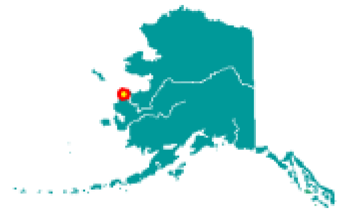
Wind Resource Assessment for
NUNAM IQUA, ALASKA
Date last modified: 2/1/2008
Compiled by: James Jensen



SITE SUMMARY

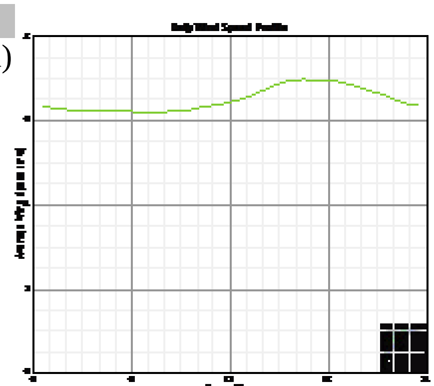
Site #: 0259
Latitude (NAD27): 62˚ 31’ 56.4” N
Longitude (NAD27): 164˚ 51’ 6.4” W
Magnetic Declination: 13˚ 29’ East
Tower Type: 30-meter NRG Tall Tower
Sensor Heights: 30m
Elevation: 3.0 meters (10 ft)
Monitor Start: 03/15/2006 00:00
Monitor End: 07/18/2007 18:00

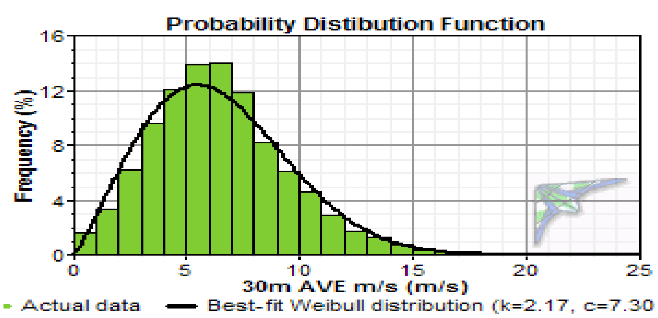
Nunam Iqua is on a south fork of the Yukon River, about 9 miles south of Alakanuk and 18 miles southwest of Emmonak on the Yukon-Kuskokwim Delta. It lies 500 miles northwest of Anchorage. Nunam Iqua is located in the Bethel Recording District. (source: Department of Community & Economic Development.

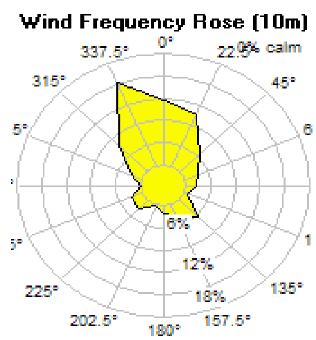
WIND RESOURCE SUMMARY

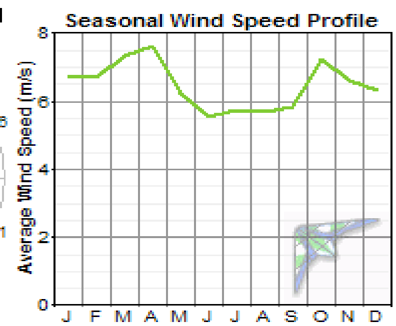
Annual Average Wind Speed (30m height): 6.5 m/s (14.5 mph)
Average Wind Power Density (30m height): 322 W/m^2
Wind Power Class (range = 1 to 7): Class 4
Rating (Poor, Marginal, Fair, Good, Excellent, Outstanding, Superb): Good
Prevailing Wind Direction: N/NW

AEA had a 30-meter meteorological tower was installed in Nunam Iqua from Oct. 2005 to July 2006. The data collected from this tower is the basis for in this report.



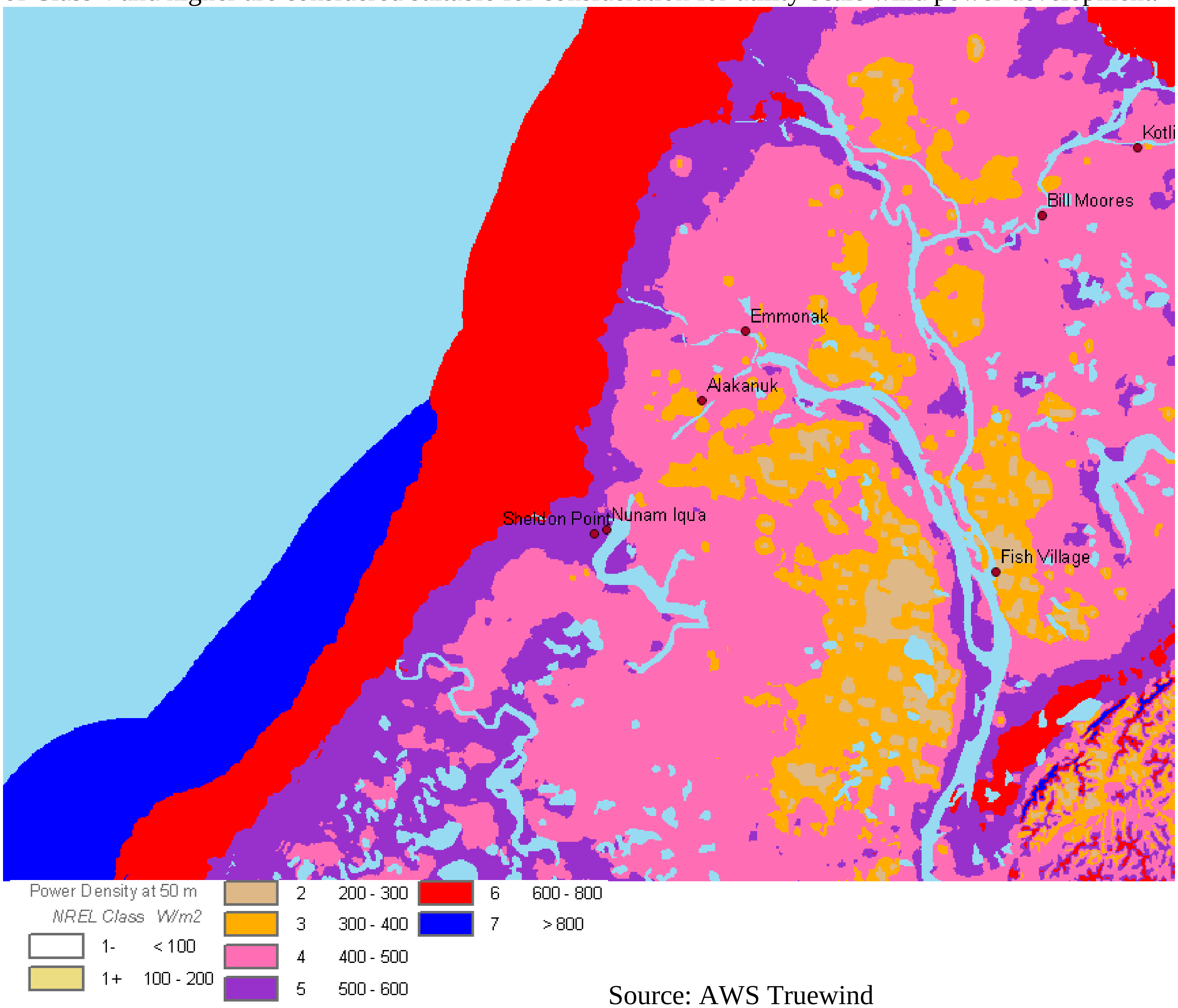






INTRODUCTION

Nunam Iqua is on a south fork of the Yukon River, about 9 miles south of Alakanuk and 18 miles southwest of Emmonak on the Yukon-Kuskokwim Delta. It lies 500 miles northwest of Anchorage. On initial review, the community of Nunam Iqua appears to have an excellent wind resource. According to the wind resource map below, Nunam Iqua is in a class 5 wind resource. However the map also shows that the wind resource nearby varies between Class 3 and Class 7. Generally, areas with wind resources of Class 4 and higher are considered suitable for consideration for utility-scale wind power development.



Source: AWS Truewind

Figure 1. Wind Resource Map of Alaska

The purpose of this monitoring effort is to verify the wind resource in Nunam Iqua and evaluate the feasibility of utilizing utility-scale wind energy in the community. This report summarizes the wind resource data collected and the long-term energy production potential of the site.

SITE DESCRIPTION

The photos below document the meteorological tower equipment that was installed in Nunam Iqua.

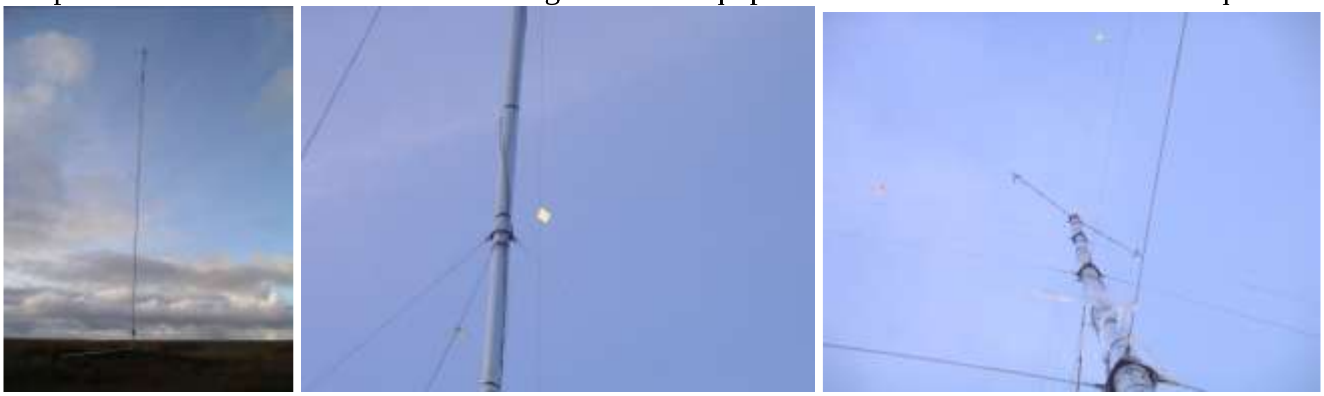


Figure 2. Photos of the Met Tower Installation in Nunam Iqua, AK

The photos in Figure 3 illustrate the surrounding ground cover and any major obstructions, which could affect how the wind flows over the terrain from a particular direction. As shown, the landscape surrounding the met tower site is free of obstructions and relatively flat.

SW W NW N

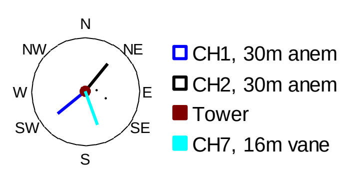
NE E SE S

Figure 3. Views Taken from Met Tower Base

Table 1 lists the types of sensors that were used, the channel of the data logger that each sensor was wired into, and where each sensor was mounted on the tower.

Table 1. Summary of Sensors Installed on the Met Tower

Ch #	Sensor Type	Height	Offset	Boom Orientation
1	#40 Anemometer	30 m	NRG Standard	230˚ True
2	#40 Anemometer	30 m	NRG Standard	40˚ True
7	#200P Wind Vane	16 m	335˚ True	155˚ True
9	#110S Temperature	3 m	NRG Standard	-



Aerial view of equipment on tower

WIND DATA RESULTS FOR NUNAM IQUA TOWER SITE

Table 2 summarizes the amount of data that was successfully retrieved from the data logger at the met tower site. The only significant data loss as a result of icing was in January and March of 2007. The software program Windographer (www.mistaya.ca) was used to fill the gaps. Windographer uses statistical methods based on patterns in the data surrounding the gap, and is good for filling short gaps in data. Note that data collected before March of 2006 was discarded because a substantial amount of data from that period was lost due to a damaged data card.

Table 2. Data Recovery Rate for Met Tower Anemometers

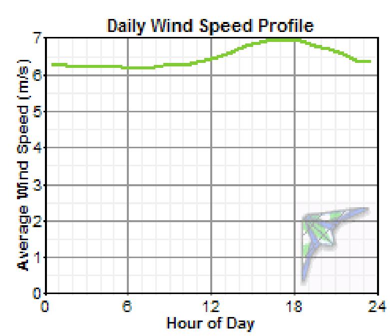
Year	Month	Records	Recovery Rate (%)
2006	Mar	2,447	100.0
2006	Apr	4,320	100.0
2006	May	4,461	99.9
2006	Jun	4,320	100.0
2006	Jul	4,464	100.0
2006	Aug	4,464	100.0
2006	Sep	4,320	100.0
2006	Oct	4,464	100.0
2006	Nov	4,317	99.9
2006	Dec	4,424	99.1
2007	Jan	3,488	78.1
2007	Feb	4,022	99.8
2007	Mar	4,190	93.9
2007	Apr	4,320	100.0
2007	May	4,464	100.0
2007	Jun	4,320	100.0
2007	Jul	2,556	100.0
All data		69,361	98.2

Wind Speed Measurements

The table below summarizes the wind speed data collected at the Nunam Iqua met tower site.

Table 3. Summary of Nunam Iqua Wind Speed Data, 30-meter Height

Annual Average	6.5 m/s
Highest Month	April (7.6 m/s)
Lowest Month	June (5.5 m/s)
Hour of Peak Wind	16:00
Max 10-minute average	23.8 m/s
Max gust	29.1 m/s



The seasonal wind speed profile shows that the transition months into and out of winter have the strongest average winds. The daily wind speed profile shows that wind speeds are typically greater in the afternoon and evening hours and calmer in the morning.

Wind Frequency Distribution

A common method of displaying a year of wind data is a wind frequency distribution, which shows the percent of time that each wind speed occurs. Figure 4 shows the measured wind frequency distribution as well as the best matched Weibull distribution, which is commonly used to approximate the wind speed frequency distribution.

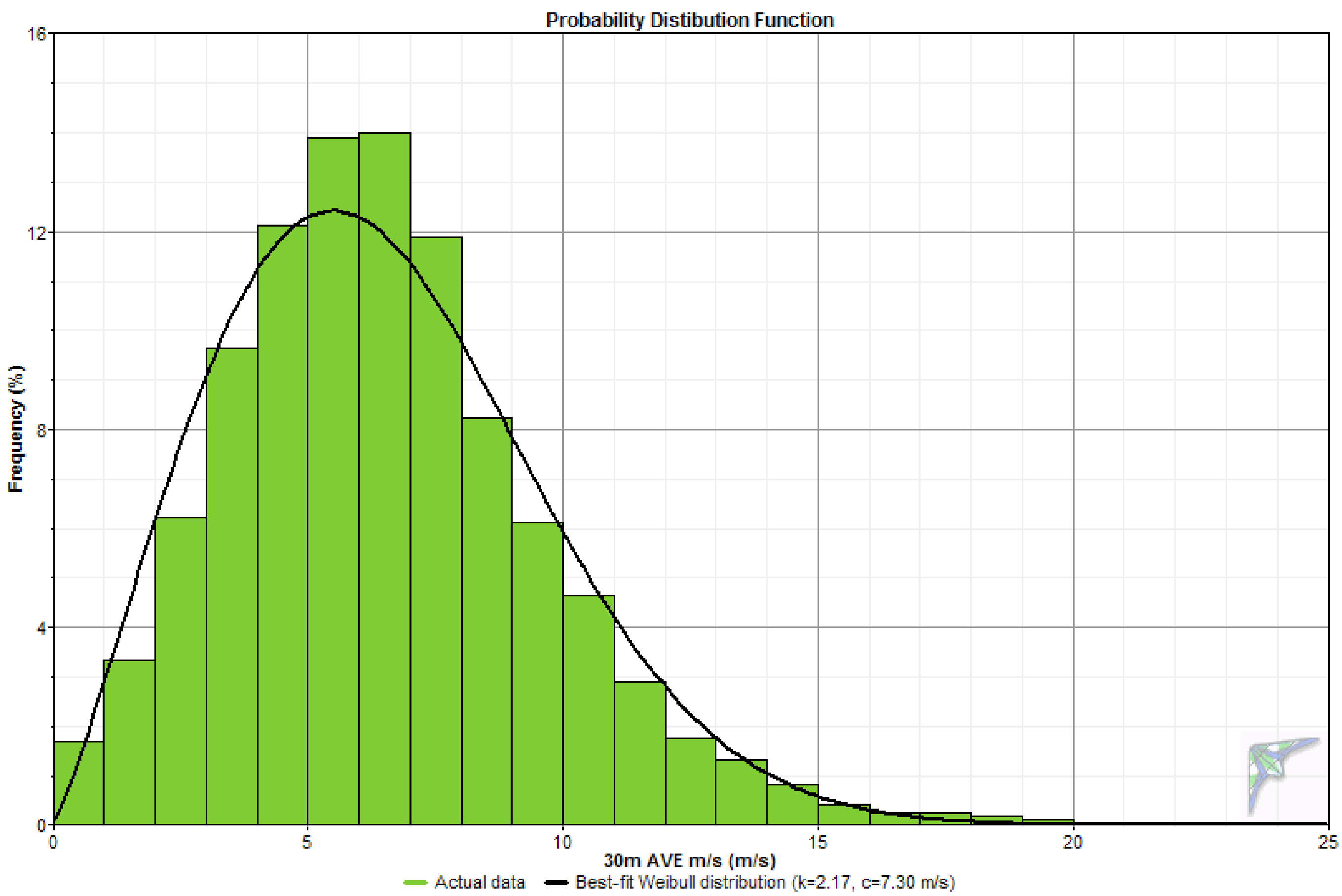


Figure 4. Wind Speed Frequency Distribution of Met Tower Data, 30-meter height

The cut-in wind speed of many wind turbines is 4 m/s and the cut-out wind speed is usually 25 m/s. The frequency distribution shows that about 79% of the wind in Nunam Iqua is within this operational zone.

Wind Direction

Wind power roses show the percent of total power that is available in the wind by direction. The annual wind power rose for the Nunam Iqua met tower site is shown below.

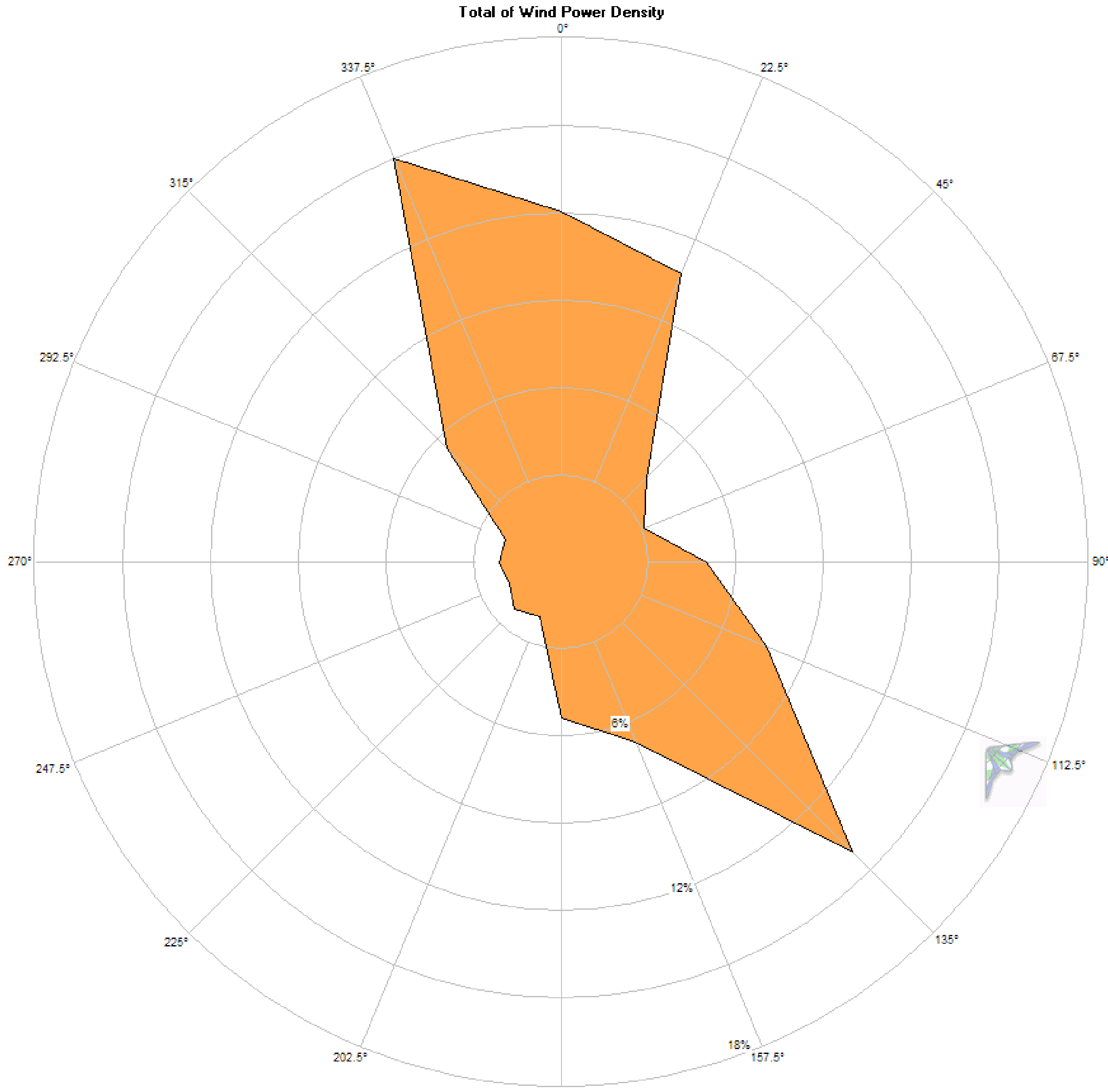


Figure 5. Annual Wind Power Rose for Met Tower Site

Monthly wind power roses for the Nunam Iqua met tower site are shown on the next page. Most of the wind power is coming from either the northwest or the southeast. This is likely the result of summer sea breezes and off shore flow as storms move through the Bering Sea.

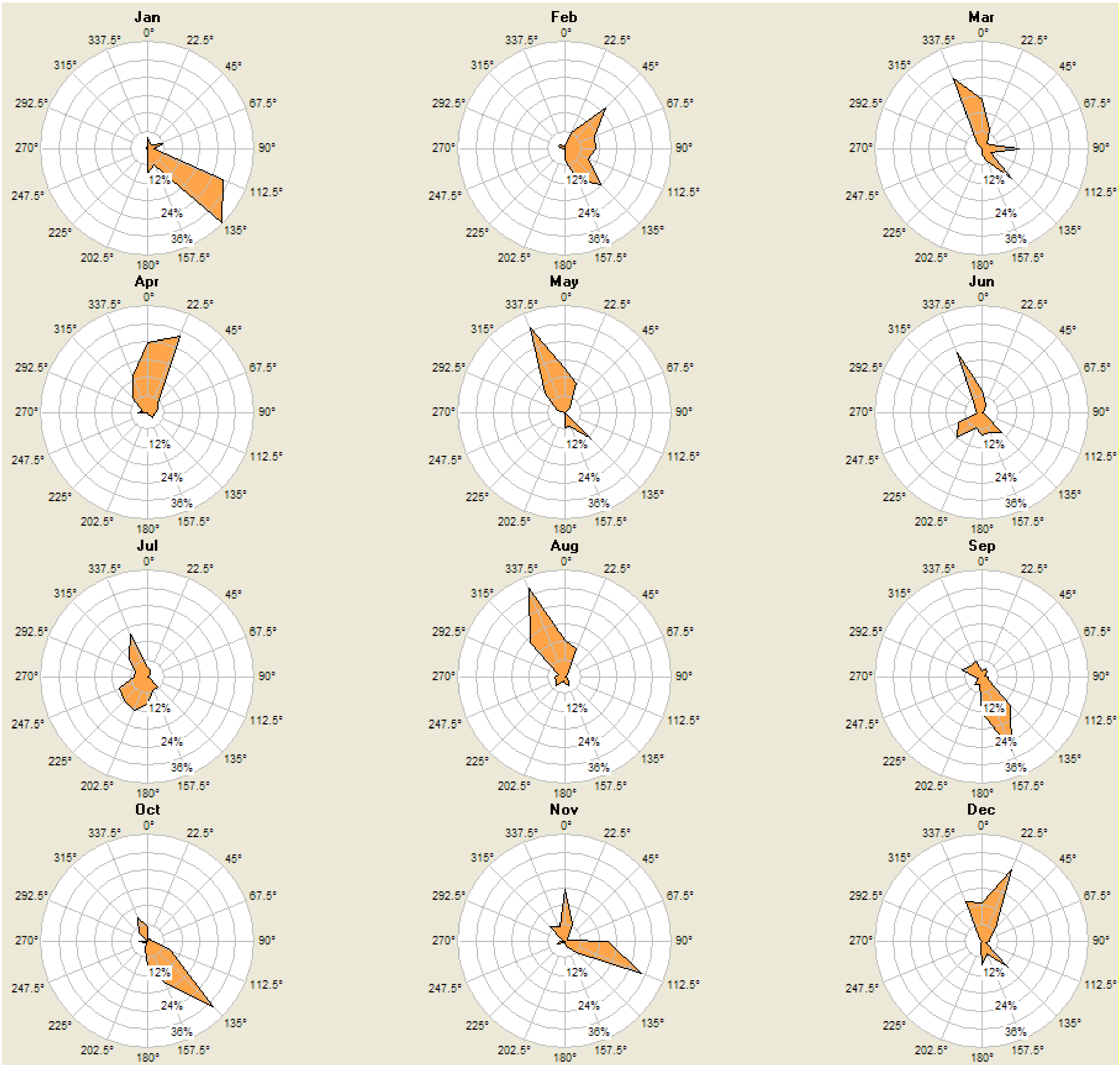


Figure 6. Monthly Wind Power Roses for Met Tower Site

The directions shown by the monthly wind power roses are based on very small sample sizes. This makes the uncertainty in their results quite high.

Turbulence Intensity

Turbulence intensity is the most basic measure of the turbulence of the wind. Typically, a turbulence intensity of around 0.10 is desired for minimal wear on wind turbine components. As shown in Figure 7, the turbulence intensity from all directions is low and unlikely to contribute to excessive wear of wind turbines.

Dir	Turbulence Intensity
N	0.08
NE	0.09
E	0.10
SE	0.09
S	0.11
SW	0.12
W	0.11
NW	0.10
Ave	0.10

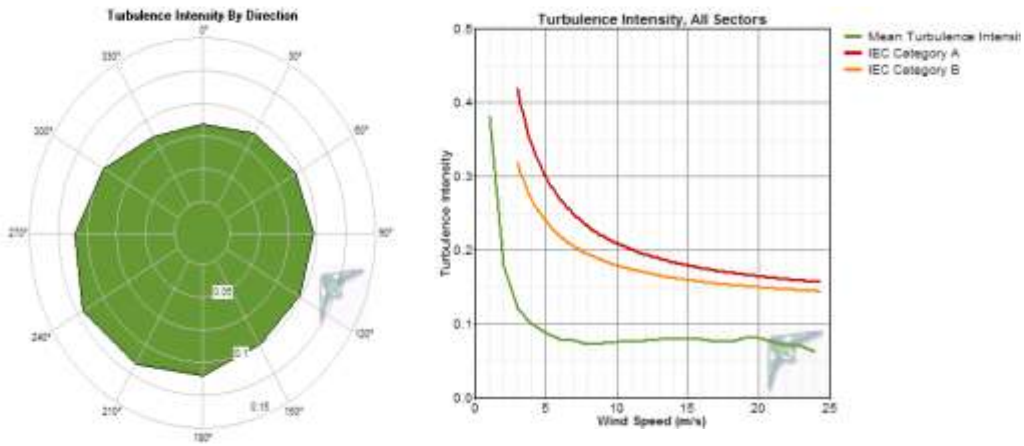


Figure 7. Turbulence Intensity Characteristics of Met Tower Site

Figure 7 plots the average turbulence intensity versus wind speed for the met tower site as well as for Category A and B turbulence sites as defined by the International Electrotechnical Commission Standard 61400-1, 2nd Edition. Category A represents a higher turbulence model than Category B. In this case, the met tower data is less turbulent than both categories across the whole range of wind speeds.

Wind Shear

Typically, wind speeds increase with height above ground level. This vertical variation in wind speed is called wind shear and is influenced by surface roughness, surrounding terrain, and atmospheric stability. Since wind speeds were only measured at one height (30 m) no analysis can be done on wind shear. However given the flat terrain surrounding the site wind shear is likely to be low.

Temperature

The air temperature can affect wind power production in two primary ways: 1) colder temperatures lead to higher air densities and therefore more power production, and 2) some wind turbines shut down in extremely cold situations (usually around –25°C). The monthly average temperatures at the tower are shown below. The temperature dropped below -25°C less than 1% of the year. Additionally during the periods of extreme cold the winds are typically very light. This alleviates the concern that extremely cold temperatures will limit wind turbine output.

Table 4. Monthly Average Temperatures

Month	Measured (˚C)
Jan	-9.8
Feb	-8.6
Mar	-13.5
Apr	-4.9
May	3.0
Jun	10.2
Jul	13.8
Aug	11.5
Sep	9.9
Oct	4.4
Nov	-3.6
Dec	-11.7
Ave	0.7

Potential Power Production from Wind Turbines

Two turbines, listed in **Error! Reference source not found.**, were used to calculate the potential energy production at the met tower site based on the resource data set. The wind resource was adjusted to these heights based on a assumed wind shear coefficient of 0.14. Also, since wind turbine power curves are based on a standard air density of 1.225 kg/m3, the wind speeds measured at the met tower site are adjusted to create standard wind speed values that can be compared to the standard power curves

Results are shown in **Error! Reference source not found.**. Among the results is the gross capacity factor, which is defined as the actual amount of energy produced divided by the maximum amount of energy that could be produced if the wind turbine were to operate at rated power for the entire year. Inefficiencies such as transformer/line losses, turbine downtime, soiling of the blades, yaw losses, array losses, and extreme weather conditions can further reduce turbine output. The gross capacity factor is multiplied by 0.80 to account for these factors, resulting in the net capacity factor listed.

Table 5. Potential Power Production by Turbine

	Rated Power (kW)	Hub Height (m)	Time At Rated Output (%)	Average **Gross** Power Output (kW)	Annual **Gross** Energy Output (kWh/yr)	Average **Gross** Capacity Factor (%)
Entegrity eW-15 60 Hz	50	31	8.84	16.7	146,425	33.4
Northern Power NW 100/21	100	32	3.36	30.8	269,535	30.8

	Rated Power (kW)	Hub Height (m)	Time At Rated Output (%)	Average **Net** Power Output (kW)	Annual **Net** Energy Output (kWh/yr)	Average **Net** Capacity Factor (%)
Entegrity eW-15 60 Hz	50	31	8.84	13.36	117140	26.72
Northern Power NW 100/21	100	32	3.36	24.64	215628	24.64

CONCLUSION

This report provides a summary of wind resource data collected from March 2006 through July 2007 in Nunam Iqua, Alaska. Both the raw data and the processed data will be available on the Alaska Energy Authority website.

It is estimated that the long-term annual average wind speed at the site is 6.5 m/s at a height of 30 meters above ground level. Taking the local air density and wind speed distribution into account, the average wind power density for the site is 322 W/m^2. This information means that Nunam Iqua has a low Class 4 wind resource, which is "good" for wind power development. The ice filtered wind data set from the monitoring period was used to make predictions as to the potential energy production from wind turbines at the site. The net capacity factor for community scale wind turbines would range from 20 – 30%.