# Wainwright Wind-Diesel Hybrid Feasibility Study

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This report was prepared by V3 Energy, LLC under contract to WHPacific for a North Slope Borough project to assess the technical and economic feasibility of installing wind turbines in a wind-diesel hybrid power system design for the villages of Point Hope, Point Lay, and Wainwright, Alaska. This report addresses Wainwright.

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# **Executive Summary**

The measured high Class 4 to Class 5 wind resource in Wainwright, based on a wind classification system with a range of 1 (poor) to 7 (superb) in terms of wind energy potential, is excellent with an average wind velocity of 6.96 m/s (15.5 mph) at 30 meters elevation. Additionally, the test location experiences low turbulence and relatively low probability of extreme wind events, making Wainwright a superior candidate for a wind energy project.

Two potential wind turbine sites were investigated for this study: Site A, the location of the meteorological test tower that collected wind data for this project, is located northeast of the village near the power plant and just beyond the protective snow fence; and site B, located two further miles to the northeast, along the road leading to the landfill and village water source. Given the similarity of terrain between the sites, each was considered to have equivalent wind resource potential. Site A has an FAA-imposed height restriction which would require shorter turbine tower heights, whereas Site B has no height restrictions. Site A requires construction of an access road but is relatively close to existing power distribution. Site B is adjacent to good road access but requires construction of 1-1/2 miles of power distribution line for connection to the power grid. A power line to serve site B would have other potential uses however.

With an excellent wind resource and considering NSB's goal to offset as much as possible the usage of expensive fossil fuel to generate electricity, medium or high penetration wind-diesel power configurations are the most suitable choice for Wainwright. There have been significant challenges to date though with implementing high penetration wind-diesel systems in rural Alaska due to complexity, high capital cost and operational problems. With an understanding that NSB must provide very high power system reliability, only the medium penetration configuration was modeled in this study as it represents a robust middle ground between insufficient fuel savings of the low penetration approach and the expense and considerable complexity of high penetration wind. A medium penetration approach would employ wind turbine capacity capable to approximately match peak load on windy days. In Wainwright, this would offset 20 to 50 percent of annual diesel energy production. To maintain reliability, "spinning reserve" (an on-line diesel generator operating between 10% and 100% rated output) would be maintained at all times to supplement the electrical load in anticipation of fluctuating wind conditions. During higher winds and lower electrical load, surplus wind-generated electricity would be shunted to an electric boiler to supplement thermal heat loads.

Based on the average and peak electrical loads in Wainwright, only new wind turbines between 100 and 350 kW rated power were considered in this study. Market availability for turbines in this size range is very limited worldwide and more limited yet in the United States, so only the fully arctic-rated 100 kW Northern Power Systems Northwind 100 and the 225 kW Aeronautica AW29-225, both manufactured in the United States, were identified as turbines suitable for use in Wainwright. The 330 kW German Enercon E33 would be a very good alternate choice, but this turbine is not available in the American market. The NW100 and the AW29-225 both have a history of successful use in utility power systems and have established support in Alaska.



HOMER software was used to predict the performance of wind turbines if added to the existing Wainwright diesel power system with reference to load profile and operating costs reported to Alaska Energy Authority for the power cost equalization (PCE) program. Based on these simulations, economic analyses was performed to determine benefit/cost (B/C) ratios based on initial capital cost of wind turbines and related distribution and control system upgrades, O&M cost of the diesel plant and wind turbines, fuel cost and related avoided fuel usage. The economic analyses were tabulated using medium, high, and low fuel cost projections (as predicted by UAA's Institute for Social and Economic Research) for Sites A and B with a number of different turbine configurations at each site. Even with conservative estimates of capital costs and O&M expenses over the life of the project, the medium and high fuel cost projections yield positive benefit-to-cost ratios for either turbine at both sites. Only the low cost projection fails to predict positive project benefit-to-cost ratios.

# **1** Introduction

The North Slope Borough (NSB) contracted with WHPacific to prepare wind power feasibility studies for the villages of Wainwright, Point Lay, and Point Hope. WHPacific contracted with V3 Energy, LLC to assist with the project. This report documents the feasibility study of Wainwright; the Point Lay and Point Hope studies are contained under separate cover.

Although NSB is home to vast fields of recoverable oil and natural gas, the huge size of the borough and the relative geographic concentration of these fossil fuel resources means that a number of NSB villages, including the coastal village of Wainwright, cannot tap these resources in any practical manner and instead must rely on the importation of diesel fuel for electricity generation and thermal heating. NSB desires to reduce Wainwright's dependency on diesel fuel by developing renewable energy sources to augment the diesel generator and fuel oil boilers. Previous studies have determined that wind power has the most potential of the borough's renewable energy resources to be economically viable and hence this study focuses only on the wind resource and wind turbines to exploit that resource.

# 1.1 Scope of Work

This study, which was paid for with Alaska Energy Authority funds made available through the Alaska Renewable Energy Fund Program and with matching funds from the North Slope Borough, investigates and evaluates wind turbine power options in Point Hope, Point Lay, and Wainwright. The scope of work of this study includes:

- Select two wind turbine locations per village
- Perform geotechnical investigation at each site
- Identify land and/or regulatory issues for each site
- Conduct wind technology workshop with NSB
- Prepare conceptual design and feasibility reports

An environmental study, which is essential in determining site feasibility, will be conducted under a separate contract and is not included in this report.

# 1.2 Village of Wainwright

In 1826 the Wainwright Lagoon was named by Capt. F.W. Beechey for his officer, Lt. John Wainwright.



V3 ENERGY LLC Eagle River, Alaska 907.350.5047 F.W. Beechey for his officer, Lt. John Wainwright. An 1853 map indicates the name of the village as "Olrona." Its Inupiat name was "Olgoonik." The region around Wainwright was traditionally wellpopulated, though the present village was not established until 1904 when the Alaska Native Service built a school and instituted medical and other services. The site was reportedly chosen by the captain of the ship delivering school construction materials, because sea-ice conditions were favorable for landing. A post office was established in 1916, and a city was formed in 1962. Coal was mined at several nearby sites for village use; the closest was about seven miles away. Today, though, most houses are heated by fuel oil. A U.S. Air Force Distance Early Warning (DEW) Station was constructed nearby in the 1960's.

A federally-recognized tribe is located in the community, the Village of Wainwright. Most Wainwright inhabitants are Inupiat Eskimos who practice a subsistence lifestyle. Their ancestors were the Utukamiut (people of the Utukok River) and Kukmiut (people of the Kuk River).

According to Census 2010, there were 179 housing units in the community and 147 were occupied. Wainwright's population of 556 people is 90 percent Alaska Native, 8 percent Caucasian, and 2 percent Hispanic, multi-racial or other.

The North Slope Borough provides all utilities in Wainwright. Water is obtained from Merekruak Lake three miles northeast of the community, treated and stored in tanks. Water is hauled from this point or delivered to household tanks by truck. Hauling services are provided by the borough. The majority of homes have running water for the kitchen. Electricity is provided by North Slope Borough. There is one school located in the community, attended by 149 students. Local hospitals or health clinics include Wainwright Health Clinic. Emergency Services have coastal and air access. Emergency service is provided by 911 Telephone Service volunteers and a health aide. Auxiliary health care is provided by Wainwright Volunteer Fire Dept. (907-763-2728).

Economic opportunities in Wainwright are influenced by its proximity to Barrow and the fact that it is one of the older, more established villages. Most of the year-round positions are in borough services. The sale of local Eskimo arts and crafts supplements income. Bowhead and beluga whale, seal, walrus, caribou, polar bear, birds, and fish are harvested for subsistence.

The 2005-2009 American Community Survey (ACS) estimated 179 residents as employed. The public sector employed 55.3% of all workers. The local unemployment rate was 29.2%. The percentage of workers not in labor force was 29.9%. The ACS surveys established that average median household income (in 2009 inflation-adjusted dollars) was \$68,750 (MOE +/-\$14,285). The per capita income (in 2009 inflation-adjusted dollars) was \$20,063 (MOE +/-\$4,649). About 12.7% of all residents had incomes below the poverty level.

Note that information regarding Wainwright is drawn from the Alaska Community Database Community Information Summaries (CIS) which can be found at <u>http://www.dced.state.ak.us/dca/commdb/CIS.cfm</u>. Regarding the American Community Survey information, MOE refers to *margin of error*.

# 1.3 Climate

Wainwright is located on the Chukchi Sea coast, 3 miles northeast of the Kuk River estuary. The climate is arctic with temperatures ranging from -56° F in winter to 80 °F in summer. Precipitation is light, averaging only five inches of water equivalent annually. The Chukchi Sea is ice-free from mid-July through September.



# 1.4 Geology

Geotechnical study was accomplished at Sites A and B by Golder and Associates of Anchorage. Their report of findings may be found under separate cover.

# 1.5 Permitting

The permits that are typically required to erect wind turbines and construct supporting access roads and power distribution lines are:

- Federal Aviation Administration (FAA) obstruction notification
- State of Alaska land use, if constructing on State land
- Local land use, if constructing on Borough land
- Alaska Fish and Game fish habitat, if access road crosses stream(s)
- U.S. Army Corps of Engineers (USACE) wetlands, if constructing on identified wetlands; may require concurrence with:
  - o National Historic Preservation Act
  - Endangered Species Act, if endangered species potentially impacted
  - Consideration of essential fish habitat, if access road crosses stream(s)
  - Migratory Bird Act, U.S. Fish and Wildlife Service



# 2 Wind Resource Assessment

The wind resource measured in Wainwright is very good, with measured high wind power class 4 (good) to low wind power class 5 (excellent). In addition to strong average wind speeds and wind power density, the site experiences highly directional prevailing winds, low turbulence and calculations indicate low extreme wind speed probability.

A 34 meter met tower, erected to 30 meters, was installed in June 2009 approximately 500 meters (1,600 ft.) northeast of the village of Wainwright, near the Chukchi Sea shoreline. This site is relatively near the power plant and well exposed to winter winds with no upwind obstructions. The met tower was removed in July 2010.

# 2.1 Met tower data synopsis

Data dates	June 19, 2009 to July 16, 2010 (13 months)
Wind power class	High 4 (good) to low 5 (excellent)
Power density mean, 30 m	413 W/m <sup>2</sup> (QC'd data); 392 W/m <sup>2</sup> (with synthetic data)
Wind speed mean, 30 m	7.05 m/s (QC'd data); 6.96 m/s (with synthetic data)
Max. 10-min wind speed average	22.2 m/s
Maximum wind gust	25.8 m/s (Feb. 2010)
Weibull distribution parameters	k = 2.2, c = 7.97 m/s
Wind shear power law exponent	0.137 (moderately low)
Roughness class	1.51 (crops)
IEC 61400-1, 3 <sup>rd</sup> ed. classification	Class III-c (lowest defined and most common)
Turbulence intensity, mean	0.072 (at 15 m/s)
Calm wind frequency	16% (<3.5 m/s)

# 2.2 Data Recovery

Data recovery in Wainwright was mostly acceptable, with 75 to 80 percent data recovery of the anemometers and wind vane. Note that data recovery in December and January was particularly poor, apparently due to hoarfrost conditions during this deep cold period of mid-winter.

# 2.3 Wind Speed

Wind data collected from the met tower, from the perspective of both mean wind speed and mean power density, indicates an excellent wind resource. The cold arctic temperatures of Wainwright contributed to the high wind power density. It is problematic, however, analyzing wind data with significant concentrated data loss, such as occurred in Wainwright during November through January, then again in March. To correct this problem, synthetic data was inserted in the data gaps to create a more realistic wind speed data profile. To be sure, long segments of synthetic data introduce uncertainty to the data set, but missing data does as well. To overcome this uncertainty, improved data collection with heated sensors would be necessary. But, considering the robust wind resource measured and noting the long-term airport AWOS data confirming the wind resource measured by the met tower, continuing a wind study with heated sensors is not truly necessary in Wainwright.





# 2.4 Wind Rose

Wind frequency rose data indicates highly directional winds from northeast to east-northeast. Power density rose data (representing the power in the wind) indicates power winds are strongly directional, from 030°T to 070°T and to a much lesser extent from 240°T. Calm frequency (percent of time that winds at 30 meter level are less than 3.5 m/s) was 16 percent during the met tower test period.



# 2.5 Turbulence Intensity

Turbulence intensity at the Wainwright test site is well within acceptable standards with an IEC 61400-1,  $3^{rd}$  edition (2005) classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.072.







## 2.6 Extreme Winds

Although thirteen months of data is minimal for calculation of extreme wind probability, use of a modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, yields reasonably good results. Extreme wind analysis indicates a highly desirable situation in Wainwright: moderately high mean wind speeds combined with low extreme wind speed probabilities. This may be explained by particular climactic aspects of Wainwright which include prominent coastal exposure, offshore wind conditions, and due to the extreme northerly latitude, lack of exposure to Gulf of Alaska storm winds.

Industry standard reference of extreme wind is the 50 year, 10-minute average probable wind speed, referred to as  $V_{ref}$ . For Wainwright, this calculates to 24.8 m/s, below the threshold of International Electrotechnical Commission (IEC) 61400-1, 3<sup>rd</sup> edition criteria (of 37.5 m/s) for a Class III site. Note that Class III extreme wind classification is the lowest defined and all wind turbines are designed for this wind regime.



# 3 Wind Project Sites

NSB requested that two wind turbine sites be identified in Wainwright. On July 6, 2011, Ross Klooster of WHPacific and Max Ahgeak of NSB Public Works Dept. traveled to Wainwright and met with Village of Wainwright and Olgoonik Corporation representatives to discuss the wind power project and to identify the two sites. This was accomplished by reviewing maps and ownership records and then driving and walking to a number of locations near the village to assess suitability for construction and operation of wind turbines. Two sites on Olgoonik Corporation land were chosen, identified as Site A and Site B in the Google Earth image below.



Wainwright site options, Google Earth image

# **3.1** Site A

Site A is a very well exposed area immediately northeast of the village and just beyond the protective snow fences on Wainwright's north side. It is an expansive location with plenty of room for a multi-turbine array, is relatively dry and hence likely to have stable permafrost for foundation construction, and would require minimal distribution line construction to connect turbines to the power plant. Unfortunately though, an FAA notice of presumed hazard (refer to Appendix A) for the site limits turbine construction to 148 ft. above ground level. With respect to the turbines options considered in this report (refer to Section 5.2), only the Aeronautica AW 29-225 on a 30 meter tower has a sufficiently low elevation tip height to meet FAA's height restrictions for this site. A possible alternative is the Northern Power Northwind 100B/21 on a 30 meter tower instead of the normal 37 meter tower (refer to Section 5.2). This possibility must be discussed with Northern Power Systems, however, as a 30 meter tower option may not be available for the B model NW100 as it had once been for their A model NW100.



#### Wainwright Site A



## **3.2** Site B

Site B shares the same apparent physical characteristics as Site A and hence it is a quite suitable location for wind turbines. A key advantage of Site B over Site A is that construction height is essentially unrestricted from an FAA perspective (refer to Appendix B). The chief disadvantage is its increased distance from Wainwright, necessitating an additional 2.4 km (1.5 mile) distribution line construction. But, turbines could be placed very near the access road, resulting in lower access road construction costs than at Site A.

#### Wainwright Site B





Wind Turbine Site	Advantages	Disadvantages
A	Olgoonik Corp. land	Turbines will be in view and possible auditory range of residents on the north side of the village
	Site is large enough to	275 to 375 meter (900 to 1,200
	accommodate several or more turbines and has sufficient room	ft) access road and distribution line construction required
	for future expansion	(depending on access direction)
	Relatively dry site; likely good	FAA determination of Notice of
	geotech conditions	Presumed Hazard (NPH) for turbines exceeding 148 ft AGL
В	Olgoonik Corp. land	2.4 km (1.5 miles) of new distribution line required
	Site is large enough to	More expensive to develop than
	accommodate several turbines and has sufficient room for future expansion	Site A
	Location is far from village and unlikely to present aesthetic and	
	noise complaints	
	Relatively dry site; likely good	
	FAA Determination of No Hazard	
	to Air Navigation for turbines up	
	to 195 ft AGL (possibly higher)	
	Site near existing road to landfill	

#### Wainwright Sites A and B comparison table

# 3.3 Other Site Options

Other than Sites A and B, something in-between, or a minor variation of either, there are no other realistic wind turbine site options for Wainwright. Terrain east of the village is possible, but the airport constrains the nearer possibilities and, importantly, a road does not exist at present in that direction, hence development costs would be extremely high. Terrain to the southwest is marginal due to its peninsula nature between Wainwright Inlet and the Bering Sea. Plus, airport runway alignment precludes this consideration. West of Wainwright is the Bering Sea and hence obviously unsuitable for turbine construction.



# 4 Wind-Diesel System Design and Equipment

Wind-diesel power systems are categorized based on their average penetration levels, or the overall proportion of wind-generated electricity compared to the total amount of electrical energy generated. Commonly used categories of wind-diesel penetration levels are low penetration, medium penetration, and high penetration, as summarized below. The wind penetration level is roughly equivalent to the amount of diesel fuel displaced by wind power. Note however that the higher the level of wind penetration, the more complex and expensive a control system and demand-management strategy is required.

Penetration	Penetratio	on Level	Operating characteristics and system requirements
	Instantaneous	Average	
Low	0% to 50%	Less than 20%	Diesel generator(s) run full time at greater than minimum loading level. Requires minimal changes to existing diesel control system. All wind energy generated supplies the village electric load; wind turbines function as "negative load" with respect to diesel generator governor response.
Medium	0% to 100+%	20% to 50%	Diesel generator(s) run full time at greater than minimum loading level. Requires control system capable of automatic generator start, stop and paralleling. To control system frequency during periods of high wind power input, system requires fast acting secondary load controller matched to a secondary load such as an electric boiler augmenting a generator heat recovery loop. At high wind power levels, secondary (thermal) loads are dispatched to absorb energy not used by the primary (electric) load. Without secondary loads, wind turbines must be curtailed to control frequency.
High (Diesels-off Capable)	0% to 150+%	Greater than 50%	Diesel generator(s) can be turned off during periods of high wind power levels. Requires sophisticated new control system, significant wind turbine capacity, secondary (thermal) load, energy storage such as batteries or a flywheel, and possibly additional components such as demand- managed devices.

# Categories of wind-diesel penetration levels

Choosing the ideal wind penetration for Wainwright depends on a number of factors, including load profile of the community, wind resource, construction cost and challenges, fuel price and also technical capability and experience of the utility with wind power and energy storage systems. There is no one "right" answer and the most optimal wind-diesel system for Wainwright may not be the one that displaces the most fuel, nor even one that has the highest estimated benefit-to-cost ratio. It is presumed for the purposes of this feasibility study that North Slope Borough's interest will be with a medium penetration option as that provides significant enough fuel savings to justify the high construction costs of a wind turbine project yet avoids the significant design complexity and operational challenges of high penetration.



# 4.1 Wind-diesel Integration Controls

Medium to high-penetration wind-diesel systems require fast-acting real and reactive power management to compensate for rapid variation in village load and wind turbine power output. A winddiesel system master controller, typically referred to as a supervisory control and data acquisition (SCADA) system, is installed to select the optimum system component configuration based on village load demand and available wind power. Regardless of the supplier, a SCADA system is capable of controlling individual components and allowing those components to communicate status to the system. A typical SCADA will consist of the following:

- Station Controller: schedules and dispatches diesel generators, wind turbines and other components units, performs remote control functions, and stores collected component and system data
- Generation Controller: monitors and controls individual diesel generators
- Wind Turbine Controller: monitors and controls individual wind turbine and dispatches wind turbines
- Feeder Monitor: monitors vital statistics of an individual distribution feeder, including ground fault information
- Demand Controller: monitors, controls, and schedules demand-managed devices

# 4.2 Energy Storage Options

Although high penetration wind power is not proposed in this feasibility study, as reference for future development, electrical energy storage provides a means of storing wind generated power during periods of high winds and releasing that power to the electrical distribution system as winds subside.

#### 4.2.1 Batteries

Batteries are most appropriate for providing medium-term energy storage to allow a transition, or bridge, between the variable output of wind turbines, and diesel generation. This bridging period is typically between five and fifteen minutes. Storage for several hours or days is also possible with batteries, but requires more capacity and higher cost. In general, the disadvantages of batteries for energy storage, even for a small utility system, are high capital and maintenance costs and limited lifetime. Of particular concern to rural Alaska communities is that batteries are heavy and expensive to transport to the site, and many contain toxic material that requires disposal as hazardous waste at the end of a battery's useful life.

Because batteries operate on direct current (DC), a converter is required when connected to an alternating current (AC) system. A typical battery storage system includes a bank of batteries and a power conversion device. Recent advances in power electronics have made solid state converter (inverter/rectifier) systems cost effective and hence the preferred power conversion device.

Despite some drawbacks, electric power storage with batteries is a proven technology, but it has seen limited use in rural Alaska wind-diesel projects to date. Wales is equipped with a high penetration wind system with battery storage that is functional, but its operational history has been very disappointing and given the design age, it is not considered a reproducible system. Kokhanok has a recently-installed



high-penetration wind-diesel system with lead-acid type battery storage, designed and constructed by Marsh Creek LLC of Anchorage, although it is not yet operational. Of interest is a 250 kW flow battery that Kotzebue Electric Association plans to install in 2012 in Kotzebue to support their planned installation of two 900 kW EWT wind turbines.

### 4.2.2 PowerStore Flywheel

Built by Powercorp Pty of Darwin, Australia, the PowerStore is a very fast-acting energy source and sink system based on a modern flywheel and bi-directional converter. During normal operation, energy is supplied to the PowerStore as a steady 12 kW load to maintain rotational energy. When necessary to control power system frequency, energy is delivered to or drawn from the flywheel. The PowerStore can absorb or deliver 300 or 1000 kW (depending on the inverter) of power in 5 milliseconds. The PowerStore has been used in rural wind-diesel and mining applications in a number of locations worldwide, including Antarctica and remote regions of Australia.



# 5 Wind Turbines and HOMER Modeling

Considering NSB's goal of displacing as much diesel fuel for electrical generation as possible and yet recognizing the present limitations of high penetration wind power in Alaska and NSB's desire to operate a highly stable and reliable electrical utility in Wainwright, only the medium penetration wind-diesel configuration scenario was modeled with HOMER software. Note that low penetration wind was not modeled as this would involve use of smaller farm-scale turbines that are not designed for severe cold climates, and low penetration would not meet NSB's goal of significantly displacing fuel usage in Wainwright.

As previously noted, a medium penetration wind-diesel configuration is a compromise between the simplicity of a low penetration wind power and the significant complexity and sophistication of the high penetration wind. With medium penetration, instantaneous wind input is sufficiently high (at 100 plus percent of the village electrical load) to require a secondary or diversion load to absorb excess wind power, or alternatively, to require curtailment of wind turbine output during periods of high wind/low electric loads. For Wainwright, appropriate wind turbines for medium wind penetration are generally in the 100 to 300 kW range with more numbers of turbines required for lower output machines compared to larger output models.

There are a number of comparative medium penetration village wind-diesel power systems presently in operation in Alaska. These include the AVEC villages of Toksook Bay, Chevak, Savoonga, Kasigluk, Hooper Bay, among others. All are characterized by wind turbines directly connected to the AC distribution system. AC bus frequency control during periods of high wind penetration, when diesel governor control would be insufficient, is managed by the sub-cycle, high resolution, and fast-switching capability of the secondary load controller (SLC). Ideally, the SLC is connected to an electric boiler serving a thermal load as this will enhance overall system efficiency by augmenting the operation of the fuel oil boiler(s) serving the thermal load.

# 5.1 Diesel Power Plant

Electric power (comprised of the diesel power plant and the electric power distribution system) in Wainwright is provided by North Slope Borough Public Works Department, the utility for all communities on the North Slope, with the exception of Deadhorse and Barrow. The existing power plant in Wainwright consists of three Caterpillar 3508 diesel generators rated at 430 kW output, and two Caterpillar 3512 diesel generator rated at 950 kW output.

Generator	Electrical Capacity	Diesel Engine Model
1	430 kW	Caterpillar 3508
2	430 kW	Caterpillar 3508
3	430 kW	Caterpillar 3508
4	950 kW	Caterpillar 3512
5	950 kW	Caterpillar 3512

#### Wainwright powerplant diesel generators



Generator sets in the Wainwright power plant are controlled by Woodward 2301A load sharing and speed control governors with protection and alarms initiated by discreet protective relays for each unit. A user-programmable PLC controller with SCADA interface automatically parallels and dispatches the diesel generators, based on system load and operator-programmable preferences, via a unit-based auto synchronizer.

# 5.2 Wind Turbines

For this study, the wind turbines considered are restricted to rated outputs of 100 to 350 kW as this size range well matches Wainwright's electric load. This eliminates the battery-charging turbines and small grid-connect home and farm-scale turbines that are insufficient for village power needs and the very large utility-scale turbines that would overwhelm the Wainwright power system. Unfortunately though, the world wind turbine market offers very few turbines in this mid or village-scale size range. Of new turbines, two American-made options are the 100 kW Northwind 100 and the 225 kW Aeronautica 29-225. The 330 kW German-made Enercon E33 would be an excellent option, but it remains unavailable to the U.S. market due to a past patent dispute between Enercon and General Electric. Remanufactured wind turbines are a possible option for NSB to consider, with the 225 kW Danish-made Vestas V27 available through Halus Power Systems of San Leandro, California.

Whether new or remanufactured, the primary criteria for wind turbines suitable for Wainwright are:

- Alternating current (AC) generator; synchronous or asynchronous are acceptable
- Cold-climate capable (rated to -40° C) with appropriate use of materials, lubricants and heaters
- IEC Class II rated
- A "known" turbine with an existing track record of installed operation
- Suitable for marine environments
- Established North American support capability, preferably with an Alaska presence

#### 5.2.1 Northern Power Systems Northwind 100

The Northwind 100 (the NW100B/21 model) wind turbine is manufactured by Northern Power Systems in Barre, Vermont. The NW100 turbine is stall-regulated, has a direct-drive permanent magnet synchronous generator, active yaw control, a 21 meter diameter rotor, is rated at 100 kW power output, and is available only on a 37 meter tubular steel tower. The NW100B/21 is fully arctic-climate certified to -40° C and is the most represented village-scale wind turbine in Alaska at present with a significant number of installations in the Yukon-Kuskokwim Delta and on St. Lawrence Island. More information can be found at: <u>http://www.northernpower.com/</u> and in Appendix C of this report.



#### NW100 wind turbine

#### *NW100B/21 power curve*



### 5.2.2 Aeronautica AW29-225

The Aeronautica AW29-225 wind turbine is manufactured new by Aeronautica in Durham, New Hampshire. This turbine was originally designed by the Danish-manufacturer Norwin in the 1980's and had a long and successful history in the wind industry before being replaced by larger capacity turbines for utility-scale grid-connect installations. The AW29-225 turbine is stall-regulated, has a synchronous (induction) generator, active yaw control, a 29 meter diameter rotor, is rated at 225 kW power output, and is available with 30, 40, or 50 meter tubular steel towers. The AW29-225 is fully arctic-climate certified to -40° C and is new to the Alaska market with no in-state installations at present. More information can be found at <u>http://aeronauticawind.com/aw/index.html</u> and in Appendix D of this report.





#### 5.2.3 Wind Turbine Performance Comparison

In the table below is an analysis of turbine output and capacity factor performance of the turbines profiled above, with comparisons of manufacturer rated output power at 100%, 90% and 80% turbine availability (percent of time that the turbine is on-line and available for energy production). Both the NW100B/21 and the AW29-225 perform very well in the Wainwright wind regime with excellent capacity factors and annual energy production.

#### Wainwright turbine capacity factor comparison

					100% av	/ailability	90% av	ailability	80% av	ailability
	Rated	Hub	Тір	Тір	Annual	Capacit	Annual	Capacit	Annual	Capacit
Turbine	Outpu	Height	Height	Height	Energy	y Factor	Energy	y Factor	Energy	y Factor
Model	t (kW)	(m)	(m)*	(ft.)*	(MWh)	(%)	(MWh)	(%)	(MWh)	(%)
NW100B/21	100	37	47.5	156	308.6	34.2	277.7	30.8	246.9	27.4
AW29-225	225	30	44.5	146	598.8	30.4	538.9	27.4	479.0	24.3
	225	40	54.5	179	649.0	32.9	584.1	29.6	519.2	26.3
	225	50	64.5	212	689.2	35.0	620.3	31.5	551.4	28.0

\*Note: assumes base of turbine tower at ground level

# 5.3 Modeling

Wind turbine and system performance modeling of wind-diesel configurations in Wainwright was accomplished with HOMER software. This software enables static modeling of a power system to demonstrate energy balances and fuel displacement with introduction of wind power. A limitation of the software is that it is not suitable for dynamic modeling. In other words, it cannot model voltage and frequency perturbations and power system dynamics, although it will provide a warning for systems that are potentially unstable.

#### 5.3.1 Electric Load

The Wainwright electric load was synthesized with the Alaska Electric Load Calculator Excel program written in 2006 by Mia Devine of the Alaska Energy Authority. This spreadsheet allows one to create a "virtual" village load in one hour increments, suitable for import into HOMER software. For this feasibility study, 2010 PCE data of reported gross kWh generated, average power, fuel usage, and powerplant efficiency was used with the Alaska Load Calculator to synthesize a 681 kW average load with a 1,111 kW peak load and approximately 380 kW minimum load. Graphical representations of the electric load are shown below.







#### 5.3.2 Thermal Load

The thermal load available to the diesel generator heat recovery system was estimated based on betterdocumented thermal loads in other villages, the size of Wainwright's electrical load, and village meter log information. Typically very difficult to quantify as accurately as the electric load, the thermal load serves as an energy "dump" in medium and high penetration wind-diesel configurations, or, more precisely, as the secondary load available to absorb excess electrical energy generated by wind turbines during periods of relatively high wind turbine output and low electric load demand.



# 5.4 Diesel Generators

The HOMER model was constructed with all five Wainwright generators, although clearly there is redundant capacity in the system. For cost modeling purposes, AEA assumes a generator O&M cost of \$0.020/kWh. This was converted to \$13.60/operating hour for each diesel generator for use in the HOMER software model (based on Wainwright's modeled average electrical load of 681 kW).

Manufacturer fuel curves for the diesel generators, provided by David Lockard of AEA in an Excel file entitled *Cat C9M C18M 3508 3512 3456 Mar* 20081, were used in the HOMER models. In addition, the diesel engines in the modeling runs were set to "optimize", which HOMER interprets as use of the most efficient diesel generator whenever possible.



Diesel generator	Caterpillar	Caterpillar	Caterpillar	Caterpillar	Caterpillar
	3508	3508	3508	3512	3512
HOMER model	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
identification					
Power output (kW)	430	430	430	950	950
Intercept coeff.	0.02368	0.02368	0.02368	0.01937	0.01937
(L/hr/kW rated)					
Slope (L/hr/kW	0.2377	0.2377	0.2377	0.2325	0.2325
output)					
Minimum electric	12% (50 kW)	12% (50 kW)	12% (50 kW)	10	10
load (%)					
Heat recovery ratio (%	18	18	18	18	18
of waste heat that can					
serve the thermal					
load)					

# Diesel generator HOMER modeling information

Intercept coefficient – the no-load fuel consumption of the generator divided by its capacity Slope – the marginal fuel consumption of the generator

#### Caterpillar 3508C fuel efficiency curve

#### Caterpillar 3512 fuel efficiency curve







# 6 Economic Analysis

Selected wind turbines in medium penetration mode are modeled in this report to demonstrate the economic viability of various configurations and fuel price points.

# 6.1 Wind Turbine Costs

Capital and installation costs of wind turbines are somewhat difficult to estimate without detailed consideration of shipping fees, foundation design, cost efficiencies with installation of multiple turbines, identification of constructor, mobilization fees, etc. Although the cost assumptions detailed below should be considered tentative, they are generally in-line with other rural Alaska wind projects of the past few years. Note that for modeling purposes, an AW29-225 on a 30 meter tower is assumed to cost 1.5 percent less than noted below.

1

### Wind turbine cost assumptions

			450-500 kW installed		
	Single Turbine		turbine o	capacity	
	NW100B	AW29-225	NW100B	AW29-225	
	(100 kW)	(225 kW)	(100 kW)	(225 kW)	
Total turbine output (kW)	100	225	500	450	
No. of turbines	1	1	5	2	
Price/turbine	\$348,000	\$580,000	\$348,000	\$580,000	
Engineering, VAR support	n/a	\$35,000	n/a	\$35,000	
Capacitors cost/turb, VAR support	n/a	\$40,000	n/a	\$80,000	
Turbine cost	\$348,000	\$655 <i>,</i> 000	\$1,740,000	\$1,355,000	
Turbine capital cost/kW	\$3,480	\$2,756	\$3,480	\$2,933	
Construction cost (estimated)	\$696,000	\$1,160,000	\$2,923,200	\$2,088,000	
Total installed cost	\$1,047,480	\$1,817,756	\$4,666,680	\$3,445,933	
Total installed cost/kW	\$10,475	\$8,079	\$9,333	\$7,658	

Note: AW29-225 price with 40 meter tower

# 6.2 Fuel Cost

A fuel price of \$5.85/gallon (\$1.55/Liter) was chosen for the initial HOMER analysis by reference to *Alaska Fuel Price Projections 2011-2035*, prepared for Alaska Energy Authority by the Institute for Social and Economic Research (ISER), dated July 7, 2011. The \$5.85/gallon price reflects the average value of all fuel prices between the 2013 (assumed project start year) fuel price of \$4.80/gallon and the 2032 (20 year project end year) fuel price of \$6.64/gallon using the medium price projection three-year moving average (MA3) analysis.

Additional analyses with ISER's low price projection MA3 and high price projection MA3 are included in the economic analysis of this report. For the high price projection, the median 2013 to 2032 three-year moving average price is \$9.06/gallon (\$2.39/Liter). For the low price projection, the average 2013 to 2032 three-year moving average price is \$2.97/gallon (\$0.79/Liter). Note also that heating fuel in HOMER is priced the same as diesel fuel.



Cost	2012 (/aal)	2022 (/22)	Average	Average
Scenario	2013 (/gai)	2032 (/gai)	(/galion)	(/Liter)
Medium	\$4.80	\$6.64	\$5.85	\$1.549
High	\$5.95	\$10.61	\$9.06	\$2.397
Low	\$3.84	\$2.71	\$2.97	\$0.785

#### Fuel cost table

ISER, MA3 cost projections

# 6.3 HOMER Modeling Assumptions

In the HOMER modeling simulations, the annual average wind speed was reduced to 6.30 m/s (from a measured 6.96 m/s) to yield an approximate turbine availability of 82 percent. This is in-line with AEA assumptions of turbine availability in their economic models. HOMER modeling assumptions are listed in the table below.

#### Basic modeling assumptions

Economic Assumptions				
Project life	20 years			
Discount rate	3%			
System fixed O&M cost	\$534,000/year (2010 PCE Report)			
Operating Reserves				
Load in current time step	10%			
Wind power output	50%			
Fuel Properties (both types)				
Heating value	42.5 MJ/kg			
Density	820 kg/m <sup>3</sup>			
Diesel Generators				
Generator capital cost	\$0 (already exist)			
O&M cost	\$13.60/hour (\$0.02/kWh)			
Time between overhauls	20,000 hours			
Overhaul cost (Cat 3508)	\$75,000			
Overhaul cost (Cat 3512)	\$100,000			
Minimum load ratio	10% or 50 kW; based on AVEC's			
	operational experience of 50 kW			
	minimum diesel loading with their			
	wind-diesel systems			
Schedule	Optimized			
Wind Turbines				
Availability	82%			
Scaled annual average wind	6.30 m/s (6.96 m/s non-scaled,			
speed	from met tower data)			
O&M cost	\$0.0469/kWh (translated to \$/year			
	based on 26% turbine CF)			
<ul> <li>NW100B/21</li> </ul>	<ul> <li>\$10,700/yr/turbine</li> </ul>			
• AW 29-225	<ul> <li>\$24,000/yr/turbine</li> </ul>			



# 6.4 Wind Power Scenario Cost Assumptions

The base or comparison scenario, which does not include wind turbines, is the existing Wainwright powerplant with its present configuration of diesel generators.

Wind turbines in a medium penetration system configuration may be constructed at Site A or Site B. Development costs between the sites will be different because of varying distances of access roads and new power distribution lines. For both sites, \$150,000 is assumed both for SCADA improvements to accommodate the inclusion of wind power into the existing diesel power plant operating system and a secondary load controller and electric boiler to allow excess wind turbine power to serve the thermal load. Additionally for both sites, \$50,000 is assumed for basic permitting and project management. As noted in the table below, these fixed costs plus the varying road access and power distribution extension development costs for each site result in total development costs of \$425,000 for Site A and \$848,000 for Site B. Typically, geotechnical studies are also included as part of the site development process to support the design of turbine foundations, but these efforts have already been accomplished.

	Base	Site A	Site B
SCADA upgrade, SLC, boiler		\$150,000	\$150,000
3Φ distribution line extension		\$100,000	\$608,000
Road extension		\$125,000	\$40,000
Permitting		\$50,000	\$50,000
	\$0	\$425,000	\$848,000
Distribution distance (miles)		0.25	1.52
Road distance (miles)		0.25	0.08
Notes:			
Distribution line, \$400K/mi			
Road, \$500K/mi			

#### Wind project cost assumptions



# 6.5 Site A Project Economics

### 6.5.1 Medium Fuel Price Projection, 82% Turbine Availability

							Heating		Total	Fuel use	
		Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
	4	\$7,026,753	2,726,518	\$47,590,456	0.464	0.22	127,908	1,127,857	331,774	105,247	1.019
	3	\$5,422,999	2,841,448	\$47,696,564	0.465	0.17	128,311	1,216,332	355,256	81,766	1.016
	5	\$8,630,507	2,635,284	\$47,836,876	0.466	0.27	122,265	1,060,087	312,378	124,643	1.013
8		\$7,806,080	2,700,557	\$47,983,548	0.468	0.22	133,673	1,112,696	329,292	107,730	1.010
6		\$5,996,480	2,828,384	\$48,075,696	0.469	0.17	129,792	1,211,925	354,483	82,539	1.008
	2	\$3,819,244	2,976,185	\$48,097,356	0.469	0.11	118,675	1,327,166	381,992	55,029	1.008
10		\$9,615,680	2,593,921	\$48,206,664	0.470	0.14	130,310	1,034,233	307,673	129,348	1.006
5		\$5,091,680	2,898,076	\$48,207,728	0.470	0.28	124,444	1,268,529	368,025	68,997	1.006
4		\$4,186,880	2,968,808	\$48,355,240	0.472	0.11	118,487	1,326,255	381,702	55,319	1.002
	6	\$10,234,262	2,565,130	\$48,396,920	0.473	0.08	115,807	1,006,952	296,634	140,388	1.002
Base s	ystem	\$0	3,258,204	\$48,473,844	0.473	0.00	97,020	1,557,106	437,021	0	1.000
3		\$3,282,080	3,039,610	\$48,503,792	0.474	0.05	112,687	1,383,874	395,393	41,629	0.999
	1	\$2,215,490	3,114,587	\$48,552,680	0.474	0.30	107,202	1,441,897	409,273	27,748	0.998
2		\$2,377,280	3,111,131	\$48,663,044	0.476	0.05	107,154	1,441,461	409,145	27,876	0.996
12		\$11,425,280	2,507,277	\$48,727,228	0.476	0.02	124,756	970,852	289,461	147,561	0.995
1		\$1,472,480	3,184,092	\$48,843,720	0.478	0.32	101,914	1,499,240	423,026	13,995	0.992

Note: AW29-225 at 30 m hub height



	8		.,				Uppting		Total	Fueluse	
		Initial	Oneration		COL	Denevueble	neating	Discol	fuelues	Fueruse	Ducient
		initiai	Operating		COE	Renewable	on arctic	Diesei	ruer use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
12		\$11,425,280	3,436,352	\$62,549,520	0.592	0.32	124,756	970,852	289,461	147,561	1.109
	6	\$10,234,262	3,517,229	\$62,561,748	0.592	0.30	115,807	1,006,952	296,634	140,388	1.108
	5	\$8,630,507	3,637,918	\$62,753,544	0.595	0.27	122,265	1,060,087	312,378	124,643	1.105
10		\$9,615,680	3,581,453	\$62,898,652	0.596	0.28	130,310	1,034,233	307,673	129,348	1.102
	4	\$7,026,753	3,791,407	\$63,433,308	0.602	0.22	127,908	1,127,857	331,774	105,247	1.093
8		\$7,806,080	3,757,478	\$63,707,864	0.605	0.22	133,673	1,112,696	329,292	107,730	1.088
	3	\$5,422,999	3,981,705	\$64,660,716	0.616	0.17	128,311	1,216,332	355,256	81,766	1.072
6		\$5,996,480	3,966,160	\$65,002,928	0.620	0.17	129,792	1,211,925	354,483	82,539	1.067
5		\$5,091,680	4,079,317	\$65,781,616	0.629	0.14	124,444	1,268,529	368,025	68,997	1.054
	2	\$3,819,244	4,202,259	\$66,338,240	0.635	0.11	118,675	1,327,166	381,992	55,029	1.045
4		\$4,186,880	4,193,950	\$66,582,260	0.638	0.11	118,487	1,326,255	381,702	55,319	1.041
3		\$3,282,080	4,308,693	\$67,384,552	0.647	0.08	112,687	1,383,874	395,393	41,629	1.029
	1	\$2,215,490	4,428,224	\$68,096,264	0.655	0.05	107,202	1,441,897	409,273	27,748	1.018
2		\$2,377,280	4,424,357	\$68,200,528	0.656	0.05	107,154	1,441,461	409,145	27,876	1.017
1		\$1,472,480	4,541,870	\$69,044,040	0.665	0.02	101,914	1,499,240	423,026	13,995	1.004
Base s	ystem	\$0	4,660,903	\$69,342,456	0.669	0.00	97,020	1,557,106	437,021	0	1.000

## 6.5.2 High Fuel Price Projection, 82% Turbine Availability

Note: AW29-225 at 30 m hub height



		1	Orientia		605	Deneurskie	Heating	Discol	Total	Fuel use	Ducient
NUA/4.00	414/20	Initial	Operating			Renewable	oil arctic	Diesel	tuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	TOTALNPC	(Ş/KVVN)	traction	(L)	arctic (L)	(gai)	(gal)	B/C ratio
Base s	ystem	\$0	1,994,452	\$29,672,408	0.298	0.00	97,020	1,557,106	437,021	0	1.000
1		\$1,472,480	1,960,810	\$30,644,380	0.308	0.02	101,914	1,499,240	423,026	13,995	0.968
	1	\$2,215,490	1,931,076	\$30,945,026	0.312	0.05	107,202	1,441,897	409,273	27,748	0.959
2		\$2,377,280	1,927,988	\$31,060,872	0.313	0.05	107,154	1,441,461	409,145	27,876	0.955
3		\$3,282,080	1,896,237	\$31,493,300	0.318	0.08	112,687	1,383,874	395,393	41,629	0.942
	2	\$3,819,244	1,871,562	\$31,663,352	0.320	0.11	118,675	1,327,166	381,992	55,029	0.937
4		\$4,186,880	1,865,024	\$31,933,728	0.323	0.11	118,487	1,326,255	381,702	55,319	0.929
5		\$5,091,680	1,833,845	\$32,374,656	0.328	0.14	124,444	1,268,529	368,025	68,997	0.917
	3	\$5,422,999	1,814,140	\$32,412,820	0.328	0.17	128,311	1,216,332	355,256	81,766	0.915
6		\$5,996,480	1,803,313	\$32,825,220	0.333	0.17	129,792	1,211,925	354,483	82,539	0.904
	4	\$7,026,753	1,767,114	\$33,316,940	0.339	0.22	127,908	1,127,857	331,774	105,247	0.891
8		\$7,806,080	1,748,332	\$33,816,836	0.344	0.22	133,673	1,112,696	329,292	107,730	0.877
	5	\$8,630,507	1,731,968	\$34,397,808	0.351	0.27	122,265	1,060,087	312,378	124,643	0.863
10		\$9,615,680	1,704,210	\$34,970,020	0.357	0.28	130,310	1,034,233	307,673	129,348	0.849
	6	\$10,234,262	1,707,343	\$35,635,212	0.365	0.30	115,807	1,006,952	296,634	140,388	0.833
12		\$11,425,280	1,670,233	\$36,274,124	0.372	0.32	124,756	970,852	289,461	147,561	0.818

#### 6.5.3 Low Fuel Price Projection, 82% Turbine Availability

Note: AW29-225 at 30 m hub height



## 6.5.4 Medium Fuel Price Projection, 100% Turbine Availability

							Heating		Total	Fuel use	
		Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
	4	\$7,026,753	2,586,900	\$45,513,288	0.440	0.27	130,331	1,036,398	308,251	128,771	1.065
	5	\$8,630,507	2,482,240	\$45,559,968	0.441	0.33	120,337	964,404	286,589	150,432	1.064
	3	\$5,422,999	2,725,361	\$45,969,488	0.445	0.21	134,589	1,136,042	335,702	101,320	1.054
	6	\$10,234,262	2,402,330	\$45,974,864	0.445	0.27	111,832	907,963	269,431	167,591	1.054
8		\$7,806,080	2,573,606	\$46,094,840	0.447	0.37	137,702	1,027,586	307,870	129,151	1.052
10		\$9,615,680	2,453,060	\$46,111,016	0.447	0.33	130,002	944,490	283,882	153,140	1.051
12		\$11,425,280	2,357,321	\$46,496,252	0.451	0.21	121,211	879,013	264,260	172,761	1.043
6		\$5,996,480	2,725,225	\$46,540,944	0.452	0.38	136,428	1,139,575	337,121	99,900	1.042
	2	\$3,819,244	2,895,555	\$46,897,780	0.456	0.14	124,392	1,270,324	368,485	68,536	1.034
5		\$5,091,680	2,810,319	\$46,902,132	0.456	0.17	130,778	1,206,445	353,295	83,726	1.034
4		\$4,186,880	2,898,534	\$47,309,748	0.460	0.13	123,471	1,276,676	369,920	67,101	1.025
3		\$3,282,080	2,986,586	\$47,714,940	0.465	0.10	116,243	1,346,799	386,537	50,485	1.016
	1	\$2,215,490	3,073,925	\$47,947,728	0.468	0.06	109,805	1,413,597	402,484	34,537	1.011
2		\$2,377,280	3,075,356	\$48,130,804	0.470	0.06	109,427	1,416,688	403,201	33,821	1.007
Base sy	ystem	\$0	3,258,204	\$48,473,844	0.473	0.00	97,020	1,557,106	437,021	0	1.000
1		\$1,472,480	3,166,071	\$48,575,620	0.475	0.02	102,977	1,486,865	420,038	16,984	0.998

Note: AW29-225 at 30 m hub height



# 6.6 Site B Project Economics

### 6.6.1 Medium Fuel Price Projection, 82% Turbine Availability

						Heating		Total	Fuel use	
	Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
4	\$7,550,287	2,670,358	\$47,278,476	0.460	0.24	129,245	1,090,797	322,336	114,685	1.025
5	\$9,178,464	2,574,359	\$47,478,420	0.462	0.18	121,712	1,021,703	302,091	134,930	1.021
3	\$5,922,110	2,795,617	\$47,513,820	0.463	0.29	130,905	1,184,553	347,545	89,476	1.020
	\$8,229,080	2,664,076	\$47,863,800	0.467	0.24	134,941	1,088,098	323,128	113,894	1.013
6	\$10,806,641	2,499,973	\$47,999,920	0.468	0.18	114,365	967,067	285,715	151,306	1.010
	\$10,038,680	2,553,106	\$48,022,452	0.468	0.12	130,468	1,007,999	300,784	136,238	1.009
	\$6,419,480	2,798,638	\$48,056,144	0.469	0.29	131,760	1,191,084	349,496	87,525	1.009
2	\$4,293,933	2,944,576	\$48,101,788	0.469	0.33	120,895	1,304,882	376,691	60,330	1.008
	\$5,514,680	2,873,096	\$48,259,092	0.471	0.15	126,227	1,250,872	363,831	73,191	1.004
ystem	\$0	3,258,204	\$48,473,844	0.473	0.00	97,020	1,557,106	437,021	0	1.000
	\$4,609,880	2,948,598	\$48,477,568	0.474	0.12	119,908	1,312,079	378,332	58,689	1.000
	\$11,848,280	2,463,254	\$48,495,272	0.474	0.34	123,952	943,641	282,059	154,962	1.000
	\$3,705,080	3,024,477	\$48,701,648	0.476	0.08	113,694	1,373,315	392,869	44,152	0.995
1	\$2,665,756	3,098,467	\$48,763,112	0.477	0.05	108,230	1,430,728	406,594	30,427	0.994
	\$2,800,280	3,100,936	\$48,934,376	0.479	0.05	107,799	1,434,404	407,451	29,570	0.991
	\$1,895,480	3,179,008	\$49,191,088	0.482	0.02	102,215	1,495,726	422,177	14,844	0.985
	AW29 4 5 3 6 2 ystem	Initial           AW29         capital           4         \$7,550,287           5         \$9,178,464           3         \$5,922,110           \$8,229,080         \$8,229,080           6         \$10,806,641           \$10,038,680         \$6,419,480           2         \$4,293,933           \$5,514,680         \$11,848,280           \$3,705,080         \$3,705,080           1         \$2,665,756           \$2,800,280         \$1,895,480	Initial capitalOperating cost (\$/yr)4\$7,550,2872,670,3585\$9,178,4642,574,3593\$5,922,1102,795,617\$8,229,0802,664,0766\$10,806,6412,499,973\$10,038,6802,553,106\$6,419,4802,798,6382\$4,293,9332,944,576\$5,514,6802,873,096\$5,514,6802,948,598\$11,848,2802,948,598\$11,848,2802,463,254\$3,705,0803,024,4771\$2,665,7563,098,467\$2,800,2803,100,936\$1,895,4803,179,008	Initial AW29Operating capitalTotal NPC4\$7,550,2872,670,358\$47,278,4765\$9,178,4642,574,359\$47,478,4203\$5,922,1102,795,617\$47,513,820\$8,229,0802,664,076\$47,863,8006\$10,806,6412,499,973\$47,999,920\$10,038,6802,553,106\$48,022,452\$6,419,4802,798,638\$48,022,452\$6,419,4802,798,638\$48,056,1442\$4,293,9332,944,576\$48,101,788\$5,514,6802,873,096\$48,259,092ystem\$03,258,204\$48,473,844\$4,609,8802,948,598\$48,477,568\$11,848,2802,463,254\$48,405,272\$3,705,0803,024,477\$48,701,6481\$2,665,7563,098,467\$48,763,112\$2,800,2803,100,936\$48,934,376\$1,895,4803,179,008\$49,191,088	AW29Initial capitalOperating cost (\$/yr)COE4\$7,550,2872,670,358\$47,278,4760.4605\$9,178,4642,574,359\$47,478,4200.4623\$5,922,1102,795,617\$47,513,8200.463\$8,229,0802,664,076\$47,863,8000.4676\$10,806,6412,499,973\$47,999,9200.468\$10,038,6802,553,106\$48,022,4520.468\$6,419,4802,798,638\$48,056,1440.4692\$4,293,9332,944,576\$48,101,7880.469\$5,514,6802,873,096\$48,259,0920.471ystem\$03,258,204\$48,473,8440.473\$4,609,8802,948,598\$48,477,5680.474\$11,848,2802,463,254\$48,495,2720.474\$3,705,0803,024,477\$48,701,6480.4761\$2,665,7563,098,467\$48,934,3760.479\$1,895,4803,179,008\$49,191,0880.482	AW29Initial capitalOperating cost (\$/yr)Total NPCCOE (\$/kWh)Renewable fraction4\$7,550,2872,670,358\$47,278,4760.4600.245\$9,178,4642,574,359\$47,478,4200.4620.183\$5,922,1102,795,617\$47,513,8200.4630.29\$8,229,0802,664,076\$47,863,8000.4670.246\$10,806,6412,499,973\$47,999,9200.4680.18\$10,038,6802,553,106\$48,022,4520.4680.12\$6,419,4802,798,638\$48,056,1440.4690.292\$4,293,9332,944,576\$48,101,7880.4690.33\$5,514,6802,873,096\$48,259,0920.4710.15ystem\$03,258,204\$48,477,5680.4740.12\$11,848,2802,948,598\$48,477,5680.4740.34\$3,705,0803,024,477\$48,701,6480.4790.05\$2,800,2803,100,936\$48,934,3760.4790.05\$1,895,4803,179,008\$49,191,0880.4820.02	Heating OperatingCOERenewable oil arcticAW29capitalCost (\$/yr)Total NPC(\$/kWh)fraction(L)4\$7,550,2872,670,358\$47,278,4760.4600.24129,2455\$9,178,4642,574,359\$47,478,4200.4620.18121,7123\$5,922,1102,795,617\$47,513,8200.4630.29130,905\$8,229,0802,664,076\$47,863,8000.4670.244134,9416\$10,806,6412,499,973\$47,999,9200.4680.18114,365\$10,038,6802,553,106\$48,022,4520.4680.12130,468\$6,419,4802,798,638\$48,056,1440.4690.29131,7602\$4,293,9332,944,576\$48,101,7880.4690.33120,895\$5,514,6802,873,096\$48,259,0920.4710.15126,227ystem\$03,258,204\$48,477,5680.4740.12119,908\$11,848,2802,463,254\$48,477,5680.4740.12119,908\$11,848,2803,024,477\$48,701,6480.4760.08113,6941\$2,665,7563,098,467\$48,73,1120.4770.05108,230\$2,800,2803,100,936\$48,934,3760.4780.02102,215\$1,895,4803,179,008\$49,191,0880.4820.02102,215	InitialOperatingCOERenewablereactionOil arcticDieselAW29capitalcost (\$/yr)Total NPC(\$/kWh)fraction(L)arctic (L)4\$7,550,2872,670,358\$47,278,4760.4600.24129,2451,090,7975\$9,178,4642,574,359\$47,478,4200.4620.18121,7121,021,7033\$5,922,1102,795,617\$47,513,8200.4630.29130,9051,184,553\$8,229,0802,664,076\$47,863,8000.4670.244134,9411,088,0986\$10,806,6412,499,973\$47,999,9200.4680.18114,365967,067\$10,038,6802,553,106\$48,022,4520.4680.12130,4681,007,999\$6,419,4802,798,638\$48,056,1440.4690.29131,7601,191,0842\$4,293,9332,944,576\$48,101,7880.4690.33120,8951,304,882\$5,514,6802,873,096\$48,259,0920.4710.15126,2271,250,872ystem\$03,258,204\$48,477,5680.4740.34123,952943,641\$4,609,8802,948,598\$48,477,5680.4740.34123,952943,641\$4,609,8802,948,598\$48,477,5680.4740.34123,952943,641\$4,609,8802,948,598\$48,477,5680.4740.34123,952943,641\$4,609,8802,948,598\$48,477,5680.474 <td>Initial         Operating         COE         Renewable         oil arctic         Diesel         fuel use           AW29         capital         cost (\$/yr)         Total NPC         (\$/kWh)         fraction         (L)         arctic (L)         (gal)           4         \$7,550,287         2,670,358         \$47,278,476         0.460         0.24         129,245         1,090,797         322,336           5         \$9,178,464         2,574,359         \$47,478,420         0.462         0.18         121,712         1,021,703         302,091           3         \$5,922,110         2,795,617         \$47,513,820         0.463         0.29         130,905         1,184,553         347,545           \$8,229,080         2,664,076         \$47,863,800         0.467         0.24         134,941         1,088,098         323,128           6         \$10,806,641         2,499,973         \$47,999,920         0.468         0.18         114,365         967,067         285,715           \$10,038,680         2,553,106         \$48,022,452         0.468         0.12         130,468         1,007,999         30,784           \$2,4,293,933         2,944,576         \$48,017,88         0.469         0.29         131,760         1</td> <td>Initial         Operating         COE         Renewable fraction         Initial         Operating (u)         Fuel use avoided avoided           AW29         capital         cost (\$/yr)         Total NPC         (\$/kWh)         fraction         (L)         arctic (L)         (gal)         (gal)           4         \$7,550,287         2,670,358         \$47,278,476         0.460         0.24         129,245         1,090,797         322,336         114,685           5         \$9,178,464         2,574,359         \$47,478,420         0.462         0.18         121,712         1,021,703         302,091         134,930           3         \$5,922,110         2,795,617         \$47,513,820         0.463         0.29         130,905         1,184,553         347,545         89,476           \$8,229,080         2,664,076         \$47,863,800         0.467         0.24         134,941         1,088,098         323,128         113,894           6         \$10,806,641         2,499,973         \$47,999,920         0.468         0.18         114,365         967,067         285,715         151,306           \$10,038,680         2,553,106         \$48,022,452         0.468         0.12         130,468         1,007,99         300,784         <td< td=""></td<></td>	Initial         Operating         COE         Renewable         oil arctic         Diesel         fuel use           AW29         capital         cost (\$/yr)         Total NPC         (\$/kWh)         fraction         (L)         arctic (L)         (gal)           4         \$7,550,287         2,670,358         \$47,278,476         0.460         0.24         129,245         1,090,797         322,336           5         \$9,178,464         2,574,359         \$47,478,420         0.462         0.18         121,712         1,021,703         302,091           3         \$5,922,110         2,795,617         \$47,513,820         0.463         0.29         130,905         1,184,553         347,545           \$8,229,080         2,664,076         \$47,863,800         0.467         0.24         134,941         1,088,098         323,128           6         \$10,806,641         2,499,973         \$47,999,920         0.468         0.18         114,365         967,067         285,715           \$10,038,680         2,553,106         \$48,022,452         0.468         0.12         130,468         1,007,999         30,784           \$2,4,293,933         2,944,576         \$48,017,88         0.469         0.29         131,760         1	Initial         Operating         COE         Renewable fraction         Initial         Operating (u)         Fuel use avoided avoided           AW29         capital         cost (\$/yr)         Total NPC         (\$/kWh)         fraction         (L)         arctic (L)         (gal)         (gal)           4         \$7,550,287         2,670,358         \$47,278,476         0.460         0.24         129,245         1,090,797         322,336         114,685           5         \$9,178,464         2,574,359         \$47,478,420         0.462         0.18         121,712         1,021,703         302,091         134,930           3         \$5,922,110         2,795,617         \$47,513,820         0.463         0.29         130,905         1,184,553         347,545         89,476           \$8,229,080         2,664,076         \$47,863,800         0.467         0.24         134,941         1,088,098         323,128         113,894           6         \$10,806,641         2,499,973         \$47,999,920         0.468         0.18         114,365         967,067         285,715         151,306           \$10,038,680         2,553,106         \$48,022,452         0.468         0.12         130,468         1,007,99         300,784 <td< td=""></td<>

Note: AW29-225 at 40 m hub height



### 6.6.2 High Fuel Price Projection, 82% Turbine Availability

							Heating		Total	Fuel use	
		Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
	6	\$10,806,641	3,417,027	\$61,643,372	0.582	0.33	114,365	967,067	285,715	151,306	1.125
	5	\$9,178,464	3,543,974	\$61,903,848	0.585	0.34	121,712	1,021,703	302,091	134,930	1.120
12		\$11,848,280	3,368,572	\$61,964,124	0.586	0.29	123,952	943,641	282,059	154,962	1.119
10		\$10,038,680	3,518,527	\$62,385,472	0.590	0.29	130,468	1,007,999	300,784	136,238	1.112
	4	\$7,550,287	3,704,954	\$62,670,644	0.594	0.24	129,245	1,090,797	322,336	114,685	1.106
8		\$8,229,080	3,701,214	\$63,293,788	0.601	0.24	134,941	1,088,098	323,128	113,894	1.096
	3	\$5,922,110	3,911,125	\$64,109,772	0.610	0.18	130,905	1,184,553	347,545	89,476	1.082
6		\$6,419,480	3,920,410	\$64,745,280	0.617	0.18	131,760	1,191,084	349,496	87,525	1.071
5		\$5,514,680	4,040,876	\$65,632,708	0.627	0.15	126,227	1,250,872	363,831	73,191	1.057
	2	\$4,293,933	4,153,636	\$66,089,540	0.632	0.12	120,895	1,304,882	376,691	60,330	1.049
4		\$4,609,880	4,162,924	\$66,543,668	0.637	0.12	119,908	1,312,079	378,332	58,689	1.042
3		\$3,705,080	4,285,460	\$67,461,888	0.648	0.08	113,694	1,373,315	392,869	44,152	1.028
	1	\$2,665,756	4,403,504	\$68,178,760	0.656	0.05	108,230	1,430,728	406,594	30,427	1.017
2		\$2,800,280	4,408,724	\$68,390,960	0.658	0.05	107,799	1,434,404	407,451	29,570	1.014
1		\$1,895,480	4,534,063	\$69,350,880	0.669	0.02	102,215	1,495,726	422,177	14,844	1.000
Base sy	ystem	\$0	4,660,903	\$69,342,456	0.669	0.00	97,020	1,557,106	437,021	0	1.000

Note: AW29-225 at 40 m hub height



					<i>v</i>						
							Heating		Total	Fuel use	
		Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
Base s	ystem	\$0	1,994,452	\$29,672,408	0.298	0.00	97,020	1,557,106	437,021	0	1.000
1		\$1,895,480	1,958,181	\$31,028,262	0.313	0.02	102,215	1,495,726	422,177	14,844	0.956
	1	\$2,665,756	1,922,703	\$31,270,714	0.316	0.05	108,230	1,430,728	406,594	30,427	0.949
2		\$2,800,280	1,922,693	\$31,405,090	0.317	0.05	107,799	1,434,404	407,451	29,570	0.945
3		\$3,705,080	1,888,402	\$31,799,734	0.322	0.08	113,694	1,373,315	392,869	44,152	0.933
	2	\$4,293,933	1,855,282	\$31,895,842	0.323	0.12	120,895	1,304,882	376,691	60,330	0.930
4		\$4,609,880	1,854,560	\$32,201,054	0.326	0.12	119,908	1,312,079	378,332	58,689	0.921
	3	\$5,922,110	1,790,607	\$32,561,810	0.330	0.18	130,905	1,184,553	347,545	89,476	0.911
5		\$5,514,680	1,820,992	\$32,606,444	0.331	0.15	126,227	1,250,872	363,831	73,191	0.910
6		\$6,419,480	1,787,984	\$33,020,170	0.335	0.18	131,760	1,191,084	349,496	87,525	0.899
	4	\$7,550,287	1,738,246	\$33,411,002	0.340	0.24	129,245	1,090,797	322,336	114,685	0.888
8		\$8,229,080	1,729,674	\$33,962,256	0.346	0.24	134,941	1,088,098	323,128	113,894	0.874
	5	\$9,178,464	1,700,790	\$34,481,924	0.352	0.29	121,712	1,021,703	302,091	134,930	0.861
10		\$10,038,680	1,683,317	\$35,082,188	0.359	0.29	130,468	1,007,999	300,784	136,238	0.846
	6	\$10,806,641	1,673,759	\$35,707,940	0.366	0.33	114,365	967,067	285,715	151,306	0.831
12		\$11,848,280	1,647,613	\$36,360,600	0.373	0.34	123,952	943,641	282,059	154,962	0.816

### 6.6.3 Low Fuel Price Projection, 82% Turbine Availability

Note: AW29-225 at 40 m hub height



## 6.6.4 Medium Fuel Price Projection, 100% Turbine Availability

							Heating		Total	Fuel use	
		Initial	Operating		COE	Renewable	oil arctic	Diesel	fuel use	avoided	Project
NW100	AW29	capital	cost (\$/yr)	Total NPC	(\$/kWh)	fraction	(L)	arctic (L)	(gal)	(gal)	B/C ratio
	4	\$7,550,287	2,529,530	\$45,183,300	0.436	0.30	130,752	999,424	298,593	138,428	1.073
	5	\$9,178,464	2,420,412	\$45,188,076	0.436	0.35	119,114	926,227	276,180	160,841	1.073
	6	\$10,806,641	2,336,369	\$45,565,904	0.441	0.23	109,724	868,578	258,468	178,553	1.064
	3	\$5,922,110	2,676,668	\$45,744,160	0.443	0.39	136,954	1,102,640	327,502	109,520	1.060
10		\$10,038,680	2,410,831	\$45,905,760	0.445	0.29	129,503	918,092	276,775	160,246	1.056
8		\$8,229,080	2,535,529	\$45,951,352	0.445	0.35	138,585	1,002,385	301,445	135,576	1.055
12		\$11,848,280	2,313,133	\$46,261,848	0.449	0.40	119,832	852,388	256,861	180,160	1.048
6		\$6,419,480	2,693,804	\$46,496,472	0.451	0.22	138,381	1,117,530	331,813	105,209	1.043
	2	\$4,293,933	2,861,227	\$46,861,760	0.455	0.15	126,877	1,246,066	362,733	74,289	1.034
5		\$5,514,680	2,783,514	\$46,926,332	0.456	0.18	132,688	1,187,504	348,796	88,226	1.033
4		\$4,609,880	2,876,827	\$47,409,796	0.462	0.14	125,021	1,261,391	366,291	70,730	1.022
3		\$3,705,080	2,970,067	\$47,892,168	0.467	0.10	117,375	1,335,262	383,788	53,234	1.012
	1	\$2,665,756	3,056,633	\$48,140,728	0.470	0.07	110,919	1,401,569	399,601	37,421	1.007
2		\$2,800,280	3,064,481	\$48,392,016	0.473	0.06	110,118	1,409,122	401,384	35,637	1.002
Base sy	ystem	\$0	3,258,204	\$48,473,844	0.473	0.00	97,020	1,557,106	437,021	0	1.000
1		\$1,895,480	3,160,669	\$48,918,248	0.479	0.02	103,299	1,483,109	419,130	17,891	0.991

Note: AW29-225 at 40 m hub height



# 7 Conclusion and Recommendations

The prospect of wind power in Wainwright is excellent due to the relatively high average wind speed, high wind power density, highly directional winds, and lack of extreme wind events. In anticipation of medium to high fuel price projections over a 20-year project period and even with the conservative nature of the cost and performance assumptions, the economic analyses contained in this report show positive benefit-to-cost ratios for incorporation of wind power into the Wainwright power system.

It is highly recommended and strongly urged that NSB pursue a conceptual design for a wind-diesel power system for Wainwright. Although the prospects of a high penetration wind-diesel system, based on present experience in Alaska with current technology, do not seem favorable at this time, upgrade to high penetration will be a strong consideration in the near future and is the natural evolution of the recommended medium penetration configuration option modeled in this study.



# Appendix A: Notice of Presumed Hazard, Site A





Mail Processing Center Federal Aviation Administration Southwest Regional Office Obstruction Evaluation Group 2601 Meacham Boulevard Fort Worth, TX 76137

Issued Date: 08/19/2011

Kent Grinage North Slope Borough P.O. Box 69 Barrow, AK 99723

# **\*\* NOTICE OF PRESUMED HAZARD \*\***

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Wind Turbine AIN Wind Turbine Site A
Location:	Wainwright, AK
Latitude:	70-38-44.96N NAD 83
Longitude:	160-00-49.41W
Heights:	195 feet above ground level (AGL)
	238 feet above mean sea level (AMSL)

Initial findings of this study indicate that the structure as described exceeds obstruction standards and/or would have an adverse physical or electromagnetic interference effect upon navigable airspace or air navigation facilities. Pending resolution of the issues described below, the structure is presumed to be a hazard to air navigation.

If the structure were reduced in height so as not to exceed 148 feet above ground level (191 feet above mean sea level), it would not exceed obstruction standards and a favorable determination could subsequently be issued.

To pursue a favorable determination at the originally submitted height, further study would be necessary. Further study entails distribution to the public for comment, and may extend the study period up to 120 days. The outcome cannot be predicted prior to public circularization.

If you would like the FAA to conduct further study, you must make the request within 60 days from the date of issuance of this letter.

See Attachment for Additional information.

NOTE: PENDING RESOLUTION OF THE ISSUE(S) DESCRIBED ABOVE, THE STRUCTURE IS PRESUMED TO BE A HAZARD TO AIR NAVIGATION. THIS LETTER DOES NOT AUTHORIZE CONSTRUCTION OF THE STRUCTURE EVEN AT A REDUCED HEIGHT. ANY RESOLUTION OF THE ISSUE(S) DESCRIBED ABOVE MUST BE COMMUNICATED TO THE FAA SO THAT A FAVORABLE DETERMINATION CAN SUBSEQUENTLY BE ISSUED.

# IF MORE THAN 60 DAYS FROM THE DATE OF THIS LETTER HAS ELAPSED WITHOUT ATTEMPTED RESOLUTION, IT WILL BE NECESSARY FOR YOU TO REACTIVATE THE STUDY BY FILING A NEW FAA FORM 7460-1, NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION.

If we can be of further assistance, please contact our office at (907) 271-5863. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2011-WTW-9177-OE.

Signature Control No: 147442963-148168743

(NPH-WT)

Robert van Haastert Specialist

Attachment(s) Additional Information Map(s)

#### Additional information for ASN 2011-WTW-9177-OE

ASN 2011-WTW-9177-OE

AbbreviationsAGL - Above Ground LevelRWY - runwayVFR - Visual Flight RulesMSL - Mean Sea Levelnm - nautical mileIFR - Instrument Flight RulesMSL - Mean Sea Levelnm - nautical mileDA - Decision AltitudeMDA - Minimum Decent AltitudeNEH - No Effect HeightICA - Initial Climb AreaPart 77 - Title 14 (CFR) Part 77, Safe, Efficient Use and Preservation of the Navigable Airspace

Our study has disclosed that this proposed wind turbine at 195 AGL / 238 MSL is within protected surfaces at Wainwright (AWI) airport, AK.

At the proposed height, this structure will penetrate this AWI protected airport surface:

Section 77.19(a) - A height exceeding a horizontal plane 150 feet above the established airport elevation. This would exceed the VFR maneuvering areas for Category A and Category B aircraft (horizontal surface) at AWI by 47 feet

A favorable FAA Determination can be written for a revised 148 AGL/ 191 MSL structure.

Additionally, if the traffic pattern can be restricted entirely south of the airport, then a favorable Determination can be issued at the proposed heights.

If you would like to continue with the original proposed 195 AGL / 238 MSL height, further FAA study will be required. To initiate further FAA study will require notification from you requesting further FAA study. An email request for further FAA study will suffice. Further FAA study will involve a public notice circularization and 37 day comment period. The outcome can not be predicted prior to public circularization. You also have the option at this point to terminate the proposal.

Please email me at Robert.van.Haastert@faa.gov, with your intentions for this aeronautical study.



# Appendix B: Determination of No Hazard, Site B



Mail Processing Center Federal Aviation Administration Southwest Regional Office Obstruction Evaluation Group 2601 Meacham Boulevard Fort Worth, TX 76137

Issued Date: 08/19/2011

Kent Grinage North Slope Borough P.O. Box 69 Barrow, AK 99723

# **\*\* DETERMINATION OF NO HAZARD TO AIR NAVIGATION \*\***

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Wind Turbine AIN Wind Turbine Site B
Location:	Wainwright, AK
Latitude:	70-39-26.03N NAD 83
Longitude:	159-58-09.83W
Heights:	195 feet above ground level (AGL)
	244 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure does not exceed obstruction standards and would not be a hazard to air navigation provided the following condition(s), if any, is(are) met:

As a condition to this Determination, the structure is marked/lighted in accordance with FAA Advisory circular 70/7460-1 K Change 2, Obstruction Marking and Lighting, white paint/synchronized red lights - Chapters 4,12&13(Turbines).

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be completed and returned to this office any time the project is abandoned or:

\_\_\_\_\_ At least 10 days prior to start of construction (7460-2, Part I)

\_\_\_X\_\_ Within 5 days after the construction reaches its greatest height (7460-2, Part II)

Any height exceeding 195 feet above ground level (244 feet above mean sea level), will result in a substantial adverse effect and would warrant a Determination of Hazard to Air Navigation.

This determination expires on 02/19/2013 unless:

- (a) extended, revised or terminated by the issuing office.
- (b) the construction is subject to the licensing authority of the Federal Communications Commission (FCC) and an application for a construction permit has been filed, as required by the FCC, within 6 months of the date of this determination. In such case, the determination expires on the date prescribed by the FCC for completion of construction, or the date the FCC denies the application.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

Additional wind turbines or met towers proposed in the future may cause a cumulative effect on the national airspace system. This determination is based, in part, on the foregoing description which includes specific coordinates and heights . Any changes in coordinates will void this determination. Any future construction or alteration requires separate notice to the FAA.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

Any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light, regardless of its position, should be reported immediately to (800) 478-3576 so a Notice to Airmen (NOTAM) can be issued. As soon as the normal operation is restored, notify the same number.

If we can be of further assistance, please contact our office at (907) 271-5863. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2011-WTW-9178-OE.

Signature Control No: 147442966-148168755 Robert van Haastert Specialist (DNE-WT)

Attachment(s) Map(s)



# Sectional Map for ASN 2011-WTW-9178-OE



# Appendix C: Northwind 100 Wind Turbine



# Northern Power® 100 ARCTIC Community Scale Wind Turbine for Cold Climates



# Not all turbines operate well in extreme environments. The **Northern Power** 100 Arctic is designed for them.



#### Superior by design-Proven through experience

Northern Power Systems knows extreme environments. Our early HR3 turbine model has survived 198 mph winds and -60° C temperatures in Antarctica and still continues to operate. We have shipped more than 20 turbines into Alaska and have produced over 3.8 million kilowatt hours to date. Based on over 30 years of proven wind experience, the Northern Power team has created an arctic turbine model that is truly best in class for cold and icy environments.

The Northern Power 100 (NPS 100) Arctic turbine shares a number of the advanced design elements that make Northern Power's standard NPS 100 the ideal turbine choice in mainstream markets. Additional features and design enhancements in this specialized model ensure optimum performance for your wind project no matter the frigid conditions—so that you can achieve your renewable energy goals whether you are located in the tundra or the Alps.

# Military Bases • Universities • Corporations • Hotels & Resorts • Libraries



# Direct. To Cold Climates Everywhere.

Wind power has been in use around the world for decades. Even so, the mainstream technology used in most wind turbines today is not always the best fit for specialized environments. Arctic conditions where temperatures reach below -20° C (-4° F) and ice buildup is common, can negatively impact wind turbine operations. Demanding environments require specialized solutions and that is why Northern Power Systems has designed the state-of-the-art Northern Power 100 Arctic turbine.

Public Schools • Small Businesses • Greenhouses • Municipal Buildings



# Our Design

#### The right technology: Permanent Magnet Direct Drive (PMDD)

Northern Power's PMDD technology is designed for superior performance in all environments, but it also forms the basis of our superior performance in Arctic conditions.

- >> Low maintenance: Our PMDD technology and simple design architecture are why the NPS 100 Arctic requires only minimal preventative maintenance—once per year. In this way you can set your maintenance schedule to avoid particularly harsh seasons. Additionally, the gearless technology bypasses much of the long-term maintenance issues that are associated with the more conventionally designed gearbox turbines.
- >> Better energy capture: All turbines can make more power in cold environments, but Northern Power has developed an advanced design and control system that takes advantage of the high air densities associated with very cold temperatures.

#### The Right Options

Aside from the obvious benefits of choosing a turbine that has been optimized to operate specifically for your cold weather region, we also offer remote monitoring and wind diesel options.

- SmartView Products: Our web based monitoring and reporting platform supports a range of options—from reporting, supervisory controls, and turbine monitoring from your PC to remote diagnostics services from Northern Power Systems—to ensure optimum turbine performance and avoiding unnecessary service calls.
- >> Wind Diesel: Our state-of-the-art turbine combined with our advanced control systems and years of expertise allow for the seamless integration into your diesel grid, enabling utilities to save fuel, cut emissions, and reduce diesel maintenance.

# Island Communities • Ski Resorts • Auto Dealerships • Rural Utilities • Farms



Your Solution

#### Customized blades for icy conditions

Like most other turbines, the Northern Power 100 Arctic has a safety feature that automatically shuts the turbine off when too much ice has built up on the

blades. But each moment that turbines are not operating translates to lost power and money. To maximize uptime in cold and icy environments, our blades come with a specially formulated **hydro phobic polymer coating** ensuring a **smooth surface** so ice cannot easily build up on the blades. If ice does form, our **black blades** absorb the sun's heat and allow for ice to be shed easily.

#### Advanced turbine design for arctic conditions: Ensuring reliability and accessibility

- >> Blades: Fiberglass reinforced and unique aerodynamic design
- >> Materials: Low temperature castings ensure safe operation of the turbine to -40° C
- >> Heating: Power converter and controls cabinet are heated to maximize operation, expanding possible operating temperatures
- >> Controls: Air density compensation enables maximum energy capture in cold environments
- >> Tubular Tower & Enclosed Heated Nacelle: Maintenance and service personnel are protected from uncomfortable and often dangerous conditions

# Manufacturing Facilities • Remote Villages • Hospitals • Sports Facilities

#### Annual Energy Production: 21-Meter Rotor

Standard Air Density, Rayleigh Wind Speed Distribution



#### **Specifications**

Model	Northern Power 100 ARCTIC
Design Class	Class S (air density 1.34 kg/m³, average annual wind below 8.3 m/s, 50-yr peak gust below 56 m/s)
Design Life	20 years
Hub Height	37 m (121 ft)
Rotor Diameter	21 m (69 ft)
Rated Electrical Power	100 kW, 3 Phase, 480 VAC, 60 Hz
Cut-In Wind Speed	3.5 m/s (7.8 mph)
Gearbox Type	No gearbox (direct drive)
Generator Type	Permanent magnet, passively cooled
Apparent Noise Level	55 dBA at 30 meters (98 ft)

For more information, see the Northern Power 100 ARCTIC Specifications Sheet.

All specifications subject to change without notice.



Northern Power Systems has over 30 years of experience in developing advanced, innovative wind turbines. The company's next generation wind turbine technology is based on a vastly simplified architecture that utilizes a unique combination of permanent magnet generators and direct-drive design. This revolutionary new approach delivers higher energy capture, eliminates drive-train noise, and significantly reduces maintenance and downtime costs. Northern Power Systems is a fully integrated company that designs, manufactures, and sells wind turbines into the global marketplace.

29 Pitman Road Barre, VT 05641 USA

#### 222 Third Street, Suite 3300 Cambridge, MA 02141 USA

1375 South 25<sup>th</sup> Street Saginaw, MI 48601 USA Thurgauerstrasse 40 8050 Zurich, Switzerland

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Printed in the USA with soy based inks on recycled paper containing post consumer fiber. Printed by Phoenix Press, proud owner of a Northern Power 100 wind turbine.

# Appendix D: Aeronautica AW29-225 Wind Turbine



# PRODUCT SPECIFICATIONS

Model 29-225



# 225 Kilowatts of Power -Filling the Mid-Scale Gap

For too long the wind industry has been looking for a turbine that produces much more than 100 kilowatts of power, without having to go to the size or expense of a 600 or 750 kilowatt machine. With the public now aware that wind power can be a viable source of electrical energy, customers want to know what it can do for their local factory, shopping center or school. The Aeronautica 29-225 fills that need.

The origin of this superb turbine goes back 25 years, with the first machines of this class installed in 1984. Over 360 turbines were installed across Denmark, the USA, Germany and Sweden. In California, these Norwin turbines - then manufactured under the *DanWin* trade name - constantly scored among the highest marks for Up-Time Availability and Capacity Factor.

At less than 180' tall on a 40m monopole tower, the 29 -225 is a great stall-regulated wind turbine that will fit on many suburban and urban properties. *It ships in standard shipping containers, making delivery to most locations a breeze.* Erection can be made by readily available smaller cranes that can be mobilized easily. Its simplicity of design has created both a robust and very cost effective turbine for commercial, industrial or municipal needs.

With its low profile and efficient output, the 29-225 is a great match for many distributed generation applications. And *Aeronautica* wind turbines are *all manufactured in the United States*, reducing shipping costs and delivery times.

The industry has been waiting for a USbuilt turbine like this for applications such as community wind, municipal, industrial, tribal lands, schools, military, wind parks and more. The wait is now over!

Fast Facts: Orientation: *Upwind* Rotor Diameters: *29m* Rotor Speed: *37.9 RPM at Load* Hub Height: *30, 40, 50m* Regulation: Stall Regulated with Fail-Safe Tip Brakes Blades: *Fiber Reinforced Polyester*   225kW design for Class I, II or III winds

◆ Low overall height profiles: from 146'(44.5m) to 211'(64.5m)

Stall Regulated simplicity

 Erection and transport via common equipment - ships in standard containers!





#### 225kW System Specifications:

LLOKW Oyster	n opcomoditions.
Wind Class:	IEC Class IA
Blades:	3 blades, upwind orientation,
	Fiberglass reinforced polyester
Rotor:	
Power regulation:	Stall Regulation
Rotor size:	29m diameter
Rotor speed:	37.9 rpm at Load
Swept area:	664 m² (7,145 ft²)
Tilt angle:	5°
Coning angle:	0°
Brake, normal:	Fail Safe Mechanical Disk Brake
Brake, emergency:	Turning Blade Tip Brakes
Pitch Angle:	Approximately 2.3 °, adjusted during run-in
Mechanical brake:	Fail-safe type disk brake on high-speed shaft
Brake torque:	2x of nominal torque (1x by normal braking sequence)
RPM max. value:	1920 (60 Hz), 1600 (50 Hz), on the high-speed shaft

225 kW

#### **Generator:**

Nom. Electric Power: Generator: Generator speed: Loss in generator: Generator cut-in: Grid connection:

# Weights: Rotor w/blades:

Nacelle (excl. Rotor):	
Mass (total):	

#### **Certification:**

Previously Certified by GL **Current Certification Pending** 

Approx. 10,600 lbs ( 4,818 kg)

Approx. 15,260 lbs ( 6,936 kg) Approx. 25,860 lbs (11,754 kg)

Single Wound Synch. Induction, 4 pole DW, IP54

1800 (60 Hz) or 1500 (50 Hz) rpm

Thyristor controlled gradual cut-in

Approx. 3% at Full Load

480 v, 60 Hz (std) or 50 Hz



Yaw motors: Yaw brakes: Yaw bearing: Cut-in wind speed: Cut-out wind speed: Survival wind speed: Controller: Noise:

2 pcs. electrical drives 3 pcs. active hydraulic brakes Slide bearing 4 m/s, based on 10 min average 25 m/s (60mph) based on 5 min average 67 m/s (150 mph) **CC Electronics** Operating Temp. Range: -20C TO +50C (Hi and Low Temp. Options Available) 98 dBA Sound Power (at Nacelle) 8 m/s

#### **Monopole Tower**

Construction: Nacelle access: Surface treatment:

Conical Steel, White, 30, 40, 50m towers available Interior tower ladder through locked door In accordance with ISO 12944 Laser inspected flanges Ultrasonic inspection of raw materials and welds

#### SCADA:

Included in electrical cabinets at base of tower Remote surveillance and operation via Internet or ADSL

#### Safety:

Induction generator has inherent anti-islanding Fail-safe hydraulic disk brake Grid monitoring for shutdown and operational performance Fall protection ladder system Lightning protected

Warranty: Two year standard warranty. Extended warranties available.

Service Agreements: Annual Service Contracts are required under warranty period and are available upon request

Shipping: All Prices are FOB our plants







The Power and Energy Curves shown are valid for 1.225kg/m3 air density, clean blades and undisturbed horizontal air flow. In the stall range, at wind speeds over 16 m/s, the power factor may deviate from that shown. For the Energy Graph, a Rayleigh wind speed distribution and 100% availability is assumed



- 500,000 sf Nacelle Manufacturing Facility at GOSS International, Durham NH
- 750kW turbine on assembly line
- Main Headquarters, Plymouth, MA
- Aeronautica 750 high above Chicago



America's Wind Turbine Company

11 Resnik Road, Plymouth, MA 02360 1-800-360-0132 www.AeronauticaWind.com