Power Cost Equalization program to help make electricity affordable.
- Increased self-reliance using a clean, renewable local energy resource.
- More of the money needed to generate electricity spent locally, benefiting the local economy.
- New construction and maintenance jobs for local residents and other rural Alaskans.

More information on the Kotzebue developments can be found at: www.kotzelectric.com

7 Special Consideration for Wind Turbines in the North

7.1 Rime Ice

Structural ice loading is always a concern when engineering machinery for cold climates. Wind energy is no exception, especially with respect to the dynamics of the large rotors that are directly exposed to the environment. Changes to the aerodynamics of the wind turbine blades due to rotor blade icing can seriously affect a turbine's performance. Beyond the loss of control, blade icing can lead to a decrease in power output, an increase in fatigue loading, unbalanced rotor loads, or long periods without production as an iced turbine is very unlikely to self start if it stopped due to erratic behaviour caused by ice accretion. Small amounts of clear ice on the leading edge of a blade increase the blade's chord length and can actually increase the blade's lift. This coupled with increased air density at cold temperatures, can lead to turbine overproduction. Ice throw is also a potential safety hazard.

Ice accretes on wind turbines when, at below freezing temperatures, water droplets present in the air, either in the form of rain or clouds, collide with the blades. Frost and the freezing of condensed water vapour on turbine blades pose negligible impacts for the operation of a turbine. There are two main categories of atmospheric icing known as wet or glaze ice, and dry or rime ice. As the name would indicate, wet icing occurs when the impinging water droplet does not freeze completely on contact, and part of the impacting mass can either be partially lost or freeze in a different location from the point of impact due to run-back. Dry icing occurs when there is no liquid or run-off, rather the droplets freeze on contact with the surface, as would be the case in a supercooled fog or cloud at temperatures well below freezing.

For wind turbines, glaze ice tends to be the result of freezing rain. Although unavoidable, freezing rain is infrequent and is usually predictable and detectable at meteorological stations and can thus be planned for. Glaze ice does not pose a major problem for wind turbines, even in areas such as Atlantic Canada where glaze icing is common.

The most severe problem for wind turbines comes from in-cloud icing, which is common for turbines located in hilly or mountainous terrain. When the temperature is below freezing, a cloud consists of supercooled water droplets, which result in ice accretion if they collide with the cold turbine blades. In practice, rime ice collects most heavily within 10 to 15 percent of the chord length, from the leading edge of the turbine blade. Near the stagnation point, the greatest number of water droplets depart from the sharp turns that the streamlines make around the airfoil nose and collide with the blade. Therefore, rime ice accretion tends to result in an elongation of the turbine blade's chord length. The change in chord length and surface roughness, result in an increased drag and a decrease in lift as the blade will be pitched according to the un-iced profile. This results in a decrease in power and a loss of control, both of which can easily ruin a project that would be economically feasible were icing not present.

Yukon Energy Corporation (YEC) currently has two grid-connected wind turbines operating in severe rime-icing conditions on Haeckel Hill just beside the city of

Whitehorse. YEC has operated a 150 kW Bonus fixed-pitch machine since 1993, and a variable-pitch 660 kW Vestas machine since 2000. YEC has had to make some modifications (Maissan, 2001) to the turbines in order to ensure that they continue to operate throughout the winter. Both wind turbines have had their blades painted black, in order to maximize passive solar heating immediately after icing events. The blades are also coated with a low-adhesion coating to attempt to reduce the adhesion strength of the ice to the blades. Resistance blade heaters were also added to the leading edge of the turbine blades. The overall performance of these modifications is still under investigation, but it is clear that these changes have drastically improved the turbines' availability during the icing season. The energy required to run the blade heaters is outweighed by the significant increase in machine availability.

Although rime icing can be a serious concern for wind turbines in the North, it is also a site-specific phenomenon, and depending on the site location may or may not be a problem. Based on observations at the various communities, and conversations with local residents it was apparent that Sachs Harbour may face severe icing conditions, Tuktoyaktuk may experience occasional rime icing, while icing may be light to insignificant in Holman and Paulatuk.

7.2 Cold Temperature Materials

Due to the extreme cold temperatures in Canada's arctic it is necessary to use high-strength materials, as well as low viscosity gearbox oils. Such modifications are available in a standard cold-weather package from AOC. More details on the AOC 15/50 wind turbines can be found in Appendix A.

8 Wind-Energy Grid Penetration

The word 'penetration' is often used in reference to the rated capacity of the installed wind turbines compared to the maximum and minimum community loads. Although no formal definition exists for different levels of penetration, the following descriptions are generally accepted for the different configurations.

A 'low-penetration' system is one when the maximum rated capacity of the wind component of the system does not exceed the minimum load of the community. In this case the wind energy simply acts as a negative load for the diesel generator. As such low-penetration systems of up to 15-20% of the community load can easily be met without significant changes to the system control or the grid stability, as the diesel generators continue to set the grid frequency. Because a wind turbine typically operates with an average output 25-35% of its rated power, low-penetration systems have significant, but minimal overall fuel and emissions savings, yet still incur high capital costs.

A 'high-penetration' system is one where the wind energy is above the community demand for extended periods of time, such that the diesel generators can be shut off completely when there is significant wind. The diesel generator is only used for meeting peak demands and periods of low winds. The advantage of such system is significant overall fuel savings, as well as spreading overhead costs out amongst a number of turbines increasing the economies of scale. The disadvantage to such a system is the need for more complex controls, to regulate the diesel engines as well as to control grid frequency.

Furthermore, the diesel generators are shut down when the electricity supplied by the wind turbines is significantly higher than the community load. The extra power can therefore be used as a heating load or stored in a long-term (12-24 hour) storage system. In either case, the generated electricity will be consumed at a lower price than if it was used from a diesel source. Although, if a high-penetration wind-energy system further offsets fossil fuels used for heating it will have an increased environmental benefit, the reduced selling price will hamper the overall project economics.

Finally, a ‘medium-penetration’ system is a system in between the previously described ‘low-’ and ‘high-penetration’ configurations. A medium-penetration system will be able to meet the entire community load using on wind power a certain wind speeds and community demands, but not for extended periods of time. In this case, depending on the level of penetration, the diesel generators may never turn off, but simply idle when there is significant wind, or the system may use short-term storage (30 sec- 5 min) to enable generator sets to be shut down completely during periods of high winds or low loads. Depending on the configuration, a medium-penetration system can experience the benefits or the drawbacks of either the low- and high-penetration configurations or both.

As a general rule, long-term energy storage does not make economic sense for wind-diesel systems. This is partly because additional control systems and storage architecture must be built into the overall system, but also due to the fact that energy transfers from one form to another always incurs additional losses. Therefore unless the wind-generated power is significantly less than the offset diesel price, the additional overhead costs and additional transfer losses associated with energy storage will often cancel any price advantage the wind system may have. The same can be said for dump load heating, as the electricity generated and then used as a heat source, must be competitive with simply burning the diesel fuel for heat directly. A notable exception to this rule is if the wind-powered heating system is enough to offset major capital costs such as an additional boiler.

9 Economic Viability

9.1 RETScreen Analysis

RETScreen software was used to develop an economic overview of the opportunities for wind energy systems in the four communities. RETScreen is a tool developed by Natural Resources Canada to be used as a pre-feasibility assessment of the economics of renewable energy systems. For more detailed technical analysis, it would be recommended to use analysis software such HOMER and Hybrid2 developed by the American National Renewable Energy Laboratory (NREL). These software packages allow for the systems architecture design optimization as well as system performance analyses.

Two wind energy penetration cases were examined for each of the four communities: a low-penetration system where approximately 15% of the community's peak load is service by the rated capacity of the installed wind power; and a high-penetration system where the wind energy component meets the 75% of the community's peak load. Wind speeds were taken from the sources indicated in section 2.3, and are assumed to have been taken at the standard airport height of 10 m. Holman and Paulatuk have additional higher wind speed scenarios that represent the proposed new sites. For Holman an expected wind of 6.8 m/s is expected, and for Paulatuk it is 5.2 m/s. Because of airport restrictions and geography it is not expected that Tuktoyaktuk and Sachs Harbour will have significantly better winds at the proposed new sites.

Table 9 lists the assumptions made for the various cases. A RETScreen analysis of high and low penetration sample for Sachs Harbour, and a high-penetration – high-wind speed case for Holman can be found in Appendix B.

Table 9: RETScreen assumptions

System Configuration	Wind Speed (m/s)	Grid Peak (kW)	Installed Wind Capacity (kW)	Number of AOC 15/50 Turbines	Tower Height (m)	Cost of displaced Fuel ($/kWh)
Tuk, Low	4.8	843	150	3	25	0.167
Tuk, High	4.8	843	650	13	25	0.167
Holman, Low	4.6	495	75	2	30	0.245
Holman, High	4.6	495	350	7	30	0.245
Holman, Low+	6.8	495	75	2	25	0.245
Holman, High+	6.8	495	350	7	25	0.245
Sachs, Low	5.7	221	50	1	25	0.171
Sachs, High	5.7	221	150	3	25	0.171
Paulatuk, Low	4.5	270	50	1	40	0.243
Paulatuk, High	4.5	270	150	3	40	0.243
Paulatuk, Low+	5.2	270	50	1	25	0.243
Paulatuk, High+	5.2	270	150	3	25	0.243

+ Cases with expected improved wind speeds at the proposed new sites.

AOC turbines were chosen for the analysis as they are the turbines that are currently being used in the Kotzebue, cold-climate, high-penetration wind-diesel system, as well as the fact that they are likely the turbine that Canada's leading wind-diesel experts have had the most experience with. The shape factor for the Weibull wind speed frequency distribution was determined in section 2.5 to be approximately 1.6 for all communities.

Icing and blade soiling losses were assumed to be 10% for Sachs Harbour, 5% for Tuktoyaktuk and 2% for both Holman and Paulatuk.

All of the configurations assumed that the 25 m tilt/up tower was purchased from AOC. In the cases of Holman and Paulatuk, it was assumed that an additional height of 5 m and 15 m could be reached respectively due to the local topography. This assumes that these turbines are placed in areas where there are no improved wind speeds.

The power curve for an AOC 15/50 is shown in Figure 15.

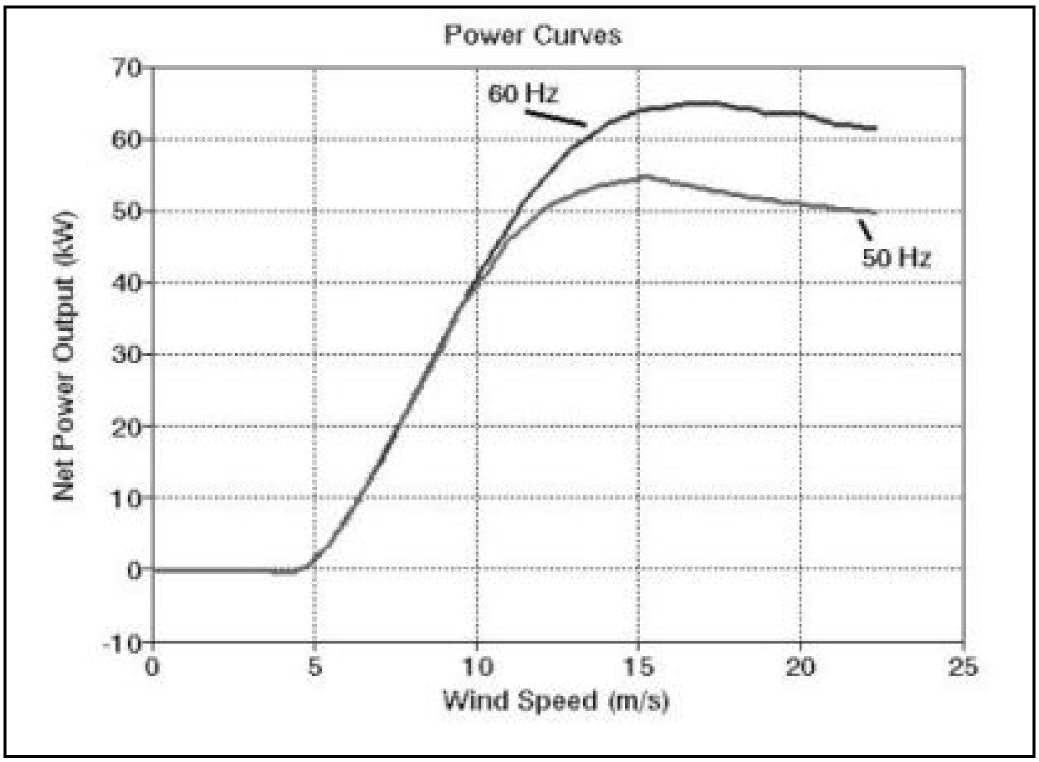


Figure 15 - AOC 15/50 Manufacturer's Power Curve.

9.2 RETScreen Results

There are several key inputs that will greatly alter the overall finances of a wind project. As such it is necessary to compare several scenarios for each community to assess the possible project costs and benefits. Table 10 lists the variables that were held constant for each scenario.

Table 10: Community Inputs

System Configuration	Installed Wind Capacity (kW)	Cost of displaced Fuel - 2003 ($/kWh)	Overall System Installed Cost (C$)	Annual Power Produced (kWh)	Displaced Greenhouse Gases (Tonnes/year)
Tuktoyaktuk, Low	150	0.167	733,872	279,000	250
Tuktoyaktuk, High	650	0.167	2,477,749	1,207,000	1,083
Holman, Low	75	0.245	548,653	179,000	161
Holman, High	350	0.245	1,621,068	626,000	566
Holman, Low+	75	0.245	548,653	318,000	285
Holman, High+	350	0.245	1,621,068	1,112,000	997
Sachs, Low	50	0.171	292,824	134,000	120
Sachs, High	150	0.171	812,172	363,000	326
Paulatuk, Low	50	0.243	301,046	97,000	87
Paulatuk, High	150	0.243	827,772	290,000	260
Paulatuk, Low+	50	0.243	301,046	113,000	101
Paulatuk, High+	150	0.243	827,772	339,000	304

+ Cases with expected improved wind speeds at the proposed new sites

Because NTPC is willing to purchase wind-generated electricity at rates comparable to displaced diesel fuel, the costs of diesel fuel are critical for the overall financial success of a proposed project. The costs of diesel fuel have risen quite dramatically in many communities in the north. For example in Cambridge Bay, the costs of diesel fuel in 1996 where 0.5263 $/L, and rose to 0.7644 $/L by the year 2000, an annual increase of 9.8%. Given the current global instability in many of the key oil producing countries it is difficult to predict long-term oil prices. Two scenarios are therefore presented which consider annual fuel costs increasing by 4% and 9.8%, which are chosen to represent more stabilized global oil prices, and a continued sharp increase respectively. For the case of higher projected wind speeds at Holman two scenarios are 4% and 2%.

Table 11 presents the estimated annual cost of producing wind energy in the four Inuvialuit communities, based on the displaced diesel fuel cost. The net present value of the system was determined using a 75% debt-financed over 15 years at a 7% interest rate, and a 15-year project life. It was also assumed that each project was able to receive the 0.8 ¢/kWh from the Federal Wind Power Production Incentive (WPPI) available for wind projects installed before March 31, 2007. Any project installed before 2006, would be eligible for a 1.0 ¢/kWh credit from the same program.

Table 11: RETScreen financial analysis results

System Configuration	Installed Wind Capacity (kW)	4% Annual Fuel Increase		9.8% Annual Fuel Increase	
		Cost of Producing Wind Energy ($/kWh)	Net Present Value of Project (C$ 2003)	Cost of Producing Wind Energy ($/kWh)	Net Present Value of Project (C$ 2003)
Tuktoyaktuk, Low	150	0.3451	(463,483)	0.2233	(226,406)
Tuktoyaktuk, High	650	0.2129	(622,526)	0.1347	691,790
Holman, Low	75	0.3423	(245,221)	0.1880	261,596
Holman, High	350	0.2390	53,212	0.1313	1,612,068
Holman, Low^{+}	75	0.2021	190,885	0.2454^{++}	(1,372)$^{++}$
Holman, High^{+}	350	0.1435	1,579,585	0.1743^{++}	906,684^{++}
Sachs, Low	50	0.3553	(233,300)	0.2306	(116,300)
Sachs, High	150	0.2795	(426,815)	0.1814	(55,052)
Paulatuk, Low	50	0.4681	(244,303)	0.2963	(91,361)
Paulatuk, High	150	0.3377	(306,397)	0.2133	152,429
Paulatuk, Low^{+}	50	0.4023	(202,416)	0.2527	(23,431)
Paulatuk, High^{+}	150	0.2912	(182,591)	0.1839	354,362

$^{+}$ Cases with expected improved wind speeds at the proposed new sites.

$^{++}$ A 2% increase in annual fuel prices was assumed (identical to inflation), to ensure a conservative estimate.

RETScreen defines the cost per kWh in the following way: “The model calculates the renewable energy production cost per kWh. It is defined as the avoided cost of energy required for the project to break-even. Hence it is the value that when assigned to the avoided cost of energy results in a NPV of zero.”

It can be seen that high penetration systems tend to have the best economic forecast, although for the most part all of the net present values are negative for both the high and low penetration configurations. However, the overall success of any given project depends greatly on the forecast price of displaced diesel fuel.

Holman appears to have the best prospect for the development of a wind energy program, partly due to a good wind resource, but also because of the extremely high diesel fuel costs.

It is important to also note that these estimates assume that the turbines are not down for any significant period of time during their 15 year lives. It has been NTPC’s experience that this is difficult to achieve. Again, a high-penetration system would have advantages in this respect, as a more aggressive wind-development program would justify a more extensive local training program to develop local expertise capable of maintaining the turbines. Furthermore, the overall economics of the program would be much less affected by the failure of one or two turbines. The higher capital costs would of course result in a higher risk, particularly if technical difficulties were encountered that affected production from the entire wind farm.

10 Funding Sources

Various programs currently exist from the federal government to encourage the development of renewable energy resources. Information on all of these incentives is available on the world-wide web. Pertinent sources of funding are listed in Appendix C.

Natural Resources Canada has implemented a “Wind Power Production Incentive” (WPPI). For the first 10 years of a wind turbine’s life, it guarantees an additional 0.01 C$/kWh for turbines commissioned after March 31, 2003 and on or before March 21, 2006, and 0.008 C$/kWh for turbines commissioned after March 31, 2006 and on or before March 31, 2007. The program is available on a first-come, first-served basis, although special care will be taken to facilitate all provinces and territories that want to participate in the program.

11 Conclusions

All four Inuvialuit communities depend on fossil fuels for electricity generation and space heating. The cost of energy is very high, and is dictated by factors outside the control of the communities. Furthermore, reliance of the communities on fossil fuels is ultimately unsustainable, as well as contributing to local and global environmental quality and health degradation. The driving factor behind the majority of community members desire to see wind energy implemented in their communities is to reduce the cost of energy for residents as well as commercial interests. Establishing a sustainable energy supply is a further motivation. The reduction of greenhouse gas emissions and other environmental impacts are also important, albeit secondary considerations compared with energy costs and ensuring local sustainability.

Generally speaking, new technological deployment tends to experience initial difficulties primarily due to the lack of operational and installation experience. Moreover, the geographic isolation of the Inuvialuit communities is not only the major cause of high electricity costs, but is also the largest barrier to the development of alternative energy sources such as wind turbines.

The mean annual wind speeds have been reviewed from several reports and established for each community. For 10 m heights above ground the mean annual wind speeds are, for Sachs Harbour: 5.7 m/s; Tuktoyaktuk: 4.8 m/s, Holman: 4.6 m/s; and Paulatuk: 4.5 m/s. The wind monitoring stations that were used in the data analysis were the airports and are not considered ideal locations for optimum wind energy potential. Two preferred sites have been recommended here for each community. Holman and Paulatuk have potentially better wind regimes at the best recommended hilltop sites with mean annual winds up to 6.8 and 5.2 m/s respectively. Sachs Harbour faces potential problems with icing. In terms of wind power classification, Sachs Harbour is considered class 4, which makes it suitable for wind energy developments. Holman and Paulatuk, however, graduate from class 2 to classes 6 and 3 respectively.

Preliminary assessment of potential sites has been conducted and techno-socio-economic analysis performed using RETScreen Software. The overall economics of each system depends not only on the wind resource, but also on the method of financing the project as well as the costs of displaced diesel fuel. Although a 9.8% annual increase in diesel prices was seen by Cambridge Bay between 1996 and 2000, it may be unrealistic, and an unwise business move to assume that an elevated rate of increase will continue over a 15-year horizon for all of the Inuvialuit communities. A more conservative estimate of diesel price increases indicate that wind generated electricity does not appear to be economically viable based on the current wind data. All four communities show negative net present values of low and high-penetration systems when compared solely to the displaced cost of diesel fuel, based on current airport data. However, our analysis indicates that all four Inuvialuit communities appear to have some potential for wind energy systems, if other factors such as environmental costs, sustainability and local self-sufficiency are factored into the project either by the communities' willingness to pay for the development of sustainable options, or federal or territorial credits are awarded for energy systems that do not emit greenhouse gases. Furthermore, by projecting wind speeds to the top of some hills close to the community of Holman, both low and high-penetration systems are economically viable, without additional sustainability credits. Holman is therefore the best candidate for immediate further investigation.

Past experience with wind energy systems in the Northwest Territories and Nunavut have shown that system availability and reliability is the dominant factor in determining the overall success of a project. Availability is often heavily influenced by the ability for contractors outside of the community to ship components and travel to the community to troubleshoot problems. These maintenance costs are therefore very high, and represent a significant relative cost to smaller projects such as one or two wind turbines. Larger projects will therefore reduce these relative costs, as well as justify investing in local technical training.

12 Recommendations

To reduce the overhead costs of a wind program an aggressive multi-community development plan is recommended. This will not only spread many of the capital costs over multiple projects, but will also result in the most significant impacts on diesel displacement, while creating and keeping local expertise. An overall strategy should be developed towards eventually establishing wind energy systems in all of the Inuvialuit communities that prove to have viable wind resources. NTPC has indicated that it would purchase wind-generated electricity at displaced diesel fuel costs as opposed to developing the wind program internally. Therefore in order to facilitate the development of wind as a sustainable resource, a wind-monitoring program should be established, and published in a public domain to encourage and facilitate independent power producers. Similar programs have been developed by the Yukon Development Corporation, Hydro-Québec and BC Hydro.

The preferred sites need to be analyzed further and discussed with the leaders of each community. After final selection of the sites is made, land use permits will be required and capital purchases will need to be made for wind monitoring study. The estimated budget for one year of wind monitoring in all communities, including equipment and other costs can range from $120,000 to $200,000. It is highly recommended that a wind monitoring study be conducted prior to the government agencies or the power corporation making significant capital expenditures.

Low-penetration systems have the advantage of minimizing the overall project costs, and therefore capital risks. They also have the smallest grid impact, and are therefore easier to control to maintain overall power quality. For these reasons, many low-penetration systems have been piloted throughout the North and other areas in remote Canada for the past 20 years, with a marginal success rate. A high-penetration system involves a much more significant capital cost and risk, as well as the need for more complex power control systems. The advantages of high-penetration systems are that they will spread the overhead costs associated with a wind-monitoring program, contractor travel costs and import and shipping expenses. A high-penetration system will also have a much more significant impact on diesel fuel savings, and therefore air emission. Such a system will also lend itself to cogeneration options such as supplemental heating or even energy storage systems such as flywheels or eventually hydrogen. However, the most significant advantage of a high-penetration in the Inuvialuit region would be the ability to justify significant local training, and have a full-time local maintenance expert. This will not only improve the overall reliability of the system, but will also minimize the number of trips required by contractors outside of the community and territory, and will also increase the overall local economic benefit by investing in local job creation. High-penetration wind-diesel systems are being pursued in many locations throughout the world including cold and remote locations such as Antarctica and Alaska. The elevated project costs and risks however, will necessitate a wind-monitoring program.

Given the current diesel prices, and the potential wind resource, the community of Holman should be pursued as an initial development. A wind monitoring program and community energy planning would be invaluable first steps towards this goal.

To mitigate climate change and to promote long-term sustainability of these communities, significant financial commitment from the government agencies is needed to help subsidize the development of integrated wind energy systems. Natural Resources Canada's WPPI should be taken advantage of for any wind turbines built in the NWT in the next 4 years. However, the program is only of marginal assistance to remote communities due to the relatively low overall energy output of medium-scale wind turbines, and due to the high overhead costs of installing a wind turbine. NTPC, in unison with Yukon Energy and Nunavut Power should consider pursuing the federal government for a more appropriate incentive program for remote wind-diesel applications.

Integrated hybrid systems are recommended for introducing new technologies, especially in the cold climate regions of these communities. Further studies are needed to assess the excess capacity available to be utilized for the production of hydrogen as a fuel, which can be used on-site and/or stored and transported. At this stage, the production and on-site application of hydrogen is prohibitive, as the fuel cell technology is still in its infancy and systems are not yet commercially available. Further development and availability of such systems may ultimately lend itself towards the possibility of hydrogen production, which could be used in either fuel cells or modified internal combustion engines, providing a 100% self-contained sustainable energy supply.

Strategic development for wind energy should be conducted by keeping in mind the capacity building as one of its objectives. Aurora College has a network of trainers located in most of the NWT communities. They could be easily trained as Train-the-Trainer. Residents and NTPC employees of these communities have shown their willingness to assist in monitoring activities and/or to undergo further training for operating the turbines. It is recommended that Aurora Research Institute develop such a training program as an addition to research being conducted in this critical area of work. Such an approach would minimize the costs of consultants brought in from the south, by spreading the costs amongst as many turbines as possible at a time. Furthermore, this approach would justify larger capital investments particularly in training local expertise and the purchases of any necessary specialized equipment.

Siting turbines have been a source of major delays in the development of wind energy. It is therefore critical that community members are engaged in the decision making process, and other regional authorities, such as Transport Canada, Arctic Airports, the Inuvialuit Development Corporation and Municipal and Community Affairs are involved very early in the planning stages. Developing community energy plans will help address these issues and options for the communities.

13 References

Adelaar, M. and S. Graham. Community specific energy supply in the Yukon and Northwest Territories. Technical report, Department of Indian Affairs and Northern Development, 1981.

Ahrens, C. D.. Meteorology Today. Brooks/Cole, sixth edition, 2000.

Ah-You, K. and Leng, G., "Renewable Energy in Canada's Remote Communities", Renewable Energy for Remote Communities Program, Natural Resources Canada, 1999.

Arctic Energy Alliance, "Review of Technical and Economic Viability of Wind Energy Systems in the NWT and Nunavut", prepared for NWT Power Corporation, 2000.

Barkstrom, B. R. Surface meteorology and solar energy data set. http://eosweb.larc.nasa.gov/sse/, 2002. data for the RETScreen Renewable Energy Project Analysis Software.

Burton, T., Sharpe, D., Jenkins, N. and Bossanyi, E (2001) Wind Energy Handbook, John Wiley and Sons, Ltd., Toronto, Canada.

Brothers, C., Personal Communication. Site Manager, Atlantic Wind Test Site, North Cape, Prince Edward Island, Canada, 2002

Cheriyan, H., "Wind Energy Study of Selected Communities in the North West Territories", prepared for Canada Centre for Mineral and Energy Technology 1995.

D. Elliott and M. Schwartz. Wind energy potential in the United States. Published at www.nrel.gov, September 1993.

Elliott, D. L., C. G. Holladay, W. R. Barchet, H. P. Foote, and W. F. Sandusky. Wind energy resource atlas of the united states. Technical Report Publ. No. DOE/CH10093-4, prepared for U.S. Dept. Energy by Pacific Northwest Laboratory, Richland WA. Solar Energy Res. Inst., Golden CO., 1987.

Env. Canada. Canadian Climate Normals Vol. 5 1951-1980. Environment Canada, 1982.

Finstad, K. and Makkonen, L., "Modelling of Rime Icing of Wind Turbines", Proceedings of the 6th International Workshop on the Atmospheric Icing of Structures, Budapest, Hungary, 1993.

Gipe, P., Wind Power for Home and Business; Renewable Energy for the 1990s and Beyond, Chelsea Green Publishing, 1993.

Jagpal, P. and A. Fehr. Solar and wind energy projects relevant to the NWT. Technical report, Aurora College, 1996.

Janz, B., Howell, D.G. and Serna, A., "Wind Energy in the Northwest Territories", prepared for the Science Advisory Board of the Northwest Territories, 1982.

Kimura, S., Seifert, H. and Tammelin, B., "Effect of ice accretion on elasticity of the rotor blade", Wind Power in Cold Climate BOREAS II Conference Proceedings, Finnish Meteorological Institute, Helsinki, 1994.

Kotzebue Electrical Association, http://www.kotzelectric.com

Llinca A., E. McCarthy, J. Chaumel, and J. Retiveau. Wind potential assessment of Quebec Province. Paper submitted for publication in Renewable Energy, An International Journal.

Lodge, M., "Wind-Diesel Systems for Remote Communities", prepared for Canada Centre for Mineral and Energy Technology, 2001.

Maissan, J.F., "Wind Power Development in Sub-Arctic Conditions with Severe Rime Icing", Presented at the Circumpolar Climate Change Summit and Exposition, Whitehorse, Yukon, March 19-21, 2001.

Natural Resources Canada, RETScreen Database - Canadian Remote Communities, 1997.

Nor'wester Energy Systems. Evaluation and assessment of sachs harbour for a wind energy project. Technical report, Government of the Northwest Territories, 1988.

Tammelin, B., Cavaliere, M., Hannele, H., Morgan, C., Seifert, H., and Santti, K., Wind Energy Production in Cold Climates, European Commission DG XII, Non Nuclear Energy Programme, Finnish Meteorological Institute Publication, 2000.

Unies Consulting Engineers Ltd., "Investigation of the Viability of a Remote Wind/Hydroelectric Power Supply in the Northwest Territories", prepared for Remote Communities Demonstration Program of Energy, Mines and Resources Canada, 1985.

Walmsley, J.L. and R. J. Morris. Wind energy resource maps for Canada. Technical report, Atmospheric Environment Service, 1997.

Wilson, H.P. Winds and currents in the Beaufort Sea. In The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, 1974.

Wilson, C. Climatology of the cold regions: Northern hemisphere II. Technical Report Mongraph I-A3b, Cold Regions Research and Engineering Laboratory, August 1969.

Appendix A –Medium Scale Wind Turbine Specifications

A.1 AOC 15/50

PERFORMANCE PARAMETERS:	
Rated Electrical Power	50 kW @12.0 m/s (26.8 mph)
Wind Speed	@hub height 25 m (82 ft)
cut-in	4.6 m/s (10.2 mph)
shut-down (high wind)	22.4 m/s (50 mph)
Peak (survival)	59.5 m/s (133 mph)
Calculated Annual Output	
@ 100 % availability	5.4 m/s (12 mph) 85,000 kWh
	6.7 m/s (15 mph) 145,000 kWh
	8.0 m/s (18 mph) 199,000 kWh

AOC 15/50 Wind Turbine

- AOC 15/50 WTG [ ] 60 Hz, [ ] 50 Hz - standard 80 ft galvanized tower
- Tower Safety Climbing Cable and harness
- Anchor Bolts and template for standard concrete foundation (12 bolts per turbine, see note 1)

Tower Options

- 100 ft. Tower Option
- 80 ft. Tilt Down Tower Option

Resistive Soft Start Equipment

- Watts transducer and current transformer
- SCADA data interface
- 9 Bay controller for SCADA Interface
- Digital Display for System Monitoring
- Stainless Steel Control Enclosures (Required for exposed marine or tropical moist environment)
- NEMA 4 Control Enclosures -Control Box, Dynamic Brake Box (Required for Controls not in a weatherized shelter)
- Tropical Package for generator
- Modified Cold Weather Package Category 1
  - Transmission and Parking Brake Heater - Enclosure Heater and insulation - Low Temperature Lubrication
- Severe Cold Weather Package Category 2 (<-40° C)
  - Transmission and Parking Brake Heater -Enclosure Heater and insulation - Low Temperature Lubrication - Arctic Turbine Shaft

Design, Service, Support, and Freight

- Design Utility Interface per person per day
- Export Packing Turbine
- Travel to site
- AOC site support at project site per person per day
- List of recommended on-site Spare Parts for one or two turbines per site or Service Center
- Service and Maintenance Kit
- Documentation package
- Special engineering

NOTE 1: Non standard foundation configurations may require special anchor bolts.
NOTE 2: Freight, fees, import duties, and taxes are the responsibility of the buyer.
NOTE 3: All travel, Per Diem, and incidental expenses are for the account of the buyer.
NOTE 4: Support structure or mounting hardware and connectors for control boxes are the responsibility of the buyer.
NOTE 5: Recommended for weak grid or high penetration wind diesel systems.

A.2 Vergnet GEV 15/60

GEV 15/60

ROTOR

* DOUBLE BLADED DOWN-WIND HUB WITH VARIABLE PITCH
* SPEED AND STARTING CONTROL BY INERTIAL BLADE PITCH (PASSIVE)
* HYDRAULIC SAFETY SYSTEM CONTROLLED BY PLC

TOWER

* 24, 30 or 40 METERS
* GUYED TILTING TOWER (4 ANCHORS)
* 6 M OR 11 M TOWER TUBULAR PARTS CONNECTED WITH FLANGES
* ERECTION BY ELECTRIC WINCH WITH GIN POLE

GENERATOR

* PLANETARY GEARBOX WITH RECTIFIED TEETH
* IP 55 ASYNCHRONOUS GENERATOR EXCITED BY GRID OR CAPACITORS
* POWER FACTOR COMPENSATION

MATERIALS

* COMPOSITE WITH REINFORCED LEADING EDGE
* SPHEROIDAL GRAPHITE CAST IRON
* ZINC COATED, ELECTROPLATED OR STAINLESS STEEL
* GALVANISED AND STAINLESS STEEL ACCESSORIES
* THREE LAYER EPOXY COATING

YAW

* PASSIVE

BRAKES

* AERODYNAMIC BRAKE WITH HYDRAULIC CONTROL
* MANUAL CONTROL PARKING BRAKE INTEGRATED TO THE GENERATOR

TECHNICAL SPECIFICATIONS

ROTOR

DIAMETER	15 m
STARTING/NOMINAL PITCH	6°/1°
NOMINAL ROTATION SPEED	92 rpm
CUT-IN WIND SPEED	5 m/s
RATED WIND SPEED	15 m/s
MAXIMUM WIND SPEED (TOWER UP)	50 m/s
SURVIVAL WIND SPEED (TOWER DOWN)	85 m/s

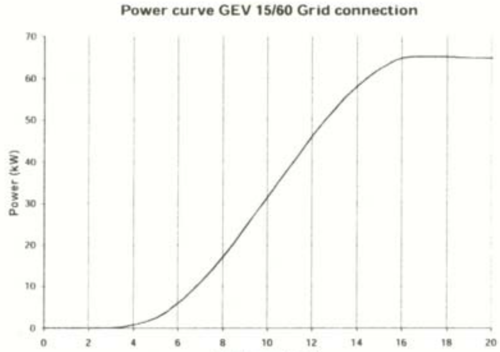
GENERATOR

RATED POWER	60 kW
GEARBOX RATIO	16,75
VOLTAGE FREQUENCY	400 V / 690 V TRIPHASE / 50 Hz
NEUTRAL	AVAILABLE

WEIGHT & VOLUMS

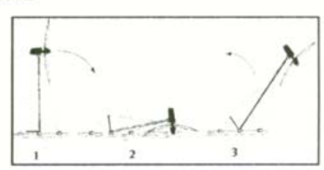
NACELLE WEIGHT	2400 kg
TOTAL WEIGHT	24m / 5800kg 30m / 6500kg 40m / 7200 kg
TOTAL PACKED VOLUME WITH TOWER	(40ft CONTAINER PACKAGING) 24m/24m3 30m/28m3 40m/35 m3

Power curve GEV 15/60 Grid connection



OPTIONS

* REMOTE MONITORING SYSTEM FOR GEV 15/60 WIND FARM
* "MARINE" : REINFORCED PROTECTION AND SEALING FOR HIGH CORROSION AREA
* COLD CLIMATES (UP TO -30°C)
* "60 Hz"



TILTING TOWER SYSTEM

VERGNET

Wind Energy Department - 160 rue des sables de Sary - 45770 SARAN FRANCE

TEL : +33 (0) 2.38.52.39.70 - FAX : +33 (0) 2.38.52.35.83

E-mail : eole@vergnet.fr - www.vergnet.fr

Appendix B – RETScreen Analysis

B.1 Sachs Harbour: Low Penetration System

RETScreen® Energy Model - Wind Energy Project

Site Conditions		Estimate	Notes/Range
Project name		Sachs-AOC-low	
Project location		Sachs Harbour	
Nearest location for weather data		user defined	*See Weather Database*
Annual average wind speed	m/s	5.7	
Height of wind measurement	m	10.0	3.0 to 100.0
Wind shear exponent	-	0.14	0.10 to 0.25
Wind speed at 10 m	m/s	5.7	
Average atmospheric pressure	kPa	100.7	60.0 to 103.0
Annual average temperature	°C	-9	-20 to 30

System Characteristics		Estimate	Notes/Range
Grid type	-	Isolated-grid	
Grid peak load	kW	**221**	
Wind turbine rated power	kW	50	*Complete Equipment Data sheet*
Number of turbines	-	1	
Wind plant capacity	kW	50	
Hub height	m	40.0	6.0 to 100.0
Wind speed at hub height	m/s	6.9	3.0 to 15.0
Wind penetration level	%	22.6%	
Suggested wind energy absorption rate	%	90%	
Wind energy absorption rate	%	95%	
Array losses	%	0%	0% to 20%
Airfoil soiling and/or icing losses	%	10%	1% to 10%
Other downtime losses	%	5%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	50	50	
	MW	0.05	0.05	
Unadjusted energy production	MWh	158	158	
Pressure adjustment coefficient	-	0.99	0.99	0.59 to 1.02
Temperature adjustment coefficient	-	1.09	1.09	0.98 to 1.15
Gross energy production	MWh	170	170	
Losses coefficient	-	0.83	0.83	0.75 to 1.00
Specific yield	kWh/m²	797	797	150 to 1,500
Wind plant capacity factor	%	32%	32%	20% to 40%
Renewable energy collected	MWh	141	141	
Renewable energy delivered	MWh	134	**134**	
	GJ	483	483	
Excess RE available	MWh	7	**7**	
				Complete Cost Analysis sheet

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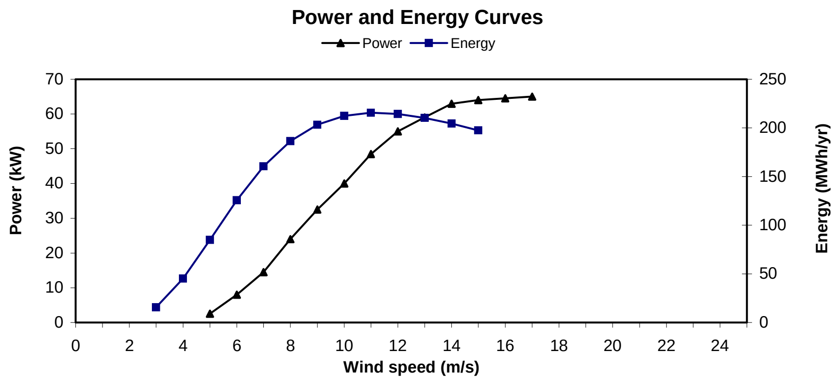
RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	50	See Product Database
Hub height	m	40.0	6.0 to 100.0
Rotor diameter	m	15	7 to 72
Swept area	m²	177	35 to 4,075
Wind turbine manufacturer		Atlantic Orient	
Wind turbine model		AOC 15/50	
Energy curve data source	-	Custom	Weibull wind distribution
Shape factor	-	1.6	1.0 to 3.0

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	-	-
1	-	-
2	-	-
3	-	15.5
4	-	45.2
5	2.5	84.8
6	8.0	125.6
7	14.5	160.4
8	24.0	186.3
9	32.5	203.2
10	40.0	212.3
11	48.5	215.5
12	55.0	214.4
13	59.0	210.4
14	63.0	204.5
15	64.0	197.4
16	64.5	-
17	65.0	-
18	-	-
19	-	-
20	-	-
21	-	-
22	-	-
23	-	-
24	-	-
25	-	-



Return to Energy Model sheet

RETScreen® Cost Analysis - Wind Energy Project

Type of project: Standard | Currency: Canada | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost			Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study									
Other	Cost	1	CAD	27,000	CAD	27,000		-	-
Sub-total:					CAD	27,000	9.0%		
Development									
Other	Cost	1	CAD	15,000	CAD	15,000		-	-
Sub-total:					CAD	15,000	5.0%		
Engineering									
Other	Cost	1	CAD	20,000	CAD	20,000		-	-
Sub-total:					CAD	20,000	6.7%		
Renewable Energy (RE) Equipment									
Wind turbine(s)	kW	50	CAD	2,430	CAD	121,500		-	-
Spare parts	%	3.0%	CAD	121,500	CAD	3,645		-	-
Transportation	turbine	1	CAD	10,000	CAD	10,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					CAD	135,145	45.2%		
Balance of Plant									
Wind turbine(s) foundation(s)	turbine	1	CAD	10,000	CAD	10,000		-	-
Wind turbine(s) erection	turbine	1	CAD	10,000	CAD	10,000		-	-
Road construction	km	0.00	CAD	45,000	CAD	-		-	-
Transmission line and substation	project	1	CAD	7,500	CAD	7,500		-	-
Control and O&M building(s)	building	1	CAD	7,500	CAD	7,500		-	-
Transportation	project	1	CAD	5,000	CAD	5,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					CAD	40,000	13.4%		
Miscellaneous									
Training	p-d	14	CAD	750	CAD	10,500		-	-
Commissioning	p-d	5	CAD	750	CAD	3,750		-	-
Interest during construction	%	0.0%	CAD	237,145	CAD	-		-	-
Contingencies	%	20%	CAD	237,145	CAD	47,429		-	-
Sub-total:					CAD	61,679	20.6%		
Initial Costs - Total					CAD	298,824	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost			Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M									
Land lease	%	2.0%	CAD	22,925	CAD	459		-	-
Property taxes	%	0.6%	CAD	22,925	CAD	138		-	-
Insurance premium	%	4.0%	CAD	22,925	CAD	917		-	-
Transmission line maintenance	%	3.0%	CAD	7,500	CAD	225		-	-
Parts and labour	kWh	134,065	CAD	0.020	CAD	2,681		-	-
Community benefits	-	0	CAD	-	CAD	-		-	-
Travel and accommodation	p-trip	5	CAD	3,000	CAD	15,000		-	-
General and administrative	%	5%	CAD	19,419	CAD	971		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Contingencies	%	10%	CAD	19,419	CAD	1,942		-	-
Annual Costs - Total					CAD	22,332	100.0%		

Periodic Costs (Credits)		Period	Unit Cost			Amount		Interval Range	Unit Cost Range
Drive train	Cost	10 yr	CAD	-	CAD	-		-	-
Blades	Cost	20 yr	CAD	-	CAD	-		-	-
					CAD	-		-	-
End of project life	Credit	-	CAD	-	CAD	-			*Go to GHG Analysis sheet*

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Sachs-AOC-low	Grid peak load	kW	221
Project location		Sachs Harbour			
Renewable energy delivered	MWh	134	GHG analysis sheet used?	yes/no	Yes
Excess RE available	MWh	7	Net GHG emission reduction	t_{CO2}/yr	120
Firm RE capacity	kW	-	Net GHG emission reduction - 15 yrs	t_{CO2}	1,804
Grid type		Isolated-grid			

Financial Parameters

Avoided cost of energy	CAD/kWh	0.1710	Debt ratio	%	75.0%
RE production credit	CAD/kWh	0.008	Debt interest rate	%	7.0%
RE production credit duration	yr	10	Debt term	yr	10
RE credit escalation rate	%	0.0%			
GHG emission reduction credit	CAD/t_{CO2}	-	Income tax analysis?	yes/no	No
Avoided cost of excess energy	CAD/kWh	-			
Energy cost escalation rate	%	9.8%			
Inflation	%	2.0%			
Discount rate	%	9.6%			
Project life	yr	15			

Project Costs and Savings

Initial Costs			
Feasibility study	9.0%	CAD	27,000
Development	5.0%	CAD	15,000
Engineering	6.7%	CAD	20,000
RE equipment	45.2%	CAD	135,145
Balance of plant	13.4%	CAD	40,000
Miscellaneous	20.6%	CAD	61,679
Initial Costs - Total	100.0%	**CAD**	**298,824**
Incentives/Grants		CAD	-
Periodic Costs (Credits)			
Drive train		CAD	-
Blades		CAD	-
		CAD	-
End of project life - Credit		CAD	-

Annual Costs and Debt		
O&M	CAD	22,332
Debt payments - 10 yrs	CAD	31,909
Annual Costs - Total	**CAD**	**54,242**
Annual Savings or Income		
Energy savings/income	CAD	22,925
Capacity savings/income	CAD	-
RE production credit income - 10 yrs	CAD	1,073
Annual Savings - Total	**CAD**	**23,998**

Financial Feasibility

			Calculate RE production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	0.4%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	0.4%			
Simple Payback	yr	179.4	Project equity	CAD	74,706
Year-to-positive cash flow	yr	14.8	Project debt	CAD	224,118
Net Present Value - NPV	CAD	(116,276)	Debt payments	CAD/yr	31,909
Annual Life Cycle Savings	CAD	(14,940)	Debt service coverage	-	0.11
Profitability Index - PI	-	(1.56)	RE production cost	CAD/kWh	0.2306

Yearly Cash Flows

Year #	Pre-tax CAD	After-tax CAD	Cumulative CAD
0	(74,706)	(74,706)	(74,706)
1	(28,444)	(28,444)	(103,150)
2	(26,433)	(26,433)	(129,583)
3	(24,189)	(24,189)	(153,771)
4	(21,689)	(21,689)	(175,460)
5	(18,907)	(18,907)	(194,367)
6	(15,814)	(15,814)	(210,181)
7	(12,380)	(12,380)	(222,562)
8	(8,571)	(8,571)	(231,133)
9	(4,348)	(4,348)	(235,480)
10	330	330	(235,151)
11	36,344	36,344	(198,806)
12	42,072	42,072	(156,734)
13	48,404	48,404	(108,330)
14	55,401	55,401	(52,929)
15	63,129	63,129	10,200

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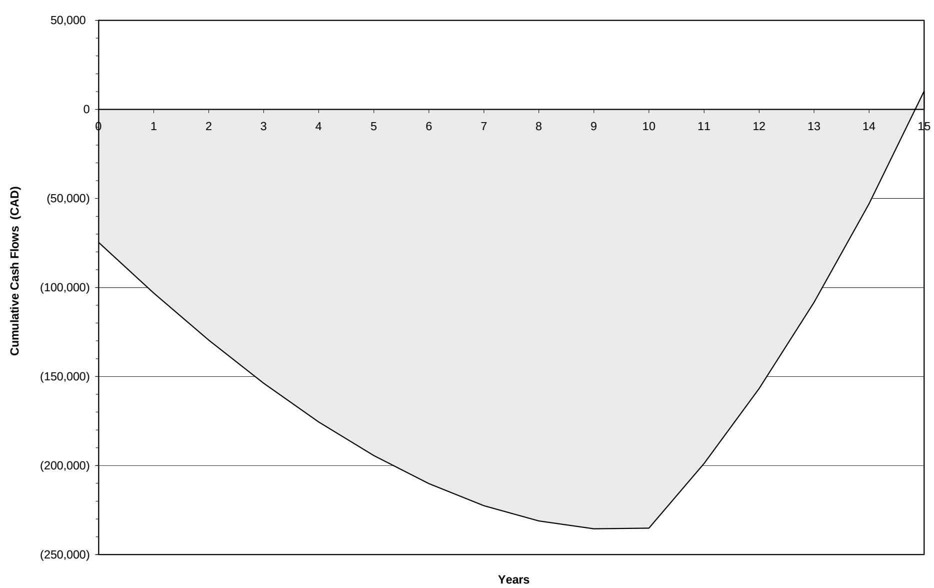
Cumulative Cash Flows Graph

Wind Energy Project Cumulative Cash Flows
Sachs-AOC-low, Sachs Harbour

Year-to-positive cash flow 14.8 yr **IRR and ROI 0.4%** **Net Present Value CAD (116,276)**



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B.2 Sachs Harbour: High Penetration System

RETScreen® Energy Model - Wind Energy Project

Site Conditions		Estimate	Notes/Range
Project name		**Sachs-AOC-high**	
Project location		**Sachs Harbour**	
Nearest location for weather data		user defined	*See Weather Database*
Annual average wind speed	m/s	5.7	
Height of wind measurement	m	10.0	3.0 to 100.0
Wind shear exponent	-	0.14	0.10 to 0.25
Wind speed at 10 m	m/s	5.7	
Average atmospheric pressure	kPa	100.7	60.0 to 103.0
Annual average temperature	°C	-9	-20 to 30

System Characteristics		Estimate	Notes/Range
Grid type	-	Isolated-grid	
Grid peak load	kW	**221**	
Wind turbine rated power	kW	50	*Complete Equipment Data sheet*
Number of turbines	-	3	
Wind plant capacity	kW	150	
Hub height	m	25.0	6.0 to 100.0
Wind speed at hub height	m/s	6.5	3.0 to 15.0
Wind penetration level	%	67.9%	
Suggested wind energy absorption rate	%	See manual	
Wind energy absorption rate	%	95%	
Array losses	%	0%	0% to 20%
Airfoil soiling and/or icing losses	%	10%	1% to 10%
Other downtime losses	%	5%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	50	150	
	MW	0.05	0.15	
Unadjusted energy production	MWh	142	427	
Pressure adjustment coefficient	-	0.99	0.99	0.59 to 1.02
Temperature adjustment coefficient	-	1.09	1.09	0.98 to 1.15
Gross energy production	MWh	154	461	
Losses coefficient	-	0.83	0.83	0.75 to 1.00
Specific yield	kWh/m²	720	720	150 to 1,500
Wind plant capacity factor	%	29%	29%	20% to 40%
Renewable energy collected	MWh	127	382	
Renewable energy delivered	MWh	121	**363**	
	GJ	436	1307	
Excess RE available	MWh	6	**19**	
				Complete Cost Analysis sheet

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RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	50	See Product Database
Hub height	m	25.0	6.0 to 100.0
Rotor diameter	m	15	7 to 72
Swept area	m²	177	35 to 4,075
Wind turbine manufacturer		Atlantic Orient	
Wind turbine model		AOC 15/50	
Energy curve data source	-	Custom	Weibull wind distribution
Shape factor	-	1.6	1.0 to 3.0

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	-	-
1	-	-
2	-	-
3	-	15.5
4	-	45.2
5	2.5	84.8
6	8.0	125.6
7	14.5	160.4
8	24.0	186.3
9	32.5	203.2
10	40.0	212.3
11	48.5	215.5
12	55.0	214.4
13	59.0	210.4
14	63.0	204.5
15	64.0	197.4
16	64.5	-
17	65.0	-
18	-	-
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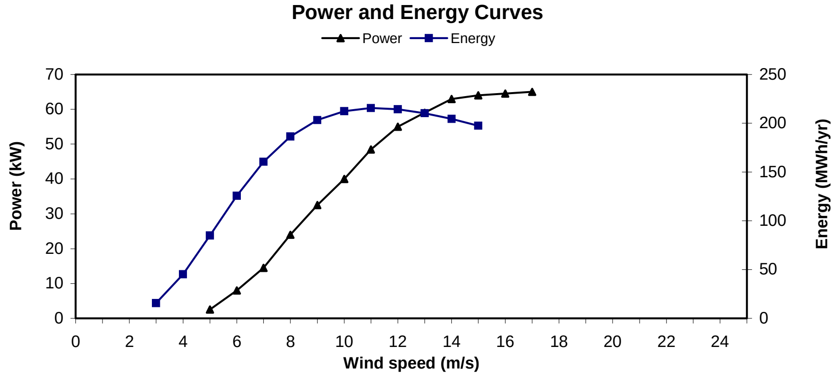
24	-	-
25	-	-

Power and Energy Curves



Return to Energy Model sheet

RETScreen® Cost Analysis - Wind Energy Project

Type of project: Standard | Currency: Canada | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost		Amount		Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study									
Other	Cost	1	CAD	27,000	CAD	27,000		-	-
Sub-total:					**CAD**	**27,000**	3.3%		
Development									
Other	Cost	1	CAD	25,000	CAD	25,000		-	-
Sub-total:					**CAD**	**25,000**	3.1%		
Engineering									
Other	Cost	1	CAD	60,000	CAD	60,000		-	-
Sub-total:					**CAD**	**60,000**	7.4%		
Renewable Energy (RE) Equipment									
Wind turbine(s)	kW	150	CAD	2,430	CAD	364,500		-	-
Spare parts	%	3.0%	CAD	364,500	CAD	10,935		-	-
Transportation	turbine	3	CAD	25,000	CAD	75,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					**CAD**	**450,435**	55.5%		
Balance of Plant									
Wind turbine(s) foundation(s)	turbine	3	CAD	10,000	CAD	30,000		-	-
Wind turbine(s) erection	turbine	3	CAD	10,000	CAD	30,000		-	-
Road construction	km	0.00	CAD	45,000	CAD	-		-	-
Transmission line and substation	project	1	CAD	12,500	CAD	12,500		-	-
Control and O&M building(s)	building	1	CAD	25,000	CAD	25,000		-	-
Transportation	project	1	CAD	5,000	CAD	5,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					**CAD**	**102,500**	12.6%		
Miscellaneous									
Training	p-d	14	CAD	750	CAD	10,500		-	-
Commissioning	p-d	5	CAD	750	CAD	3,750		-	-
Interest during construction	%	0.0%	CAD	664,935	CAD	-		-	-
Contingencies	%	20%	CAD	664,935	CAD	132,987		-	-
Sub-total:					**CAD**	**147,237**	18.1%		
Initial Costs - Total					**CAD**	**812,172**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost		Amount		Relative Costs	Quantity Range	Unit Cost Range
O&M									
Land lease	%	2.0%	CAD	62,073	CAD	1,241		-	-
Property taxes	%	0.6%	CAD	62,073	CAD	372		-	-
Insurance premium	%	4.0%	CAD	62,073	CAD	2,483		-	-
Transmission line maintenance	%	3.0%	CAD	12,500	CAD	375		-	-
Parts and labour	kWh	362,997	CAD	0.020	CAD	7,260		-	-
Community benefits	-	0	CAD	-	CAD	-		-	-
Travel and accommodation	p-trip	5	CAD	3,000	CAD	15,000		-	-
General and administrative	%	5%	CAD	26,732	CAD	1,337		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Contingencies	%	10%	CAD	26,732	CAD	2,673		-	-
Annual Costs - Total					**CAD**	**30,742**	100.0%		

Periodic Costs (Credits)		Period	Unit Cost		Amount		Interval Range	Unit Cost Range
Drive train	Cost	10 yr	CAD	-	**CAD**	**-**	-	-
Blades	Cost	20 yr	CAD	-	**CAD**	**-**	-	-
					CAD	**-**	-	-
End of project life	Credit	-	CAD	-	**CAD**	**-**		*Go to GHG Analysis sheet*

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Sachs-AOC-high	Grid peak load	kW	221
Project location		Sachs Harbour			
Renewable energy delivered	MWh	363	GHG analysis sheet used?	yes/no	Yes
Excess RE available	MWh	19	Net GHG emission reduction	t_{CO2}/yr	326
Firm RE capacity	kW	-	Net GHG emission reduction - 15 yrs	t_{CO2}	4,885
Grid type		Isolated-grid			

Financial Parameters

Avoided cost of energy	CAD/kWh	0.1710	Debt ratio	%	75.0%
RE production credit	CAD/kWh	0.008	Debt interest rate	%	7.0%
RE production credit duration	yr	10	Debt term	yr	10
RE credit escalation rate	%	0.0%			
GHG emission reduction credit	CAD/t_{CO2}	-	Income tax analysis?	yes/no	No
Avoided cost of excess energy	CAD/kWh	-			
Energy cost escalation rate	%	9.8%			
Inflation	%	2.0%			
Discount rate	%	9.6%			
Project life	yr	15			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.3%	CAD	27,000	O&M	CAD	30,742
Development	3.1%	CAD	25,000			
Engineering	7.4%	CAD	60,000	Debt payments - 10 yrs	CAD	86,726
RE equipment	55.5%	CAD	450,435	**Annual Costs - Total**	**CAD**	**117,468**
Balance of plant	12.6%	CAD	102,500			
Miscellaneous	18.1%	CAD	147,237	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**CAD**	**812,172**	Energy savings/income	CAD	62,073
				Capacity savings/income	CAD	-
Incentives/Grants		CAD	-	RE production credit income - 10 yrs	CAD	2,904
				Annual Savings - Total	**CAD**	**64,977**
Periodic Costs (Credits)						
Drive train		CAD	-			
Blades		CAD	-			
		CAD	-			
End of project life - Credit		CAD	-			

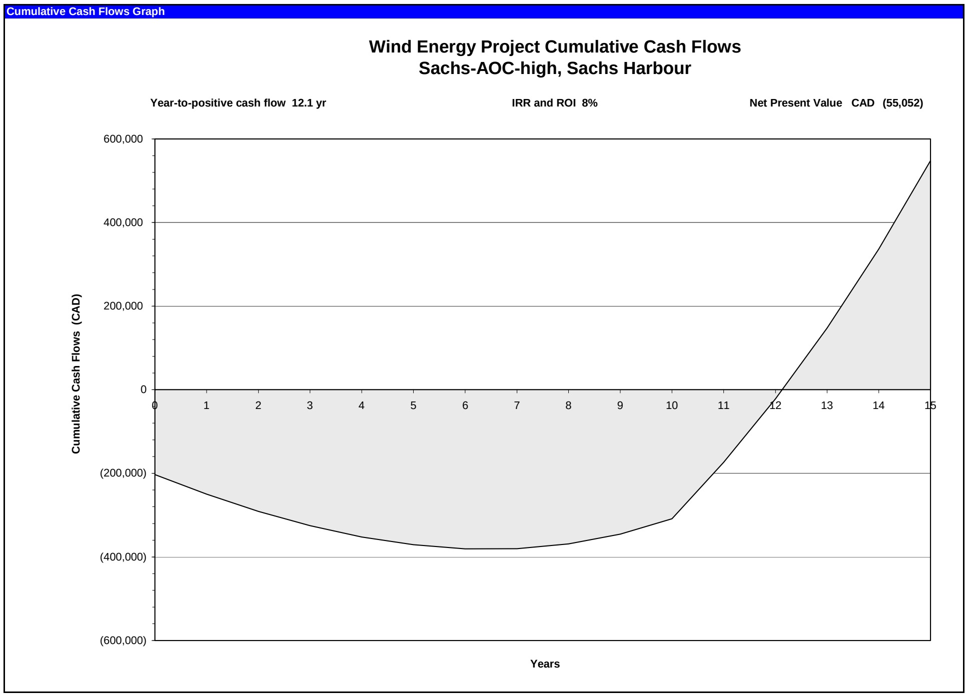
Financial Feasibility

			Calculate RE production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	8.0%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	8.0%			
Simple Payback	yr	23.7	Project equity	CAD	203,043
Year-to-positive cash flow	yr	12.1	Project debt	CAD	609,129
Net Present Value - NPV	CAD	(55,052)	Debt payments	CAD/yr	86,726
Annual Life Cycle Savings	CAD	(7,082)	Debt service coverage	-	0.46
Profitability Index - PI	-	(0.27)	RE production cost	CAD/kWh	0.1814

Yearly Cash Flows

Year #	Pre-tax CAD	After-tax CAD	Cumulative CAD
0	(203,043)	(203,043)	(203,043)
1	(47,023)	(47,023)	(250,066)
2	(40,971)	(40,971)	(291,037)
3	(34,277)	(34,277)	(325,313)
4	(26,877)	(26,877)	(352,190)
5	(18,700)	(18,700)	(370,890)
6	(9,671)	(9,671)	(380,561)
7	296	296	(380,265)
8	11,294	11,294	(368,971)
9	23,425	23,425	(345,546)
10	36,801	36,801	(308,745)
11	135,367	135,367	(173,378)
12	151,615	151,615	(21,764)
13	169,514	169,514	147,750
14	189,228	189,228	336,978
15	210,936	210,936	547,914

Cumulative Cash Flows Graph



B.3 Holman: High Penetration System

RETScreen® Energy Model - Wind Energy Project

Site Conditions		Estimate	Notes/Range
Project name		**Hol-AOC-high**	
Project location		**Holman**	
Nearest location for weather data		user defined	*See Weather Database*
Annual average wind speed	m/s	6.8	
Height of wind measurement	m	10.0	3.0 to 100.0
Wind shear exponent	-	0.14	0.10 to 0.25
Wind speed at 10 m	m/s	6.8	
Average atmospheric pressure	kPa	100.7	60.0 to 103.0
Annual average temperature	°C	-9	-20 to 30

System Characteristics		Estimate	Notes/Range
Grid type	-	Isolated-grid	
Grid peak load	kW	**495**	
Wind turbine rated power	kW	50	*Complete Equipment Data sheet*
Number of turbines	-	7	
Wind plant capacity	kW	350	
Hub height	m	25.0	6.0 to 100.0
Wind speed at hub height	m/s	7.7	3.0 to 15.0
Wind penetration level	%	70.7%	
Suggested wind energy absorption rate	%	See manual	
Wind energy absorption rate	%	95%	
Array losses	%	0%	0% to 20%
Airfoil soiling and/or icing losses	%	5%	1% to 10%
Other downtime losses	%	5%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	50	350	
	MW	0.05	0.35	
Unadjusted energy production	MWh	177	1,239	
Pressure adjustment coefficient	-	0.99	0.99	0.59 to 1.02
Temperature adjustment coefficient	-	1.09	1.09	0.98 to 1.15
Gross energy production	MWh	191	1,337	
Losses coefficient	-	0.88	0.88	0.75 to 1.00
Specific yield	kWh/m²	944	944	150 to 1,500
Wind plant capacity factor	%	38%	38%	20% to 40%
Renewable energy collected	MWh	167	1,170	
Renewable energy delivered	MWh	159	**1,112**	
	GJ	572	4001	
Excess RE available	MWh	8	**59**	
				Complete Cost Analysis sheet

Version 2000 - Release 2

NRCan/CEDRL

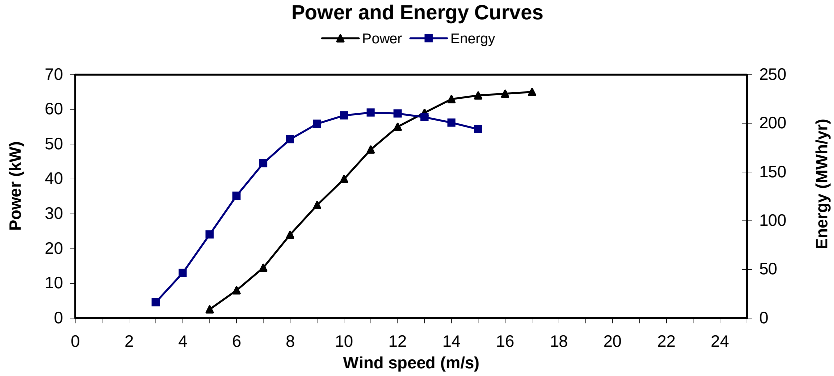
RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	50	See Product Database
Hub height	m	25.0	6.0 to 100.0
Rotor diameter	m	15	7 to 72
Swept area	m²	177	35 to 4,075
Wind turbine manufacturer		Atlantic Orient	
Wind turbine model		AOC 15/50	
Energy curve data source	-	Custom	Weibull wind distribution
Shape factor	-	1.6	1.0 to 3.0

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	-	-
1	-	-
2	-	-
3	-	16.4
4	-	46.5
5	2.5	85.9
6	8.0	125.5
7	14.5	159.0
8	24.0	183.6
9	32.5	199.4
10	40.0	208.0
11	48.5	211.1
12	55.0	210.1
13	59.0	206.3
14	63.0	200.7
15	64.0	194.1
16	64.5	-
17	65.0	-
18	-	-
19	-	-
20	-	-
21	-	-
22	-	-
23	-	-
24	-	-
25	-	-

Power and Energy Curves



Return to Energy Model sheet

RETScreen® Cost Analysis - Wind Energy Project

Type of project: Standard | Currency: Canada | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost		Amount		Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study									
Other	Cost	1	CAD	23,000	CAD	23,000		-	-
Sub-total:					CAD	23,000	1.4%		
Development									
Other	Cost	1	CAD	25,000	CAD	25,000		-	-
Sub-total:					CAD	25,000	1.5%		
Engineering									
Other	Cost	1	CAD	60,000	CAD	60,000		-	-
Sub-total:					CAD	60,000	3.7%		
Renewable Energy (RE) Equipment									
Wind turbine(s)	kW	350	CAD	2,430	CAD	850,500		-	-
Spare parts	%	3.0%	CAD	850,500	CAD	25,515		-	-
Transportation	turbine	7	CAD	25,000	CAD	175,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					CAD	1,051,015	64.8%		
Balance of Plant									
Wind turbine(s) foundation(s)	turbine	7	CAD	7,500	CAD	52,500		-	-
Wind turbine(s) erection	turbine	7	CAD	7,500	CAD	52,500		-	-
Road construction	km	0.25	CAD	40,000	CAD	10,000		-	-
Transmission line and substation	project	1	CAD	25,000	CAD	25,000		-	-
Control and O&M building(s)	building	1	CAD	35,000	CAD	35,000		-	-
Transportation	project	1	CAD	5,000	CAD	5,000		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Sub-total:					CAD	180,000	11.1%		
Miscellaneous									
Training	p-d	14	CAD	750	CAD	10,500		-	-
Commissioning	p-d	5	CAD	750	CAD	3,750		-	-
Interest during construction	%	0.0%	CAD	1,339,015	CAD	-		-	-
Contingencies	%	20%	CAD	1,339,015	CAD	267,803		-	-
Sub-total:					CAD	282,053	17.4%		
Initial Costs - Total					CAD	1,621,068	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost		Amount		Relative Costs	Quantity Range	Unit Cost Range
O&M									
Land lease	%	2.0%	CAD	272,322	CAD	5,446		-	-
Property taxes	%	0.6%	CAD	272,322	CAD	1,634		-	-
Insurance premium	%	4.0%	CAD	272,322	CAD	10,893		-	-
Transmission line maintenance	%	3.0%	CAD	25,000	CAD	750		-	-
Parts and labour	kWh	1,111,518	CAD	0.020	CAD	22,230		-	-
Community benefits	-	0	CAD	-	CAD	-		-	-
Travel and accommodation	p-trip	5	CAD	3,000	CAD	15,000		-	-
General and administrative	%	5%	CAD	55,954	CAD	2,798		-	-
Other	Cost	0	CAD	-	CAD	-		-	-
Contingencies	%	20%	CAD	55,954	CAD	11,191		-	-
Annual Costs - Total					CAD	69,942	100.0%		

Periodic Costs (Credits)		Period	Unit Cost		Amount			Interval Range	Unit Cost Range
Drive train	Cost	10 yr	CAD	-	CAD	-		-	-
Blades	Cost	20 yr	CAD	-	CAD	-		-	-
					CAD	-		-	-
End of project life	Credit	-	CAD	-	CAD	-			*Go to GHG Analysis sheet*

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		Hol-AOC-high	Grid peak load	kW	495
Project location		Holman			
Renewable energy delivered	MWh	1,112	GHG analysis sheet used?	yes/no	Yes
Excess RE available	MWh	59	Net GHG emission reduction	t_{CO2}/yr	997
Firm RE capacity	kW	-	Net GHG emission reduction - 20 yrs	t_{CO2}	19,944
Grid type		Isolated-grid			

Financial Parameters

Avoided cost of energy	CAD/kWh	0.2450	Debt ratio	%	75.0%
RE production credit	CAD/kWh	0.008	Debt interest rate	%	8.0%
RE production credit duration	yr	10	Debt term	yr	15
RE credit escalation rate	%	0.0%			
GHG emission reduction credit	CAD/t_{CO2}	-	Income tax analysis?	yes/no	No
Avoided cost of excess energy	CAD/kWh	-			
Energy cost escalation rate	%	2.0%			
Inflation	%	2.0%			
Discount rate	%	7.0%			
Project life	yr	20			

Project Costs and Savings

Initial Costs			
Feasibility study	1.4%	CAD	23,000
Development	1.5%	CAD	25,000
Engineering	3.7%	CAD	60,000
RE equipment	64.8%	CAD	1,051,015
Balance of plant	11.1%	CAD	180,000
Miscellaneous	17.4%	CAD	282,053
Initial Costs - Total	**100.0%**	**CAD**	**1,621,068**
Incentives/Grants		CAD	-
Periodic Costs (Credits)			
Drive train		CAD	-
Blades		CAD	-
		CAD	-
End of project life - Credit		CAD	-

Annual Costs and Debt		
O&M	CAD	69,942
Debt payments - 15 yrs	CAD	142,041
Annual Costs - Total	**CAD**	**211,983**
Annual Savings or Income		
Energy savings/income	CAD	272,322
Capacity savings/income	CAD	-
RE production credit income - 10 yrs	CAD	8,892
Annual Savings - Total	**CAD**	**281,214**

Financial Feasibility

			Calculate RE production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	22.9%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	22.9%			
Simple Payback	yr	7.7	Project equity	CAD	405,267
Year-to-positive cash flow	yr	5.0	Project debt	CAD	1,215,801
Net Present Value - NPV	CAD	906,684	Debt payments	CAD/yr	142,041
Annual Life Cycle Savings	CAD	85,585	Debt service coverage	-	1.52
Profitability Index - PI	-	2.24	RE production cost	CAD/kWh	0.1743

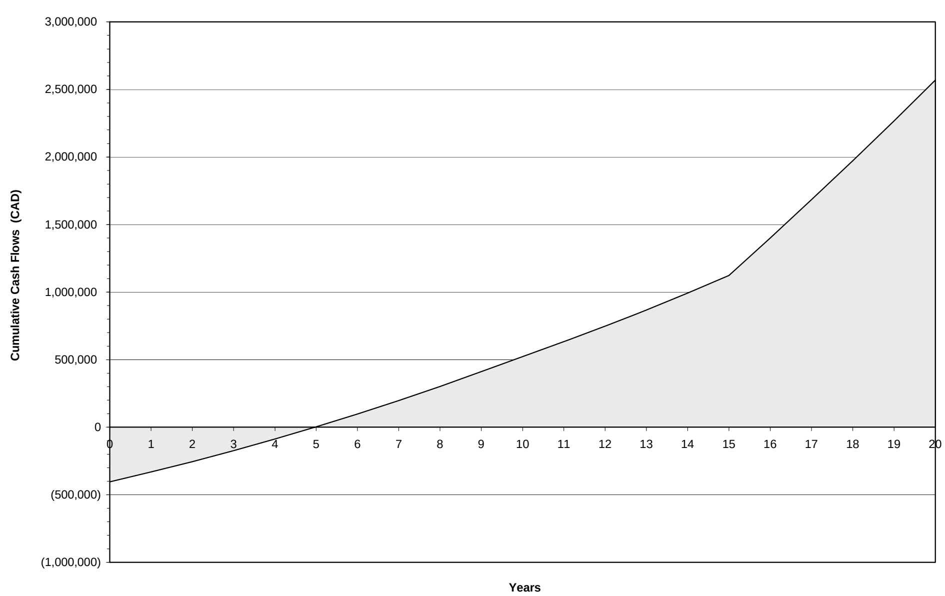
Yearly Cash Flows

Year #	Pre-tax CAD	After-tax CAD	Cumulative CAD
0	(405,267)	(405,267)	(405,267)
1	73,278	73,278	(331,989)
2	77,407	77,407	(254,582)
3	81,618	81,618	(172,964)
4	85,913	85,913	(87,051)
5	90,294	90,294	3,243
6	94,763	94,763	98,006
7	99,321	99,321	197,328
8	103,971	103,971	301,299
9	108,713	108,713	410,012
10	113,551	113,551	523,563
11	109,592	109,592	633,155
12	114,625	114,625	747,780
13	119,758	119,758	867,538
14	124,994	124,994	992,533
15	130,335	130,335	1,122,868
16	277,824	277,824	1,400,692
17	283,381	283,381	1,684,073
18	289,048	289,048	1,973,121
19	294,829	294,829	2,267,950
20	300,726	300,726	2,568,676

Cumulative Cash Flows Graph

Wind Energy Project Cumulative Cash Flows
Hol-AOC-high, Holman

Year-to-positive cash flow 5 yr **IRR and ROI 22.9%** **Net Present Value CAD 906,684**



Appendix C – Possible Sources of Funding

C.1 Technology Early Action Measures (TEAM)

http://www.climatechange.gc.ca/english/action_plan/na_b19.shtml#5

Technology Early Action Measures (TEAM) encourages the deployment and development of technologies that reduce GHG emissions and help the economy by demonstrating solutions that can move quickly to market. Projects provide innovative, cost-effective solutions to climate change, for example, by reducing emissions from energy and industrial processes, offering new ways to reduce energy consumption or to expand the use of alternative fuels.

TEAM investment has accelerated the development of new technologies which, in some cases, will be in the marketplace many years ahead of schedule. This partnership between government and industry will ensure a competitive Canadian position in GHG reduction technologies across all sectors of the economy, and in all regions of Canada and internationally.

TEAM projects are delivered through existing federal technology programs and are extensively networked with partners in industry, communities and internationally.

C.2 Climate Change Technology Development and Innovation Program

http://www.climatechange.gc.ca/english/action_plan/na_b12.shtml

The Government of Canada, through the Action Plan, is investing $19 million over five years in the Climate Change Technology Development and Innovation Program. This program is designed to:

1. accelerate development of cost-effective greenhouse gas (GHG) mitigation technologies;
2. build the knowledge foundation for long-term technological advances; and
3. build alliances and partnerships to help plan and advance research and development.

Program Description

This program will strengthen S&T and innovation capacity, boosting the Canadian innovation system and industrial competitiveness. It will improve planning and foster increased partnerships throughout federal, provincial and academic milieus.

It will fund five interrelated initiatives which stimulate innovative thinking, create networks of expertise and develop conceptual technologies and future directions for research and technology.

Novel Next Generation Technologies

This initiative will stimulate creative thinking on new and fundamentally different concepts and investigate their potential to deliver new technologies to reduce GHG emissions in the medium to long term. Target groups are academia and federal and provincial government science-based departments and agencies.

R&D for Innovative GHG Reduction Technologies

This initiative consists of 11 projects, balanced between short-term and long-term R&D, and among various industry sectors. The projects focus on oxygen/carbon dioxide (CO_2) recycle combustion; advanced power cycles; distributed power systems; sequestration of CO_2 in oil sands tailings and gas hydrates; electricity generation from agri-food, municipal wastes and landfill gas; refined multiphase granular flow processes; gas flaring; electricity from fuel cells using hydrogen derived from bio-solids; and sustainable community designs.

Technology Road Maps

The technology road mapping initiative is an industry-led planning process to identify and advance promising climate change technologies. These climate change technology road maps will act as catalysts, stimulating sectors to collaborate and invest in the development of innovative climate change technology solutions. The road maps selected to date are in the areas of carbon dioxide capture and geological storage, clean combustion technology, fuel cell commercialization, oil sands development, and sustainable fuels and chemicals production from biomass.

Establishing Technology Networks

Three network managers will create networks of experts from industry, academia and government to exchange information and ideas and to promote collaboration in networks on CO_2 management, eco-sustainable community and process integration for energy efficiency.

Technology Strategic Planning Workshops

Two workshops for researchers and decision makers from industry, academia and governments to exchange information on recent developments and on new initiatives will help guide innovation investments.

Climate Change Measures

The Government of Canada's investment in the Climate Change Technology and Innovation Program is one of a series of practical, concrete measures that are part of the $500-million Action Plan 2000 on Climate Change. Over the next five years, the Government will invest $1.1 billion in the Action Plan and other climate change initiatives that, when fully implemented, are expected to take Canada about one-third of the way to the GHG-reduction targets that it agreed to during the Kyoto Protocol negotiations in 1997. At that time, Canada undertook to reduce its GHG emissions to six percent below 1990 levels during the period between 2008 and 2012, about a 26-percent reduction from "business-as-usual" levels.

For more information, contact:
Graham Campbell
Office of Energy Research and Development
Natural Resources Canada
(613) 995-8860

C.3 Renewable Energy Deployment Initiative For Industry (REDI)

http://www.climatechange.gc.ca/english/action_plan/na_b9.shtml

Introduction

Residential, commercial and institutional buildings contribute directly to Canada's greenhouse gas (GHG) emissions by burning fossil fuels to generate heat. This represents 10 percent of total emissions in Canada. In addition, the buildings sector contributes indirectly to GHG emissions through electricity consumption, such as lighting and power for workplaces.

The Government of Canada, through its Action Plan 2000 on Climate Change, is investing $2 million over 5 years to extend the voluntary Renewable Energy Deployment Initiative (REDI) to industrial organizations. This existing Government of Canada program stimulates market demand among business, federal, institutional and municipal organizations for commercially reliable, cost-effective renewable energy systems for space and water heating and cooling. This extension is expected to reduce GHG emissions by 0.1 megatonne by 2010.

Program Description

The program aims to significantly increase the use of the following:

- solar heating systems for plant fresh-air ventilation;
- ground-source heat pumps for plant space-heating;
- solar hot water systems in manufacturing activities requiring sizeable amounts of hot water;
- biomass combustion systems where biomass waste is still disposed of or landfilled rather than used for energy purposes; and
- photovoltaic and wind on-site generation systems such as those used to monitor remote production equipment.

The program has two components. The first component is the creation and implementation of market development strategies that address barriers in specific energy-consuming industries where promising markets exist for renewable energy systems. The second is the provision of financial incentives to building and facility owners for the purchase and installation of qualifying systems, such as solar and biomass heating systems, in targetted markets.

Climate Change Measures

The Government of Canada's investment in REDI for Industry is one of a series of practical, concrete measures that are part of the $500-million Action Plan 2000 on Climate Change. Over the next five years, the Government will invest $1.1 billion in the Action Plan and other climate change initiatives that, when fully implemented, are expected to take Canada about one-third of the way to the GHG-reduction targets that it agreed to during the Kyoto Protocol negotiations in 1997. At that time, Canada undertook to reduce its GHG emissions to six percent below 1990 levels during the period between 2008 and 2012, about a 26-percent reduction from "business-as-usual" levels.

For more information, contact:

Celia Kirlew,
Renewable Energy Policy
Natural Resources Canada
(613) 943-2215

For more information on the Government of Canada's Action Plan 2000 on Climate Change, please visit www.climatechange.gc.ca.

Appendix D – Proposal for Wind Monitoring Program

The following is the procedure for assessing wind regime and a rough budget estimate to carry out the program in the four key Inuvialuit communities in the NWT.

The rough cost for phases two to four of the project is 112 000$. This will essentially provide one year of analyzed data for four Inuvialuit communities. Phase five is the dismantling phase and is likely to cost another 30 000$. It is recommended that the stations be moved to four other northern communities for further wind monitoring.

After the potential sites have been selected we apply for the land use permits, order the wind monitoring kits, and organize the hiring of personnel in each community.

The first four phases are shown in Table 9. We need to decide on who the partners are, that is, who will maintain the stations, collect the cards and send them out for downloading. Can they do it voluntarily? Who will download and keep the data and who will analyze the data and report? Who will trouble shoot station problems? The fifth phase of dismantling the tower will need to be reviewed at a later date.

Although we have budgeted originally for 20-m towers it may be wise to use 30-m towers as this is likely to be the hub height of the wind turbines and would more accurate for wind analysis.

D.1 Budget

The budget for the proposed wind-monitoring program is shown in Table 8 as being around $119 000 for one year of wind monitoring. Add $9 000 for 30-m towers instead of 20-m ones, and $10 000 for an extra year of monitoring. This cost could rise to rise to about $200 000 if we lose some towers, instruments, discover icing situations in communities other than Sachs Harbour.

Table 12: Estimated budget for carrying out wind monitoring in the four Inuvialiut communities for one year.

Phase Two: Wind station installations			
Travel, accomodation, per diems (2 pers)		$	12,000.00
Four NRG 20-m tower kits*	2090$USx4 ~3500$x4	$	14,000.00
NRG Heated wind sensors for Sachs **	3000$ US	$	5,500.00
Temp sensors for each kit	800$US	$	1,400.00
NRG Install kit	1000$US	$	1,200.00
EEReader II	375$US	$	650.00
Shipping appox. 3000 lb	3$ per lb	$	9,000.00
Misc (batteries, wire, etc.)		$	1,000.00
Preparation work	7 x 480	$	3,360.00
14 days labourer	14 x 350	$	4,900.00
14 days of installs	14 x 480	$	6,800.00
	Subtotal:	$	59,810.00
	25% contingency	$	14,952.50
	Total:	**$**	**74,762.50**
Phase Three: One Year* operation of Wind Station**			
Mailing chips to principal investigator		$	500.00
Download data from chips****	day labour / month	$	5,760.00
Travel, accomodation, per diems*****		$	6,000.00
Misc		$	500.00
7 days of visits	7 x 480$/day	$	3,360.00
	Subtotal:	$	16,120.00
	25% contingency	$	4,030.00
	Total:	**$**	**20,150.00**

Phase Four: Data Analysis and Reporting		
collecting & analysing the wind data	20 x 480	$ 9,600.00
Producing reports	20 x 480	$ 9,600.00
	Subtotal:	$ 19,200.00
	25% contingency	$ 4,800.00
	Total:	**$ 24,000.00**
Total cost for phases Two-Four	**$**	**118,912.50**
Phase Five: Wind station dismantling		
Travel, accomodation, per diems		$ 6,000.00
Shipping appox. 3000 lb	3$ per lb	$ 9,000.00
Misc		$ 500.00
14 days labourer	14 x 350	$ 4,900.00
14 days of installs	14 x 480	$ 6,800.00
	Subtotal:	$ 27,200.00
	25% contingency	$ 6,800.00
	Total:	**$ 34,000.00**

Notes:
* To use four 30-m towers kits intead of 20-m add $9 000.
** Electrical connection costs assumed covered by NTPC
*** If a second year is needed, add $10 000.
**** this is for the principal investigator's time, it is assumed that NTPC will provide the extra time for employees to collect data chips. This is about one hour per month in Sachs Harbour, Tuktoyaktuk, and Paulatuk. In Holman this may likely be a half day per month.
***** Includes costs for flights in case project leader must fly into communities to troubleshoot problems.

D.2 Schedule

Table 13 is a proposed schedule assuming that this proposal is accepted in April 2003. Equipment orders can be done as late as June. Installations could be delayed until August or September.

Table 13: Proposed schedule for the Inuvialuit wind monitoring project.