Point Lay 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 Point Lay.

Contents

Executive Summary

The measured high Class 4 to Class 5 wind resource in Point Lay, 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 6.63 m/s (14.8 mph) at 30 meters elevation. Additionally, the test location experiences low turbulence and relatively low probability of extreme wind events (the latter a reference to Wainwright data), making Point Lay a superior candidate for a wind energy project.

Two potential wind turbine sites were investigated for this study: Site A, located on a fairly low but well-exposed north-south trending hill immediately north of the village and immediately south of the mouth of the Kokolik River; and site B, located in a well exposed area south of the village between the village and the airport. Although Site A is higher and more exposed than Site B, for this study each site was considered to have equivalent wind resource potential, which was collected near Site B. Site A would require construction of an access road and distribution line extension, but has not turbine height restrictions. Site B would require less road and distribution line construction but has an FAA-imposed height restriction due to proximity to the airport

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 Point Lay. 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 Point Lay, 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 Point Lay, 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 planned new Point Lay 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 Point Lay; the Wainwright 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 Point Lay, 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 Point Lay'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

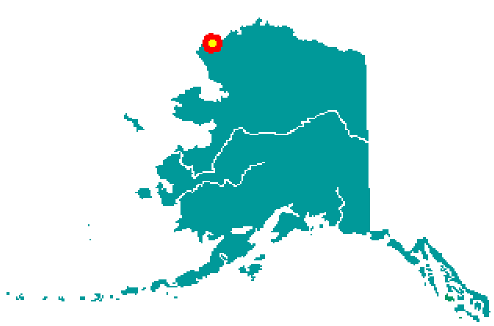
This study, which was paid for with Alaska Energy Authority funds made available through the Alaska Renewable Energy Fund Program and with matching funds from the North Slope Borough, investigates and evaluates wind turbine power options in Point Hope, Point Lay, and Wainwright. The scope of work of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

Point Lay is one of the more recently established Inupiaq villages on the Arctic coast and has historically been occupied year-round by a small group of one or two families. They were joined in 1929-30 by several more families from Point Hope. The deeply-indented shoreline has prevented effective bowhead whaling, but the village participates in beluga whaling. In 1974, the village moved from the old site on a gravel barrier island just offshore. The old village site is now used as a summer hunting camp. Some residents of Barrow and Wainwright relocated to Point Lay in the mid-1970s. Later that decade, due to seasonal flooding from the Kokolik River, the village relocated again to a site near



the Air Force Distance Early Warning station to the south. Homes were relocated to the new town site.

Point Lay is a traditional Inupiat Eskimo village, with a dependence upon subsistence activities. The sale and importation of alcohol is banned in the village. According to Census 2010, there were 70 housing units in the community and 60 were occupied. Its population of 189 people is 88 percent Alaska Native, 10 percent Caucasian, and 2 percent Hispanic, Pacific Islander, multi-racial and other.

Water is obtained from a lake near the community and is treated and stored in a tank. Households have water delivered to home tanks, which allows running water for the kitchen. Electricity is provided by North Slope Borough. There is one school located in the community, attended by 87 students. Local hospitals or health clinics include Point Lay Clinic. Emergency Services have coastal and air access. Emergency service is provided by 911 Telephone Service volunteers and a health aide. Auxiliary healthcare is provided by Point Lay Volunteer Fire Dept. (907-833-2714). A public 4,500' long by 100' wide gravel airstrip, owned by the U.S. Air Force, provides Point Lay's only year-round access. Marine and land transportation provide seasonal access.

Most year-round employment opportunities are with the borough government. Subsistence activities provide food sources. Seals, walrus, beluga, caribou, and fish are staples of the diet.

The 2005 to 2009 American Community Survey estimated 59 (MOE +/-25) residents as employed. The ACS surveys established that average median household income (in 2009 inflation-adjusted dollars) was $46,875 (MOE +/-$36,041). The per capita income (in 2009 inflation-adjusted dollars) was $14,067 (MOE +/-$4,832). About 16.8% (MOE +/-19.2%) of all residents had incomes below the poverty level.

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

1.3 Climate

Point Lay is located just south of the mouth of the Kokolik River, about 300 miles southwest of Barrow. The climate is arctic. Temperatures range from -55 F in winter to 78 °F in summer. Precipitation is light, averaging seven inches annually with 21 inches of snow. The Chukchi Sea is ice-free from late June until 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:
    - 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 Point Lay is very good, measured at high wind power class 4 (good) to low wind power class 5 (excellent). In addition to strong average wind speed and wind power density, the site experiences highly directional prevailing winds and low turbulence.

A thirty meter NRG met tower was supplied to the Point Lay's Cully Corporation in 2006 by the National Renewable Energy Laboratory's (NREL) under their anemometer loan program. A number of details of the project are not known, including the rationale for choosing the test site, but the location of the tower is desirable for a wind resource assessment as it is well away from obstructions such as buildings and well exposed to winds from all directions. Although data collection in 2006 and 2007 was slightly short of twelve months, the met tower was returned to operational status in June 2011, enabling additional data collection to strengthen the earlier data set.

2.1 Met tower data synopsis

Data dates	October 5, 2006 to September 11, 2007
Wind power class	High 4 (good) to low 5 (excellent)
Power density mean, 30 meters	403 W/m^2
Wind speed mean, 30 meters	6.63 m/s
Weibull distribution parameters	k = 1.74, c = 7.44 m/s
Wind shear power law exponent	0.142 (moderate), June to September data only
Roughness class	0.54 (snow surface), June to September only
IEC 61400-1, 3rd ed. classification	Class III-c (likely, based on nearby Wainwright data)
Turbulence intensity, mean	0.072 (at 15 m/s)
Calm wind frequency	23% (less than 3.5 m/s)

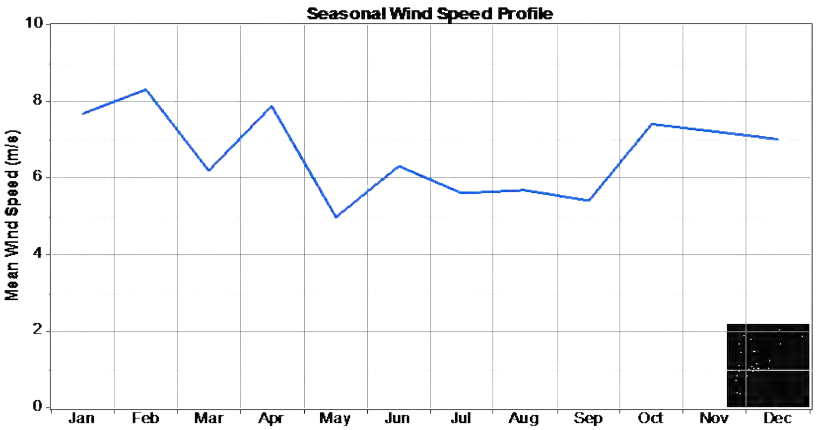
2.2 Data Recovery

Specific sensor data recovery problems typical of Alaska met tower operations, such as freezing rain, hoarfrost, and rime icing, likely occurred to some extent during the nearly one year met tower study in Point Lay, but original data was not available, other than in an Excel file with data from June 7 through September 11, 2007. Although this three month data set could be reviewed for data loss typically due to atmospheric icing conditions, such weather does not occur during the months of June, July, August and (early) September. All met tower data (including that not included in the Excel file download of original data) is summarized in several WindPRO software reports prepared by the National Renewable Energy Laboratory.

2.3 Wind Speed

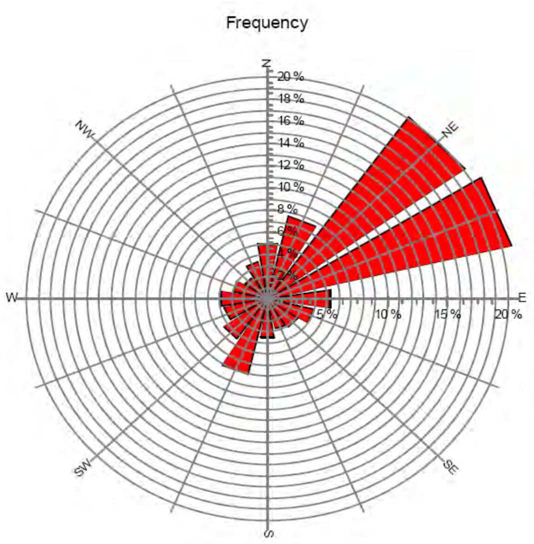
Wind data collected from the met tower and summarized in the NREL WindPRO reports, from the perspective of both mean wind speed and mean power density, indicates an excellent wind resource. Note that temperature data was not included in the analysis of power density. Given the extremely cold temperatures, and hence high air densities, of Point Lay, true wind power density will be higher yet, categorizing Point Lay more solidly as wind power class 5. For purposes of analysis, wind data monthly wind speed summaries contained in the 30 meter WindPRO report, along with other statistical data gleaned from the three-month Excel data, was used to synthesize a virtual data set. This enabled certain mathematic and graphical analyses not contained in the WindPRO reports.

Wind speed profile (30 meter height)



2.4 Wind Rose

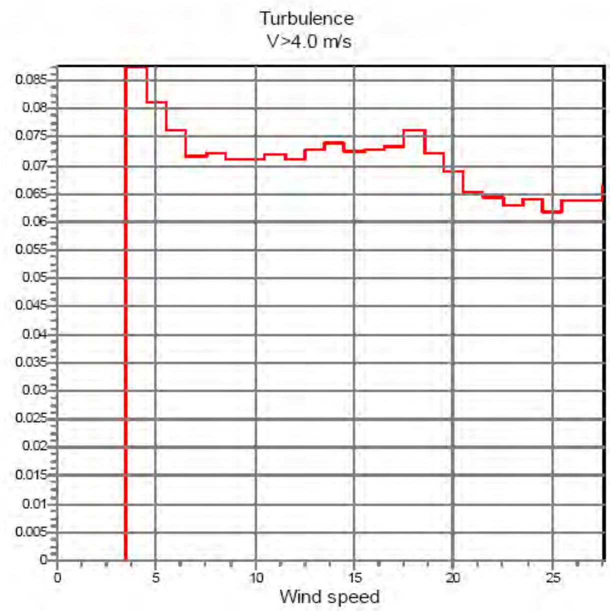
Wind frequency rose data (from NREL's WindPRO report) indicates highly directional winds from northeast to east-northeast. Although the NREL report did not show a power density rose, Wainwright data confirms the Point Lay directional frequency and indicates that power winds are nearly exclusively northeast to east-northeast, which presumably is representative of Point Lay.

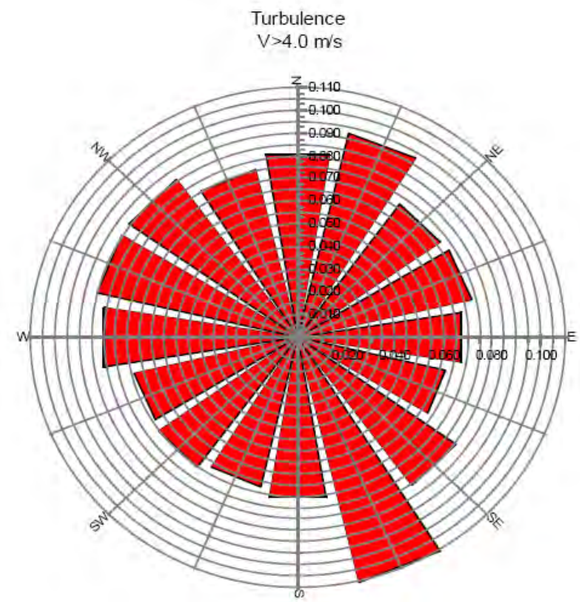


2.5 Turbulence Intensity

From the NREL report, turbulence intensity at the Point Lay test site is well within acceptable standards with an IEC 61400-1, 3rd edition (2005), classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.072

Turbulence graphs





3 Wind Project Sites

NSB requested that two wind turbine sites be identified in Point Lay. On June 24, 2011, Ross Klooster of WHPacific, Doug Vaught of V3 Energy LLC, and Max Ahgeak of NSB Public Works Dept. traveled to Point Lay and met with City of Point Lay and Cully 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 Cully Corporation land were chosen, identified as Site A and Site B in the Google Earth image below. The Cully Corporation controls much of the land surrounding Point Lay and has championed wind power in Point Lay for a number of years, including working with NREL in 2006 for the met tower that measured the local wind resource. With this in mind, locating wind turbines on Cully Corporation land is highly desirable.

Point Lay site options, Google Earth image

3.1 Site A

Site A is located on a fairly low but well-exposed north-south trending hill immediately north of the village and immediately south of the mouth of the Kokolik River. Site A presents a number of positive features for a wind power site including a large enough area for several wind turbines, clear exposure in all directions, relative proximity to existing three-phase power distribution, and dry tundra. Additionally, and very importantly, the Federal Aviation Administration (FAA) made a determination of no hazard for wind turbines up to 195 ft. (60 meters) above ground level, which enables significant flexibility with turbine selection (refer to Appendix A). Less positive features of Site A include its proximity to Point Lay residences and the possible preclusion of future residential development along this ridge, which is the natural direction of future housing expansion for the village.

Point Lay Site A

3.2 Site B

Site B is located in a well exposed area south of the village between the village and the airport. Positive features of Site B for wind power development is that it is on the "industrial" side of Point Lay, has good wind exposure in all directions, is very near existing three-phase power distribution, and would require minimal access improvements. Adversely, however, an FAA determination of notice of presumed hazard for wind turbines at Site B indicated that turbines would be restricted to 162 ft. AGL, limiting turbine options to the Northwind 100B/21 or the Aeronautica AW29-225 to a 30 meter tower (refer to Appendix B). The Site B area also is a bit constrained, which may restrict the option of future wind power expansion at this site.

Point Lay Site B

Point Lay Sites A and B comparison table

Wind Turbine Site	Advantages	Disadvantages
A	Cully Corp. land	Possible area of village expansion
	Site large enough to accommodate several turbines	Turbines will be in view and possible auditory range of village residents
	Relatively dry site; likely good geotech conditions	Possible avian conflicts with near proximity to mouth of the Kokolik River
	FAA Determination of No Hazard (DNH) for turbines up to 195 ft (59.5 meters) AGL	Somewhat limited space for future expansion
	Short road and distribution line required	
B	Cully Corp. land	FAA determination of Notice of Presumed Hazard (NPH) for turbines exceeding 162 ft AGL
	Short road and distribution line required	Somewhat limited space for future expansion
	Location is on the "industrial" side of the village with less viewshed and possible noise issues	
	Relatively dry site; likely good geotech conditions	

3.3 Other Site Options

Other than Sites A and B, the only other realistic area for wind turbines in Point Lay is the terrain east of the village. Although expansive and easily large enough to contain many wind turbines, it is characterized by very marshy and wet conditions which would require considerable fill material for construction. Additionally, with prevailing northeasterly to easterly winds, turbines east of the village would have to be located reasonably distant to avoid noise and downwind ice throw problems. Also, the absence of electric power distribution east of the village presents a further disadvantage and would increase development costs.

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.

Categories of wind-diesel penetration levels

Penetration	Penetration 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.

Choosing the ideal wind penetration for Point Lay 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 Point Lay 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 wind-diesel 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 Point Lay, 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 Point Lay.

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 Point Lay, 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 Point Lay 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 Point Lay consists of five Caterpillar 3406B diesel generators and one Caterpillar 3412 diesel generator, all rated at 330 kW. This power plant is due to be replaced in 2013, however, with four Caterpillar 3508C diesel generators, all rated at 600 kW. Because the power plant will be upgraded soon, wind-diesel system modeling for this report is based on the configuration of the new plant.

Point Lay powerplant diesel generators (planned, 2013)

Generator	Electrical Capacity	Diesel Engine Model
1	600 kW	Caterpillar 3508C
2	600 kW	Caterpillar 3508C
3	600 kW	Caterpillar 3508C
4	600 kW	Caterpillar 3508C

The control system for the new power plant will consist of Woodward EasyGen 3200P2 generator controller/protective relay package for each of the four new Cat 3508C generators, General Electric Multiline 350 feeder protection package for each of the two feeders, and an Allen Bradley 1769 PLC for automated system control.

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 Point Lay'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 Point Lay 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 Point Lay are:

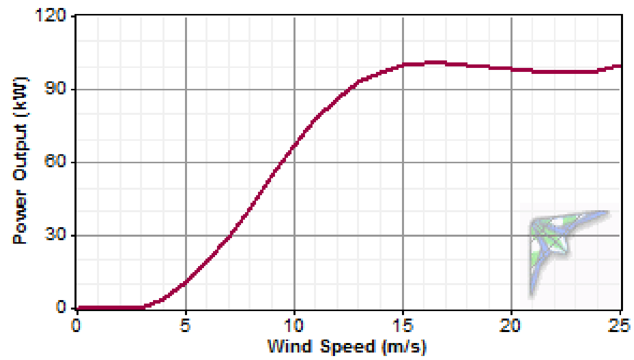
- Alternating current (AC) generator; synchronous or asynchronous are acceptable
- Cold-climate capable (rated to -40° C) with appropriate use of materials, lubricants and heaters
- IEC Class II rated
- A "known" turbine with an existing track record of installed operation
- Suitable for marine environments
- 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: http://www.northernpower.com/ and in Appendix C of this report.

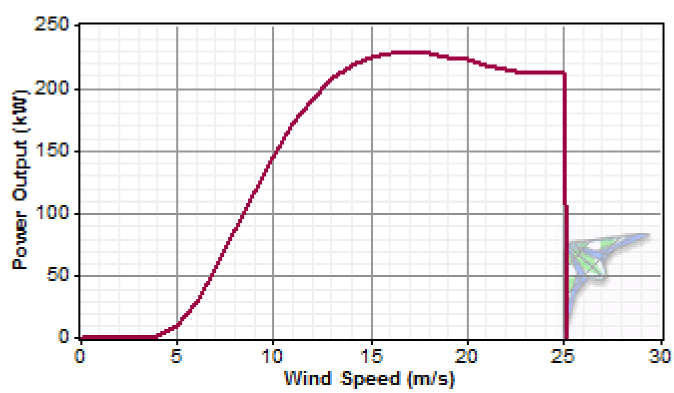
NW100 wind turbine

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 http://aeronauticawind.com/aw/index.html and in Appendix D of this report.

Aeronautica AW29-225	*AW29-225 power curve*
	

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 well in the wind regime of Point Lay with excellent capacity factors and annual energy production.

Turbine capacity factor comparison

					100% availability		90% availability		80% availability	
Turbine Model	Rated Output (kW)	Hub Height (m)	Tip Heigh t (m)*	Tip Heigh t (ft.)*	Annual Energy (MWh)	Capacit y Factor (%)	Annual Energy (MWh)	Capacit y Factor (%)	Annual Energy (MWh)	Capacit y Factor (%)
NW100B/21	100	37	47.5	156	282.5	31.3	254.3	28.2	226.0	25.0
AW29-225	225	30	44.5	146	552.4	28.0	497.2	25.2	441.9	22.4
	225	40	54.5	179	594.3	30.2	534.9	27.2	475.4	24.2
	225	50	64.5	212	627.2	31.8	564.5	28.6	501.8	25.4

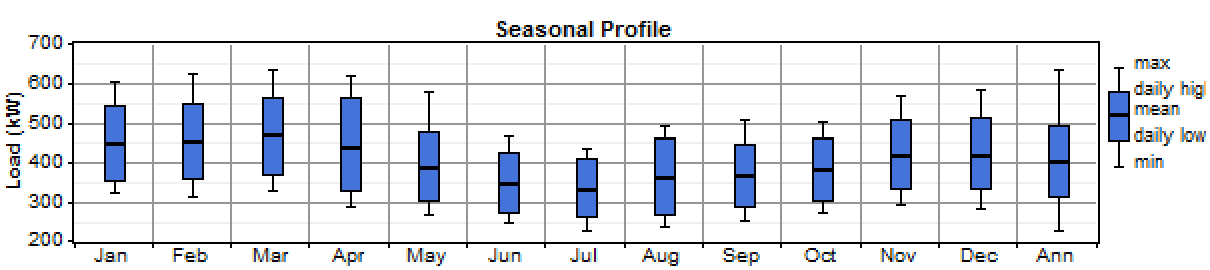
*Note: assumes base of turbine tower at ground level

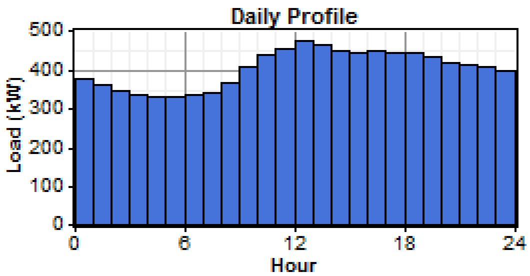
5.3 Modeling

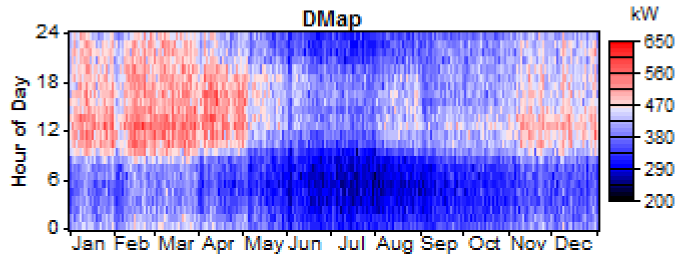
Wind turbine and system performance modeling of wind-diesel configurations in Point Lay was accomplished with HOMER software. This software enables static modeling of a power system to demonstrate energy balances and fuel displacement with introduction of wind power. A limitation of the software is that 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 Point Lay 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, 2009 and 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 402 kW average load with a 632 kW peak load and approximately 230 kW minimum load. Graphical representations of the electric load are shown below.

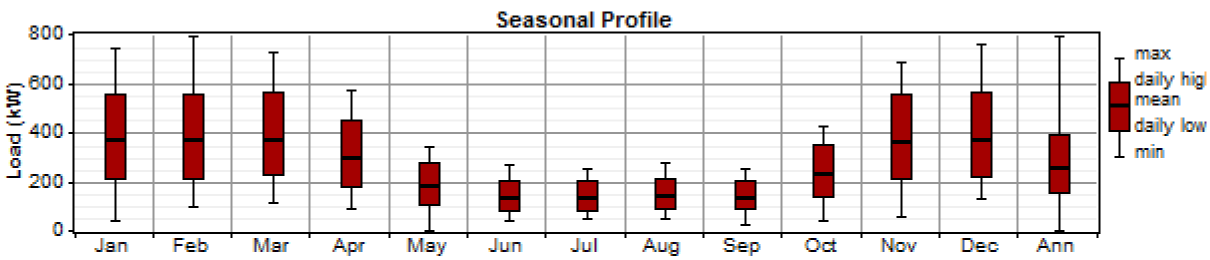


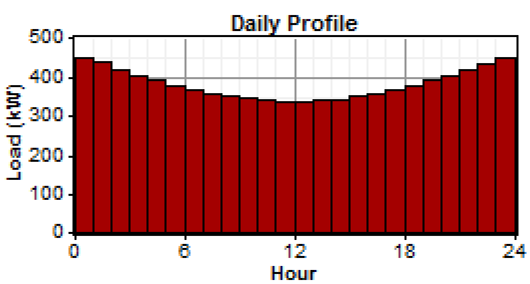


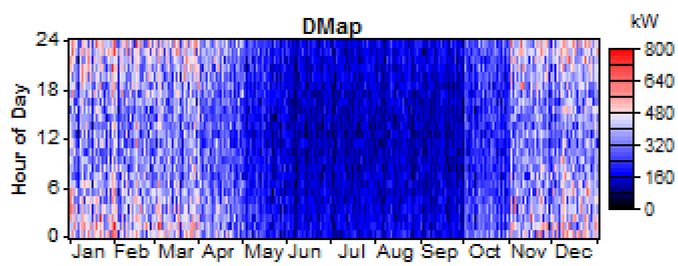


5.3.2 Thermal Load

The thermal load available to the diesel generator heat recovery system was estimated based on better-documented thermal loads in other villages, the size of Point Lay'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.







5.3.3 Diesel Generators

The Point Lay power plant is scheduled for replacement in 2013 at a new location and with four new diesel generators and switchgear. Because the new diesel generators will be redundant in capacity, the HOMER model was constructed with three (of the four new) 600 kW Caterpillar 3508C diesel generators. For cost modeling purposes, AEA in their Renewable Energy Fund grant program assumes a generator O&M cost of $0.020/kWh. This was converted to $8.00/operating hour for each diesel generator for use in the HOMER software model (based on Point Lay's modeled average electrical load of 402 kW).

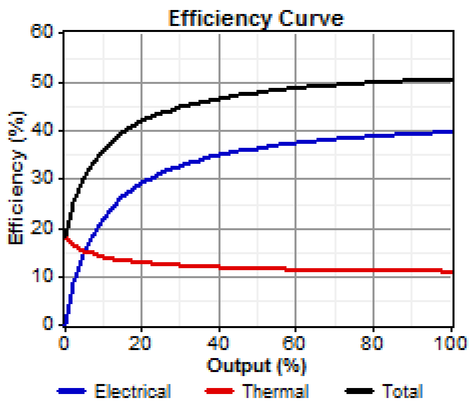
Manufacturer fuel curves for the diesel generators, provided by David Lockard of AEA in an Excel file entitled *Cat C9M C18M 3508 3512 3456 Mar* 20081, were used in the HOMER models. In addition, the diesel engines in the modeling runs were set to "optimize", which HOMER interprets as use of the most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

Diesel generator HOMER modeling information

Diesel generator	Caterpillar 3508C	Caterpillar 3508C	Caterpillar 3508C
HOMER model identification	Cat 1	Cat 2	Cat 3
Power output (kW)	600	600	600
Intercept coefficient (L/hr/kW rated)	0.02368	0.02368	0.02368
Slope (L/hr/kW output)	0.2377	0.2377	0.2377
Minimum electric load (%)	10	10	10
Heat recovery ratio (percent of waste heat that can serve the thermal load)	18	18	18

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



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. Basic economic modeling assumptions of this feasibility study that are default assumptions of Alaska Energy Authority in their Renewable Energy Fund grant program are a 20 year project life and a three percent discount or interest rate (the cost of money). Based on Point Lay's 2009 and 2010 PCE data, an annual utility fixed operations and maintenance (O&M) cost of $500,000 is assumed.

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.

Wind turbine cost assumptions

	Single Turbine		450-500 kW installed turbine capacity	
	NW100B (100 kW)	AW29-225 (225 kW)	NW100B (100 kW)	AW29-225 (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	$655,000	$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 $6.79/gallon ($1.80/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 $6.79/gallon price reflects the average value of all fuel prices between the 2013 (assumed project start year) fuel price of $5.50/gallon and the 2032 (the 20 year project end year) fuel price of $7.75/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 $10.73/gallon ($2.84/Liter). For the low price projection, the average 2013 to 2032 three-year moving average price is $3.24/gallon ($0.86/Liter). Note also that heating fuel in HOMER is priced the same as diesel fuel.

Fuel cost table

Cost Scenario	2013 (/gal)	2032 (/gal)	Average (/gallon)	Average (/Liter)
Medium	$5.50	$7.75	$6.79	$1.80
High	$6.91	$12.64	$10.73	$2.84
Low	$4.32	$2.92	$3.24	$0.86

ISER, MA3 cost projections

6.3 Modeling Assumptions

In the HOMER modeling simulations, the annual average wind speed was reduced to 6.00 m/s (from a measured 6.63 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	$500,000/year (average of 2009 and 2010 PCE Reports)
Operating Reserves	
Load in current time step	10%
Wind power output	50%
Fuel Properties (both types)	
Heating value	42.5 MJ/kg (126,000 Btu/gal)
Density	820 kg/m^3 (6.84 lbs./gal)
Diesel Generators	
Generator capital cost	$150,000
O&M cost	$8.00/hour ($0.02/kWh)
Time between overhauls	20,000 hours
Overhaul cost	$75,000
Minimum load ratio	10% or 60 kW; based on AVEC's operational experience of 50 kW minimum diesel loading with their wind-diesel systems
Schedule	Optimized
Wind Turbines	
Availability	Approx. 82%
Scaled annual average wind speed	6.00 m/s (6.63 m/s non-scaled, from met tower data)
O&M cost	$0.0469/kWh (translated to $/year based on 26% turbine CF)

- NW100B/21 — $10,700/yr/turbine
- AW 29-225 — $24,000/yr/turbine

6.4 Wind Power Site Cost Assumptions

The base or comparison scenario, which does not include wind turbines, is construction of the new power plant with four Caterpillar 3508C generators valued at $150,000 each. Additionally, a capital cost of $150,000 is assumed for the new SCADA system. The cost of the power plant itself is not modeled as it is a necessary expense in any scenario.

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 new 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 $524,000 for Site A and $309,000 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.

Wind project cost assumptions

	Base	Site A	Site B
SCADA system for new diesel generators	$150,000		
SCADA upgrade, SLC, boiler		$150,000	$150,000
3Φ distribution line extension		$144,000	$64,000
Road extension		$180,000	$45,000
Permitting and project mgmt.		$50,000	$50,000
	$150,000	$524,000	$309,000
Distribution line distance (miles)		0.36	0.16
Road distance (miles)		0.36	0.09

Notes:

Distribution line, $400K/mi

Road, $500K/mi

6.5 Site A Project Economics

6.5.1 Medium Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
	2	$4,419,933	2,297,079	$38,594,668	0.592	0.17	174,942	744,008	242,787	53,364	1.023
	3	$6,048,110	2,189,002	$38,614,936	0.593	0.24	159,150	686,526	223,428	72,723	1.023
5		$5,640,680	2,232,376	$38,852,788	0.597	0.20	174,804	705,247	232,510	63,641	1.016
4		$4,735,880	2,297,855	$38,922,152	0.599	0.16	178,197	744,151	243,685	52,466	1.014
	4	$7,676,287	2,107,562	$39,031,484	0.601	0.30	142,745	645,771	208,327	87,825	1.012
7		$7,450,280	2,128,771	$39,121,012	0.602	0.27	159,804	650,991	214,213	81,939	1.009
3		$3,831,080	2,372,867	$39,133,352	0.603	0.12	175,266	794,629	256,247	39,904	1.009
	1	$2,791,756	2,448,868	$39,224,724	0.604	0.08	169,469	847,052	268,566	27,586	1.007
2		$2,926,280	2,451,944	$39,405,012	0.608	0.08	169,003	850,713	269,410	26,742	1.002
Base system		$600,000	2,613,749	$39,485,984	0.609	0.00	155,736	965,197	296,151	0	1.000
9		$9,259,880	2,045,406	$39,690,348	0.613	0.33	145,223	608,716	199,191	96,960	0.995
1		$2,021,480	2,532,205	$39,694,300	0.613	0.04	162,359	907,712	282,714	13,438	0.995

Note: AW29-225 at 40 m hub height

6.5.2 High Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
	4	$7,676,287	2,927,618	$51,231,844	0.750	0.30	142,745	645,771	208,327	87,825	1.109
9		$9,259,880	2,829,502	$51,355,728	0.753	0.33	145,223	608,716	199,191	96,960	1.107
7		$7,450,280	2,971,998	$51,666,104	0.759	0.27	159,804	650,991	214,213	81,939	1.100
	3	$6,048,110	3,068,505	$51,699,716	0.759	0.24	159,150	686,526	223,428	72,723	1.099
5		$5,640,680	3,147,629	$52,469,440	0.774	0.20	174,804	705,247	232,510	63,641	1.083
	2	$4,419,933	3,252,788	$52,813,204	0.780	0.17	174,942	744,008	242,787	53,364	1.076
4		$4,735,880	3,257,097	$53,193,252	0.788	0.16	178,197	744,151	243,685	52,466	1.068
3		$3,831,080	3,381,558	$54,140,116	0.806	0.12	175,266	794,629	256,247	39,904	1.050
	1	$2,791,756	3,506,050	$54,952,924	0.821	0.08	169,469	847,052	268,566	27,586	1.034
2		$2,926,280	3,512,449	$55,182,652	0.826	0.08	169,003	850,713	269,410	26,742	1.030
1		$2,021,480	3,645,079	$56,251,040	0.846	0.04	162,359	907,712	282,714	13,438	1.010
Base system		$600,000	3,779,520	$56,829,712	0.857	0.00	155,736	965,197	296,151	0	1.000

Note: AW29-225 at 40 m hub height

6.5.3 Low Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
Base system		$600,000	1,560,072	$23,809,924	0.385	0.00	155,736	965,197	296,151	0	1.000
1		$2,021,480	1,526,339	$24,729,546	0.403	0.04	162,359	907,712	282,714	13,438	0.963
	1	$2,791,756	1,493,338	$25,008,856	0.408	0.08	169,469	847,052	268,566	27,586	0.952
2		$2,926,280	1,493,411	$25,144,456	0.411	0.08	169,003	850,713	269,410	26,742	0.947
3		$3,831,080	1,461,166	$25,569,544	0.419	0.12	175,266	794,629	256,247	39,904	0.931
	2	$4,419,933	1,433,266	$25,743,304	0.422	0.17	174,942	744,008	242,787	53,364	0.925
4		$4,735,880	1,430,847	$26,023,272	0.428	0.16	178,197	744,151	243,685	52,466	0.915
5		$5,640,680	1,405,128	$26,545,436	0.438	0.20	174,804	705,247	232,510	63,641	0.897
	3	$6,048,110	1,394,067	$26,788,306	0.442	0.24	159,150	686,526	223,428	72,723	0.889
7		$7,450,280	1,366,623	$27,782,174	0.461	0.27	159,804	650,991	214,213	81,939	0.857
	4	$7,676,287	1,366,358	$28,004,236	0.465	0.30	142,745	645,771	208,327	87,825	0.850
9		$9,259,880	1,336,702	$29,146,636	0.487	0.33	145,223	608,716	199,191	96,960	0.817

Note: AW29-225 at 40 m hub height

6.5.4 Medium Fuel Price Projection, 100% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
	3	$6,048,110	2,098,374	$37,266,608	0.567	0.29	153,815	641,650	210,162	85,989	1.060
	4	$7,676,287	2,002,337	$37,466,000	0.571	0.35	133,173	597,946	193,162	102,989	1.054
	2	$4,419,933	2,224,510	$37,515,020	0.572	0.20	176,615	702,073	232,150	64,001	1.053
5		$5,640,680	2,156,582	$37,725,168	0.576	0.24	174,788	663,197	221,396	74,755	1.047
7		$7,450,280	2,039,803	$37,797,388	0.577	0.32	153,413	608,038	201,176	94,975	1.045
4		$4,735,880	2,232,349	$37,947,592	0.580	0.19	180,940	705,064	234,083	62,068	1.041
9		$9,259,880	1,943,938	$38,180,764	0.584	0.38	135,313	563,264	184,565	111,587	1.034
3		$3,831,080	2,321,594	$38,370,536	0.588	0.14	178,799	762,701	248,745	47,406	1.029
	1	$2,791,756	2,409,550	$38,639,776	0.593	0.10	172,324	822,408	262,809	33,342	1.022
2		$2,926,280	2,417,631	$38,894,516	0.598	0.10	171,488	829,208	264,385	31,767	1.015
1		$2,021,480	2,514,691	$39,433,728	0.608	0.05	163,615	896,810	280,165	15,986	1.001
Base system		$600,000	2,613,749	$39,485,984	0.609	0.00	155,736	965,197	296,151	0	1.000

Note: AW29-225 at 40 m hub height

6.6 Site B Project Economics

6.6.1 Medium Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
5		$5,425,680	2,232,376	$38,637,788	0.593	0.20	174,804	705,247	232,510	63,641	1.022
4		$4,520,880	2,297,855	$38,707,152	0.594	0.16	178,197	744,151	243,685	52,466	1.020
	2	$4,170,474	2,325,356	$38,765,888	0.596	0.15	174,095	760,523	246,927	49,225	1.019
	3	$5,782,369	2,224,551	$38,878,064	0.598	0.22	160,791	704,603	228,638	67,514	1.016
7		$7,235,280	2,128,771	$38,906,008	0.598	0.27	159,804	650,991	214,213	81,939	1.015
3		$3,616,080	2,372,867	$38,918,352	0.598	0.12	175,266	794,629	256,247	39,904	1.015
2		$2,711,280	2,451,944	$39,190,016	0.604	0.08	169,003	850,713	269,410	26,742	1.008
	1	$2,558,579	2,464,007	$39,216,780	0.604	0.08	168,368	856,528	270,778	25,373	1.007
	4	$7,394,264	2,148,164	$39,353,524	0.607	0.28	146,060	664,798	214,229	81,922	1.003
9		$9,044,880	2,045,406	$39,475,348	0.609	0.33	145,223	608,716	199,191	96,960	1.000
1		$1,806,480	2,532,205	$39,479,296	0.609	0.04	162,359	907,712	282,714	13,438	1.000
Base system		$600,000	2,613,749	$39,485,984	0.609	0.00	155,736	965,197	296,151	0	1.000

Note: AW29-225 at 30 m hub height

6.6.2 High Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
9		$9,044,880	2,829,503	$51,140,728	0.749	0.33	145,223	608,716	199,191	96,960	1.111
7		$7,235,280	2,971,998	$51,451,108	0.754	0.27	159,804	650,991	214,213	81,939	1.105
	4	$7,394,264	2,991,457	$51,899,584	0.763	0.28	146,060	664,798	214,229	81,922	1.095
5		$5,425,680	3,147,629	$52,254,444	0.770	0.20	174,804	705,247	232,510	63,641	1.088
	3	$5,782,369	3,124,561	$52,267,944	0.770	0.22	160,791	704,603	228,638	67,514	1.087
4		$4,520,880	3,257,097	$52,978,252	0.784	0.16	178,197	744,151	243,685	52,466	1.073
	2	$4,170,474	3,297,358	$53,226,832	0.788	0.15	174,095	760,523	246,927	49,225	1.068
3		$3,616,080	3,381,558	$53,925,116	0.802	0.12	175,266	794,629	256,247	39,904	1.054
2		$2,711,280	3,512,450	$54,967,656	0.822	0.08	169,003	850,713	269,410	26,742	1.034
	1	$2,558,579	3,529,899	$55,074,560	0.824	0.08	168,368	856,528	270,778	25,373	1.032
1		$1,806,480	3,645,079	$56,036,044	0.842	0.04	162,359	907,712	282,714	13,438	1.014
Base system		$600,000	3,779,520	$56,829,712	0.857	0.00	155,736	965,197	296,151	0	1.000

Note: AW29-225 at 30 m hub height

6.6.3 Low Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
Base system		$600,000	1,560,072	$23,809,924	0.385	0.00	155,736	965,197	296,151	0	1.000
1		$1,806,480	1,526,339	$24,514,546	0.399	0.04	162,359	907,712	282,714	13,438	0.971
	1	$2,558,579	1,500,605	$24,883,794	0.406	0.08	168,368	856,528	270,778	25,373	0.957
2		$2,711,280	1,493,411	$24,929,456	0.407	0.08	169,003	850,713	269,410	26,742	0.955
3		$3,616,080	1,461,167	$25,354,546	0.415	0.12	175,266	794,629	256,247	39,904	0.939
	2	$4,170,474	1,446,815	$25,695,424	0.421	0.15	174,095	760,523	246,927	49,225	0.927
4		$4,520,880	1,430,847	$25,808,272	0.423	0.16	178,197	744,151	243,685	52,466	0.923
5		$5,425,680	1,405,128	$26,330,436	0.433	0.20	174,804	705,247	232,510	63,641	0.904
	3	$5,782,369	1,411,081	$26,775,682	0.442	0.22	160,791	704,603	228,638	67,514	0.889
7		$7,235,280	1,366,623	$27,567,176	0.457	0.27	159,804	650,991	214,213	81,939	0.864
	4	$7,394,264	1,385,958	$28,013,812	0.466	0.28	146,060	664,798	214,229	81,922	0.850
9		$9,044,880	1,336,703	$28,931,636	0.483	0.33	145,223	608,716	199,191	96,960	0.823

Note: AW29-225 at 30 m hub height

6.6.4 Medium Fuel Price Projection, 82% Turbine Availability

NW100	AW29	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Heating oil arctic (L)	Diesel arctic (L)	Total fuel use (gal)	Fuel use avoided (gal)	Project B/C ratio
5		$5,425,680	2,156,582	$37,510,168	0.572	0.24	174,788	663,197	221,396	74,755	1.053
	3	$5,782,369	2,134,948	$37,545,004	0.572	0.27	156,208	659,545	215,523	80,629	1.052
7		$7,235,280	2,039,802	$37,582,384	0.573	0.32	153,413	608,038	201,176	94,975	1.051
	2	$4,170,474	2,254,117	$37,706,032	0.575	0.19	176,032	719,080	236,489	59,662	1.047
4		$4,520,880	2,232,349	$37,732,588	0.576	0.19	180,940	705,064	234,083	62,068	1.046
	4	$7,394,264	2,044,346	$37,808,968	0.577	0.33	137,221	616,845	199,225	96,927	1.044
9		$9,044,880	1,943,938	$37,965,768	0.580	0.38	135,313	563,264	184,565	111,587	1.040
3		$3,616,080	2,321,594	$38,155,536	0.584	0.14	178,799	762,701	248,745	47,406	1.035
	1	$2,558,579	2,425,737	$38,647,420	0.593	0.09	171,149	832,546	265,177	30,974	1.022
2		$2,711,280	2,417,631	$38,679,516	0.594	0.10	171,488	829,208	264,385	31,767	1.021
1		$1,806,480	2,514,691	$39,218,728	0.604	0.05	163,615	896,810	280,165	15,986	1.007
Base system		$600,000	2,613,749	$39,485,984	0.609	0.00	155,736	965,197	296,151	0	1.000

Note: AW29-225 at 40 m hub height

7 Conclusion and Recommendations

The prospect of wind power in Point Lay 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 Point Lay power system.

It is highly recommended and strongly urged that NSB pursue a conceptual design for a wind-diesel power system for Point Lay. 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

Aeronautical Study No.
2011-WTW-9175-OE

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 PIZ Wind Turbine Site A
Location:	Point Lay, AK
Latitude:	69-45-09.87N NAD 83
Longitude:	163-00-22.43W
Heights:	195 feet above ground level (AGL)
	220 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 (220 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.

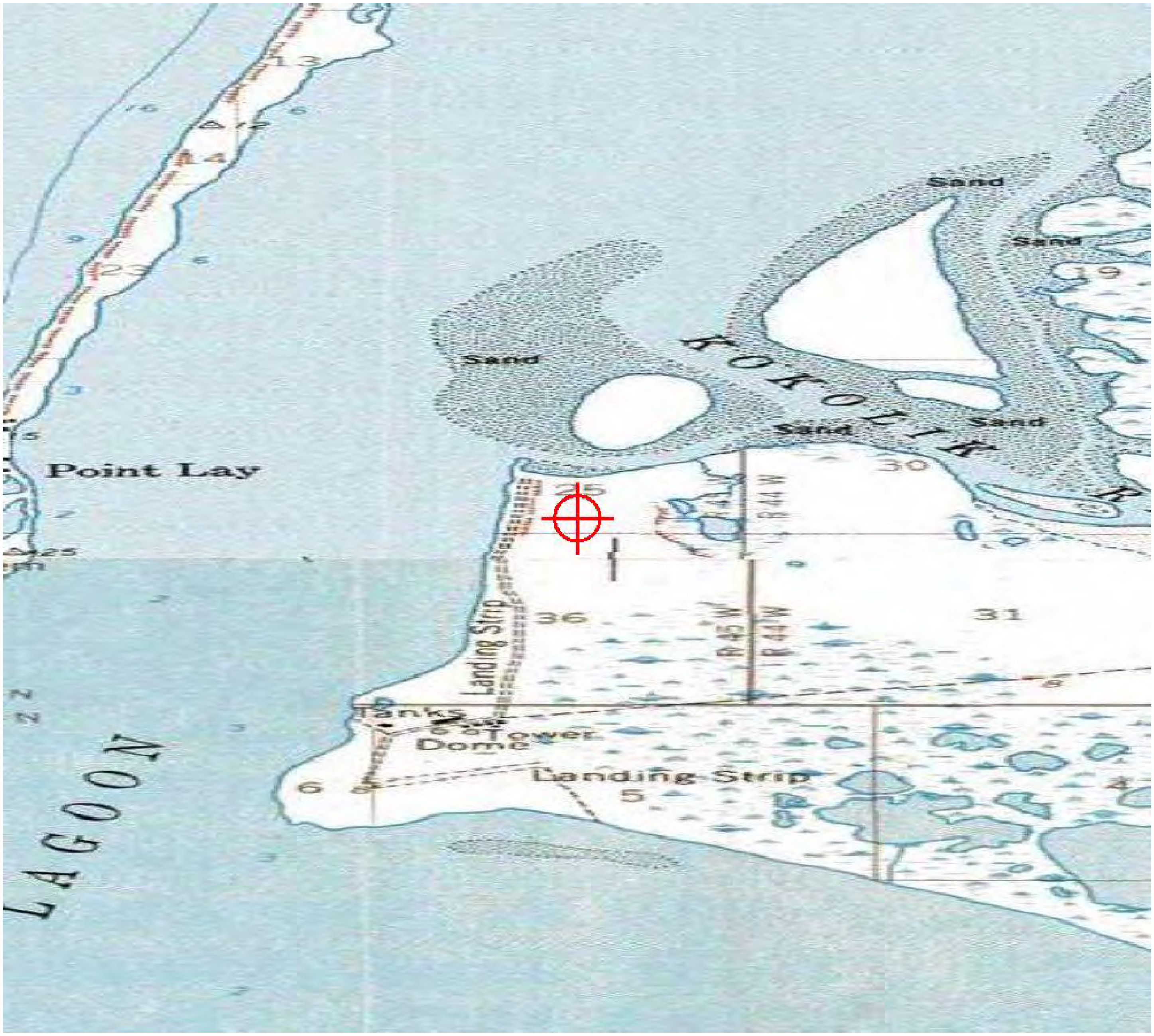
If we can be of further assistance, please contact our office at (907) 271-5863. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2011-WTW-9175-OE.

Signature Control No: 147442461-148160073 (DNE -WT)

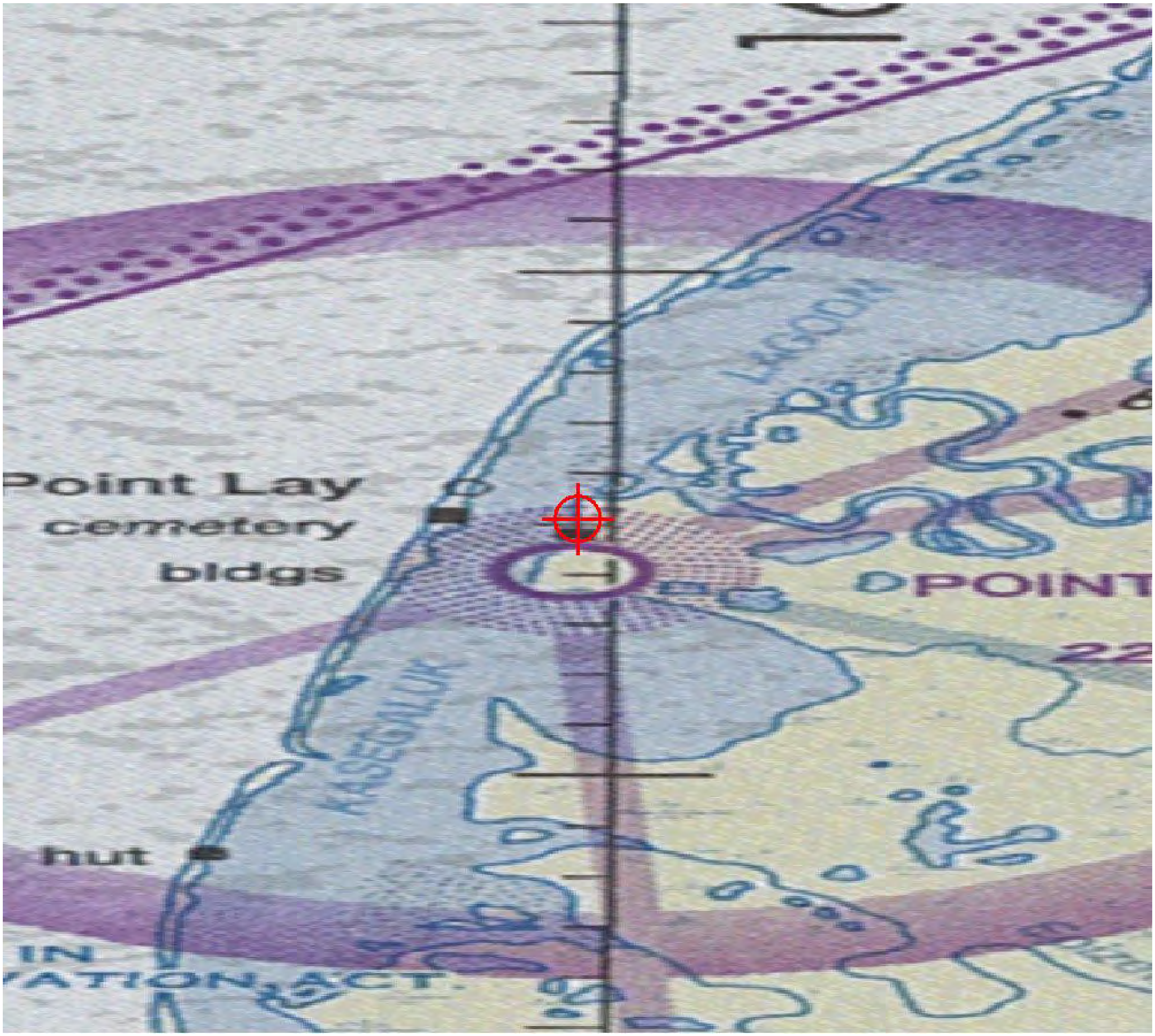
Robert van Haastert
Specialist

Attachment(s)
Map(s)

TOPO Map for ASN 2011-WTW-9175-OE



Sectional Map for ASN 2011-WTW-9175-OE



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

Aeronautical Study No.
2011-WTW-9176-OE

Issued Date: 08/30/2011

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 PIZ Wind Turbine Site B
Location:	Point Lay, AK
Latitude:	69-44-14.60N NAD 83
Longitude:	163-01-05.70W
Heights:	195 feet above ground level (AGL)
	205 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 162 feet above ground level (172 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-9176-OE.

Signature Control No: 147442463-148661313 (NPH -WT)

Robert van Haastert
Specialist

Attachment(s)
Additional Information

Additional information for ASN 2011-WTW-9176-OE

ASN 2011-WTW-9176-OE

Abbreviations

VFR - Visual Flight Rules	AGL - Above Ground Level	RWY - runway
IFR - Instrument Flight Rules	MSL - Mean Sea Level	nm - nautical mile
DA - Decision Altitude	MDA - Minimum Decent Altitude	
NEH - No Effect Height	ICA - Initial Climb Area	

Part 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 / 205 MSL is within protected surfaces at Point Lay (PIZ) airport, AK.

At the proposed height, this structure will penetrate this PIZ 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 PIZ by 33 feet

A favorable FAA Determination can be written for a revised 162 AGL/ 172 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 / 205 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 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

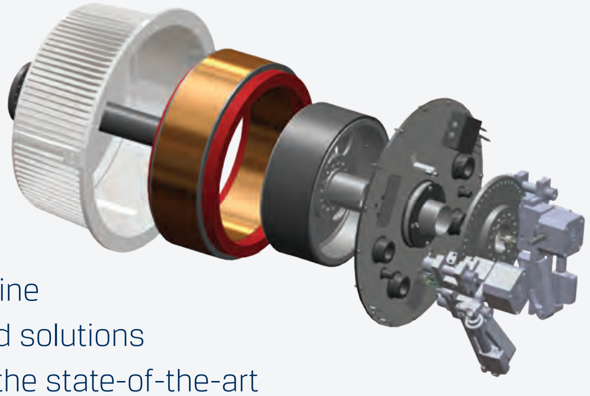
Northern Power Systems knows extreme environments. Our early HR3 turbine model has survived 198 mph winds and -60° C temperatures in Antarctica and still continues to operate. We have shipped more than 20 turbines into Alaska and have produced over 3.8 million kilowatt hours to date. Based on over 30 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.

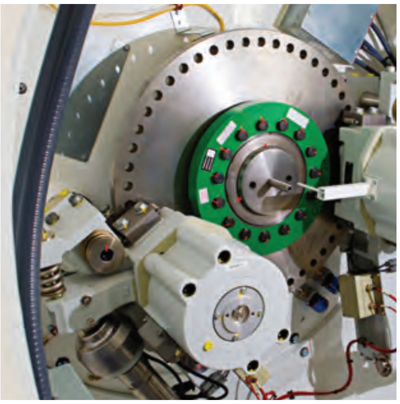
To Cold Climates Everywhere.



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.

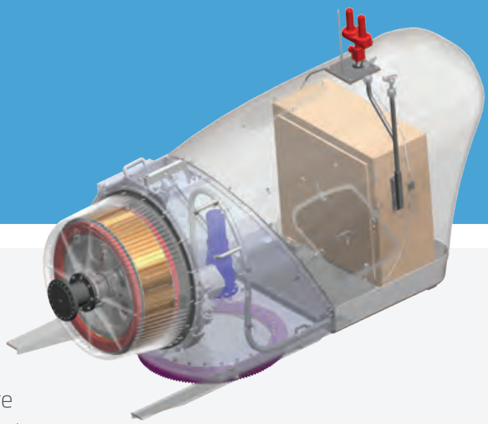
- **Low maintenance:** Our PMDD technology and simple design architecture are why the NPS 100 Arctic requires only minimal preventative maintenance—once per year. In this way you can set your maintenance schedule to avoid particularly harsh seasons. Additionally, the gearless technology bypasses much 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.

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.

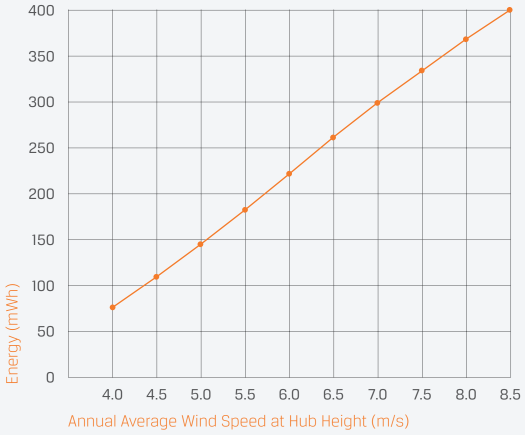
Advanced turbine design for arctic conditions: Ensuring reliability and accessibility

- **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/m^3, 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

WWW.NORTHERNPOWER.COM
1 877 90 NORTH +41 44 307 3733

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 25th Street
Saginaw, MI 48601 USA

Thurgauerstrasse 40 8050
Zurich, Switzerland

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.

NPS-0411

Appendix D: Aeronautica AW29-225 Wind Turbine

Aeronautica Windpower

PRODUCT SPECIFICATIONS

Model

29-225

US-Built, 225kW Mid-Scale Electric Wind Turbine Generators

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.

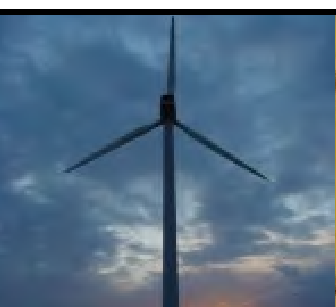
At less than 180' tall on a 40m monopole tower, the 29-225 is a great stall-regulated wind turbine that will fit on many suburban and urban properties. *It ships in standard shipping containers, making delivery to most locations a breeze.* Erection can be made by readily available smaller cranes that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

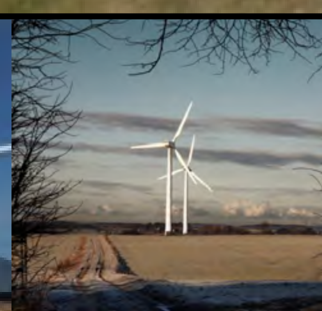
With its low profile and efficient output, the 29-225 is a great match for many distributed generation applications. And *Aeronautica* wind turbines are *all manufactured in the United States*, reducing shipping costs and delivery times.

The industry has been waiting for a US-built 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:

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

Generator:

Nom. Electric Power:	225 kW
Generator:	Single Wound Synch. Induction, 4 pole DW, IP54
Generator speed:	1800 (60 Hz) or 1500 (50 Hz) rpm
Loss in generator:	Approx. 3% at Full Load
Generator cut-in:	Thyristor controlled gradual cut-in
Grid connection:	480 v, 60 Hz (std) or 50 Hz

Weights:

Rotor w/blades:	Approx. 10,600 lbs (4,818 kg)
Nacelle (excl. Rotor):	Approx. 15,260 lbs (6,936 kg)
Mass (total):	Approx. 25,860 lbs (11,754 kg)

Certification: Previously Certified by GL
Current Certification Pending

Operational:

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

Monopole Tower

Construction:	Conical Steel, White, 30, 40, 50m towers available
Nacelle access:	Interior tower ladder through locked door
Surface treatment:	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

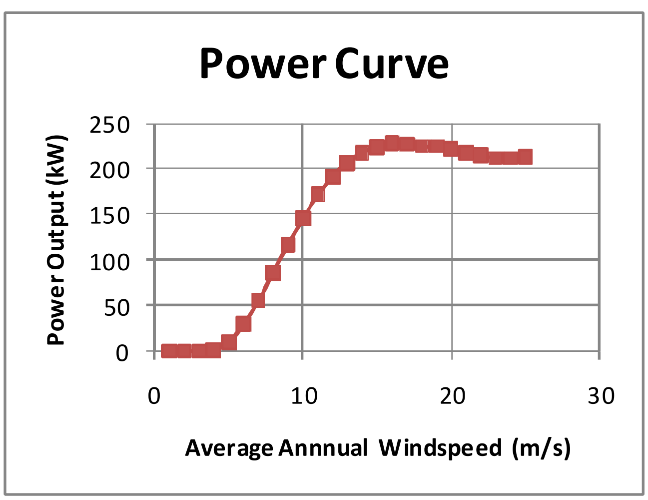
Safety:

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.

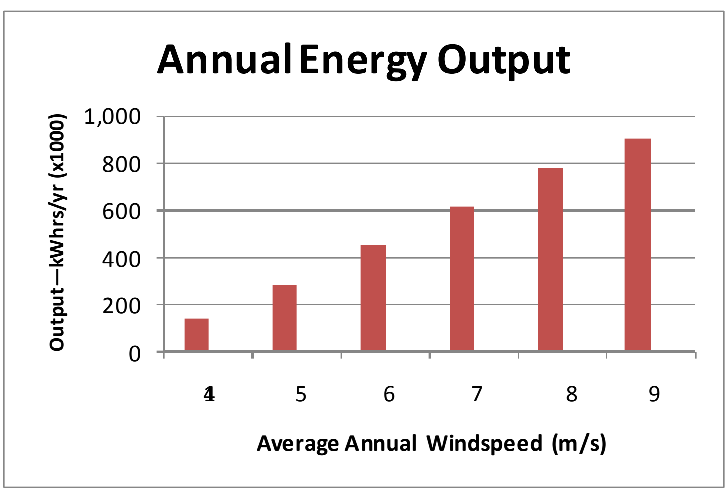
Service Agreements: Annual Service Contracts are required under warranty period and are available upon request

Shipping: All Prices are FOB our plants



Power Table

m/s	kW
5	8.7
6	28.3
7	54.1
8	84.6
9	114.7
10	145.8
11	172.8
12	196.8
13	212.3
14	219.6
15	224.1
16	228.3
17	225.8
18	225.8
19	225.8
20	222.0
21	218.8
22	215.2
23	212.3



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

AERONAUTICA Windpower™

America's Wind Turbine Company

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