Point Hope Wind-Diesel Conceptual Design Report

12 December 2014

This report prepared for

North Slope Borough

by

WHPacific

and

V3 Energy LLC

This report was written by Douglas Vaught, P.E. of V3 Energy, LLC under contract to WHPacific Solutions Group for development of wind power in the village of Point Hope, Alaska. This analysis is part of a wind energy design project for the North Slope Borough and funded by the Alaska Energy Authority.

Contents

Introduction

North Slope Borough is the electric utility for the City of Point Hope. In 2009 North Slope Borough contracted WHPacific to install met towers and perform wind resource assessment analyses in five Borough communities: Point Hope, Wainwright, Atqasuk, Kaktovik, and Anaktuvuk Pass (a wind resource assessment was previously completed by U.S. DOE for Point Lay). This was followed in 2011 with a contract to WHPacific to write feasibility studies for the villages of Point Hope, Point Lay, and Wainwright. WHPacific subcontracted V3 Energy, LLC to assist with both efforts. In 2013 North Slope Borough contracted WHPacific Solutions Group to complete the conceptual design phase of the project in anticipation of Alaska Energy Authority authorizing wind power design projects for the three communities.

WHPacific Solutions Group has contracted V3 Energy, LLC to re-evaluate the wind resource assessment and feasibility study for each community, update the power systems modeling with a selection of appropriate village-scale wind turbines, perform preliminary economic analyses of the proposed projects, and due to funding constraints, prepare a "light" conceptual design report. This conceptual design report for the village of Point Hope is a culmination of that effort.

Project Management

The North Slope Borough, Department of Public Works, has executive oversight of this project. North Slope Borough and the City of Point Hope wish to install wind turbines in Point Hope primarily to reduce diesel fuel consumption and save money, but also to:

- Reduce long-term dependence on outside sources of energy
- Reduce exposure to fuel price volatility
- Reduce air pollution resulting from reducing fossil fuel combustion
- Reduce possibility of spills from fuel transport & storage
- Reduce North Slope Borough's carbon footprint and its contribution to global climate change.

Executive Summary

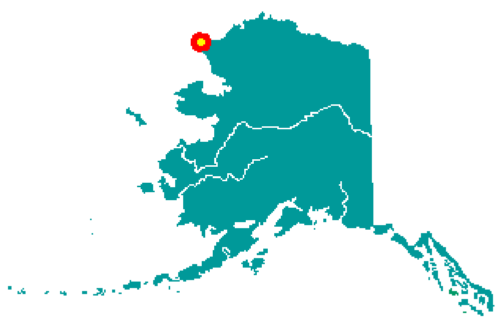
WHPacific Solutions Group and V3 Energy, LLC recommend the new 360 kW Northern Power System 360-39 wind turbine in a medium penetration mode for a Point Hope wind power project. This recommendation is based on Northern Power System's track record and support network in Alaska, the ability to achieve turbine commonality with all four Borough wind power project communities (Point Hope, Point Lay, Wainwright, and Kaktovik), and Northern Power System's factory technical support.

The recommended wind turbine site location is Site B near the airport; chosen for its lower development cost than alternate sites and its displacement from cultural use areas east of the village.

The reader is cautioned to note that this conceptual design report was prepared as an abbreviated or "light" version of a typical conceptual design. With that in mind, although turbine choice, site location, and wind power penetration goals are presented, discussed and/or recommended in this report, further conversation and collaboration with North Slope Borough project management, Tikigaq Corporation, and the community of Point Hope is recommended before the project progresses to detailed design.

Point Hope

Point Hope (Tikeraq) peninsula is one of the oldest continuously occupied locations in Alaska. Several



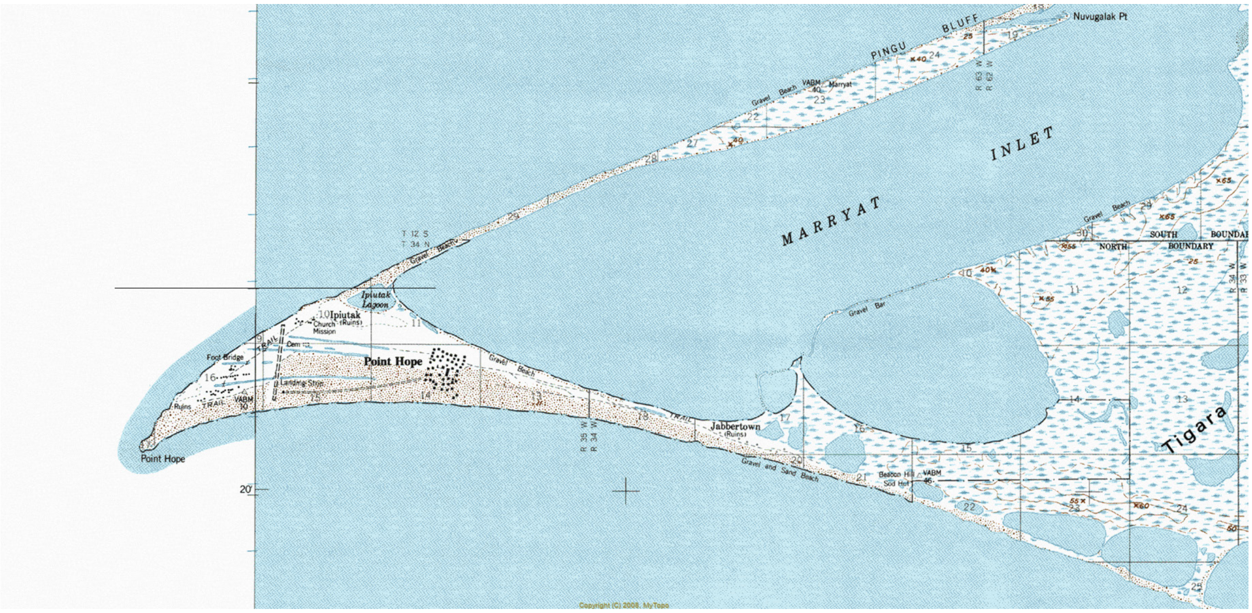
Inupiat Eskimo settlements have existed on the peninsula over the past 2,500 years, including more recently Old and New Tigara, Ipiutak, Jabbertown, and present Point Hope. The peninsula allows access to marine mammals and ice conditions enable easy boat launchings into open leads early in the spring whaling season. The people were traditionally dominant and exercised control over an extensive area, from the Utukok to Kivalina Rivers and far inland. By 1848 commercial whaling activities brought an influx of Westerners, many of whom employed Point Hope villagers. By the late 1880s, the whalers established shore-based whaling stations such as Jabbertown. These disappeared in the early 1900's with the demise of whaling. The Point Hope city government was incorporated in 1966. In the early 1970s, the village moved to a new site just east of the old village because of erosion and periodic storm-surge flooding. Most of the housing was moved on runners to the new site. New houses were constructed by the borough and individuals.

A federally-recognized tribe is located in the community, the Native Village of Point Hope. Point Hope residents (Tikeraqmuit Inupiat Eskimos) are dependent upon marine subsistence. This highly favorable site, with its abundant resources, has enabled the Tikeraqmuit to retain strong cultural traditions after more than a century of outside influences. The sale, importation, and possession of alcohol are banned in the village. The Point Hope population of 674 people is approximately 89 percent Alaska Native, five percent Caucasian, four percent multi-racial, and two percent Hispanic, black or other.

The North Slope Borough provides all utilities in Point Hope. Water is derived from a lake six miles to the east and is treated and stored in a tank. A number of homes have water tanks with delivery, which provides running water for kitchens; others haul water. Electricity is provided by North Slope Borough. There is one school located in the community which has 222 students. Emergency Services have coastal and air access. Emergency service is provided by 911 Telephone Service volunteers and a health aide based at the Point Hope Clinic. Auxiliary health care is provided by the Point Hope Volunteer Fire Dept.

Most full-time positions in Point Hope are with the city and borough governments. Residents manufacture whalebone masks, baleen baskets, ivory carvings, and Eskimo clothing. Seals, bowhead whales, beluga whales, caribou, polar bears, birds, fish, and berries are utilized.

Topographic map of Point Hope



Google Earth image of Point Hope

Wind Resource Assessment

The wind resource measured in Point Hope is superior, with measured high wind power class 6 (outstanding). In addition to high annual mean wind speed and wind power density, Point Hope 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 at the northeast corner of Point Hope between the village water storage tank and a large snow fence to the north. This site was chosen as it is near the power plant and other existing electrical power infrastructure and did not present obstruction problems for airport operations. The met tower was removed in July 2010 and a wind resource assessment report was forwarded to North Slope Borough in August, 2010.

Met tower data synopsis

Data dates	June 16, 2009 to July 15, 2010 (13 months)
Wind power class	6 (outstanding)
Power density mean, 30 m	515 W/m^2
Wind speed mean, 30 m	7.12 m/s
Max. 10-min wind speed average	27.9 m/s
Maximum wind gust	32.2 m/s (Dec. 2009)
Weibull distribution parameters	k = 1.82, c = 7.92 m/s
Wind shear power law exponent	0.110 (low)
Roughness class	0.27 (rough sea)
IEC 61400-1, 3rd ed. classification	Class III-c (lowest defined and most common)
Turbulence intensity, mean	0.073 (at 15 m/s)
Calm wind frequency	20% (<3.5 m/s)

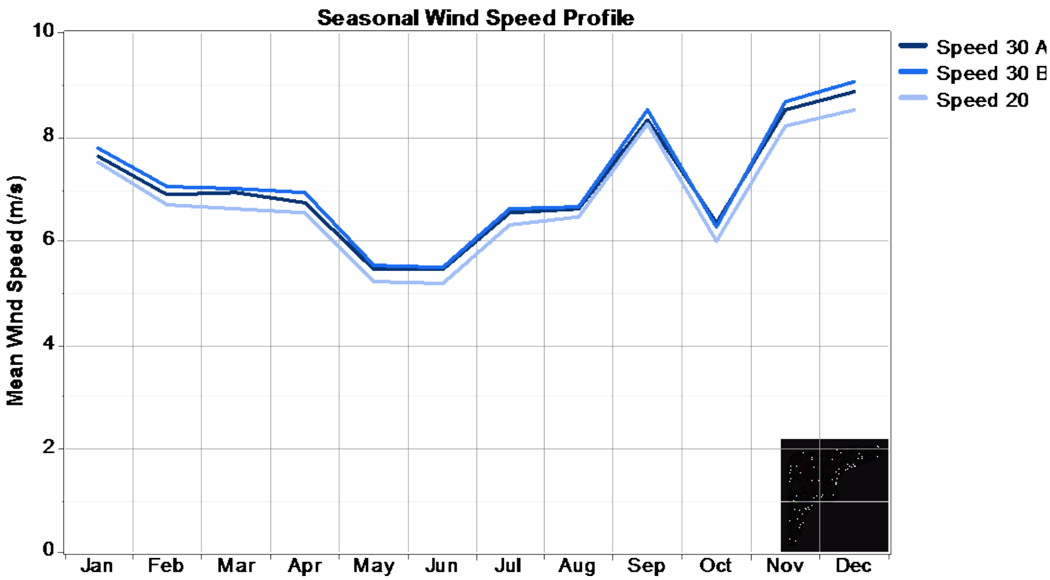
Data Recovery

Met tower data recovery in Point Hope was outstanding, with nearly 100 percent functionality of the anemometers, wind vane and temperature sensor. This is remarkable anywhere in Alaska, but even more so on the Chukchi Sea coast of the North Slope with its intensely cold winter temperatures.

Wind Speed

Wind data collected from the met tower, from the perspective of both mean wind speed and mean power density, indicates an outstanding wind resource. The minor discrepancy in mean wind speed between the 30 m A and the 30 m B anemometer is due to the placement of the of the 30 m A anemometer at 178° T. With frequent northerly winds, the 30m A anemometer experienced some minor tower shadowing effects. The cold arctic temperatures of Point Hope contributed to the high wind power density, a key consideration of wind turbine performance.

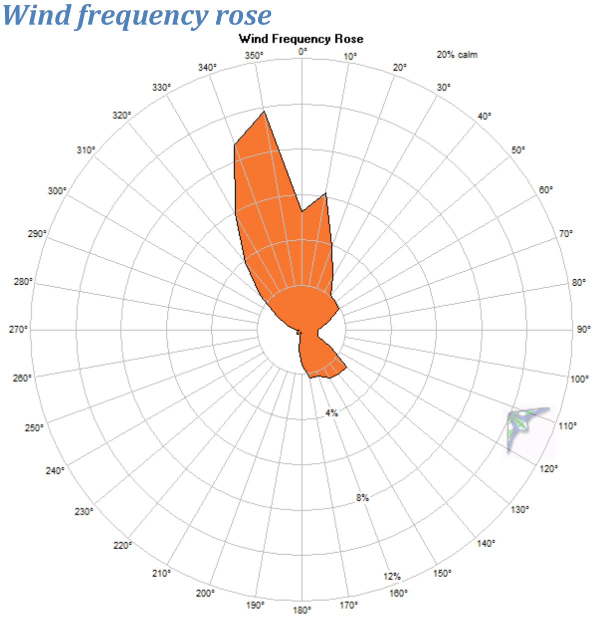
Wind speed profile



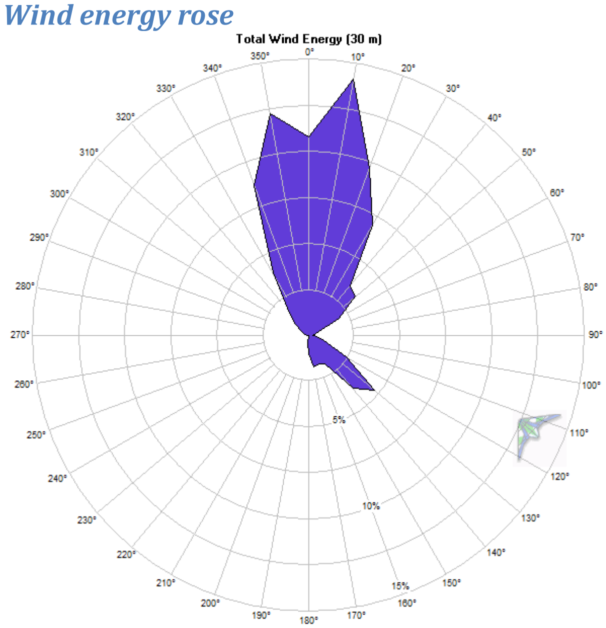
Wind Rose

Wind frequency rose data indicates highly directional winds from the north and southeast. Power density rose data (representing the power in the wind) indicates power winds are strongly directional, from 345°T to 025°T and to a lesser extent from 130°T. Calm frequency (percent of time that winds at the 30 meter level are less than 3.5 m/s) was 20 percent during the met tower test period.

Wind frequency rose



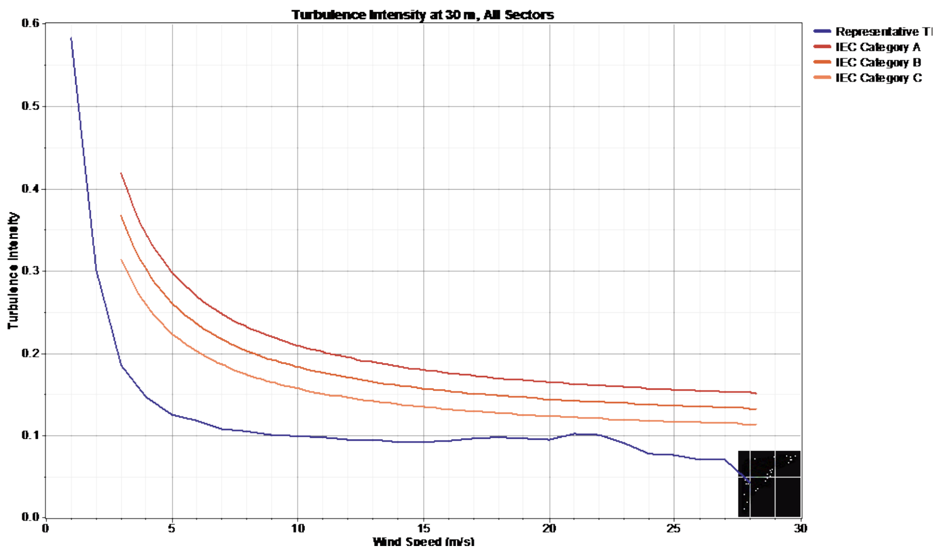
Wind energy rose



Turbulence Intensity

Turbulence intensity at the Point Hope 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 0.073.

Turbulence graph



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 desirable situation in Point Hope: high mean wind speeds combined with low extreme wind speed probabilities. This may be explained by particular climactic aspects of Point Hope which include prominent coastal exposure, offshore wind conditions, and due to the extreme northerly latitude, lack of exposure to Gulf of Alaska or other sub-tropical-origin storm winds.

Industry standard reference of extreme wind is the 50 year, 10-minute average probable wind speed, referred to as V_{ref}. For Point Hope, this calculates to 36.8 m/s, below the threshold of International Electrotechnical Commission (IEC) 61400-1, 3rd 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. For the design phase of the project, however, the wind data should be re-examined by the turbine manufacturer to ensure turbine IEC classification suitability.

Point Hope met tower Gumbel distribution of extreme wind

	V_{ref}	Gust	IEC 61400-1, 3rd ed.	
Period (years)	(m/s)	(m/s)	Class	V_{ref}, m/s
2	27.2	32.4	I	50.0
10	32.0	38.2	II	42.5
15	33.2	39.6	III	37.5
30	35.3	42.1	S	

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
50	36.8	43.9		
100	38.9	46.4		
average gust factor:	1.19			

The complete V3 Energy, LLC wind resource assessment report of Point Hope is forwarded with this conceptual design report.

Cold Climate Considerations of Wind Power

Point Hope's harsh climate conditions is an important consideration should wind power be developed in the community. The principal challenges with respect to turbine selection and subsequent operation is severe cold and icing. Many wind turbines in standard configuration are designed for a lower operating temperature limit of -20° C (-4° F), which clearly would not be suitable for Point Hope, nor anywhere in Alaska. A number of wind turbine manufacturers offer their turbine in an "arctic" configuration which includes verification that structural and other system critical metal components are fatigue tested for severe cold capability. In addition, arctic-rated turbines are fitted with insulation and heaters in the nacelle and power electronics space to ensure proper operating temperatures. With an arctic rating, the lower temperature operating limit generally extends to -40° C (-40° F). On occasion during winter Point Hope may experience temperatures colder than -40° C, at which point the wind turbines would shut down. Temperatures below -40° C are relatively infrequent however and when they do occur, are generally accompanied by calm or light winds.

A second aspect of concern regarding Point Hope's arctic climate is icing conditions. Atmospheric icing is a complex phenomenon characterized by astonishing variability and diversity of forms, density, and tenacity of frozen precipitation, some of which is harmless to wind turbine operations and others highly problematic. Although highly complex, with respect to wind turbines and aircraft five types of icing are recognized: clear ice, rime ice, mixed ice, frost ice, and SLD ice (www.Wikipedia.org/wiki/icing_conditions).

- Clear ice is often clear and smooth. Super-cooled water droplets, or freezing rain, strike a surface but do not freeze instantly. Forming mostly along the stagnation point on an airfoil, it generally conforms to the shape of the airfoil.
- Rime ice is rough and opaque, formed by super-cooled drops rapidly freezing on impact. Often "horns" or protrusions are formed and project into the airflow.
- Mixed ice is a combination of clear and rime ice.
- Frost ice is the result of water freezing on unprotected surfaces. It often forms behind deicing boots or heated leading edges of an airfoil and has been a factor airplane crashes.
- SLD ice refers to ice formed in super-cooled large droplet (SLD) conditions. It is similar to clear ice, but because droplet size is large, it often extends to unprotected parts of a wind turbine (or aircraft) and forms large ice shapes faster than normal icing conditions.

SLD ice on an airplane

Wind Project Sites

As part of the 2011 feasibility study, North Slope Borough requested that two wind turbine sites be identified in Point Hope. On July 7 and 8, 2011, Ross Klooster of WHPacific, Doug Vaught of V3 Energy, LLC, and Max Ahgeak of North Slope Borough Public Works Dept. traveled to Point Hope and met with Village of Point Hope and Tikigaq 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.

Identifying suitable wind turbine sites in Point Hope proved somewhat difficult due to complicated land ownership with many native allotments near the village, airport-related air traffic operations limitations, and cultural and traditional land use considerations that would be incompatable with wind turbine construction and operation. Two sites on Tikigaq Corporation land were eventually chosen, identified as Site A and Site B. Site A is located on the isthmus between the village and the mainland, and Site B is located between the village and the airport at the tip of the peninsula. Both sites are identified in the Google Earth image below.

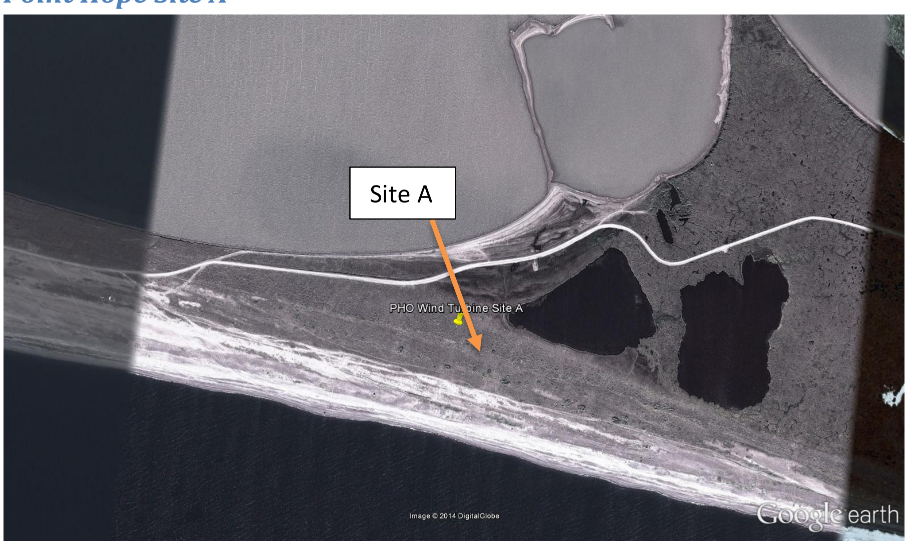
Later conversations between Ross Klooster of WHPacific and Price Leavitt of North Slope Borough identified Site C along the beach strand but closer to the village than Site A. Site D is located north of the strand access road and can be considered a variation of Site C. Both sites are on Tikigaq Corporation property.

Point Hope site options

Site A

Site A, at 4.25 km (2.6 miles) from the village, is perhaps further than ideal given that new power distribution lines must be constructed the entire distance to this site. However, it is the location on the strand preferred by village leadership as it avoids traditional use areas and Native allotments. The Site A parcel is land owned by Tikigaq Corporation, appears to be largely free of permafrost but is somewhat constrained in size. A key advantage of Site A is that turbine height up to 200 ft. above ground level (AGL) is unrestricted from an FAA perspective (refer to Appendix A).

Point Hope Site A



Site B

Site B is west of Point Hope near the airport and very near existing 3-phase power distribution lines. The Site B parcel is land owned by Tikigaq Corporation, is large enough to accommodate several wind turbines and is presumed to be permafrost-free. This site would be the least costly to develop due to minimal extension of power distribution and is not near traditional and cultural use areas, although the community cemetery is relatively nearby. But, the site is near the airport and may be height restricted. The FAA notice criteria tool (requested at 200 ft. AGL) indicates possible navigation signal reception interference (refer to Appendix B), but likely this is a resolvable problem.

Point Hope Site B

Site C

Site C is east of the village but closer than Site A. This site is located south of the strand road between a smaller Native Allotment to the west and continuous block of several larger Allotments to the east. Site C is larger than Site A and more turbines could be sited as this location. A possible drawback however is proximity to traditional and cultural use areas on the Chukchi Sea beach. The FAA notice criteria tool (requested at 200 ft. AGL) indicates possible navigation signal reception interference (refer to Appendix C), but less than at Site B and very likely a resolvable issue.

Point Hope Site C

Site D

Site D is immediately north of Site C on the north side of the strand access road. This site has an advantage of displacement from traditional and cultural use areas compared to Site C and also presents a long east-to-west alignment which is advantageous for siting wind turbines with Point Hope's predominant northerly winds. As with Site C, Site D is larger than Site A and more turbines could be sited as this location. Same as for Site C, the FAA notice criteria tool (requested at 200 ft. AGL) indicates possible navigation signal reception interference (refer to Appendix C), but less than at Site B and very likely a resolvable issue.

Point Hope Site D

Point Hope wind turbine site options table

Site	Advantages	Disadvantages
A	• Tikigaq Corp. land • Site large enough to accommodate up to three wind turbines • Short new access from strand road • Unrestricted turbine height • Likely dry site and good geotech conditions	• 4.0 km (2.5 mi) of new distribution line required; route traverses several Native Allotments; existence of utility easement along road unkonwn • Constrained site (only 1,000 ft. east-to-west); future expansion likely not possible due to Native Allotments east and west
B	• Tikigaq Corp. land • Very short (~1,000 ft) new distribution line to existing 3-phase power serving the airport • Short new access road; minimal cost • Large site able to accommodate several wind turbines; sufficient room for future expansion • Dry site; likely good geotech conditions for turbine foundations • Removed from traditional and cultural use areas • No Native Allotment space restrictions	• Proximity to the airport; possible navigation signal interference; possible high hub height limitation (note a 2011 FAA determination noted 158 ft. acceptable with no further review) • Near the community cemetery (approx. 1,500 ft.)
C	• Tikigaq Corp. land • Short new access road; minimal cost • Dry site; likely good geotech conditions • Site larger than Site A with room for future expansion	• 1.4 km (0.9 mi) of new distribution line required • Possible airport navigation signal interference for very high hub-height wind turbines • Possibly too near traditional and cultural use areas on the beach
D	• Tikigaq Corp. land • Very short new access road(s); minimal cost • Dry site; likely good geotech conditions • Site larger than Site A with extensive room for future expansion	• Possible airport navigation signal interference for very high wind turbines • Possibly too near traditional and cultural use areas on the beach, but further than Site C

Other Site Options

Other than locating wind turbines at the met tower site, which would be too close to the village and not recommended, Sites A, B, C and D represent the best site options for a wind power project in Point Hope. Land further east of Site A is possible of course, but one must go a considerable distance to avoid Native Allotments constraints. For this, there would be no wind energy benefit and a considerable financial penalty to construct power distribution and an access road across undeveloped marshy tundra.

Recommended Site Option

WHPacific Solutions Group and V3 Energy, LLC recommend Site B as the preferred site option for a wind turbine project in Point Hope, presuming a satisfactory FAA obstruction determination can be obtained (based on the 2011 study, this is likely for lower hub height turbines of approx. 30 meters). This recommendation is based on lowest construction cost due to very short new distribution required to connect the turbines to the existing grid, avoidance of traditional and cultural use areas on the strand east of the community, and placement of wind turbines near an existing developed area (the airport and the community tank farm).

WHPacific Solutions Group and V3 Energy, LLC note however that Tikigaq Corp. leadership has indicated Site A as the preferred site option for a wind power project. Site A is unrestricted with respect to turbine height, which is advantageous, but it would be the most expensive to develop (by a considerable margin compared to Site B due to 2.5 additional miles of new power distribution line compared to Site B). Also, Site A is the most constrained with respect to number of turbines possible and hence would severely limit or possibly preclude future wind power expansion.

Wildlife/Avian Study

North Slope Borough commissioned ABR, Inc. of Fairbanks, Alaska to summarize the biological resources of Point Hope, including both plant and animal species, to support the wind project development effort. ABR's work is documented in a report titled: *Site Characterization and Avian Field Study for the Proposed Community-Scale Wind Project in Northern Alaska*.

The ABR study states: The objectives of the Site Characterization Study (SCS) were to: (1) compile and review existing land cover map products to prepare generalized land cover maps; (2) characterize the biological resources present; (3) summarize the potential exposure of biological (particularly avian) resources to impacts; and (4) identify field studies to identify site-specific risks to biological resources (particularly birds). The objectives of the field studies conducted in 2013 were to: (1) describe temporal and spatial patterns of habitat use of all birds within and near proposed wind-sites; and (2) provide a summary of the exposure of focal species to collision risk at each proposed site. This final report summarizes the SCS and field data to describe the relative exposure of the focal species to the proposed wind-energy development at the 3 villages.

An excerpt from ABR's report: "In Point Hope, Site A is located on a narrow part of the peninsula and has large water bodies to both the north (Marryat Inlet) and south (Chukchi Sea). We found both nesting and brood-rearing birds in the small ponds west of the site. Most of the bird movements around Site A were east–west along the northern and southern coastlines. Site B is farther from small ponds and coastlines that focus bird movements, but it is closer to the point of the peninsula. Birds may fly over the tip of the peninsula rather than around it, especially during inclement weather (when the exact tip of the peninsula would be difficult to see), thereby increasing their risk of collision with turbine structures. Nonetheless, the probability of interaction probably is higher at Site A because of the short distances between the site and the water bodies. Based on an evaluation of the habitat at both locations and the recorded bird movements at Site A (but not Site B), we may expect Site B to have fewer avian issues with the proposed development."

The reader is cautioned that the ABR report is complex and that the preceding paragraph does not adequately summarize ABR's conclusions; it is included in this CDR for reference only. The reader is strongly encouraged to consult the ABR report for a complete understanding the plant and wildlife species of concern and potential impacts of a wind project in Point Hope.

The complete ABR, Inc. site characterization and avian field study report of the proposed Point Hope wind farm is forwarded with this conceptual design report.

Geotechnical Report

WHPacific commissioned Golder Associates of Anchorage, Alaska to perform a non-field study assessment of likely geotechnical conditions in Point Hope, Point Lay, and Wainwright in order to identify potential hazards and provide conceptual foundation recommendations for the proposed wind tower sites in the three communities. Golder's work is documented in a report titled: *Geotechnical Review and Feasibility Studies for Wind Turbines: Point Hope, Point Lay, and Wainwright, Alaska*, dated January 27, 2012.

The Golder report states the following regarding Point Hope: The village is located on a gravel spit extending to the west about 6 miles from the tundra mainland. The spit is bordered by the Chukchi Sea and has been formed by long shore currents moving along the shoreline. The gravel spit is about 4000 feet wide and consists of a series of beach ridges and intervening swales that parallel the axis of the spit to about elevation 14 feet on the north side. The swales between the beach lines are 2 feet to 4 feet lower than the tops of the ridges.

The spit is actively eroding from the west and aggrading on south. North of the village, near the border with Marryat Inlet, alluvial deposits of stratified silt and sand with peat and tundra vegetation are typical. Polygonal ice wedge terrain is evident from aerial photography along the southern shore of Marryat Inlet. In the 1970s, erosion along the northwest beach of the spit, measured at 8.8 feet per year, prompted the village to move. By the late 1970s, the majority of the village has moved eastward on the spit approximately 2 miles, bringing it to its current location. The village is currently located near the center of the spit in an area that has been leveled by filling the beach troughs with fill material. The village area is un-vegetated, but the troughs of the old beach lines reportedly had thin organic deposits before that were covered by fill.

The permafrost conditions are unique at the proposed Northwind 100 tower location in Point Hope. While permafrost is present, it is typically ice poor - a condition where ice is not present in concentrations exceeding thawed state saturation and individual sand and gravel particles have grain-to-grain contact in the permafrost. If permitted to thaw, the permafrost will generally experience thaw strains based on ice to water phase change volumes, but thaw strains in ice-poor materials generally do not exceed the volumetric change due to ice/water phase change. Seasonal frost heave is generally low in this area, primarily related to the coarse-grained nature of the in-place soil. In general, the granular soils at Point Hope are considered non-frost susceptible.

Accordingly, many structures in Point Hope are founded on post and pad or at-grade foundation with or without passive subgrade cooling and rigid insulation.

A site-specific geotechnical exploration is required for turbine foundation system. However, based on nearby geotechnical data, it may be possible to use a concrete or steel frame mat foundation system for this site. The mat foundation can be founded on the prepared in-place granular soils but a structural fill section between the foundation and the in-place soil should be considered.

Structural fill should be Alaska Department of Transportation and Public Facilities (ADOT&PF) sub-base A or similar material. Rigid insulation under the mat foundation should also be considered. If used, the rigid insulation should have a compressive strength suitable for the design loads, both sustained and transient. Fill should be placed and compacted in a thawed state. Structural fill should be placed in nominal one foot thick lifts compacted to at least 95 percent of maximum dry density as determined by the modified Proctor test method.

A mat foundation system will rely solely on gravity to resist overturn and uplift loads, which may be considerable with the Northwind 100 turbine systems. The civil and structural design will determine the depth of excavation and fill requirements above the mat foundation. Mat foundation embedment depths on the order of 10 to 12 feet may be necessary to develop adequate overturning and uplift resistance.

Passive subgrade cooling may be required under the mat foundation. If so, Arctic Foundations, Inc. (AFI) Flat Loop passive subgrade cooling may be considered. The AFI Flat Loop passive subgrade cooling system may be installed within the structural fill.

Subgrade cooling will provide several engineering advantages. Thaw into the underlying soil will be limited reducing the volumetric ice to water thaw strain discussed above. If frozen throughout the project design life, the underlying soil will have a greater allowable bearing capacity and stiffness relative to thaw state conditions.

The complete Golder Associates geotechnical review report of the proposed Point Hope wind farm is forwarded with this conceptual design report.

Noise Analysis

As part of a 2007 Powercorp Alaska, LLC Preliminary Wind Feasibility Report of Kaktovik, Point Hope and Point Lay, Michael Minor & Associates of Portland, Oregon was commissioned to complete a desktop analysis of the expected noise impact of wind turbines at Site A (this was the only site considered at that time). This work was documented in a report titled: *Noise Analysis Memorandum of the Point Hope Wind Farm*, dated October 14, 2007.

The noise analysis memorandum summary stated: This project will install a wind turbine generator farm outside of Point Hope, Alaska. The project proposes to use one Vestas V47, four Vestas V27's, or one Führländer 600 wind turbine generator(s). The wind turbine nearest to the eastern edge of town will be located approximately 3,400 feet to the west. Noise due to the operation of the wind turbines is expected to be audible in the town, although the overall noise levels are low and are not projected to exceed 31 to 34 dBA. In addition, the noise from the wind turbines should not exceed the ambient by more than 1 to 5 dBA except in extreme cases accompanied by high winds, low ambient noise levels and frozen ground.

The complete Michael Minor & Associates noise analysis memorandum of a Point Hope wind farm is forwarded with this conceptual design report.

Permitting and Environmental Review

The environmental permitting requirements listed below are discussed in *Alaska Wind Energy Development: Best Practices Guide to Environmental Permitting and Consultations*, a study prepared by URS Corporation for the Alaska Energy Authority in 2009.

Alaska Pollution Discharge Elimination System

State regulations (18 AAC 83) require that all discharges to surface waters, including storm water runoff, be permitted under the Alaska Pollution Discharge Elimination System (APDES). The goal of the program is to reduce or eliminate pollution and sediments in stormwater and other discharges to surface water. Under the state APDES program, projects that disturb one or more acre of ground are subject to the terms of the Alaska Construction General Permit (CGP) and are required to develop a project Storm Water Pollution Prevention Plan (SWPPP) outlining measures to control or eliminate pollution and sediment discharges. The proposed projects in Point Hope, Point Lay and Wainwright are likely to disturb more than one acre of ground during the construction of proposed wind turbines, supporting infrastructure and access roads and would be subject to the requirements of the CGP. Prior to construction, the contractor would be required to file a Notice of Intent (NOI) with the Alaska Department of Environmental Conservation (ADEC) prior to submitting the project SWPPP. ADEC would issue an APDES permit following the public comment period.

US. Fish and Wildlife Service/National Marine Fisheries Service

Both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) list Threatened and Endangered (T&E) that may occur in the vicinity of Point Hope, Point Lay, and Wainwright, Alaska. T&E species listed by the USFWS in the vicinity of the project area may include the short tailed albatross, polar bear, Steller's eider, spectacled eider. Candidate species that may be found in the area include the yellow billed loon, Kittlitz's murrelet, and the Pacific walrus. While NMFS lists marine T&E species, the bearded seal and ring seal may haul on beaches in the vicinity of the project area. A discussion with the USFWS will be initiated, and at a minimum, a letter and a map will be sent requesting their opinion regarding the level of consultation needed to proceed with the construction of the project.

USFWS regulations and guidance under the Migratory Bird Treaty Act prohibits the taking of active bird nests, eggs and young. In their Advisory: Recommended Time Periods for Avoiding Vegetation Clearing in Alaska in order to protect Migratory Birds, USFWS has developed "bird windows" statewide that prohibit clearing activity. The bird window for the Northern region of Alaska, including the communities of Point Hope, Point Lay and Wainwright is June 1st – July 31st for shrub and open type habitats (tundra and wetlands) and May 20th – September 15th for nesting seabird colonies. The clearing window for black scoter habitat is through August 10th. Clearing prior to these dates is allowed. If clearing has already occurred then construction may proceed during these dates.

USFWS Wind Turbine Guidelines Advisory Committee developed guidelines and recommendations for wind power projects to avoid impacts to birds and bats. These recommendations have been released to the public as draft U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines and will be referred to during design and construction of a wind turbine project in Point Hope, Point Lay and Wainwright.

In February 2014, ABR Inc. completed a report prepared for the North Slope Borough titled "Site Characterization and Avian Field Study for the Proposed Community-Scale Wind Project in Northern Alaska". The study was for the communities of Point Hope, Point Lay and Wainwright. The ABR study characterized habitat, bird abundance, migration and nesting movements of observed species and analysis of the impacts on species of concern, specifically spectacled eiders (endangered), Steller's eiders (endangered) and yellow-throated loons (threatened). The site characterization was focused on a one-mile radius study area surrounding each of the proposed turbine locations in each of the communities. The study concluded that both the most abundant bird species and those with limited populations like the Steller's and spectacled eiders are most at risk from wind infrastructure. The ABR report states impacts to Steller's eiders should be considered in all three project areas. Spectacled eiders were not recorded near any of the proposed turbine locations and concluded the risk to this species are low. Yellow billed loons, a USFWS species of concern, were active in Point Hope, were active to a lesser extent in Point Lay, and not recorded in Wainwright. Red throated loons, which is a BLM Alaska Natural Heritage Program "watch" species, were absent from Point Hope but were observed in Point Lay and Wainwright. Red throated loons were the most observed among the focal species discussed in the report and were often observed flying low, below the rotor swept area (RSA). The report concludes that post-construction monitoring data suggests wind infrastructure operates in rural Alaska with limited direct impacts to bird species; however, some impacts would be expected due to migration and breeding movements. Turbine selection and temporal adjustments to operation could mitigate potential impacts.

Federal Aviation Administration

Prior to turbine construction an FAA Notice of Proposed Construction or Alteration (Form 7460-1) is require to be completed. Filing a 7460-1 may result in additional discussions with the FAA regarding turbine siting and appropriate lighting requirements that would need to be incorporated into the project specifications.

U.S. Army Corps of Engineers

The US Army Corps of Engineers (USACE) requires a permit for the placement of fill in "waters of the United States", including wetlands and streams, under Section 404 of the Clean Water Act (CWA). The proposed wind turbine site(s) and supporting infrastructure in Point Hope, Point Lay and Wainwright may be all, or partially located on wetlands. The project must receive a Section 404 permit from the Alaska District USACE and an accompanying U.S. Environmental Protection Agency (EPA) Section 401 Water Quality Certification if the project is situated on, or will impact waters of the US. Currently, Individual Permits and Nationwide 12 permits are being issued for wind power projects in Alaska. An individual permit would be required for activities related to the construction of access roads or pads in wetlands. A Nationwide 12 Permit would be appropriate for activities related to utility installation (i.e. power lines). Depending on the site selection and potential impacts, a jurisdictional determination (wetland delineation) may be necessary to obtain a Section 404 permit.

Alaska Department of Fish and Game

The Alaska Department of Fish and Game (ADF&G) oversees activities that may have an impact on fish habitat and anadromous fish streams. An ADF&G Title 16 Fish Habitat Permit would be required if the proposed project includes construction of access roads and infrastructure that may impact fish habitat or would involve installing a culvert in a fish stream.

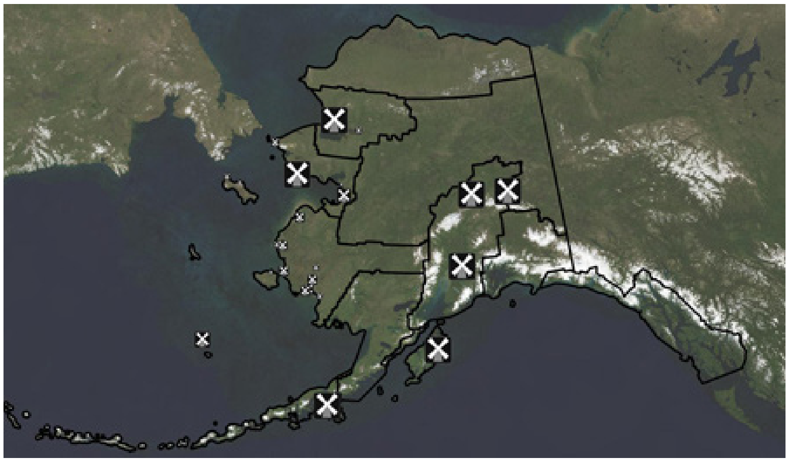
State Historic Preservation Office

Consultation with the State Historic Preservation Office (SHPO) for State of Alaska-funded projects is required under the State Historic Preservation Act. The act requires that all state projects be reviewed for potential impacts to cultural and historic resources. During the permitting phase of the project prior to construction, consultation with the SHPO would be initiated to determine if the project may impact these resources. The extent of needed infrastructure (pads and new roads) and the presence of known archaeological sites in the vicinity of the project area may trigger the SHPO to recommend an archaeological survey of the site.

Wind-Diesel Hybrid System Overview

There are now over twenty-four wind-diesel projects in the state, making Alaska a world leader in wind-diesel hybrid technology. There are a variety of system configurations and turbine types in operation and accordingly there is a spectrum of success in all of these systems. As experience and statewide industry support has increased so has overall system performance. The following figure illustrates the locations of installed wind projects in Alaska.

Alaska wind-diesel projects

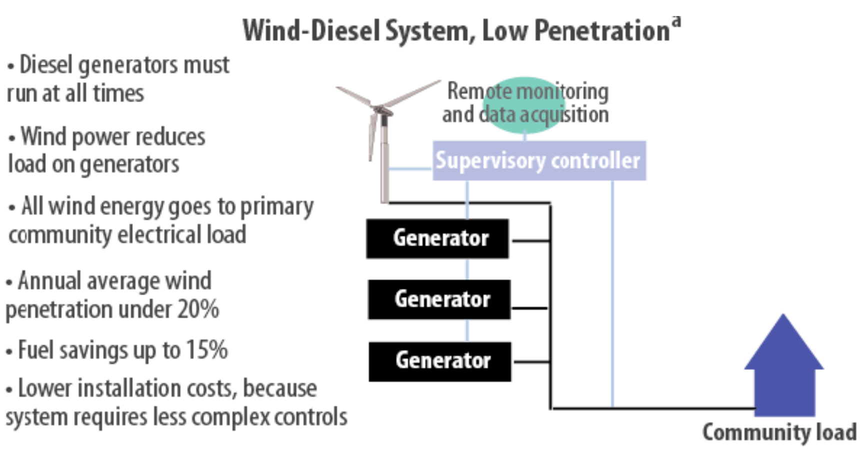


Wind-diesel Design Options

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, medium, and high; occasionally very low is also defined as a category. Wind penetration level is roughly equivalent to the amount of diesel fuel displaced by wind power. Note however a positive correlation of system control and demand-management strategy complexity with wind power penetration.

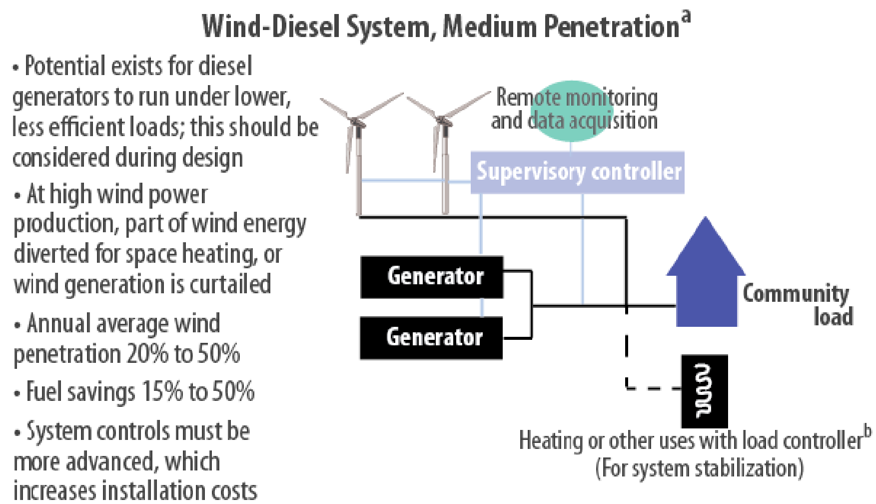
Low Penetration Configuration

Low (and extremely low) penetration wind-diesel systems require the fewest modifications to the existing system. However, they tend to be less economical than higher penetration configurations due to the limited annual fuel savings compared to fixed project costs, such as new distribution connection.



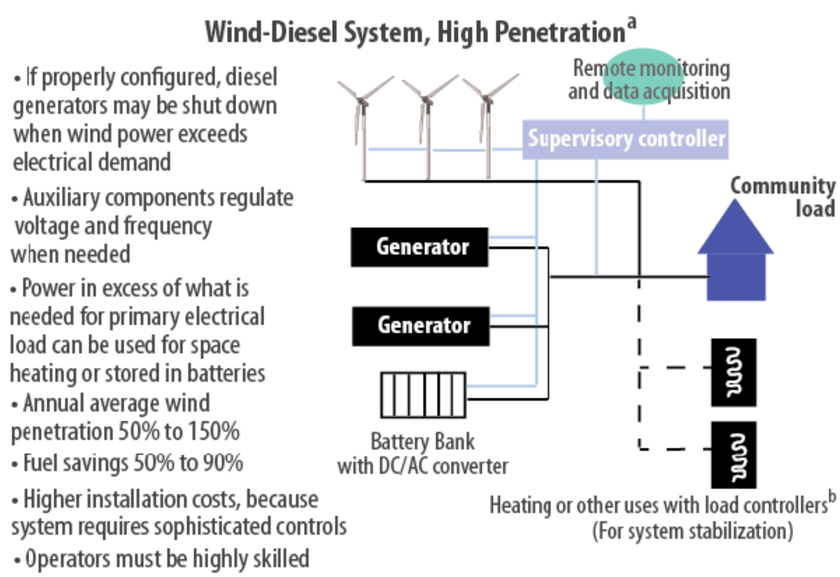
Medium Penetration Configuration

Medium penetration wind-diesel requires relatively sophisticated power quality control due to occasional circumstance of wind generation exceeding load demand and generally are with a full-time diesels-on requirement. Medium penetration is often chosen as a compromise between the minimal benefit of low penetration and the considerable complexity of high penetration, but experience has indicated that this may be misleading. Power quality can be difficult to maintain with typical medium penetration configuration design and upgrades necessary to improve power quality control edge enough toward high penetration that the greater economic benefits of high penetration wind are not captured due to insufficient wind turbine capacity.



High Penetration Configuration

High penetration configuration design typically enables diesels-off operation and uses a significant portion of the wind energy for thermal heating loads. The potential benefit of high penetration can be significant, but system complexity requires a significant investment in project commissioning, operator training, and strong management practices.



[a]Wind penetration is the percentage of electricity supplied by wind.
[b]Besides residential or commercial heating, possible other uses include charging electric cars.
Note: These are examples of systems; other configurations exist.

Wind-diesel penetration level are summarized table below in a table developed by Alaska Energy Authority. Note that instantaneous penetration level is much more important for system configuration design than average penetration. One way to appreciate instantaneous penetration and design is to think of an automobile: the brakes are designed for the maximum (or instantaneous) vehicle speed of, say, 120 mph, not the vehicle's typical day-to-day average speed of 45 mph. If the brakes were designed for average vehicle speed, one would be unable to stop when driving at highway cruising speeds, let alone maximum vehicle speed!

The annual contribution of wind energy, expressed as percentage of wind energy compared to load demand, is the average penetration level. This defines the economic benefit of a project.

Categories of wind-diesel penetration levels

Penetration Category	Wind Penetration Level		Operating Characteristics and System Requirements
	Instantaneous	Average	
Very Low	<60%	<8%	• Diesel generator(s) runs full time • Wind power reduces net load on diesel • All wind energy serves primary load • No supervisory control system
Low	60 to 120%	8 to 20%	• Diesel generator(s) runs full time • At high wind power levels, secondary loads are dispatched to insure sufficient diesel loading, or wind generation is curtailed • Relatively simple control system
Medium	120 to 300%	20 to 50%	• Diesel generator(s) runs full time • At medium to high wind power levels, secondary loads are dispatched to insure sufficient diesel loading • At high wind power levels, complex secondary load control system is needed to ensure heat loads do not become saturated • Sophisticated control system
High (Diesels-off Capable)	300+%	50 to 150%	• At high wind power levels, diesel generator(s) may be shut down for diesels-off capability • Auxiliary components required to regulate voltage and frequency • Sophisticated control system

Recommended Penetration Configuration

In general, medium penetration is a good design compromise as it enables a relatively large amount of displaced fuel usage but requires only a moderate degree of system complexity. Medium penetration is the preferred system configuration of Alaska Village Electric Cooperative (AVEC), owner and operator of eleven wind-diesel systems statewide, and Alaska's leading utility developer of wind-diesel. AVEC's experience provides a useful guide for North Slope Borough as it develops wind energy for its communities.

It should be noted however that not all world-wide designers categorize wind penetration as does Alaska Energy Authority. Many collapse the penetration categories to just two: low and high. This simplification is in recognition that system design is dependent on the percentage of instantaneous, not average penetration. The nuances beyond that are diesels-off capability and inclusion of storage options. For village wind power, a project capable of off-setting a worthwhile amount of diesel fuel and providing real economic benefit to the community invariably must be high penetration by the alternate definition. With this in mind, limiting average penetration to a compromise level of 20 to 50 percent may, in some respects, make very little sense. With a design configuration capable of controlling 100 percent and higher instantaneous penetration, there is no particular reason to limit average penetration to a pre-determined percentage as with Alaska Energy Authority's definition of medium penetration.

Wind-Diesel System Components

Listed below are the main components of a medium to high-penetration wind-diesel system:

- Wind turbine(s), plus tower and foundation
- Supervisory control system
- Secondary load (plus controller)
- Deferrable load
- Interruptible load
- Storage
- Synchronous condenser

Wind Turbine(s)

Village-scale wind turbines are generally considered to be 50 kW to 500 kW rated output capacity. This turbine size once dominated with worldwide wind power industry but has long been left behind in favor of much larger 1,500 kW plus capacity turbines. Conversely, many turbines are manufactured for home or farm application, but generally these are 10 kW capacity or less. Consequently, few new village size-class turbines are on the market, although a large supply of used and/or remanufactured turbines are available. The latter typically result from repowering older wind farms in the United States and Europe with new, larger wind turbines.

Supervisory Control System

Medium- and 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, also called a supervisory controller, would be installed inside the Point Hope power plant or in a new module adjacent to it. The supervisory controller would select the optimum system configuration based on village load demand and available wind power.

Synchronous Condenser

A synchronous condenser, also referred to as a synchronous compensator, is a specialized synchronous-type electric motor with an output shaft that spins freely. Its excitation field is controlled by a voltage regulator to either generate or absorb reactive power as needed to support grid voltage or to maintain the grid power factor at a specified level. A synchronous condenser or similar device is needed to operate in diesels-off mode with wind turbines equipped with asynchronous (induction) type generators. This is to provide the reactive power necessary for operation of the asynchronous generator.

Secondary Load

A secondary or "dump" load during periods of high wind is required for a wind-diesel hybrid power system to operate reliably and economically. The secondary load converts excess wind power into thermal power for use in space and water heating through the extremely rapid (sub-cycle) switching of heating elements, such as an electric boiler imbedded in the diesel generator jacket water heat recovery loop. A secondary load controller serves to stabilize system frequency by providing a fast responding load when gusting wind creates system instability.

An electric boiler is a common secondary load device used in wind-diesel power systems. An electric boiler (or boilers), coupled with a boiler grid interface control system, could be installed in Point Hope to absorb excess instantaneous energy (generated wind energy plus minimum diesel output exceeds electric load demand). The grid interface monitors and maintains the temperature of the electric hot water tank and establishes a power setpoint. The wind-diesel system master controller assigns the setpoint based on the amount of unused wind power available in the system. Frequency stabilization is another advantage that can be controlled with an electric boiler load. The boiler grid interface will automatically adjust the amount of power it is drawing to maintain system frequency within acceptable limits.

Deferrable Load

A deferrable load is electric load that must be met within some time period, but exact timing is not important. Loads are normally classified as deferrable because they have some storage associated with them. Water pumping is a common example - there is some flexibility as to when the pump actually operates, provided the water tank does not run dry. Other examples include ice making and battery charging. A deferrable load operates second in priority to the primary load and has priority over charging batteries, should the system employ batteries as a storage option.

Interruptible Load

Electric heating either in the form of electric space heaters or electric water boilers could be explored as a means of displacing stove oil with wind-generated electricity. It must be emphasized that electric heating is only economically viable with excess electricity generated by a renewable energy source such as wind and not from diesel-generated power. It is typically assumed that 40 kWh of electric heat is equivalent to one gallon of heating fuel oil.

Storage Options

Electrical energy storage provides a means of storing wind generated power during periods of high winds and then releasing the power as winds subside. Energy storage has a similar function to a secondary load but the stored, excess wind energy can be converted back to electric power at a later time. There is an efficiency loss with the conversion of power to storage and out of storage. The descriptions below are for information but are not currently part of the overall system design, philosophy, although could be should NSB wish to consider high wind penetration options.

Flywheel

A flywheel energy system has the capability of short-term energy storage to further smooth out short-term variability of wind power, and has the additional advantage of frequency regulation. The smallest capacity flywheel available from Powercorp (now ABB), however, is 500 kW capacity, so it is only suitable for large village power generation systems.

Batteries

Battery storage is a generally well-proven technology and has been used in Alaskan power systems including Fairbanks (Golden Valley Electric Association), Wales and Kokhanok, but with mixed results in the smaller communities. 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 5 to 15 minutes long. Storage for several hours or days is also possible with batteries, but this requires higher capacity and cost. In general, the disadvantages of batteries for utility-scale energy storage, even for small utility systems, are high capital and maintenance costs and limited lifetime. Of particular concern to rural Alaska communities is that batteries are heavy and expensive ship and most contain hazardous substances that require special removal from the village at end of service life and disposal in specially-equipped recycling centers.

There are a wide variety of battery types with different operating characteristics. Advanced lead acid and zinc-bromide flow batteries were identified as "technologically simple" energy storage options appropriate for rural Alaska in a July, 2009 Alaska Center for Energy and Power report on energy storage. Nickel-cadmium (NiCad) batteries have been used in rural Alaska applications such as the Wales wind-diesel system. Advantages of NiCad batteries compared to lead-acid batteries include a deeper discharge capability, lighter weight, higher energy density, a constant output voltage, and much better performance during cold temperatures. However, NiCad's are considerably more expensive than lead-acid batteries, experience a shorter operational life (approx. 5 years vs. 20 years for lead-acid) and one must note that the Wales wind-diesel system had a poor operational history with NiCad batteries and has not been functional for a number of years.

Because batteries operate on direct current (DC), a converter is required to charge or discharge when connected to an alternating current (AC) system. A typical battery storage system would include a bank of batteries and a power conversion device. The batteries would be wired for a nominal voltage of roughly 300 volts. Individual battery voltages on a large scale system are typically 1.2 volts DC. Recent advances in power electronics have made solid state inverter/converter systems cost effective and preferable a power conversion device. The Kokhanok wind-diesel system is designed with a 300 volts DC battery bank coupled to a grid-forming power converter for production of utility-grade real and reactive power. Following some design and commissioning delays, the solid state converter system in Kokhanok should be operational by early 2015 and will be monitored closely for reliability and effectiveness.

Wind-Diesel Philosophy

Installing wind turbines and creating a wind-diesel power system in an Alaskan village is a demanding challenge. At first glance, the benefits of wind power are manifest: the fuel is free and it is simply a manner of capturing it. The reality of course is more complicated. Wind turbines are complex machines and integrating them into the diesel power system of a small community is complicated. With wind-diesel, a trade-off exists between fuel savings and complexity. A system that is simple and inexpensive to install and operate will displace relatively little diesel fuel, while a wind-diesel system of considerable complexity and sophistication can achieve very significant fuel savings.

The ideal balance of fuel savings and complexity is not the same for every community and requires careful consideration. Not only do the wind resource, electric and thermal load profiles, and powerhouse suitability vary between villages, so does technical capacity and community willingness to accept the opportunities and challenges of wind power. For reasons that go beyond design and configuration questions, a very good wind-diesel solution for one village may not work as well in another village. Ultimately, the electric utility and village residents must consider their capacity, desire for change and growth, and long-term goals when deciding the best solution to meets their needs.

The purpose of this conceptual design report is to introduce and discuss the viability of wind power in Point Hope. As discussed, many options are possible, ranging from a very simple low penetration system to a highly complex, diesels-off configuration potentially capable of displacing 50 percent or more of fuel usage in the community. It is possible that North Slope Borough and Point Hope residents ultimately will prefer a simple, low penetration wind power system, or alternatively a very complex high penetration system, but from past discussions and work it appears that a moderate approach to wind power in Point Hope is preferable, at least initially.

With a moderately complex project design framework in mind, a configuration of relatively high wind turbine capacity with no electrical storage and no diesels-off capability was chosen. This provides sufficient wind capacity to make a substantive impact on fuel usage but does not require an abrupt transition from low to high complexity. Although conceptually elegant, there is a trade-off to consider with this approach. Installing a large amount of wind power (900 to 1,000 kW of wind capacity is recommended) is expensive, but without electrical or thermal storage some of the benefits of this wind power capacity may not be used to best advantage.

The thermodynamics of energy creation and use dictates that wind power is more valuable when used to offset fuel used by diesel generators to generate electricity than fuel used in fuel oil boilers to serve thermal loads. Referring to the energy production summaries for the turbine configurations under *Modeling Results*, one can see that the wind turbines are expected to produce relatively small amounts of excess electricity, even at 85 percent turbine availability. This excess electricity, although minimal, must be shunted via a secondary load controller to the diesel generator heat recovery loop or simple radiation heaters to avoid curtailing wind turbines during periods of high wind and relatively light electrical load.

Although perhaps not readily apparent in the report, this compromise of wind capacity versus complexity is contained within the economic benefit-to-cost tables. This compromise, which is endemic to wind-diesel, results in high capital costs, but usage of the energy generated is imperfect from an efficiency point of view. The most efficient usage of wind energy from a technical point of view – offset of electrical power, may be too expensive from a cost-benefit perspective.

It is important not to focus strictly on benefit-to-cost ratio of a particular configuration design or particular turbine option, but also consider a wider view of the proposed wind project for Point Hope. Installing approximately 900 kW capacity of wind power has considerable short-term benefit with reduction of diesel fuel usage, but more importantly it would provide a platform of sustainable renewable energy growth in Point Hope for many years to come. This could include enhancements such as additional thermal load offset, battery storage and/or use of a flywheel to enable diesels-off capability, creation of deferred heat loads such as water heating, and installation of distributed electrical home heat units (Steffes heaters or similar) controlled by smart metering. The latter, presently operational to a limited extent in the villages of Kongiganak, Kwigillingok, Tuntutuliak, has enormous potential in rural Alaska to not only reduce the very high fuel oil expenses borne by village residents, but also to improve the efficiency and cost benefit of installed and future wind power projects. These opportunities and benefits are tangible and achievable, but their cost benefit was not modeled in this report.

Lastly, it must be acknowledged that a wind power project in Point Hope will provide benefits that are not easily captured by economic modeling. These are the *externalities* of economics that are widely recognized as valuable, but often discounted because they are considered by some as soft values compared to the hard numbers of capital cost, fuel quantity displaced, etc. These include ideals such as long-term sustainability of the village, independence from foreign-sourced fuel, reduction of Point Hope's carbon footprint, and opportunities for education and training of local residents. Beyond these somewhat practical considerations, there is the simple moral argument that renewable energy is the right thing to do, especially in a community such as Point Hope that is in the vanguard of risk from rising sea level due to global warming.

Point Hope Powerplant

Electric power (comprised of the diesel power plant and the electric power distribution system) in Point Hope 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 Hope consists of four Caterpillar 3512 diesel generators, two rated at 665 kW and one rated at 950 kW output. North Slope Borough documentation indicates a powerplant efficiency of 14.56 kWh/gal, which is very good.

Point Hope powerplant diesel generators and bays

Genset	Rated Capacity	Model	Emissions	Hours*	Fuel Injection	Min Load
6	665 kW	Caterpillar 3512	Tier 2/3	<3,000	Mechanical	533 kW
7	665 kW	Caterpillar 3512	Tier 2/3	<3,000	Mechanical	533 kW
8	910 kW	Caterpillar 3512	Tier 2/3	<3,000	Mechanical	533 kW
9	1,050 kW	Caterpillar 3512	Tier 3	New	Electronic	533 kW

*Since most recent rebuild

Switchgear

Point Hope has new switchgear using Allen Bradley PLC Device Net which interfaces devices via RS485 and 10/100 Ethernet. This new equipment was installed in this year's (2014) power plant upgrade.

Geospatial Perspective of Electrical Load

The school is located adjacent to the power plant and is served directly from a dedicated 480V feeder from the power plant bus. The water treatment plant is located at the far eastern side of the village and wastewater treatment plant is located in the southwest corner of the village. All other loads are fairly evenly distributed with the power plant at the approximate center of the village.

Refer to Appendix D for the Point Hope distribution grid schematic.

Phase Balance of Electrical Load

At the present time, WHPacific Solutions Group does not have phase balance information of the Point Hope power system. Although the phases are presumed to be in balance, this this will be examined during the design phase of the project.

Transformers

The main transformers, serving each feeder at the power plant, are conservative. In an emergency, each is capable of supporting the entire village load during peak winter loads. The distribution transformers are also believed to be liberally-sized for demand with capacity to be loaded to 150% of rated load during colder winter temperatures. This is based on experience with facility loads in general; there is no recorded data to confirm this.

Phase and/or Transformer Capacity Location(s) for Additional Load

Although the Point Hope distribution system has significant reserve capacity and redundancy in its present configuration to support adding wind power generation to the grid, power lines are gradually being upgraded from #2 ACSR to 1/0 AAAC to increase conductor strength for snow and ice loading and to prevent problems related to electrolysis corrosion in the Point Hope's salt air environment. As an additional benefit, the line upgrade will increase the electrical load capacity of the system, reduce line loss, and lessen voltage drop through the system.

Note that at the 12.47 kV transmission voltage in Point Hope, 1 MW of distributed three-phase wind turbine capacity at Site B will add only 46 amps to the 220 amp capacity of the new 1/0 AAAC line, which with only the airport and tank farm load is (or will be) significantly under-utilized.

Condition of Distribution Lines, Transformers, Poles

North Slope Borough villages generally have some of the better maintained power systems in rural Alaska. The original power poles in Point Hope have largely been replaced with new, most of the secondary conductor has been replaced in the past five years, and distribution transformers are being replaced with larger transformers to meet increasing residential demand. As discussed in the preceding section, primary conductor is gradually being replaced and upgraded with larger all-aluminum alloy conductor to improve strength in wind and ice loading and prevent degradation due to electrolysis, a problem which has plagued ACSR conductor in coastal villages.

Parasitic and Other Losses

As documented in the 2013 PCE Report, distribution line loss in Point Hope for fiscal year 2013 was 13.0% and powerhouse consumption was 5.9%, yielding a remarkably low 81.1% ratio of sold vs. generated energy. This indicates a potential problem with the electrical distribution system itself and/or possibly with billing and recordkeeping. This issue will be investigated during the design phase of the project and addressed as an integral component of the wind-diesel system design and operations plan.

Wind Turbine Options

Turbine choice was oriented toward turbines that are large enough to match well with Point Hope's electrical load. Turbines that meet these criteria are generally in the 100 to 750 kW size range. The wind power industry, however, does not provide many options as village wind power is a small market worldwide compared to utility grid-connected projects where wind turbines are 1,000 kW and larger capacity, or home and farm applications where wind turbines are generally 10 kW or less capacity. For this project, five wind turbines are considered:

1. Aeronautica AW/Siva 250: 250 kW rated output; new
2. EWT DW 54-900: 900 kW rated output; new
3. Northern Power Systems 360-39-30: 360 kW rated output; new
4. Vestas V39: 500 kW rated output; remanufactured

The choice of selecting new or remanufactured wind turbines is an important consideration and one which North Slope Borough is carefully considering at present through a separately-contracted evaluation effort which included visits to the offices and factories of Aeronautica Windpower in Massachusetts, Northern Power Systems in Vermont, and Halus Power Systems in California (re-manufacturer of Vestas wind turbines). There are advantages and potential disadvantages of each turbine, including cost, support and parts availability. Note however that the five wind turbines presented in this report have solid track records and good support capacity within Alaska. The turbine evaluation report will be forwarded separately from this conceptual design report.

Aeronautica AW/Siva 250

Aeronautica Windpower, with offices in Plymouth, Massachusetts and production facilities in Portsmouth, New Hampshire, manufactures the AW/Siva 250 wind turbine in two rotor configurations: 29 meters for IEC wind class design IIA sites and 30 meters for IEC wind class IIIA sites. This turbine is a Siva (Germany) licensed design. For Point Hope, the 30 meter version likely would be most optimal. This turbine has a 30 meter rotor diameter, is rated at 250 kW power output, is stall regulated, has a gearbox-type drive system, and is equipped with asynchronous (induction type) dual-wound (50 kW and 250 kW) generators. Braking is accomplished by passive and hydraulically-actuated pivotable blade tips and hydraulic disc brakes. The turbine has active yaw control and is available with 30, 40, 45, and 50 meter tubular steel towers.

AW/Siva 250 specifications:

Operational Data

Start-up wind speed	: 3-4m/sec
Cut-out wind speed	: 25m/sec
Nominal wind speed	: 14m/sec
50 year extreme gust	: 52.5m/sec
IEC wind class design	: IIA/IIIA

Rotor

Type	: Three bladed, horizontal axis
Position	: Upwind
Rotary direction	: Clockwise, looking from front
Number of blades	: 3
Rotor diameter	: 29m/30m
Swept area	: $661m^2/707m^2$
Power regulation	: Stall
Rotor speed	: 40/24 rpm
Hub type	: Ductile cast iron
Weight of hub	: 2000kg
Weight of rotor	: 4150kg

Blades

Manufacturer	: LM Glasfiber
Blade length	: 13.4m
Type	: Self-supporting
Material	: Fiberglass reinforced polyester
Weight per blade	: 750kg

Generator

Manufacturer	: ABB/equivalent	
Type	: Dual wound, Asynchronous	
Poles	: 4/6 poles	6/8 poles
Synchronous speed	: 1006/1207 rpm	757/908 rpm
Nominal Power	: 250kW	50kW
Voltage	: 400/480 V AC	
Frequency	: 50/60 Hz	
Insulation class	: F	
Protection Class	: IP54	
Thermal protection	: PT100/thermistor	

Transmission System

Gearbox Type	: Helical, 3 Stage
Material	: Ductile Cast Iron
Gearbox Cooling	: Oil Cooler

Turbine Controller

Manufacturer	: Mita-Teknik As Denmark
Type	: Microprocessor based
Remote control	: Gateway SCADA

Hydraulic system

Manufacturer	: AVN/Hydratech
Motor speed	: 1500 rpm
Nominal effect	: 3kW
Thermal protection	: Thermorelay/thermistor

Yawing System

Type	: Active
Yaw control	: Wind vane
Yawing gear manufacturer	: Rossi/Bonfiglioli
Drives	: 2 x planetary

Braking systems

Aerodynamic Brake

Type	: Pivotable blade tips
Activation	: Passive & hydraulic

Mechanical Brake

Type	: Disc Brake
Activation	: Hydraulic

Tower

Manufacturer	: AW/Siva
Type	: Tubular
Hub Height	: 30/40/45/50m
Weight	: 18/28/34/38 t (approx)
Corrosion protection	: Hot dipped galvanized

Warranty	: 2 Years

EWT DW 54-900

The DW 52/54-900 is a direct-drive, pitch-regulated wind turbine with a synchronous generator and inverter-conditioned power output. More information regarding the EWT DW 52/54-900 wind turbine is attached and available on EWT's website: http://www.ewtdirectwind.com/. The turbine boasts a track record of over 400 operating turbines in many different wind climates. At present, six DW 900 turbines have been installed in Alaska: two each in Delta Junction, Kotzebue and Nome. For Point Hope, the 54 meter rotor version likely would be most optimal.

Type	*DW 54 / DW 52*
Rotor diameter	54.0 m / 51.5 m
Variable Rotor Speed	12 to 28 rpm
Nominal Power Output	900 kW
Cut-in wind speed	2.5 m/s
Rated wind speed	13 m/s
Cut-out wind speed (10 minute average)	25 m/s
Survival wind speed	59.5 m/s
Power output control	Pitch controlled variable speed

Type Certificate

IEC 61400 wind class IIIA (DW 54)
IEC 61400 wind class IIA (DW 52)

Drive System
Generator Synchronous air-cooled EWT-design, multi-pole, wound-rotor.
Power converter Full-power, IGBT-controlled AC-DC-AC 'back-to-back' type.

Control System
Bachman PLC control system.
Possibility for remote access via TCP / IP internet and the DMS 2.0 * SCADA system.

Tower
Type Conical tubular steel, internal ascent.
Hub heights 40, 50 and 75 meters.

Safety systems
Main brake action Individual rotor blade pitch (three independent brakes).
Fail-safe brake Individual rotor blade pitch by three independent battery-powered back-up units.

Northern Power Systems 360-39 (NPS 360-39)

At 360 kilowatts of rated power, the new-to-the-market Northern Power 360-39 is an innovative wind turbine with gearless direct drive design, permanent magnet generator, and pleasing aesthetics. The turbine will be marketed in two versions: the NPS 360 for temperature climates and the NPS 360 Arctic for cold climates such as Alaska. Differences between the two include heaters and insulation for the Arctic version, plus certification that metal used in the tower and nacelle frame are appropriate for operation to -40° C (-40° F). Note that design characteristics of the NPS 360-39 will be very similar to the NPS 100 B model turbine which is well represented in Alaska.

According to Northern Power Systems, the proprietary permanent magnet generator is central to the design of the NPS 100 (and the new NPS 360) drivetrain. Permanent magnet generators offer high efficiency energy conversion, particularly at partial load, and require no separate field excitation system. Permanent magnet generators are lighter, more efficient, and require less assembly labor than competing designs. The Northern Power permanent magnet generator was designed in conjunction with its power converter to create an optimized solution tailored for high energy capture and low operating costs.

A key element of Northern Power's direct drive wind turbine design is the power converter used to connect the permanent magnet generator output to the local power system. Northern Power designs and manufactures power converters for its wind turbines in-house, with complete hardware, control design, and software capabilities. In 2006, the American Wind Energy Association (AWEA) awarded its annual Technical Achievement Award to Northern Power's Chief Engineer, Jeff Petter. It recognized his expertise and leadership in the development of Northern Power Systems' FlexPhase™ power converter for mega-watt scale wind turbine applications. The FlexPhase power converter combines a unique, patent-pending circuit design with a high bandwidth control system to provide unique generator management, power quality, and grid support features. The FlexPhase converter platform offers a modular approach with a very small footprint and 20-year design life.

NPS 360-39 Class IIIA general information

Model	NPS 360-39
Design Class	IEC 61400-1, 3rd ed., WTGS IIIA
Power Regulation	Variable speed, pitch control
Orientation	Upwind
Yaw Control	Active
Number of Blades	Three
Rotor Diameter	39 meters
Rated Electrical Power	360 kW
Cut-in/Cut-out Wind Speeds	3 m/sec; 25 m/sec
Controller Type	PLC (programmable logic controller)
Hub Height; tower type	30 meters; 3-section tubular steel monopole

Vestas V39

Halus Power Systems of San Leandro, California remanufactures the legacy suite of Vestas wind turbines, rated from 65 kW (the V15) to 600 kW (the V44). Of most interest to North Slope Borough for Point Hope is the V39 turbine. The V39 is a 39 meter rotor diameter, 500 kW rated output, pitch-controlled, gearbox-type drive system, asynchronous double-wound generator wind turbine originally built by Vestas A/S in Denmark. The turbine has active yaw control and is available with a 40 meter steel tower as standard and higher towers by special fabrication. Although the smaller Vestas V27 nacelle, tower, and blades can be shipped in standard shipping containers, eliminating the expense and risk of damage with break bulk shipping, V39 blades would require more costly break bulk shipping.

Braking and stopping are accomplished by full feathering of the rotor blades, which is a desirable feature of pitch-controlled wind turbines. An emergency stop activates the hydraulic disk brake, which is fitted to the high speed shaft of the gearbox. All functions of the turbine are monitored and controlled by the microprocessor-based control unit. Blade position (pitch angle) is performed by the hydraulic system, which also delivers hydraulic pressure to the brake system. Both are fail-safe in the sense that loss of hydraulic pressure results in feathering of the rotor blades and activation of the disk brake. Of interest with respect to the pitch system is the mechanical interlink of the three rotor blades contained in the hub nose cone. With this simple but ingenious design, it is not possible for the turbine blades to pitch differently from each other.

A smaller version of the V39, the V27, was Vestas' workhorse turbine for many years and thousands were installed worldwide. Design of the turbine pre-dates the IEC 61400-1 standards, but by present criteria the turbine can be considered Class II-A and possibly even Class I-A. The V27 is well regarded as a rugged, tough turbine with an outstanding operational history. Four V27 wind turbines are operational in Alaska: three on Saint Paul Island and one at the Air Force's Tin City Long Range Radar Site. Additionally, two V39 wind turbines were installed by TDX Power in Sand Point, Alaska and are operational. Because of the large numbers of Vestas turbines (legacy and new) deployed in North America, Vestas continues to maintain multiple facilities in the United States including a large manufacturing facility in Colorado and an office in Portland, Oregon. Vestas can provide technical support and spare parts for their legacy turbines (from V17 through V44) as needed. In addition, due to the large number of deployed turbines in North America and worldwide, spare parts are widely available from many suppliers.

Wind-Diesel HOMER Model

Considering North Slope Borough'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 North Slope Borough's desire to operate a highly stable and reliable electrical utility in Point Hope, 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 North Slope Borough's goal of significantly displacing fuel usage in Point Hope.

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 Hope, 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.

Powerplant

Point Hope is equipped with four Caterpillar 3512 diesel generators. Note that these generators are modeled at 15 percent minimum load, but recent correspondence with North Slope Borough powerplant personnel indicates that all four generators are operated at a minimum 533 kW load. This would equate to 80% minimum load for generators 6 and 7, 58% for generator 8, and 51% for generator 9. This discrepancy will be examined in detail during the design phase of the project.

Diesel generator HOMER modeling information

Diesel generator	Cat 3512 (bays 6 and 7)	Cat 3512 (bay 8)	Cat 3512 (bay 9)
Power output (kW)	665	910	1,050
Intercept coeff. (L/hr/kW rated)	0.0194	0.0194	0.0194
Slope (L/hr/kW output)	0.2325	0.2325	0.2325

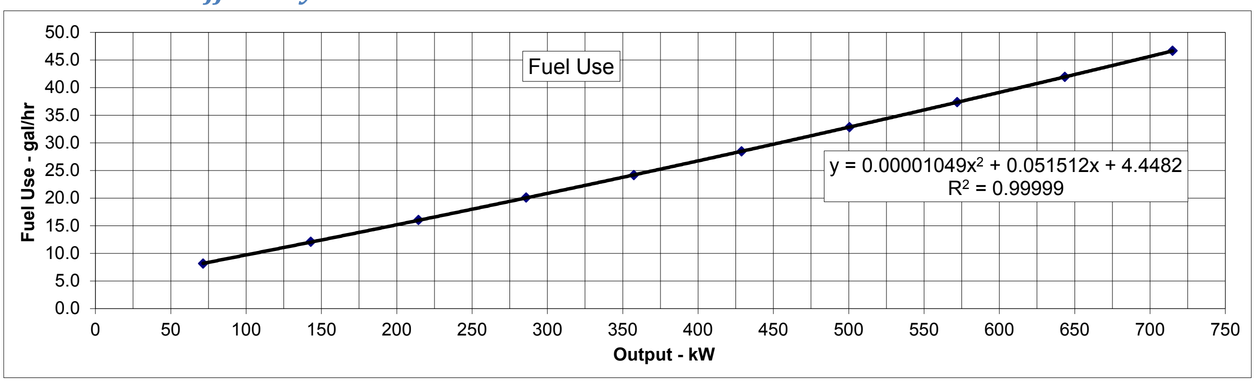
Diesel generator	Cat 3512 (bays 6 and 7)	Cat 3512 (bay 8)	Cat 3512 (bay 9)
Minimum electric load (%)	15.0% (100 kW)	15.0% (135 kW)	15% 157 kW)
Heat recovery ratio (% of generator waste heat energy available to serve the thermal load; when modeled)	35	35	35

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

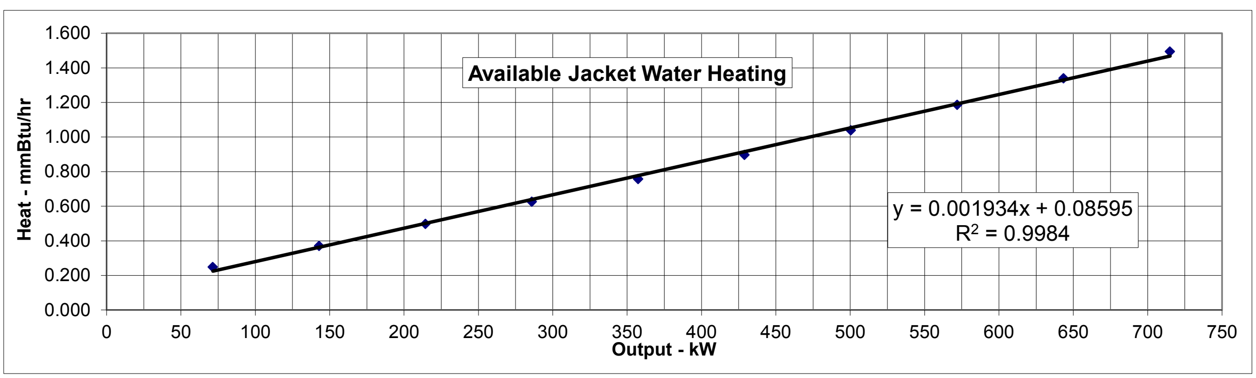
Caterpillar 3512 Fuel Efficiency

The Caterpillar 3512 is the primary diesel generator type in the Point Hope power plant. The graphs below, obtained from NC Machinery, illustrates fuel usage and heat production of the Cat 3512 diesel engine. Fuel usage information in the Homer model (as presented in the preceding table) differs slightly in that AEA testing information obtained from Mr. David Lockard was used.

Cat 3512 Fuel Efficiency



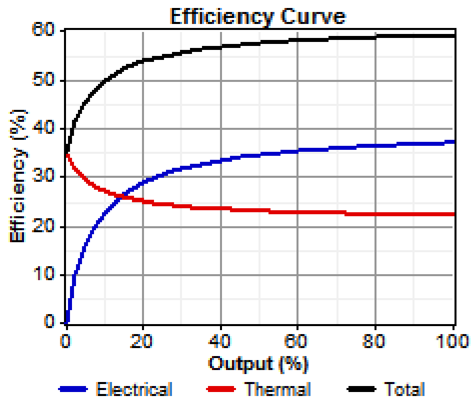
Cat 3512 Heat Production



Cat 3512 Electrical and Thermal Efficiency

Electrical and thermal efficiency of the Cat 3512 diesel engine is shown below. Note that North Slope Borough did not report a seasonal or other specific scheduling plan, hence Homer software was programmed to select the most efficient diesel for any time period. Also note that Homer was programmed to allow parallel diesel generator operation, which is verfied on review of North Slope Borough's Point Hope power plant logs.

Cat 3512 electrical and thermal efficiency curves



Cat 3512 Recovered Heat Ratio

The 35 percent heat recovery potential of the Cat 3512 generator was derived from technical data supplied by NC Power Systems. Homer software defines the heat recovery ratio as the percentage of generator waste heat energy available to serve the thermal load. Generator waste heat is energy not used for work; work being the energy output of the generator. As the table below indicates, the recovered heat ratio of the Cat 3512 generator equipped with an aftercooler (known also as an intercooler), is 41.8%. Assuming 15% system heat loss, actual heat recovery ratio is 35.5%, which was modeled at 35%.

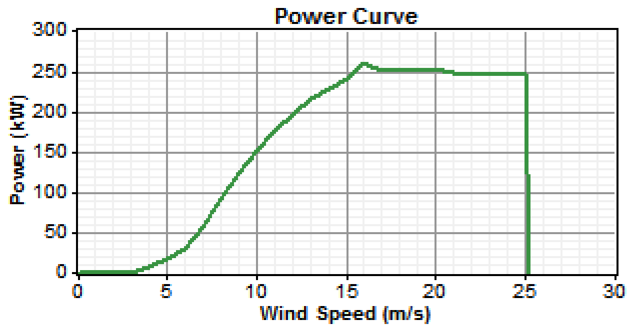
Cat 3512 heat recovery table

		rejected energy			returned energy to JW			electricity	
gen pwr	% load	rej to JW (BTU/m)	rej to atmos (BTU/m)	rej to exhaust (BTU/m)	exh rcov to 350F (BTU/m)	from oil cooler (BTU/m)	from after cooler (BTU/m)	work energy (BTU/m)	TOTAL (BTU/m)
665	100	23,146	5,857	33,610	15,753	4,896	3,037	39,865	102,478
% total energy		22.6%	5.7%	32.8%	15.4%	4.8%	3.0%	38.9%	100.0%
% of remaining non-work energy		37.0%	9.4%	53.7%	25.2%	7.8%	4.9%		
JW and aftercooler		37.0%					4.9%		41.8%
Recovered heat ratio, Homer, 15% heat loss assumed									35.5%

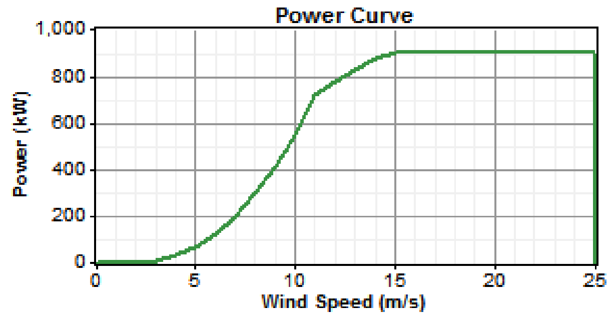
Wind Turbines

Wind turbine options for Point Hope are discussed previously in this report. For Homer modeling, standard temperature and pressure (STP) power curves were used. This is quite conservative in that actual wind turbine power production in Point Hope will typically be higher than predicted by the STP power curves due to the cold temperature climate and consequent high air density of the area.

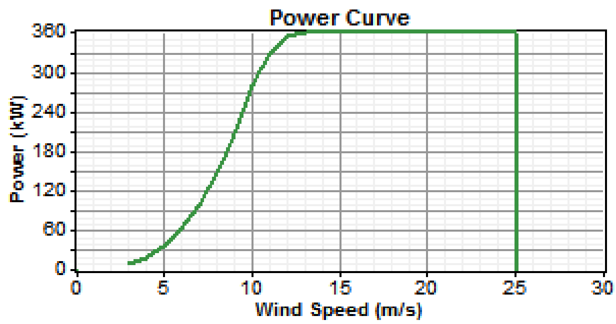
Aeronautica AW/Siva 250 power curve



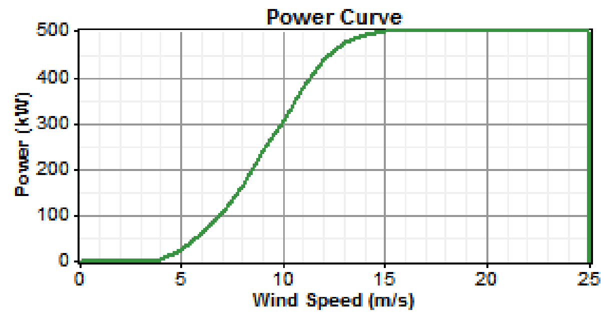
EWT DW 54-900 power curve



Northern NPS 360-39 power curve



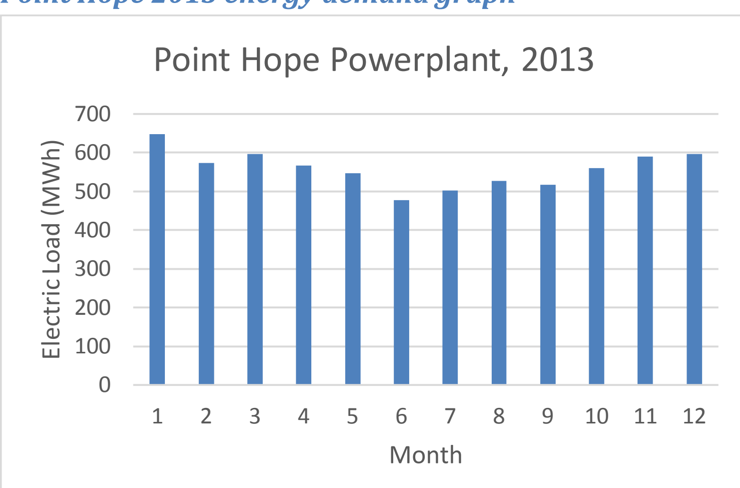
Vestas V39 power curve



Electric Load

For modeling purposes with Homer software, the Point Hope electric load was derived from calendar year 2013 powerplant data forwarded to V3 Energy, LLC by North Slope Borough in an Excel spreadsheet entitled *2013_Point_Hope_PPOR*. The spreadsheet tabulates power output log readings hand-collected (by the powerplant operators) hour for each diesel engine on-line. If two diesel engines are operating in parallel, individual generator power output is summed to equal total hour (average) load. For each day, generator output is summed to yield kWh produced per generator and aggregate. Below are the monthly Point Hope load profile for 2013, an example of daily generator output/load data, and electrical profile data used in Homer software for the system analysis.

Point Hope 2013 energy demand graph

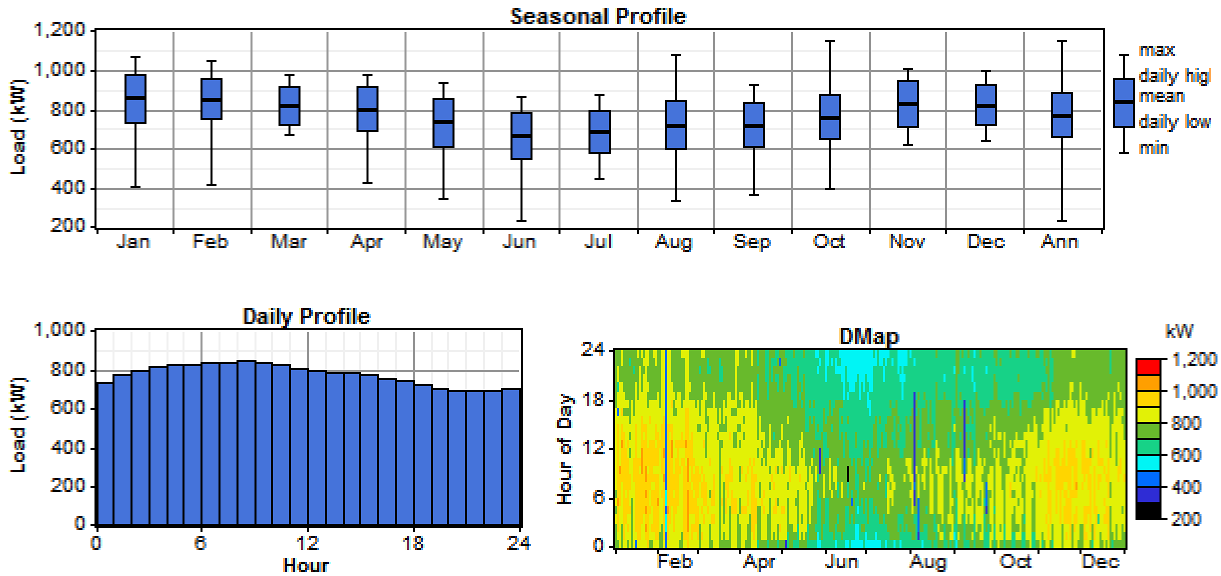


Point Hope powerplant log data, sample day

Point Hope Power Plant March 6, 2013					
Hour	**Engine 6** Caterpillar 3512 Serial # 67Z1167	**Engine 7** Caterpillar 3512 Serial # 67Z1266	**Engine 8** Caterpillar 3512 Serial # 67Z1165	**Total Hourly Total Load**	**Peak Load of the Day**
	Total Load	**Total Load**	**Total Load**		
0:00	380.00		437.00	817.00	955.00
1:00	412.00		504.00	916.00	
2:00	402.00		484.00	886.00	
3:00	413.00		478.00	891.00	
4:00		475.00	476.00	951.00	
5:00	427.00	494.00		921.00	
6:00	440.00	515.00		955.00	
7:00	261.00	318.00	317.00	896.00	
8:00		452.00	431.00	883.00	
9:00		459.00	442.00	901.00	
10:00		447.00	446.00	893.00	
11:00		427.00	410.00	837.00	
12:00		409.00	399.00	808.00	
13:00		424.00	414.00	838.00	
14:00		444.00	410.00	854.00	
15:00		436.00	418.00	854.00	
16:00		427.00	409.00	836.00	
17:00		417.00	391.00	808.00	
18:00		389.00	364.00	753.00	
19:00		371.00	346.00	717.00	
20:00		369.00	347.00	716.00	
21:00		374.00	352.00	726.00	
22:00		394.00	360.00	754.00	
23:00		380.00	350.00	730.00	
Total	2735	8421	8985	**20,141.00**	

For Homer input, load data is organized into 8,760 lines, representing 24 hours per day, 365 days per year. In a number of instances diesel generator power (load) data was missing from the data set. In these cases, missing data was interpolated with reference to data before and after the blank sections. The graphs below show a summary of the Point Hope electric load from the referenced powerplant Excel spreadsheet.

Point Hope electric load



Thermal Load

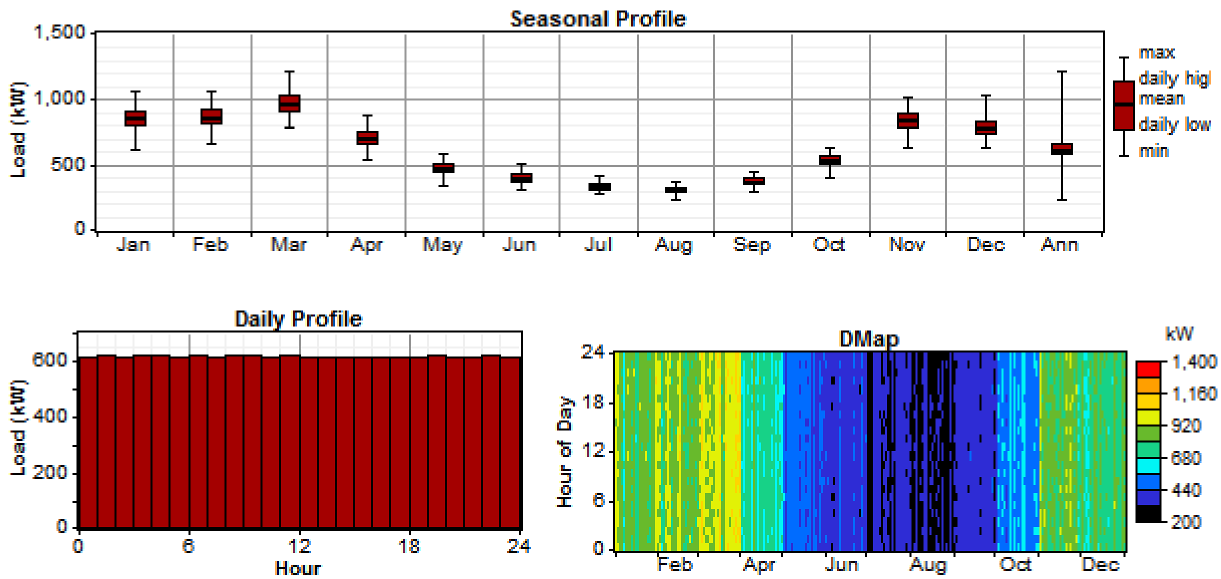
The Point Hope powerplant is equipped with a heat recovery system to extract jacket water waste heat from the diesel generators and supply it to the following village thermal (heat) loads: powerplant, school, utilidor, grey water plant, health clinic, and old water plant/washeteria. Possible additional connection points are the PSO, fire station, USDW, and the sewage treatment plant according to a February, 2010 draft RSA Engineering, Inc. report to North Slope Borough entitled *North Slope Borough Village Heat Recovery Project Analysis Report, CIP No. 13-222*. Per the RSA report, the combined design day heat load of the above-referenced structures is 4.03 MMBTU/hr. The additional thermal loads, if connected, would increase the design data heat load by 3.60 MMBTU/hr. Data from the RSA Engineering report details monthly existing waste heat (from the powerplant heat recovery system) consumption and the estimated contribution of waste heat to the actual heat load. Additional data from RSA Engineering is documented in the table below.

RSA Engineering thermal load data, existing heat loads

month	avg power (kW)	available waste heat (BTU/hr)	available heat (MMBTU)	available waste heat (kWh)	hourly heat available (kW)	waste heat consumed (BTU/hr)	waste heat consumed (kW)
1	762	2,080,440	1,498	438,996	610	2,080,440	610
2	660	1,802,429	1,298	380,333	528	1,802,429	528
3	602	1,644,099	1,184	346,923	482	1,644,099	482
4	708	1,933,398	1,392	407,969	567	1,933,398	567
5	495	1,353,368	974	285,576	397	1,353,368	397
6	737	2,013,287	1,450	424,826	590	1,065,766	312
7	532	1,453,883	1,047	306,786	426	747,920	219
8	456	1,246,681	898	263,064	365	713,918	209
9	481	1,313,466	946	277,156	385	1,511,897	443
10	629	1,719,074	1,238	362,744	504	1,479,005	433
11	523	1,429,910	1,030	301,727	419	1,429,910	419
12	709	1,937,326	1,395	408,797	568	1,937,326	568

Data from the above table and additional information obtained from RSA Engineering, Inc. for the village of Kaktovik was converted to kW (heat) load and scaled by a factor of 1.22 as adjustment for the higher thermal loads in Point Hope. Data was uploaded to Homer software to create a thermal load profile for modeling purposes. Diurnal thermal load variation is not contained in the RSA report and is unknown, hence modeled as constant.

Point Hope thermal load



Wind Turbine Configuration Options

Discussions between WHPacific Solutions Group, V3 Energy, LLC and North Slope Borough to date have indicated that the borough's goals with a wind-diesel system in Point Hope is to offset a significant percentage of fuel used in the powerplant, but not create a highly complex system with significant thermal offset and/or electrical storage capability. This philosophy dictates a medium penetration design approach (see previous section of this report) where wind power supplies a reasonably high percentage of the electric load, but diesel generation remains on-line to provide spinning reserve. Medium penetration design, though, means that instantaneous wind power will at times be well over 100 percent of the load. This can result in unstable grid frequency, which occurs when electrical power generated exceeds load demand. In a wind-diesel power system without electrical storage, there are three options to prevent this possibility:

1. Curtail one or more wind turbines to prevent instantaneous wind penetration from exceeding 100 percent (one must also account for minimum loading of the diesel generator).

2. Install a secondary load controller with a resistive heater. The secondary load controller is a fast-acting switch mechanism commanding heating elements to turn on and off to order to maintain stable frequency. The resistive heating elements can comprise a device as simple as a heater ejecting energy to the atmosphere or an interior air space, or more desirably, an electric boiler

serving one or more thermal loads. The boiler can be installed in the powerplant heat recovery loop and operate in parallel with fuel oil boilers.

3. Equip the wind turbines with output controllers (some wind turbines, such as the EWT DW 900 and the NPS 360, are pre-equipped with these controllers) to enable reduction of turbine power to match load demand. This is a more efficient turbine control strategy than curtailment, but of course presents an additional cost to the project and "wastes" wind energy in the sense that one is purposely throttling the turbine(s).

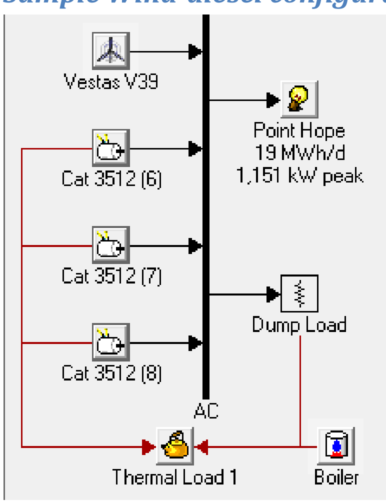
For medium penetration design, frequency control features as described above are necessary because, generally speaking, diesel generators paralleled with wind turbines during periods of high wind energy input may not have sufficient inertia to control frequency by themselves. This design philosophy is true of most wind-diesel systems presently operational in Alaska and provides a solid compromise between the minimal benefit of low penetration systems and the high cost and complexity of high penetration systems.

Many utilities prefer to install more than one wind turbine for a village wind power project to provide redundancy and continued renewable energy generation should one turbine be out-of-service for maintenance, fault, or other reasons. This guidance is modified for Point Hope in that a single single EWT DW 54-900 turbine configuration is included with the multi-turbine configuration options. Referencing the medium wind power penetration design philosophy discussed above, modeled wind turbine configuration options considered in this report are as follows:

- Aeronautica AW 250, four turbines (1,000 kW capacity)
- EWT DW 52-900, one turbine (900 kW capacity)
- Northern Power NPS 360-39, three turbines (1,080 kW capacity)
- Vestas V39, two turbines (1,000 kW capacity)

Turbine types are not mixed, however, as it is assumed that North Slope Borough will select only one type of wind turbine. A typical configuration for this project is show below.

Sample Wind-diesel configuration for Point Hope



System Modeling and Technical Analysis

Installation of wind turbines in medium penetration mode is evaluated in this report to demonstrate the economic impact of these turbines with the following configuration philosophy: turbines are connected to the electrical distribution system to serve the electrical load and a secondary load controller and an electric heater or boiler to divert excess electrical power to offset thermal load(s) via a secondary load controller.

HOMER energy modeling software was used to analyze the Point Hope power generation system. HOMER was designed to analyze hybrid power systems that contain a mix of conventional and renewable energy sources, such as diesel generators, wind turbines, solar panels, batteries, etc. and is widely used to aid development of Alaska village wind power projects. The following wind-diesel system configurations were modeled for this conceptual design report. A one-line diagram of this proposed system is presented in Appendix E.

Modeled wind-diesel configurations

Turbine	No. Turbines	Installed kW	Tower Type	Hub Height (meters)
Aeronautica AW/Siva 250	4	1,000	Monopole	30
EWT DW 52-900	1	900	Monopole	35
Northern Power NPS 360-39	3	1,080	Monopole	30
Vestas V39	2	1,000	Monopole	40

Modeling assumes that wind turbines constructed in Point Hope will operate in parallel with the diesel generators. Excess energy presumably will serve thermal loads via a secondary load controller and electric boiler that will augment the existing jacket water heat recovery system and is modeled as such in the technical analysis of this report (although not in the economic analysis).

Although not considered in this report, deferrable electric and/or remote node thermal loads could be served with excess system energy. This possibility be considered during the design phase of this project.

Technical modeling assumptions

Operating Reserves	
Load in current time step	10%
Wind power output	50% (diesels always on)
Fuel Properties (no. 2 diesel for powerplant)	
Heating value	46.8 MJ/kg (140,000 BTU/gal)
Density	830 kg/m^3 (6.93 lb./gal)
Fuel Properties (no. 1 diesel to serve thermal loads)	
Heating value	44.8 MJ/kg (134,000 BTU/gal)
Density	830 kg/m^3 (6.93 lb./gal)
Diesel Generators	
Efficiency	14.6 kWh/gal (North Slope Borough data)

Minimum load	15%
Schedule	Optimized
Wind Turbines	
Net capacity factor	85% (adjusted by reducing mean wind speed in Homer software)
Turbine hub height	As noted
Wind speed	7.12 m/s at 30 m level at met tower site; wind speed scaled to 6.51 m/s for 85% turbine net AEP
Density adjustment	Density not adjusted
Energy Loads	
Electric	18,581 kWh/day mean annual electrical load
Thermal	14,797 kWh/day mean annual via recovered heat loop
Fuel oil boiler efficiency	85%
Electric boiler efficiency	100%

Model Results

The Site B wind resource is presumed to be identical to that measured at the met tower site. Given the flat, featureless terrain between the met tower and Site B, this is a reasonable assumption. Site B may be height restricted, however, hence lowest possible turbine hub heights possible are modeled and recommended. Given the Point Hope's very strong wind resource and moderate wind shear, low hub heights are acceptable and may be desirable from an aesthetic point of view to reduce visual impact of the project. Note that turbine energy production is modeled at 85 percent net.

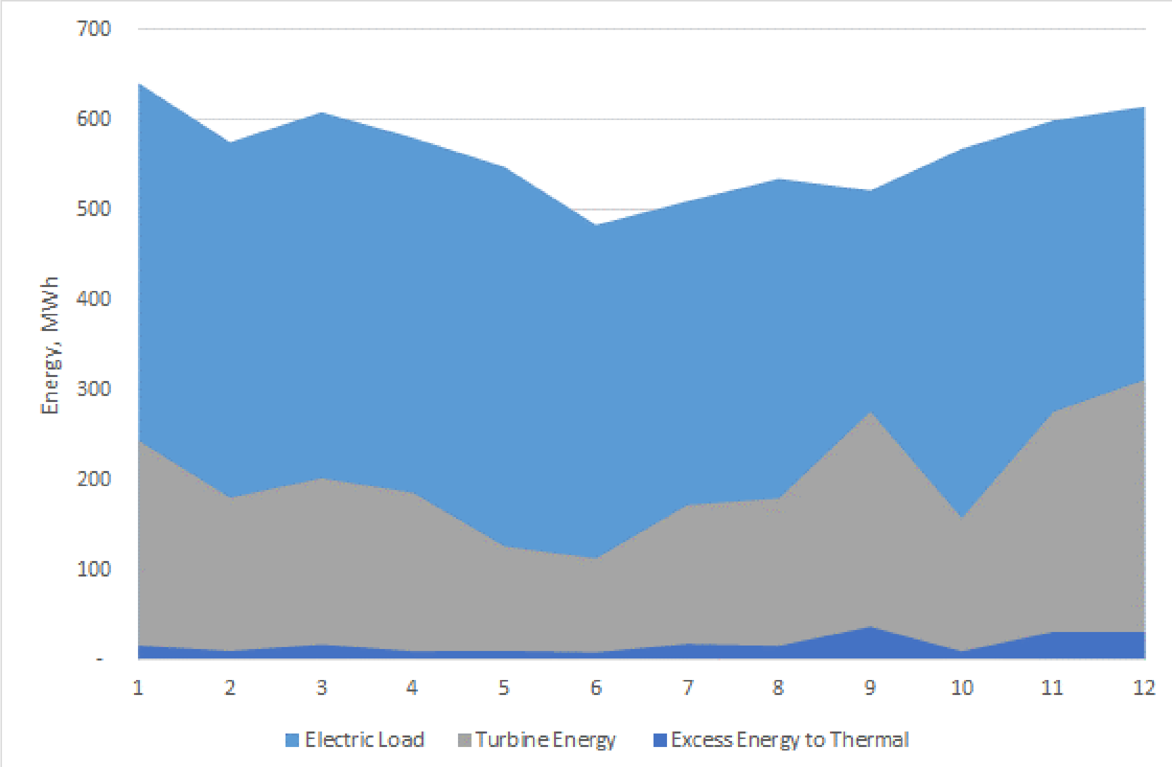
AW/Siva 250, four (4) turbines, 30 m hub height

This configuration models one AW/Siva 250 kW wind turbine at Point Hope Site B at a 30 meter hub height and generating 85 percent of maximum annual energy production.

Energy table, four AW/Siva 250's, 85% net AEP

Month	Electric Load	Turbine Energy	Energy Generated	Turbine Energy to E. Load	Wind Penetration	Excess Energy to Thermal	Excess Energy to Thermal
	kWh	kWh	kWh	kWh	%	kWh	%
1	640,644	230,781	654,616	216,809	35.3%	13,972	1.8%
2	575,127	168,833	583,608	160,352	28.9%	8,481	1.4%
3	608,327	190,746	623,308	175,765	30.6%	14,981	2.0%
4	580,039	173,588	587,959	165,668	29.5%	7,919	1.1%
5	547,631	117,371	555,992	109,010	21.1%	8,360	1.2%
6	483,177	104,066	490,095	97,148	21.2%	6,918	1.1%
7	509,560	160,015	524,592	144,983	30.5%	15,032	2.3%
8	534,461	167,712	548,011	154,162	30.6%	13,550	1.9%
9	521,565	261,974	554,006	229,533	47.3%	32,441	4.6%
10	567,839	146,336	575,308	138,866	25.4%	7,469	1.1%
11	599,124	264,158	627,745	235,537	42.1%	28,621	3.8%
12	614,571	297,734	641,967	270,337	46.4%	27,396	3.6%
Annual	6,782,000	2,283,000	6,967,000	2,098,000	32.8%	185,000	2.2%

Chart, four AW/Siva 250's



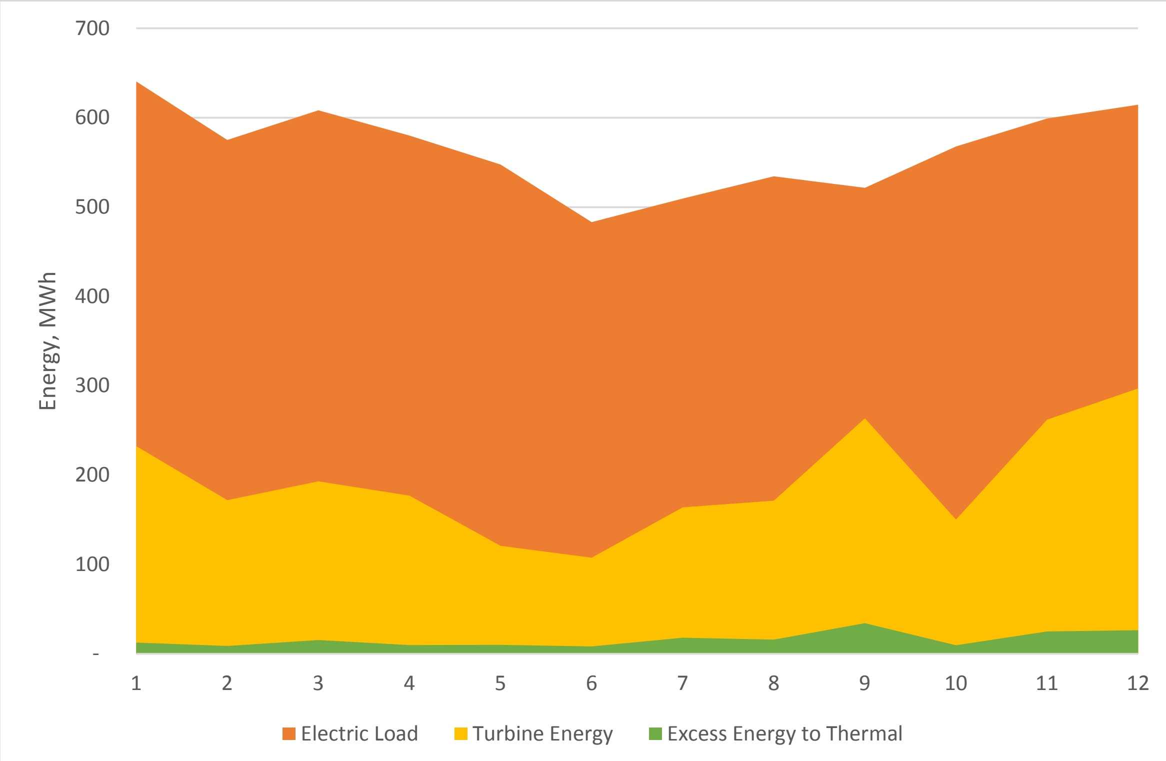
EWT DW 54-900, one (1) turbine, 35 m hub height

This configuration models one EWT DW 54-900 wind turbine at Point Hope Site B at a 35 meter hub height and generating 85 percent of maximum annual energy production.

Energy table, one DW 54-900, 85% net AEP

Month	Electric Load	Turbine Energy	Energy Generated	Turbine Energy to E. Load	Wind Penetra-tion	Excess Energy to Thermal	Excess Energy to Thermal
	kWh	kWh	kWh	kWh	%	kWh	%
1	640,644	232,492	653,244	219,892	35.6%	12,600	1.7%
2	575,127	172,026	583,909	163,244	29.5%	8,782	1.5%
3	608,327	193,052	623,751	177,628	31.0%	15,424	2.1%
4	580,039	177,069	589,808	167,300	30.0%	9,769	1.4%
5	547,631	120,868	557,628	110,872	21.7%	9,996	1.5%
6	483,177	107,588	491,456	99,309	21.9%	8,279	1.3%
7	509,560	163,927	527,571	145,916	31.1%	18,011	2.7%
8	534,461	171,410	550,327	155,544	31.1%	15,866	2.3%
9	521,565	263,582	555,854	229,293	47.4%	34,289	5.0%
10	567,839	150,269	577,425	140,683	26.0%	9,586	1.4%
11	599,124	262,093	624,136	237,081	42.0%	25,012	3.6%
12	614,571	297,036	640,990	270,618	46.3%	26,419	3.7%
Annual	6,782,000	2,311,000	6,976,000	2,117,000	33.1%	194,000	2.4%

Chart, one DW 54-900



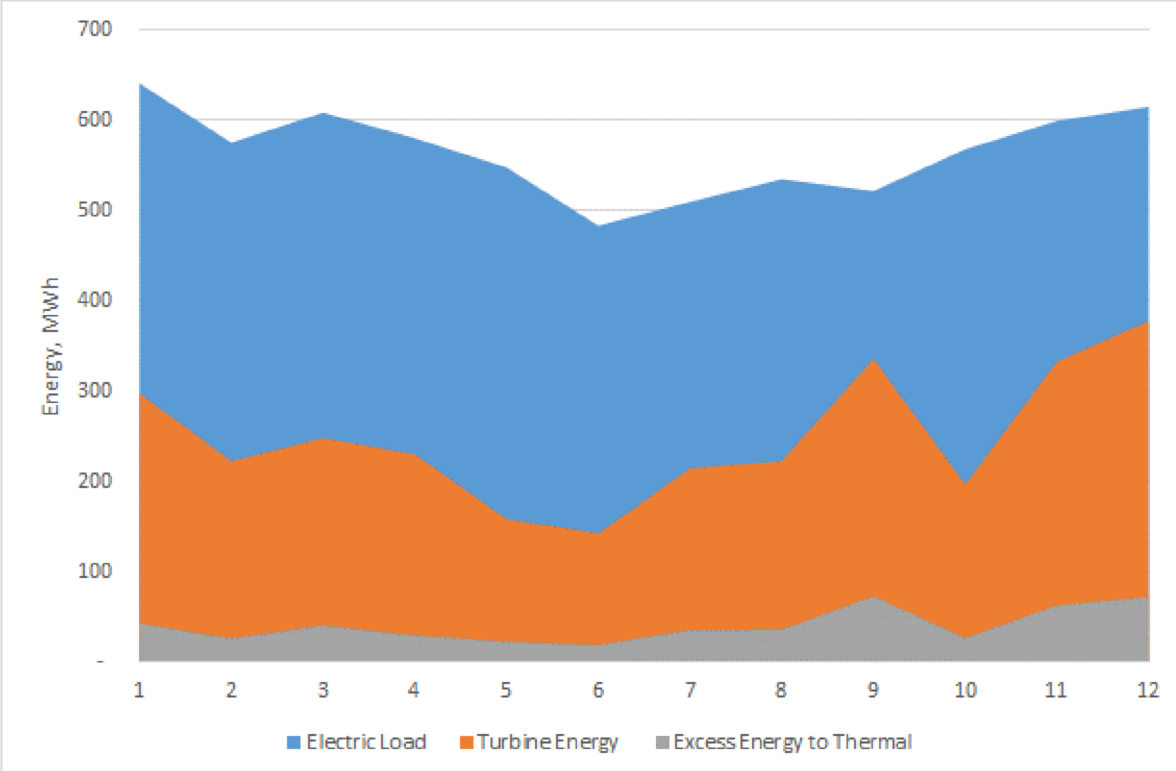
Northern Power NPS 360-39, three (3) turbines, 30 m hub height

This configuration models three Northern Power Systems NPS 360-39 wind turbines at Point Hope Site B at a 30 meter hub height and generating 85 percent of maximum annual energy production.

Energy table, three NPS 360-39's, 85% net AEP

Month	Electric Load	Turbine Energy	Energy Generated	Turbine Energy to E. Load	Wind Penetration	Excess Energy to Thermal	Excess Energy to Thermal
	kWh	kWh	kWh	kWh	%	kWh	%
1	640,644	297,469	683,137	254,975	43.5%	42,493	5.1%
2	575,127	222,764	601,257	196,633	37.0%	26,130	3.7%
3	608,327	247,907	648,786	207,448	38.2%	40,459	4.9%
4	580,039	230,337	609,628	200,748	37.8%	29,589	3.8%
5	547,631	158,416	570,472	135,576	27.8%	22,840	3.0%
6	483,177	142,330	502,314	123,193	28.3%	19,137	2.7%
7	509,560	214,447	545,204	178,803	39.3%	35,644	4.9%
8	534,461	222,762	570,451	186,771	39.1%	35,990	4.6%
9	521,565	335,652	594,832	262,385	56.4%	73,267	9.4%
10	567,839	196,586	594,334	170,091	33.1%	26,495	3.4%
11	599,124	332,756	662,255	269,625	50.2%	63,131	7.8%
12	614,571	377,469	687,032	305,008	54.9%	72,461	8.6%
Annual	6,782,000	2,979,000	7,270,000	2,491,000	41.0%	488,000	5.2%

Chart, three NPS 360-39's



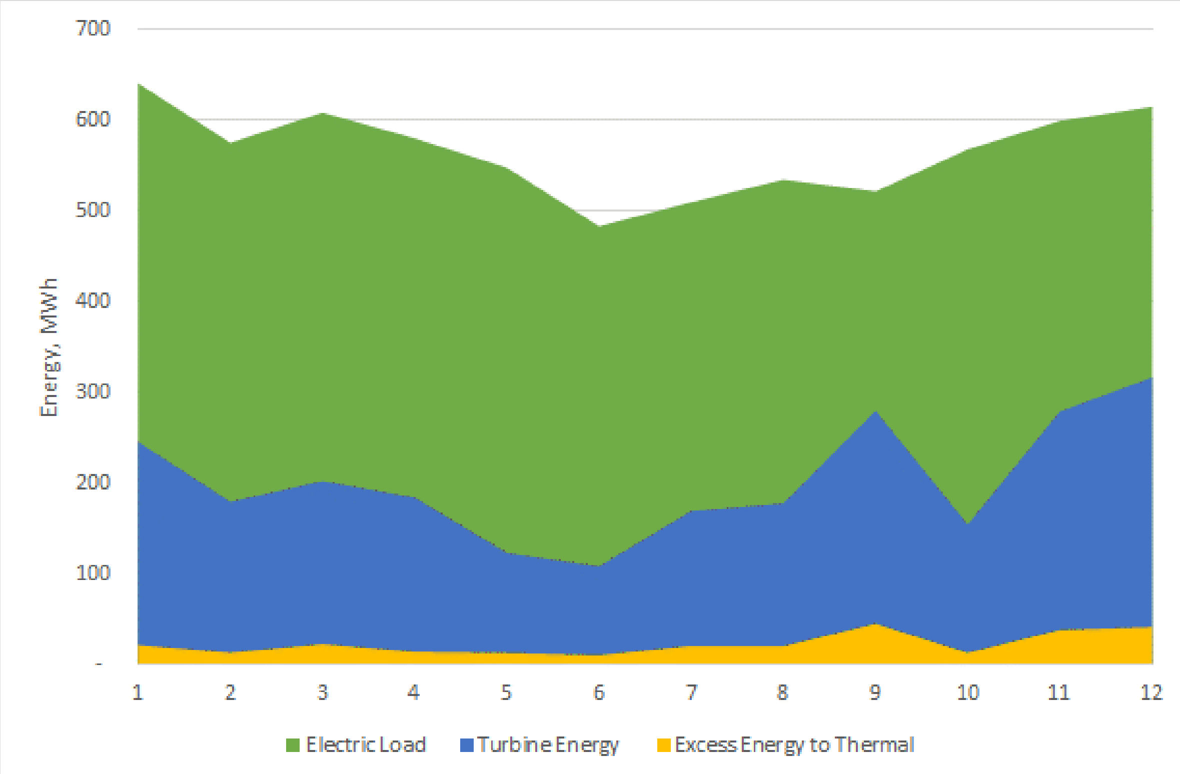
Vestas V39, two (2) turbines, 40 m hub height

This configuration models two Vestas V39 wind turbines at Point Hope Site B at a 40 meter hub height and generating 85 percent of maximum annual energy production.

Energy table, two V39's, 85% net AEP

Month	Electric Load	Turbine Energy	Energy Generated	Turbine Energy to E. Load	Wind Penetra-tion	Excess Energy to Thermal	Excess Energy to Thermal
	kWh	kWh	kWh	kWh	%	kWh	%
1	640,644	245,445	662,303	223,786	37.1%	21,659	2.8%
2	575,127	179,362	588,499	165,990	30.5%	13,373	2.1%
3	608,327	202,278	631,156	179,449	32.0%	22,829	2.9%
4	580,039	184,136	594,339	169,836	31.0%	14,299	2.0%
5	547,631	122,992	560,645	109,978	21.9%	13,014	1.8%
6	483,177	108,308	493,651	97,834	21.9%	10,474	1.6%
7	509,560	169,172	530,472	148,260	31.9%	20,912	3.1%
8	534,461	177,736	555,085	157,113	32.0%	20,623	2.8%
9	521,565	279,622	566,644	234,543	49.3%	45,079	6.2%
10	567,839	154,442	581,092	141,189	26.6%	13,253	1.8%
11	599,124	279,034	637,436	240,723	43.8%	38,312	5.0%
12	614,571	316,488	655,913	275,146	48.3%	41,342	5.3%
Annual	6,782,000	2,419,000	7,057,000	2,144,000	34.3%	275,000	3.1%

Chart, two V39's



Economic Analysis

Modeling assumptions are detailed in the table below. Many assumptions, such as project life, discount rate, operations and maintenance (O&M) costs, etc. are AEA default values. Other assumptions, such as diesel overhaul cost and time between overhaul are based on general rural Alaska power generation experience. The base or comparison scenario is the Point Hope powerplant with its present configuration of diesel generators and the existing thermal loads connected to the heat recovery loop.

Fuel Cost

A fuel price of $5.44/gallon ($1.44/Liter) was chosen for the HOMER analysis by reference to *Alaska Fuel Price Projections 2013-2035*, prepared for Alaska Energy Authority by the Institute for Social and Economic Research (ISER), dated June 30, 2103 and the *2013_06_R7Prototype_final_07012013* Excel spreadsheet, also written by ISER. The $5.44/gallon price reflects the average value of all fuel prices between the 2015 (the assumed project start year) fuel price of $4.63/gallon and the 2034 (20 year project end year) fuel price of $6.41/gallon using the medium price projection analysis with an average CO_2-equivalent allowance cost of $0.57/gallon included.

By comparison, the fuel price for Point Hope reported to Regulatory Commission of Alaska for the 2012 PCE report is $4.30/gallon ($1.14/Liter), without inclusion of the CO_2-equivalent allowance cost. Assuming a CO_2-equivalent allowance cost of $0.40/gallon (ISER *Prototype* spreadsheet, 2013 value), the 2012 Point Hope fuel price was $4.70/gallon ($1.24/Liter).

Heating fuel displacement by excess energy diverted to thermal loads is valued at $6.49/gallon ($1.72/Liter) as an average price for the 20 year project period. This price was determined by reference to the *2013_06_R7Prototype_final_07012013* Excel spreadsheet where heating oil is valued at the cost of diesel fuel (with CO_2-equivalent allowance cost) plus $1.05/gallon, assuming heating oil displacement between 1,000 and 25,000 gallons per year.

Fuel cost table, CO_2-equivalent allowance cost included

ISER med. projection	2015 (/gal)	2034 (/gal)	Average (/gallon)	Average (/Liter)
Diesel Fuel	$4.63	$6.41	$5.44	$1.44
Heating Oil	$5.68	$7.46	$6.49	$1.72

Wind Turbine Project Costs

Construction cost for wind turbine installation and integration with the diesel power plant will be accurately estimated during the design phase of the project. Project costs are estimated in this conceptual design report in order to provide comparative valuation. The client is strongly encouraged not to select the wind turbine configuration option based on cost alone, especially with the highly tentative costs presented in this conceptual design report, as other factors may be more important from an operational, maintenance, integration, and support point of view.

Economic modeling assumptions

Economic Assumptions	
Project life	20 years (2015 to 2034)
Discount rate for NPV	3% (ISER spreadsheet assumption)
System fixed capital cost (plant upgrades required to accommodate wind turbines)	Included in turbine project cost
Fuel Properties (no. 2 diesel for powerplant)	
Price (20 year average; ISER 2013, medium projection plus social cost of carbon)	$5.44/gal ($1.44/Liter)
Fuel Properties (no. 1 diesel to serve thermal loads)	
Price (20 year average; ISER 2013, medium projection plus social cost of carbon)	$6.49/gal ($1.72/Liter)
Diesel Generators	
Generator capital cost	$0 (already installed)
O&M cost	$0.02/kWh (ISER spreadsheet assumption)
Efficiency	14.6 kWh/gal (North Slope Borough data)
Wind Turbines	
Net capacity factor	85% (adjusted by reducing mean wind speed in Homer software)
O&M cost	$0.049/kWh (ISER spreadsheet assumption)

Wind Turbine Costs

Config-uration	No. Turbs	Wind Capacity (kW)	Estimated Cost (in $millions) Turbine	Freight	Install	Civil	Distribu-tion	Power-plant	Project Cost	Cost/kW
AW 250	4	1,000	2.40	0.70	2.10	2.40	0.40	0.50	8.50	$ 8,500
EWT 900	1	900	1.75	0.70	1.80	1.80	0.40	0.50	6.95	$ 7,700
NPS 360	3	1,080	2.20	0.70	2.00	2.20	0.40	0.50	8.00	$ 7,400
V39	2	1,000	1.08	0.70	1.90	2.00	0.40	0.50	6.58	$ 6,600

Modeling Results

The reader is cautioned to note that the economic benefit-to-cost ratios calculated by the ISER method do not account for heat loss from the diesel engines due to reduced loading and subsequent impact on heating fuel usage to serve the thermal loads. ISER cost modeling assumptions are noted above or are discussed in the 2013_06_R7Prototype_final_07012013 Excel spreadsheet. Net annual energy production of the wind turbines was assumed at 85 percent to reflect production losses due to operations and maintenance down time, icing loss, wake loss, hysteresis, etc.

Economic comparison table of Point Hope wind turbine options

Config-uration	Wind Turbine Capacity (kW)	Project Cost	(in $ millions) NPV Benefits	NPV Costs	B/C ratio	Diesel Fuel Saved (gal/yr)	Heat Oil Saved (gal/yr)	Petroleum Fuel Saved (gal/yr)
AW 250	1,000	8.50	10.05	7.55	1.33	143,700	4,700	148,400
EWT 900	900	6.95	10.16	6.17	1.65	145,000	5,000	150,000
NPS 360	1,080	8.00	12.53	7.11	1.76	170,600	12,500	183,100
V39	1,000	6.58	10.49	5.85	1.79	147,300	7,000	154,300

Data Analysis Uncertainty

There are a number of concern and potential problems with data used for modeling in this report. Primary among them is that Point Hope powerplant data are manually-collected log readings, *not* computer-calculated average power per hour as one might conclude by reviewing North Slope Borough's *2013_Point_Hope_PPOR* file. While manually-collected logs may be desirable from an Operations perspective, manual logs are not suitable for modeling as they represent only a brief "snapshot" of the load *at that moment* and are generally unrepresentative, sometimes dramatically so, of actual average load demand during the time period represented by the log entry.

Note that the manually-collected logs also likely account for the odd occurrences of very low electrical loads for a particular hour that are bracketed by much higher loads on either side. In reality this load variation most likely did not occur, but identifying and correcting every questionable occurrence in an 8,760 line data set is extremely tedious and was not considered necessary for this analysis.

The thermal load appears to be reasonably well documented, but the data is four years old. Additionally, the RSA Engineering report was structured such that actual load demand is not readily apparent. This will be a consideration during design should North Slope Borough wish to consider much higher wind penetrations where thermal offset would be considerably larger than modeled.

Project costs are estimated in this conceptual design report and will be determined with greater accuracy during the design phase of the project.

Discussion

For this conceptual design report, only proven and robust wind turbines were considered for evaluation, hence any of the configurations considered can be designed and operated to meet expectations of high performance and reliability. Integration requirements will vary depending on the type of electrical generator in the turbine (synchronous vs. asynchronous), inverter-conditioning, soft-start or other similar grid stability control features, VAR support if necessary, minimum loading levels of the diesel generators as a percentage of the electric load, secondary load controller resolution and response time, among others. These design elements are beyond the scope of this conceptual design project, but the technology has matured such that one may be assured that wind turbines are controllable when operating in Point Hope in a medium penetration/non-storage mode.

With these issues in mind, the primary deciding factors for selection of wind turbine(s) for Point Hope will be cost, reliability, aesthetics, redundancy, support, and commonality.

Cost

Note that the cost estimates in this report were not produced with the same level of precision and accuracy as will occur during the design phase and so should be treated with a substantial level of caution. Also note that many cost parameters such as operations and maintenance costs over the life of the project are estimated using Alaska Energy Authority default values and may not be realistic for any particular turbine configuration option. For this reason the benefit-to-cost ratios indicated in the preceding table should not be ranked nor compared. The point of including the table is to indicate that per the parameters of this analysis, all four turbine options exhibit beneficial economic potential for North Slope Borough and the community of Point Hope.

Reliability

Turbine reliability can be obtained from manufacturer data, third party reviews, and utility experience. Even with a great warranty and promises of strong manufacturer support, robust and reliable wind turbines are highly desirable. Point Hope is an isolated community and expensive to visit, so it is desirable to install equipment where the likelihood of nagging maintenance issues are minimal. All warranty and maintenance support periods eventually end, and North Slope Borough will want to be assured that the turbines they purchase will serve them well in the future.

Aesthetics

This is a highly subjective consideration that undoubtedly will elicit a number of strong and conflicting opinions. Ultimately, Point Hope residents must collectively agree on the aesthetic impact of wind turbines in their community. Simply put, wind turbines will have a visual impact in Point Hope and will easily be the highest and most dominating structure(s) for miles around. Which is preferable: one large, very high turbine or two or more smaller, clustered turbines? This is a difficult question for most people to answer in the abstract because one must mentally imagine wind turbines at Site B (or the other sites) where at present the landscape is flat, bare and nearly featureless. Software modeling that superimposes virtual wind turbine(s) onto the Google Earth image of Point Hope may prove beneficial for the discussion.

Redundancy

A single wind turbine would be redundant in the sense that diesel generation will continue to function to meet electrical load demand should the turbine be off-line for maintenance or a fault condition. On the other hand, a single wind turbine is not redundant with respect to wind generation itself. Should a single installation wind turbine be out of service for an extended period of time, wind energy would not be generated during the outage.

Support

Manufacturer warranty and support will be a primary consideration of North Slope Borough given its responsibility as electrical utility for Point Hope. The Borough must have confidence that the turbine manufacturer and/or its representatives will be available throughout the life of the project. This is a matter of trust and ultimately a value that North Slope Borough must determine for itself.

Commonality

This is a practical consideration for North Slope Borough. There are four Borough village wind projects presently entering the design phase: Point Hope, Point Lay, Wainwright, and Kaktovik. In the related Kaktovik project, North Slope Borough arranged a manufacturer site visit report in March 2014 to Halus Power Systems in California (remanufacturer of Vestas turbines), Aeronautica Windpower in Massachusetts, and Northern Power Systems in Vermont. Objectives of this trip were to meet company representatives, establish relationships, and assess the desirability and potential of each as the "fleet turbine" provider for the Borough.

There are many desirable aspects of a fleet turbine – whether a single turbine model or a family of models – that would be attractive to North Slope Borough. These include a single supplier and point of contact, a common control system for all turbines in the fleet, common parts, and utility and village technicians that learn to service only one type of turbine, not two or more.

On the other hand, given the variability in electrical load profile and site dimensions and height constraints, no one turbine manufacturer addressed in this conceptual design report provides the perfect solution for all four North Slope Borough villages. It may be more optimal cost-wise to install a turbine(s) from one manufacturer in one or more villages and turbine(s) from a different manufacturer in the remaining villages.

Turbine Recommendation

A number of factors presented in the discussion section above are the province of North Slope Borough and/or the community of Point Hope to decide, such as aesthetic considerations and confidence in manufacturer guarantees and proffered support. These factors and others will influence the turbine configuration decision for the design phase of the project. Nevertheless and with these issues in mind, the configuration of three Northern Power Systems NPS 360-39 wind turbines (with the possibility of additional turbines in the future) is recommended by WHPacific Solutions Group and V3 Energy as the preferred option for wind power development in Point Hope.

WHPacific Solutions Group and V3 Energy recommend a configuration of two Vestas V39 wind turbines as an alternate option, and a configuration of four AW/Siva 250 wind turbines as a second alternate option, but less is known about the Siva turbine compared to Vestas, hence some hesitancy about this option at the present time.

These recommendations are based on the following considerations:

- Cost – Preliminary cost modeling indicates that the EWT DW 900, NPS 360-39, and V39 options are relatively equal with respect to life-cycle economic benefit. The AW/Siva 250 option appears to have a lower life-cycle economic benefit, but still positive.
- Reliability – All turbine options presented in this report are considered to be reliable machines with proper maintenance and support.
- Aesthetics – The NPS 360-39 is offered only on a relatively low 28.5 meter tower (for a 30 meter hub height), minimizing the visual impact of this turbine compared to the others. The alternate turbines, however, are available on at least 40 meter towers on the low end, so their visual impact is not much greater.
- Redundancy – With respect to redundancy, WHPacific Solutions Group and V3 Energy recommend two or more wind turbines for Point Hope. Despite the admirably excellent availability history of the EWT wind turbine in their typical grid-connected installations, it should be recognized that all wind turbines considered in this conceptual design report have excellent availability histories when grid-connected.

  As a general rule though, wind turbine availability has been lower in Alaska village wind-diesel systems than in grid-connected applications. There are many reasons for this, principally related to integration and operational factors. Some of these issues can be mitigated with careful design and planning, but an expectation of utility-experience wind turbine availability is unrealistic in rural Alaska. With this reality in mind, installing at least two wind turbines enables continuity of wind power production should one turbine be out of service for an extended period of time.
- Support – All four turbine manufacturers evaluated in this conceptual design report are highly regarded companies with extensive depth and capability to provide warranty and continuing support over time with both factory personnel and Alaska-based representatives. In addition, all four companies will train North Slope Borough personnel to operate and maintain the turbines.
- Commonality – Considering the electric load demand and wind turbine site constraints in Point Hope, Point Lay, Wainwright and Kaktovik (North Slope Borough's companion wind power

project villages), only the Aeronautica, Northern Power Systems, and Vestas family of turbines can be used in all four communities.

It is the opinion of WHPacific Solutions Group and V3 Energy LLC that North Slope Borough will find it less demanding to manage one type of wind turbine among several village projects than two or more turbine types, other factors aside.

Single Turbine Option

The EWT DW 900 is an admirable wind turbine and highly suitable for Point Hope, but recommending it would counter the values of redundancy and commonality expressed above. Although WHPacific Solutions Group and V3 Energy believe that North Slope Borough would be better served with redundant wind turbine capacity in their project communities, this is not strictly necessary for a successful wind project. It should be noted that EWT offers performance guarantees for their turbines that mitigates the risk of a single turbine application which North Slope Borough may wish to consider.

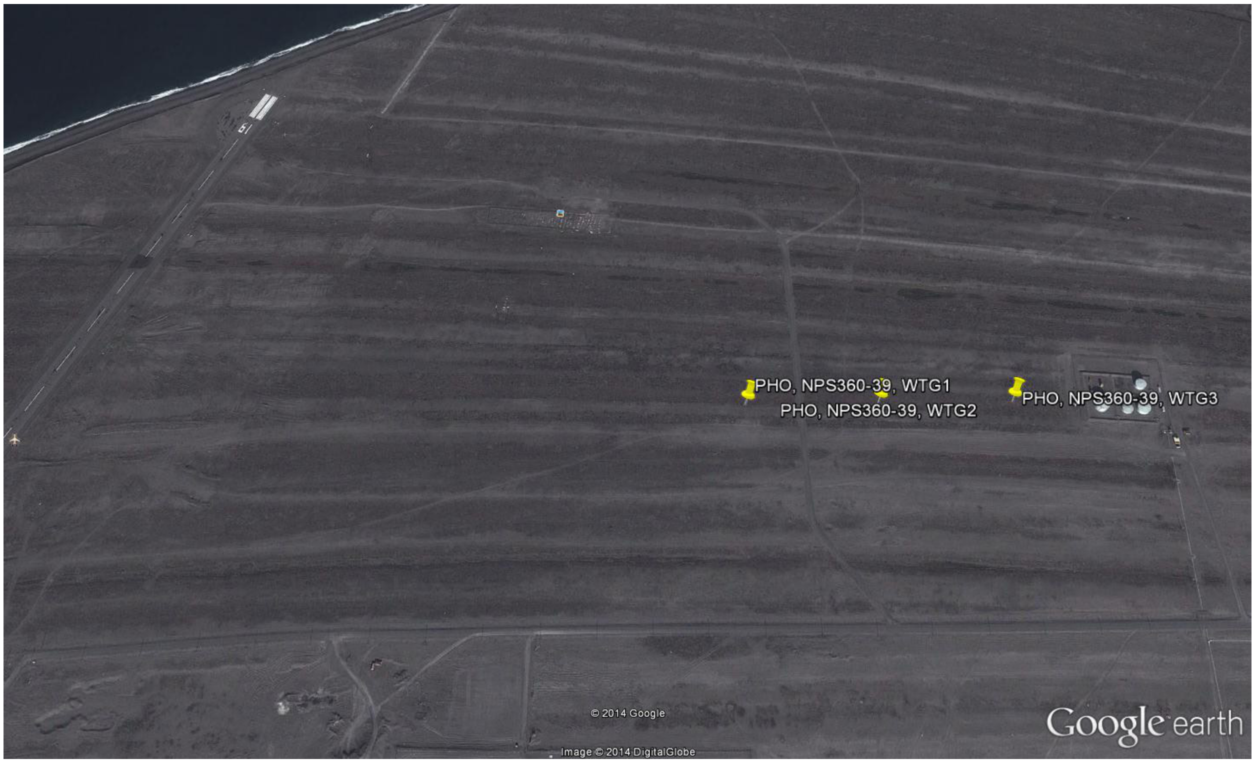
Commonality of wind turbines for all four planned wind power projects (Point Hope, Point Lay, Wainwright, and Kaktovik), however, is considered to be in the Borough's best interests and hence the recommendation of a wind turbine that will be suitable for all four communities. Should North Slope Borough be willing to consider two turbine types, the EWT DW 900 may be the best choice for Point Hope after all, especially if Site A is chosen as the project location. Given the very constrained nature of Site A, it can accommodate up to two EWT 900 turbines (this presumes future expansion) but could not accommodate the equivalent power output capacity (1,800 kW) with the other turbine models addressed in this report (except for an Aeronautica AW 750, which was not presented, but is an option).

Wind Turbine Layout

Site B boundaries are not defined at present, but given the large Tikigaq land ownership in this site area and lack of Native Allotment boundaries (except between airport access road and the coast, east side of Site B area), available land for wind turbine layout is expected to be fairly unrestricted. The image below shows three Northern Power Systems NPS 360-39 wind turbines (describer later in this report) in a west-to-east alignment with four rotor diameter (approximately 160 meters) separation. This is within the three to five rotor diameter separation generally recommended for turbine array design. Precise turbine locations with attendant wake loss (array efficiency) calculations will be modeled during the design phase of this project after site and turbine selections.

Refer to Appendix F for drawings of the existing electrical distribution system and necessary expansion to connect wind turbines located at Site B. As indicated, only approximately 800 ft. (0.15 miles) of new 12.47 kV distribution is required. Should wind turbines be located at Site A, 2.6 miles of new 12.47 kV distribution would be necessary, a distance seventeen times that for Site B.

Proposed NPS 360-39 turbine layout, Site B



Data Collection Recommendation

Prior to or at least during the design phase of the Point Hope wind power project, North Slope Borough is strongly encouraged to implement an enhanced power plant monitoring and data collection effort to obtain average and transient load and other data not presently available. To capture transient behavior, highly granular data (one second or less averaging time) is most desirable. Data of this nature is extremely valuable for the design process and significantly reduces the risk of design errors and/or omissions resulting from unknown or unrecognized behavior of existing system components.

Project Design Penetration Consideration

This conceptual design report focused on four wind turbine configuration options that achieved approximately 33 percent wind power penetration. During design, presuming that the turbine type has been selected, North Slope Borough is encouraged to consider the benefits and cost implications of additional wind turbine capacity; for instance, 50 percent and higher average wind power penetration. This evaluation can be achieved with Homer software and other modeling tools and may reveal a more optimal and beneficial wind-diesel power system for the community of Point Hope than the configurations presented in this report. Higher wind penetration though requires greater system complexity and control; these factors are inter-mutual and cannot be de-linked. But, high penetration yields the greatest benefit of wind power and North Slope Borough may want to examine and consider this option carefully before committing to a design objective.

Appendix A – FAA's Notice Criteria Tool, Site A

Federal Aviation Administration

« OE/AAA

Notice Criteria Tool

Notice Criteria Tool - Desk Reference Guide V_2014.2.0

The requirements for filing with the Federal Aviation Administration for proposed structures vary based on a number of factors: height, proximity to an airport, location, and frequencies emitted from the structure, etc. For more details, please reference CFR Title 14 Part 77.9.

You must file with the FAA at least 45 days prior to construction if:

- your structure will exceed 200ft above ground level
- your structure will be in proximity to an airport and will exceed the slope ratio
- your structure involves construction of a traverseway (i.e. highway, railroad, waterway etc...) and once adjusted upward with the appropriate vertical distance would exceed a standard of 77.9(a) or (b)
- your structure will emit frequencies, and does not meet the conditions of the FAA Co-location Policy
- your structure will be in an instrument approach area and might exceed part 77 Subpart C
- your proposed structure will be in proximity to a navigation facility and may impact the assurance of navigation signal reception
- your structure will be on an airport or heliport
- filing has been requested by the FAA

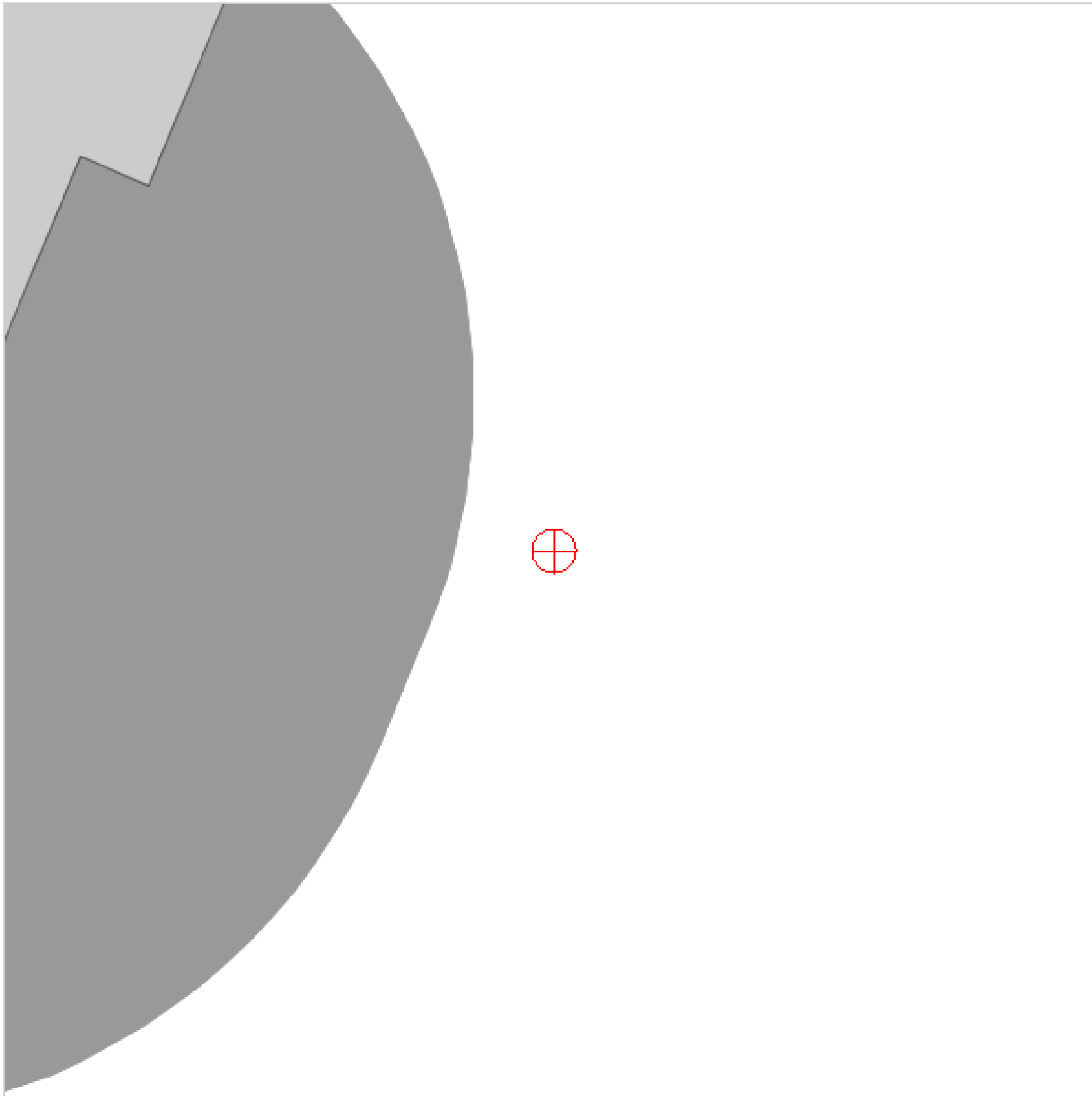
If you require additional information regarding the filing requirements for your structure, please identify and contact the appropriate FAA representative using the Air Traffic Areas of Responsibility map for Off Airport construction, or contact the FAA Airports Region / District Office for On Airport construction.

The tool below will assist in applying Part 77 Notice Criteria.

Latitude:	68 Deg 20 M 23.82 S N
Longitude:	166 Deg 37 M 32.34 S W
Horizontal Datum:	NAD83
Site Elevation (SE):	10 (nearest foot)
Structure Height (AGL):	200 (nearest foot)
Traverseway:	No Traverseway (Additional height is added to certain structures under 77.9(c))
Is structure on airport:	(●) No ( ) Yes

Results

You do not exceed Notice Criteria.



Appendix B – FAA's Notice Criteria Tool, Site B

Notice Criteria Tool

Notice Criteria Tool - Desk Reference Guide V_2014.2.0

The requirements for filing with the Federal Aviation Administration for proposed structures vary based on a number of factors: height, proximity to an airport, location, and frequencies emitted from the structure, etc. For more details, please reference CFR Title 14 Part 77.9.

You must file with the FAA at least 45 days prior to construction if:

- your structure will exceed 200ft above ground level
- your structure will be in proximity to an airport and will exceed the slope ratio
- your structure involves construction of a traverseway (i.e. highway, railroad, waterway etc...) and once adjusted upward with the appropriate vertical distance would exceed a standard of 77.9(a) or (b)
- your structure will emit frequencies, and does not meet the conditions of the FAA Co-location Policy
- your structure will be in an instrument approach area and might exceed part 77 Subpart C
- your proposed structure will be in proximity to a navigation facility and may impact the assurance of navigation signal reception
- your structure will be on an airport or heliport
- filing has been requested by the FAA

If you require additional information regarding the filing requirements for your structure, please identify and contact the appropriate FAA representative using the Air Traffic Areas of Responsibility map for Off Airport construction, or contact the FAA Airports Region / District Office for On Airport construction.

The tool below will assist in applying Part 77 Notice Criteria.

Latitude:	68 Deg 20 M 58.9 S N
Longitude:	166 Deg 46 M 22.9 S W
Horizontal Datum:	NAD83
Site Elevation (SE):	10 (nearest foot)
Structure Height (AGL):	200 (nearest foot)
Traverseway:	No Traverseway (Additional height is added to certain structures under 77.9(c))
Is structure on airport:	(●) No ( ) Yes

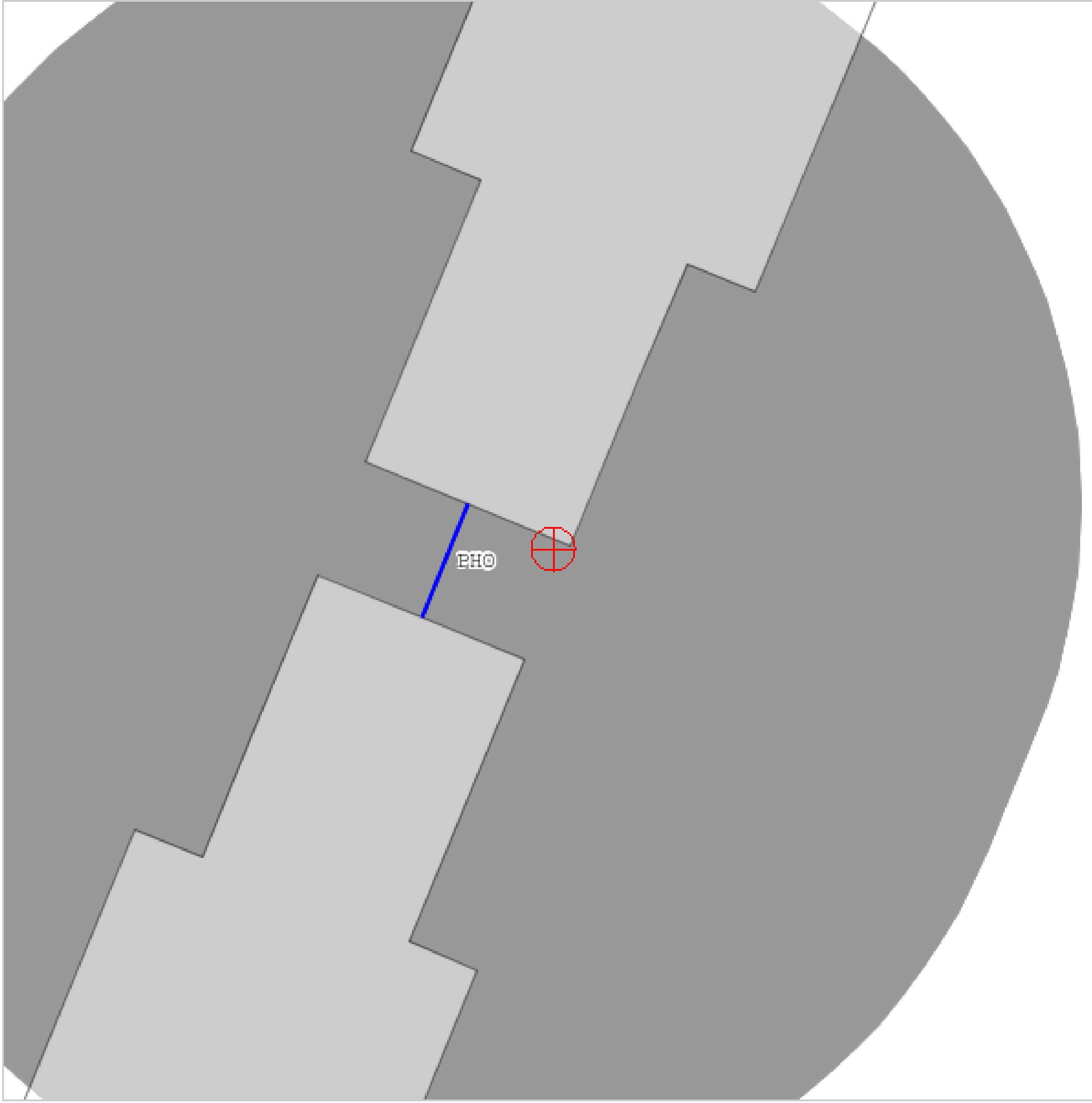
Results

You exceed the following Notice Criteria:

Your proposed structure is in proximity to a navigation facility and may impact the assurance of navigation signal reception. The FAA, in accordance with 77.9, requests that you file.

77.9(b) by 161 ft. The nearest airport is PHO, and the nearest runway is 01/19.

The FAA requests that you file


PHO

Appendix C – FAA's Notice Criteria Tool, Sites C and D

Federal Aviation Administration

« OE/AAA

Notice Criteria Tool

Notice Criteria Tool - Desk Reference Guide V_2014.2.0

The requirements for filing with the Federal Aviation Administration for proposed structures vary based on a number of factors: height, proximity to an airport, location, and frequencies emitted from the structure, etc. For more details, please reference CFR Title 14 Part 77.9.

You must file with the FAA at least 45 days prior to construction if:

- your structure will exceed 200ft above ground level
- your structure will be in proximity to an airport and will exceed the slope ratio
- your structure involves construction of a traverseway (i.e. highway, railroad, waterway etc...) and once adjusted upward with the appropriate vertical distance would exceed a standard of 77.9(a) or (b)
- your structure will emit frequencies, and does not meet the conditions of the FAA Co-location Policy
- your structure will be in an instrument approach area and might exceed part 77 Subpart C
- your proposed structure will be in proximity to a navigation facility and may impact the assurance of navigation signal reception
- your structure will be on an airport or heliport
- filing has been requested by the FAA

If you require additional information regarding the filing requirements for your structure, please identify and contact the appropriate FAA representative using the Air Traffic Areas of Responsibility map for Off Airport construction, or contact the FAA Airports Region / District Office for On Airport construction.

The tool below will assist in applying Part 77 Notice Criteria.

Latitude:	68 Deg 20 M 40.1 S N
Longitude:	166 Deg 41 M 21.1 S W
Horizontal Datum:	NAD83
Site Elevation (SE):	10 (nearest foot)
Structure Height (AGL):	200 (nearest foot)
Traverseway:	No Traverseway (Additional height is added to certain structures under 77.9(c))
Is structure on airport:	(•) No ( ) Yes

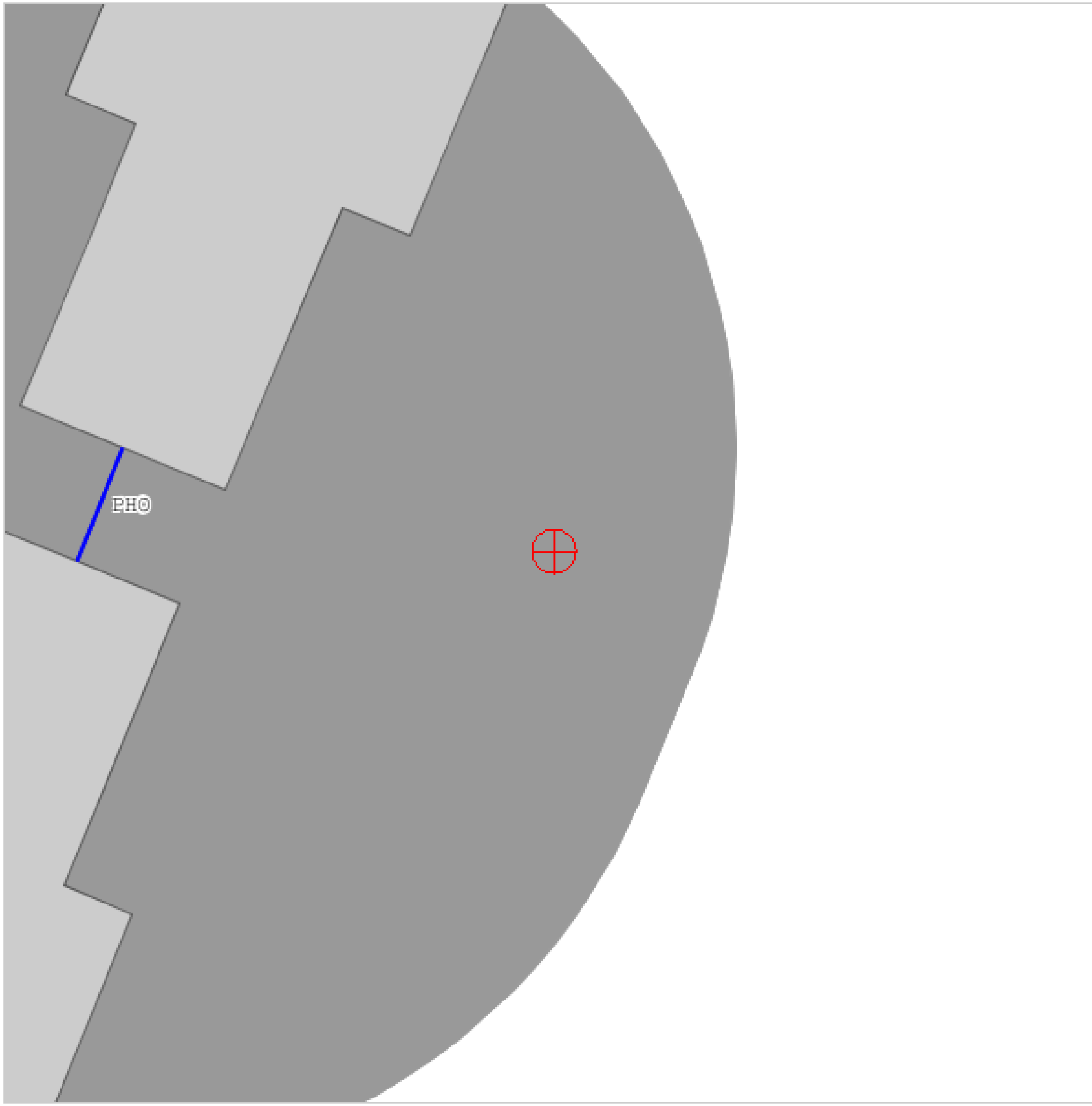
Results

You exceed the following Notice Criteria:

Your proposed structure is in proximity to a navigation facility and may impact the assurance of navigation signal reception. The FAA, in accordance with 77.9, requests that you file.

77.9(b) by 47 ft. The nearest airport is PHO, and the nearest runway is 01/19.

The FAA requests that you file


PHO

Appendix D – Power Grid, Point Hope

REV #	DRAWN BY	APRVD BY	DATE	DESCRIPTION
1	RCK	RCK	4/11/2012	FUSE COORDINATION.
2	RCK	RCK	8/30/2012	CORRECTIONS FROM FIELD NOTES, NEW DWG FORMAT
3	RCK	RCK	11/28/2012	UDATED FROM POLE SURVEY DATA (COMPLETED)

TRANSFORMER FUSE PROTECTION - 4.2Y/2.4kV

TRANSFORMER			TRANSFORMER PRIMARY FUSE				UPSTREAM FUSES	
1Ø (kVA)	**3Ø (kVA)**	Full Load Rating (AMPS)	**Fuse Type**	Min. Partial Melt (Amps @ 300s)	Max. Clearing (Amps @ 300s)	Max. Sustained Load based on min. partial melt (kW, 1Ø)	First Fuse	Next Fuse
10	**30**	4.2	**3.5 SF**	10.1	13	24	25T	40T
15	**45**	6.3	**5.2 SF**	15.7	18	38	25T	40T
25	**75**	10.4	**7.8 SF**	24	28	58	40T	65T
37.5	**112.5**	15.6	**10.4 SF**	28.5	34	68	65T	100T
50	**150**	20.8	**14 SF**	46	52	110	65T	100T
75	**225**	31.3	**21 SF**	69	86	166	100T	140T
100	**300**	41.7	**32 SF**	90	107	216	100T	140T
--	**500**	69.4	**46 SF**	109	129	785 !	140T	200T
--	**750**	104.2	**100T**	209	231	1505 !	140T	200T
--	**1000**	138.9	**140T**	315.2	382	2269 !	200T	--
--	**1500**	208.3	**200T**	494.4	596	3560 !	--	--

! - Max. 3Ø Load

LEGEND

POLE I.D. / LENGTH, CLASS / PRIMARY SUPPORT TYPE — B23L6P1 *55, 3 C1.41 — POLE, NUMBER, LENGTH, CLASS, PRIMARY ASSEMBLY,
* HEIGHT, CLASS CALCULATED FROM FIELD DATA.
! FROM 'BIRTH MARK' DATA.

Aϕ CONDUCTOR

Bϕ CONDUCTOR

Cϕ CONDUCTOR

SECONDARY MAIN

SERVICE DROP

GUY — OVERHEAD GUY

GUY ANCHOR

PAD MOUNT TRANSFORMER

25 kVA Bϕ — TRANSFORMER, POLE-MTD, SINGLE-PHASE, kVA SIZE & CONNECTED PHASE

25 kVA(EA) 75 kVA(BANK) 208Y/120V — TRANSFORMER, 3-PHASE, POLE-MTD, kVA EA., kVA BANK, VOLTAGE

LED — STREET LIGHT; TYPE 'LED', 'HPS'

NC — GANG SWITCH

STATUS: NORM. OPEN, NORM. CLOSED / NO. OF CUTOUTS / FUSE, RATING AND TYPE — 3 NC 40T — CUT-OUT SWITCH - EXISTING

= — OPEN CIRCUIT AT ADJACENT POLE

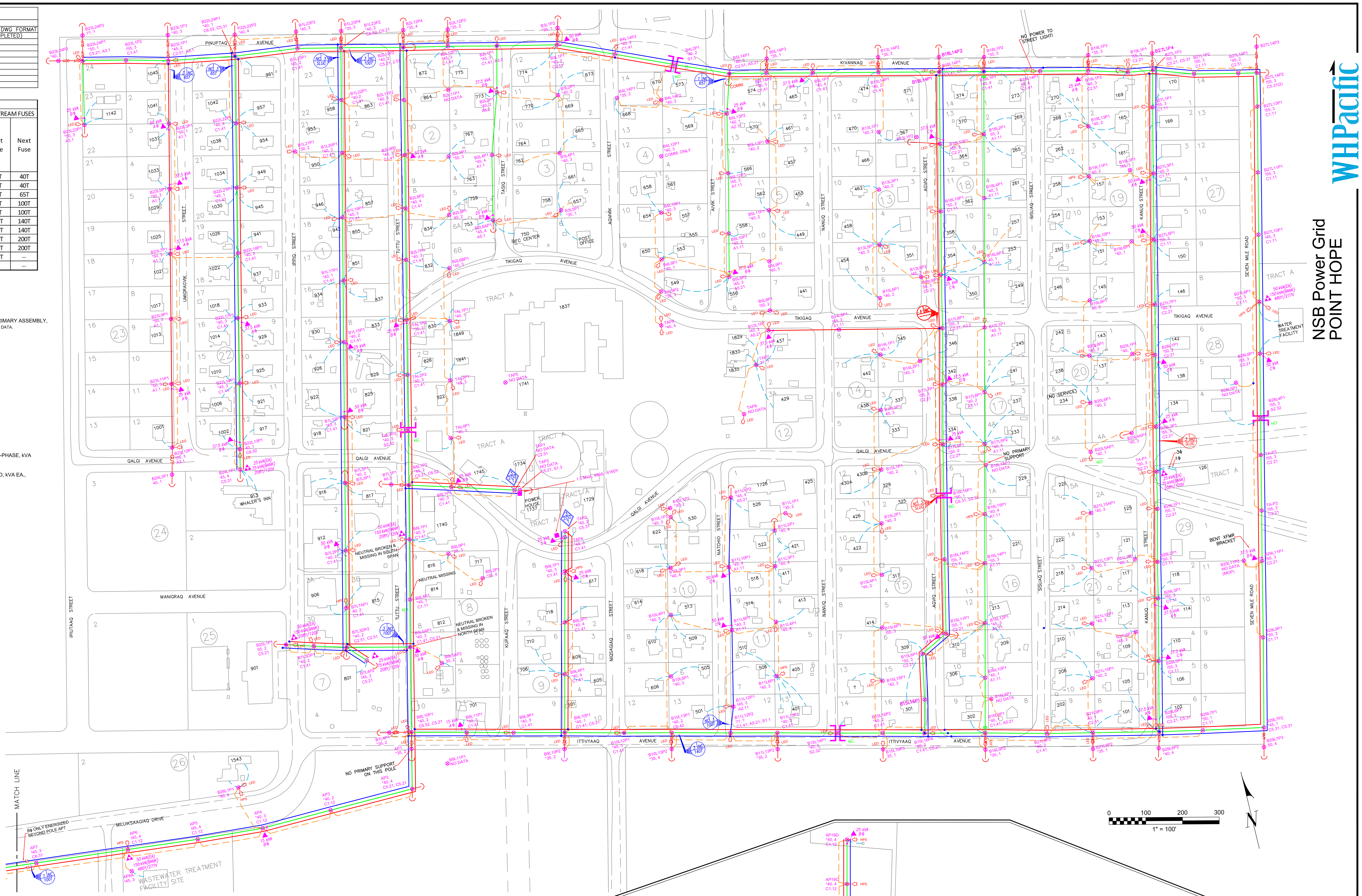
PHASE (3) / FUSE AMPACITY / FUSE TYPE — 3 140 T — PRIMARY RISER - 3 PHASE

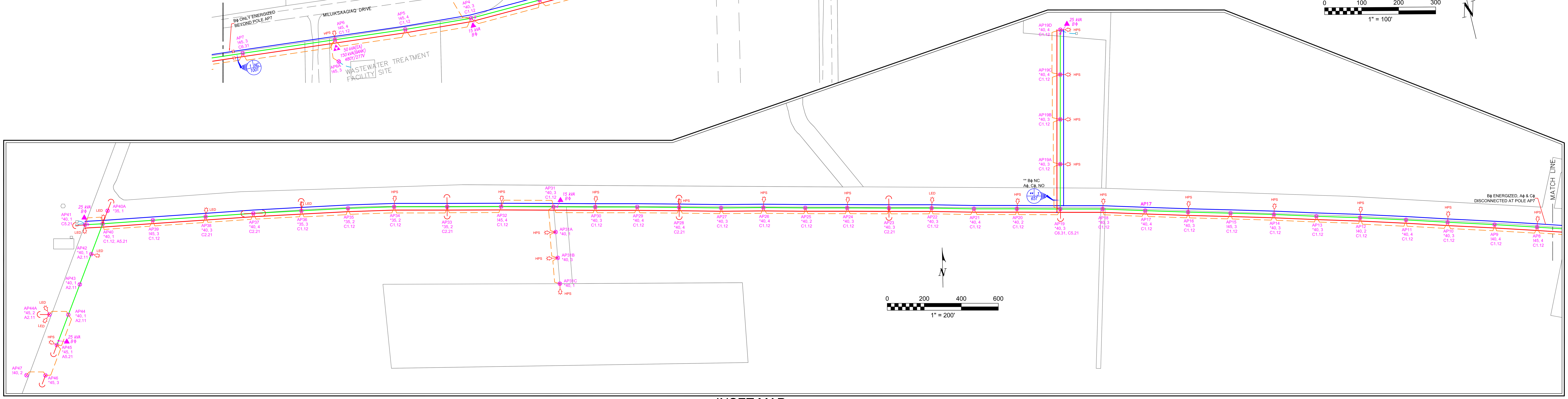
CONNECTED PHASE — A 40 T — PRIMARY RISER - 1 PHASE

LEGEND FOR POLE NUMBERING SYSTEM:

B31L1P1 — BLOCK NO., LOT NO., POLE NO.

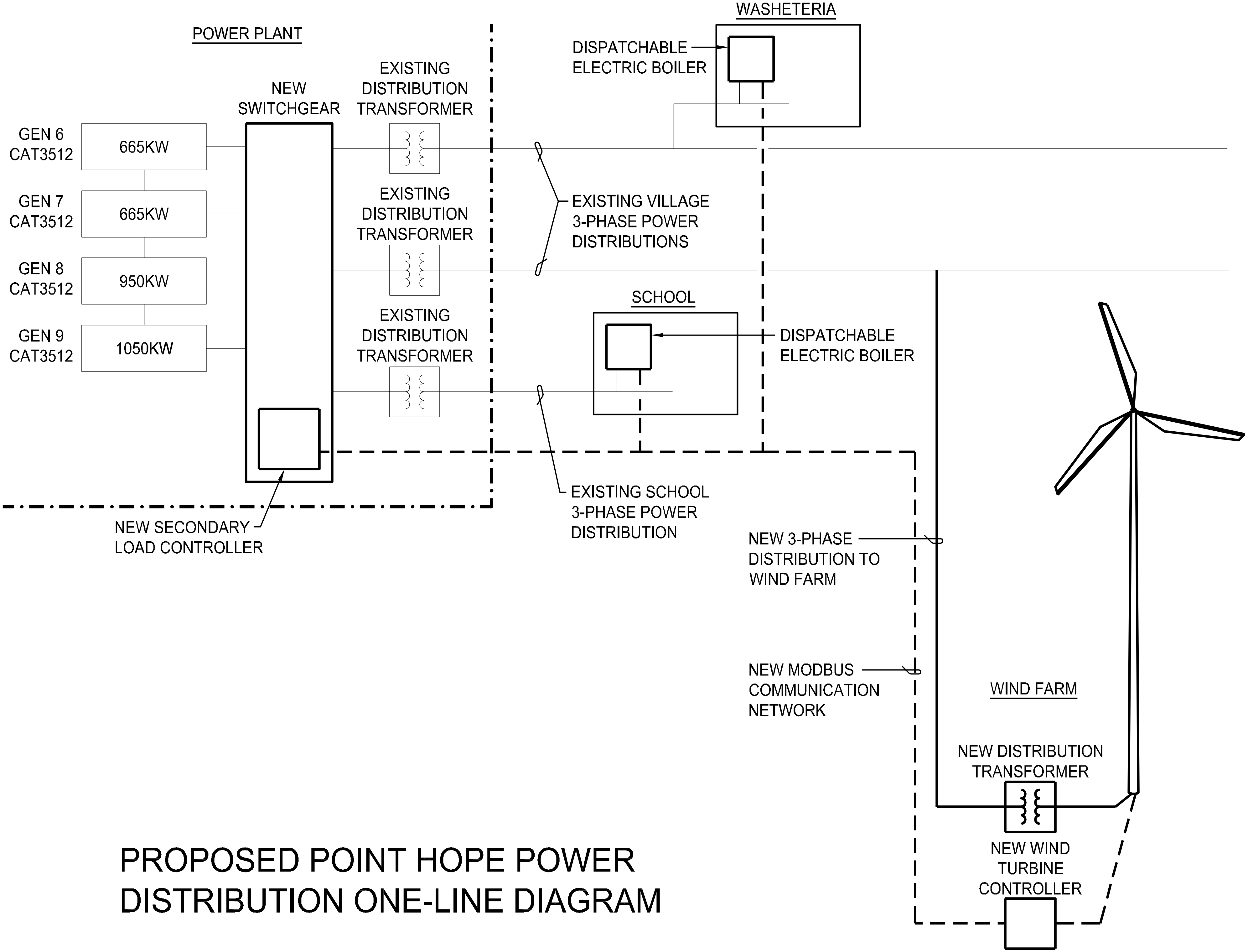
T1P2 — TRACT NO., POLE NO.





INSET MAP

Appendix E – Proposed Power Distribution One-Line Diagram



PROPOSED POINT HOPE POWER DISTRIBUTION ONE-LINE DIAGRAM

Appendix F – Power Distribution System Expansion for Sites B and A

WHPacific
300 West 31st Avenue
Anchorage, AK 99503
907-339-6500 Fax 907-339-5327
www.whpacific.com

POINT HOPE

SHEET 1 of 3	
DATE:	12/10/2014
SHEET NO.:	
E1	

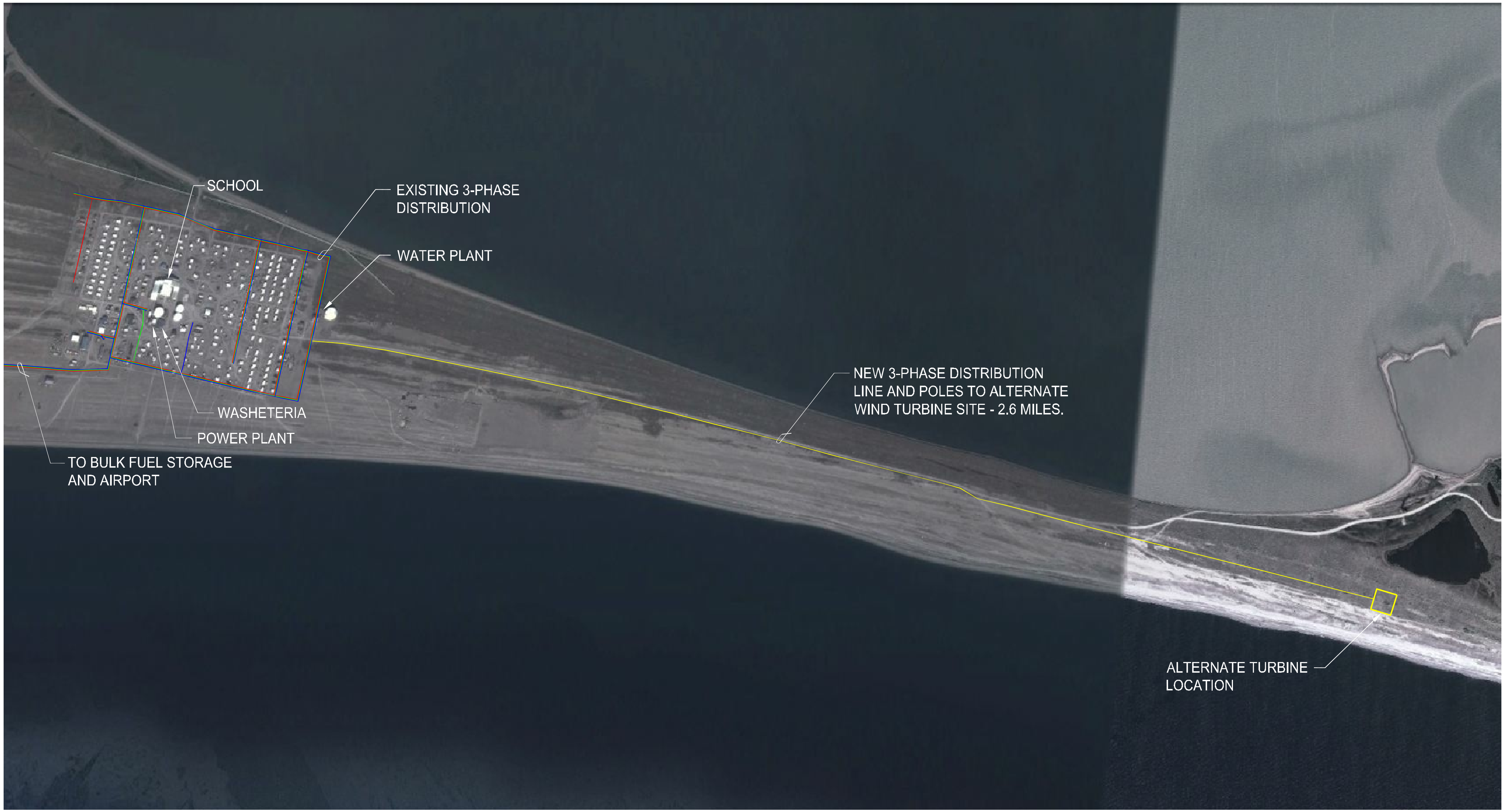
LEGEND	
(red line)	PHASE A
(green line)	PHASE B
(blue line)	PHASE C
(yellow line)	NEW 3-PHASE

SCALE: NONE

WHPacific
300 West 31st Avenue
Anchorage, AK 99503
907-339-6500 Fax 907-339-5327
www.whpacific.com

POINT HOPE

SHEET 2 of 3
DATE: 12/10/2014
SHEET NO.:
E2



LEGEND
PHASE A
PHASE B
PHASE C
NEW 3-PHASE

SCALE: NONE

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Anchorage, AK 99503
907-339-6500 Fax 907-339-5327
www.whpacific.com

POINT HOPE

SHEET 2 of 3
DATE: 12/10/2014
SHEET NO.:
E3