Saint Mary's, Alaska REF 7 Wind-Diesel Project Analysis

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This report was prepared by V3 Energy, LLC under contract to Alaska Village Electric Cooperative to assess the technical and economic feasibility of installing wind turbines at the Pitka's Point wind site, which is located near the villages of Saint Mary's and Pitka's Point. This analysis is part of a conceptual design report and final project design funded in Round IV of the Renewable Energy Fund administered by Alaska Energy Authority.

Contents

Introduction

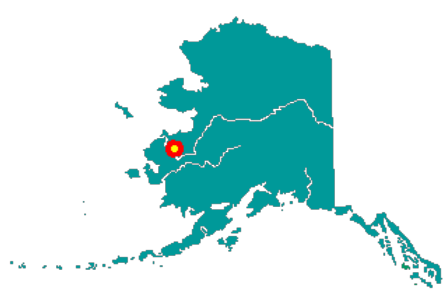
Alaska Village Electric Cooperative (AVEC) is the electric utility for the City of Saint Mary's/Andreafsky as well as the interconnected village of Pitka's Point. AVEC was awarded a grant from the Alaska Energy Authority (AEA) to complete feasibility and design work for installation of wind turbines, with planned construction completion and commencement of operational status in 2015.

Wind resource studies of the St. Mary's area began in 2007 with identification of possible wind turbine sites on Pitka's Point Corporation land and Saint Mary's corporation land, located relatively near each other between the villages of Saint Mary's and Pitka's Point. Both sites were equipped with 40 meter met towers, but the Pitka's Point site eventually proved to have the superior wind resource and was chosen as the primary site for conceptual design and feasibility work.

CRW Engineering Group, LLC was contracted by AVEC to develop a design package for a wind turbine project in Saint Mary's. This analysis is a component of that larger effort.

Village of St. Mary's/Andreafsky

St. Mary's is located 450 air miles west-northwest of Anchorage on the north bank of the Andreafsky River, five miles from its confluence with the Yukon River. The City of St. Mary's encompasses the Yupik villages of St. Mary's and Andreafsky. St. Mary's is a Yupik Eskimo community that maintains a fishing and subsistence lifestyle. The sale of alcohol is prohibited in the city. According to Census 2010, 507 people live in St. Mary's and Andreafsky. There are 209 housing units in the community and 151 are occupied. Its population is 91.5 percent Alaska Native, 3.8 percent Caucasian, and 4.7 percent multi-racial.



Water is derived from Alstrom Creek reservoir and is treated. Most homes in the village have complete plumbing and are connected to the piped water and sewer system. Waste heat from the power plant supports the circulating water system. A 1.7-million-gallon sewage lagoon provides waste treatment. A washeteria is available nearby at Pitka's Point. An unpermitted landfill is shared with Pitka's Point. Electricity is provided by AVEC with interconnection to the village of Pitka's Point and the St. Mary's airport (station code KSM). There is one school located in the community, attended by 185 students. There is a local health clinic staffed by a health practitioner and four health aides. Emergency Services have river, limited highway, and air access.

Wind Resource at Pitka's Point and Saint Mary's

The wind resource measured at the Pitka's Point met tower site is Class 6 (outstanding) by measurement of wind power density and wind speed. Extensive wind resource analysis has been conducted in the Saint Mary's region, with a met tower at a lower elevation site near Saint Mary's and another met tower near Mountain Village, in addition to the Pitka's Point met tower. Documented in *Saint Mary's Area*

Wind Power Report by V3 Energy, LLC, dated July 20, 2010, the wind resource measured at the nearby Saint Mary's met tower site is less robust than that measured at Pitka's Point and appears to experience similar icing problems. The Mountain Village wind resource is excellent with mean wind speed near that measured at Pitka's Point. Considering the inland location of Saint Mary's/Pitka's Point, the wind resource measure at the Pitka's Point met tower site is highly unusual, and very favorable, with its combination of a high annual average wind speed, relatively low elevation, likely good geotechnical conditions, and proximity to existing roads and infrastructure.

A 40 meter NRG Systems, Inc. tubular-type meteorological (met) tower was installed on Pitka's Point Native Corporation land on the bluff immediately above the Yukon River with excellent exposure to northeasterly winds down the Andreafsky River, northerly winds from the mountains and southerly winds from the flat, tundra plains leading toward Bethel. The met tower site is near an active rock quarry and visual inspection of that quarry indicates the likelihood of excellent geotechnical conditions for wind turbine foundations. Also of advantage for the site is near proximity of the road connecting Saint Mary's to Pitka's Point, the airport and Mountain Village. A two-phase power distribution line (connecting the St. Mary's powerplant to Pitka's Point as one phase and to the airport as the second phase) routes on the south side of the road. This line could be upgraded to three-phase at relatively low cost to connect wind turbines to three-phase distribution in Saint Mary's.

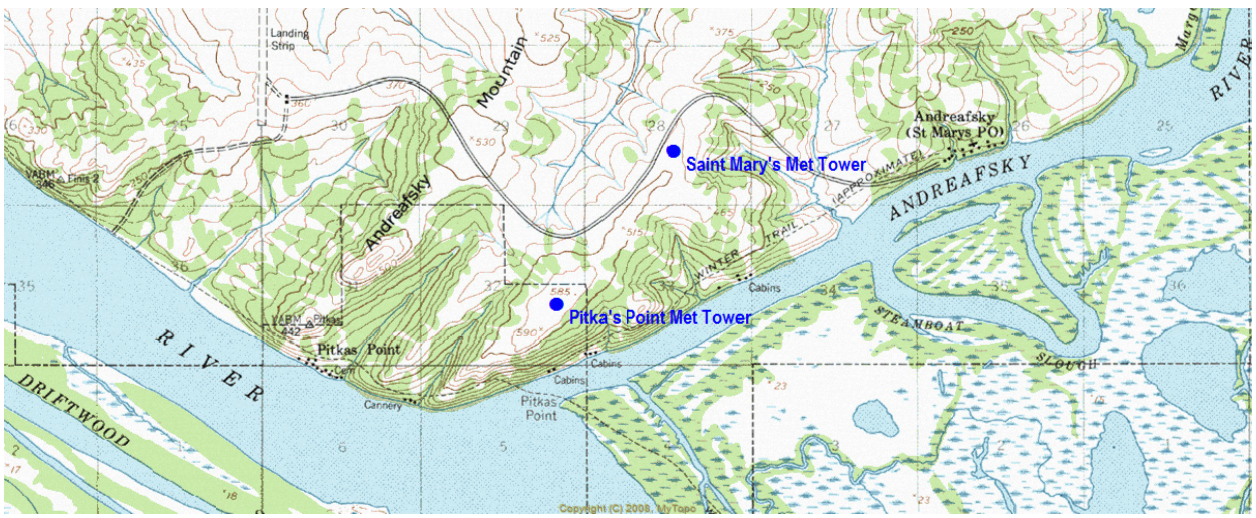
The Pitka's Point wind resource is comprehensively described in *Pitka's Point, Alaska Wind Resource Report* by V3 Energy, LLC, dated April 25, 2012 and included in Appendix A of this report.

Pitka's Point met tower data synopsis

Data dates	October 26, 2007 to February 12, 2009 (16 months)
Wind power class	Class 6 (excellent), based on wind power density
Wind power density mean, 38 m	558 W/m^2
Wind speed mean, 38 m	7.62 m/s (17.0 mph)
Max. 10-min wind speed	29.5 m/s
Maximum 2-sec. wind gust	26.3 m/s (81.2 mph), January 2008
Weibull distribution parameters	k = 1.94, c = 8.64 m/s
Wind shear power law exponent	0.176 (low)
Roughness class	2.09 (description: few trees)
IEC 61400-1, 3rd ed. classification	Class II-c (at 38 meters)
Turbulence intensity, mean (at 38 m)	0.076 (at 15 m/s)
Calm wind frequency (at 38 m)	20% (< 4 m/s) (16 mo. measurement period)

Google Earth image, Pitka's Point and Saint Mary's

Pitka's Point met tower location



Wind Speed

Anemometer data obtained from the met tower, from the perspectives of both mean wind speed and mean wind power density, indicate an outstanding wind resource.   Note that cold temperatures contributed to a higher wind power density than standard conditions would yield for the measured mean wind speeds.

Pitka's Point met tower anemometer data summary

Variable	Speed 38 m	Speed 29 m	Speed 28 m IceFree	Speed 21 m
Measurement height (m)	38	28.8	28.2	21
Mean wind speed (m/s)	7.68	7.29	7.33	6.83
MoMM wind speed (m/s)	**7.62**	**7.24**	**7.33**	**6.78**
Median wind speed (m/s)	7.20	6.80	7.00	6.40
Max wind speed (m/s)	29.50	29.20	27.50	28.40
Weibull k	1.94	1.89	2.22	1.88
Weibull c (m/s)	8.64	8.20	8.26	7.68
Mean power density (W/m²)	573	502	441	414
MoMM power density (W/m²)	**559**	**490**	**441**	**404**
Mean energy content (kWh/m²/yr)	5,015	4,396	3,861	3,627
MoMM energy content (kWh/m²/yr)	**4,897**	**4,294**	**3,861**	**3,541**
Energy pattern factor	1.95	2.00	1.73	2.01
Frequency of calms (%) (< 4 m/s)	20.4	21.9	17.6	24.7

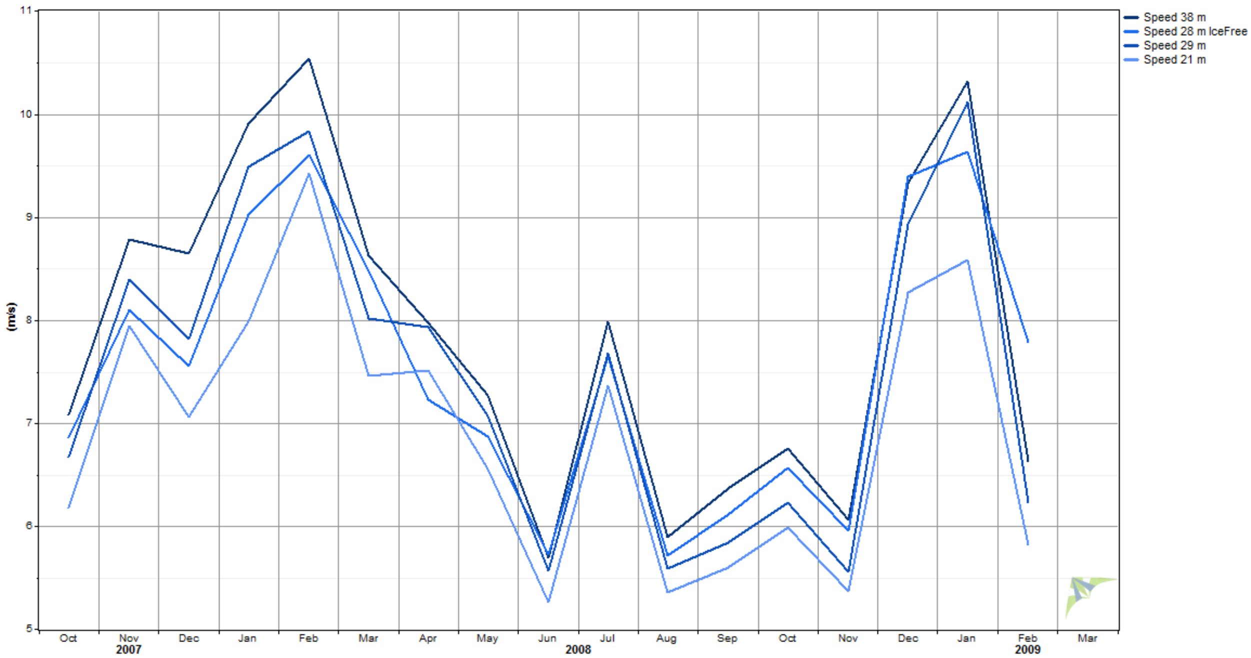
MoMM = mean of monthly means

Time series calculations indicate high mean wind speeds during the winter months with more moderate, but still relatively high, mean wind speeds during summer months. This correlates well with the Saint Mary's/Andreafsky/Pitka's Point village load profile where winter months see high demand for electricity and heat and the summer months have lower demand for electricity and heat. The daily wind profiles indicate relatively even wind speeds throughout the day with slightly higher wind speeds during night hours.

38 m anemometer data summary

Month	Mean (m/s)	Median (m/s)	Max 10-min avg (m/s)	Max gust (2 sec) (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Jan	10.17	10.70	29.5	35.9	5.34	1.97	11.45
Feb	9.21	9.20	20.1	23.3	4.07	2.41	10.36
Mar	8.62	8.50	21.8	26.3	4.33	2.07	9.71
Apr	7.98	7.80	16.9	20.6	2.83	3.05	8.90
May	7.27	6.90	21.8	27.1	3.67	2.06	8.19
Jun	5.70	5.80	13.2	15.3	2.62	2.28	6.40
Jul	7.98	7.70	21.7	26.3	3.33	2.55	8.99
Aug	5.89	5.70	15.3	17.9	2.95	2.05	6.62
Sep	6.37	6.70	12.5	16.8	2.44	2.85	7.11
Oct	6.80	6.60	20.1	24.8	3.81	1.80	7.62
Nov	7.32	6.40	24.1	29.8	4.48	1.72	8.23
Dec	8.97	8.90	22.9	27.5	4.69	1.95	10.07
Annual	7.62	7.20	29.5	35.9	4.09	1.94	8.64

Monthly time series, mean wind speeds



Extreme Winds

A modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, was used to predict extreme winds at the Pitka's Point met tower site. Sixteen months of data though are minimal at best and hence results should be viewed with caution. Nevertheless, with data available the predicted Vref (maximum ten-minute average wind speed) in a 50 year return period (in other words, predicted to occur once every 50 years) is 41.6 m/s. This result classifies the site as Class II by International Electrotechnical Commission 61400-1, 3rd edition (IEC3) criteria. IEC extreme wind probability classification is one criteria – with turbulence the other – that describes a site with respect to suitability for particular wind turbine models. Note that the IEC3 Class II extreme wind classification, which applies to the Pitka's Point met tower site, clearly indicates relatively energetic winds and turbines installed at this location should be IEC3 Class II rated.

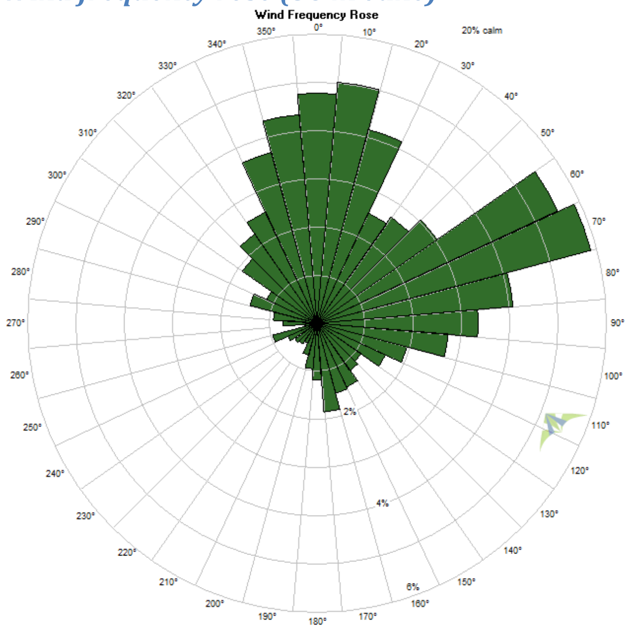
Site extreme wind probability table, 38 m data

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	IEC 61400-1, 3rd ed. V_{ref}, m/s
3	29.2	35.5	I	50.0
10	35.4	43.1	II	42.5
20	37.0	45.0	III	37.5
30	39.6	48.2	S	designer-specified
50	41.6	50.6		
100	44.2	53.8		
average gust factor:	1.22			

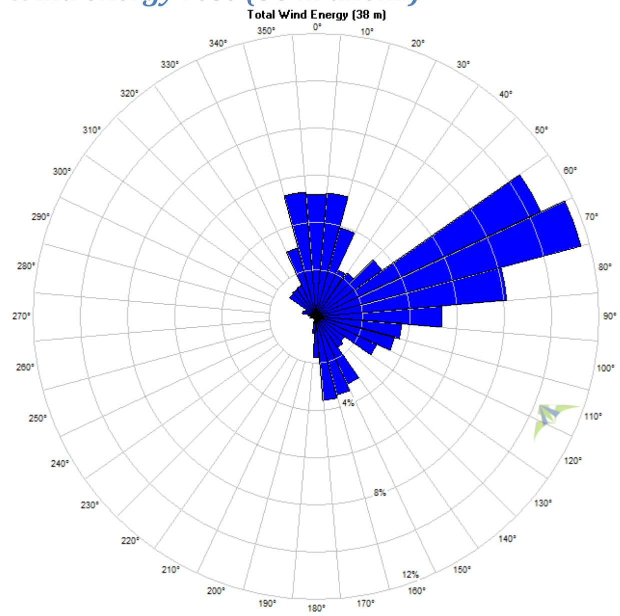
Wind Direction

Wind frequency and wind energy roses indicate that winds at the Pitka's Point met tower site are primarily bi-directional, with northerly and east-northeasterly winds predominating. A mean value rose indicates that east-northeasterly winds are of higher intensity than northerly winds, but interesting, the infrequent south-southeasterly winds, when they do occur, are highly energetic and likely indicative of storm winds.

Wind frequency rose (38 m vane)



Wind energy rose (38 m anem.)



Temperature and Density

The Pitka's Point met tower site experiences cool summers and cold winters with resulting higher than standard air density. Calculated annual air density during the met tower test period exceeds the 1.204 kg/m^3 standard air density for a 177 meter elevation by 5.7 percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

Temperature and density table

	Temperature						Air Density		
Month	Mean (°F)	Min (°F)	Max (°F)	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	4.7	-20.2	39.0	-15.1	-29.0	3.9	1.325	1.204	1.416
Feb	4.1	-24.7	32.4	-15.5	-31.5	0.2	1.343	1.264	1.430
Mar	11.0	-14.3	38.8	-11.7	-25.7	3.8	1.275	1.204	1.397
Apr	19.5	-6.3	44.2	-7.0	-21.3	6.8	1.299	1.235	1.372
May	39.4	13.8	65.5	4.1	-10.1	18.6	1.247	1.185	1.314
Jun	49.2	29.5	70.2	9.5	-1.4	21.2	1.223	1.174	1.272
Jul	50.5	37.9	81.9	10.3	3.3	27.7	1.220	1.149	1.250

	Temperature						Air Density		
Month	Mean (°F)	Min (°F)	Max (°F)	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Aug	51.3	33.1	70.9	10.7	0.6	21.6	1.218	1.173	1.263
Sep	45.1	30.0	64.6	7.3	-1.1	18.1	1.233	1.187	1.270
Oct	22.7	5.0	37.2	-5.2	-15.0	2.9	1.290	1.252	1.339
Nov	16.3	-14.6	44.6	-8.7	-25.9	7.0	1.308	1.234	1.398
Dec	13.9	-16.2	45.0	-10.1	-26.8	7.2	1.307	1.204	1.403
Annual	27.4	-24.7	81.9	-2.5	-31.5	27.7	1.273	1.149	1.430

Wind-Diesel System Design and Equipment

Wind-diesel power systems are categorized based on their average penetration levels, or the overall proportion of wind-generated electricity compared to the total amount of electrical energy generated. Commonly used categories of wind-diesel penetration levels are low penetration, medium penetration, and high penetration. The wind penetration level is roughly equivalent to the amount of diesel fuel displaced by wind power. Note however that the higher the level of wind penetration, the more complex and expensive of a control system and demand-management strategy required. Medium penetration is a good compromise between of displaced fuel usage and relatively minimal system complexity and is AVEC's preferred system configuration. Installation of four Northern Power 100 wind turbines at the Pitka's Point site would be configured at the medium penetration level.

Categories of wind-diesel penetration levels

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

Penetration	Penetration Level		Operating characteristics and system requirements
	Instantaneous	Average	
			managed devices.

HOMER energy modeling software was used to analyze the Saint Mary's power 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.

Diesel Power Plant

Electric power (comprised of the diesel power plant and the electric power distribution system) in Saint Mary's is provided by AVEC. The existing power plant in Saint Mary's consists of one Cummins diesel generator model QSX15G9 rated at 499 kW output, and two Caterpillar diesel generators, a model 3508 rated at 611 kW output and a model 3512 rated at 908 kW output.

St. Mary's power plant diesel generators

Generator	Electrical Capacity	Diesel Engine Model
1	499 kW	Cummins QSX15G9
2	611 kW	Caterpillar 3508
3	908 kW	Caterpillar 3512

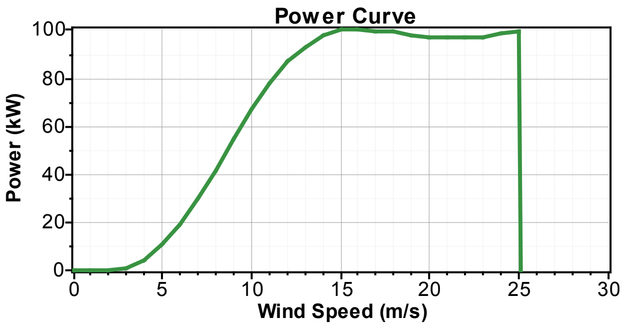
Wind Turbine

This report considers installation of four Northern Power 100 ARCTIC turbines for 400 kW installed wind capacity to serve the Saint Mary's/Andreafsky and Pitka's Point combined load.

Northern Power 100 ARCTIC

The Northern Power 100 ARCTIC, formerly known as the Northwind 100 (NW100) Arctic, is rated at 100 kW and is equipped with a permanent magnet, synchronous generator, is direct drive (no gearbox), and is equipped with heaters and has been tested to ensure operation in extreme cold climates. The turbine has a 21 meter diameter rotor operating at a 37 meter hub height. The turbine is stall-controlled and in the proposed version will be equipped with an arctic package enabling continuous operation at temperatures down to -40° C. The Northern Power 100 ARCTIC is the most widely represented village-scale wind turbine in Alaska with a significant number of installations in the Yukon-Kuskokwim Delta and on St. Lawrence Island. The Northern Power 100 ARCTIC wind turbine is manufactured in Barre, Vermont, USA. More information can be found at http://www.northernpower.com/. The turbine power curve is shown below.

Northern Power 100 ARCTIC power curve



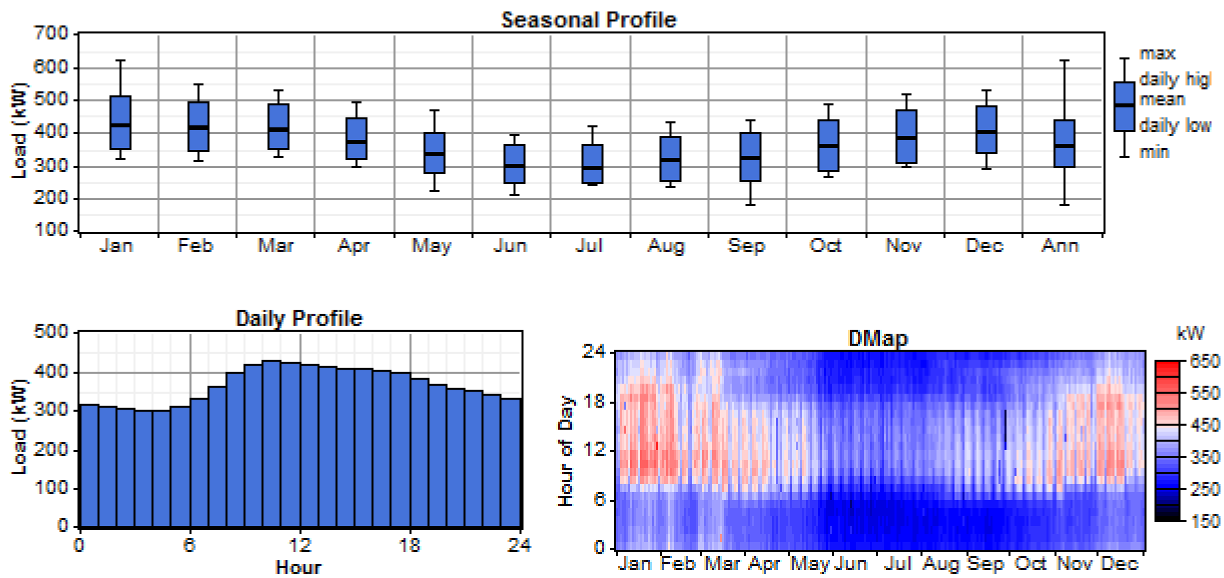
Load Demand

This analysis includes stand-alone electric and thermal load demand in St. Mary's (which includes Andreafsky and Pitka's Point).

St. Mary's Electric Load

Saint Mary's/Andreafsky load data, collected from December 26, 2009 to October 27, 2011, was received from Mr. Bill Thompson of AVEC. These data are in 15 minute increments and represent total electric load demand during each time step. The data were processed by adjusting the date/time stamps nine hours from GMT to Yukon/Alaska time, multiplying each value by four to translate kWh to kW (similar to processing of the wind turbine data), and creating January 1 to December 31 hourly load data for export to HOMER software. The resulting load is shown graphically below. Average load is 354 kW with a 621 kW peak load and an average daily load demand of 8,496 kWh. This was revised to an average daily load demand of 9,092 kWh in this report to account for recent load growth in the community.

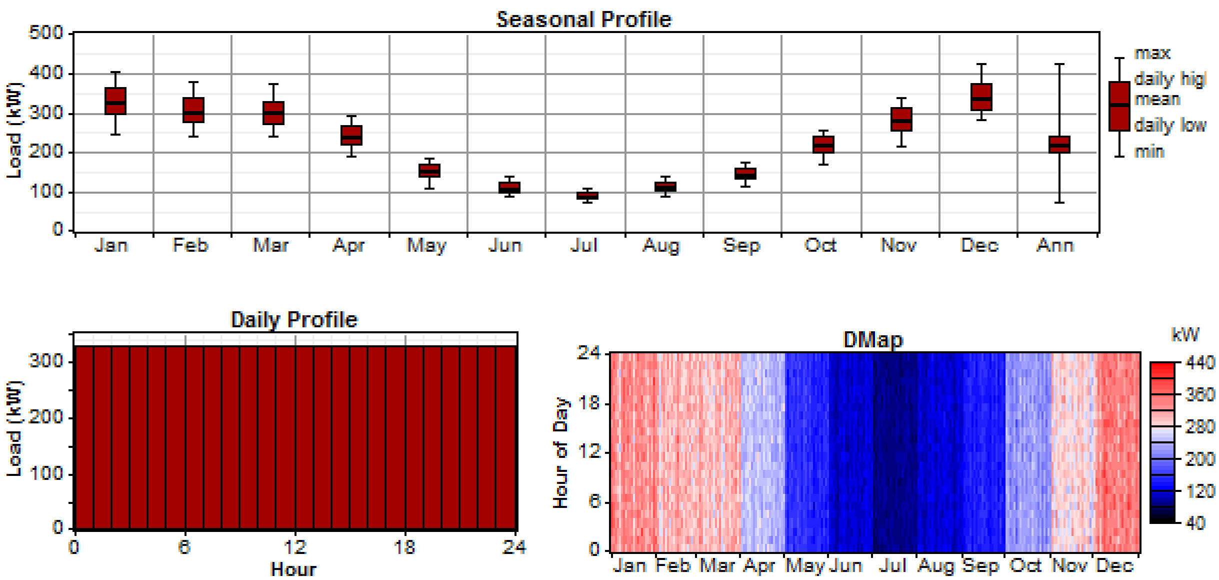
St. Mary's electric load



Thermal Load

The thermal load demand in St. Mary's is well quantified and described in a report entitled *St. Mary's, Alaska Heat Recovery Study,* prepared for the Alaska Energy Authority by Alaska Energy and Engineering, Inc., dated August 31, 2011. Thermal load data needed for HOMER modeling was extracted from a heat demand/heat available graph on page 5 of the report. Monthly thermal heat demand is graphed as a heating fuel equivalent in gallons per month, which was converted to kW demand with a conversion of 0.0312 gallons heating fuel per kWh. Although not entirely precise, the monthly heat demand was equalized across the entire day for each month and then randomized with a five percent day-to-day and five percent time step-to-time step random variability. Resulting thermal load is show below.

Saint Mary's thermal load



Diesel Generators

The HOMER model was constructed with all three St. Mary's generators. Information pertinent to the HOMER model is shown in the table below. Note that the Saint Mary's power plant is equipped with automated switchgear and can run in automatic mode with generators operating in parallel.

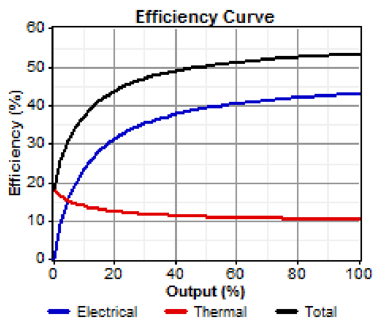
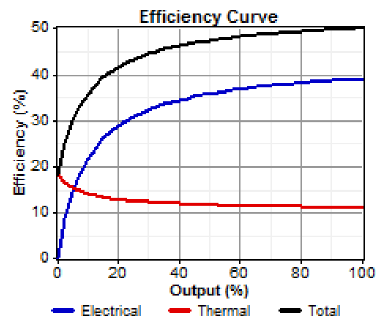
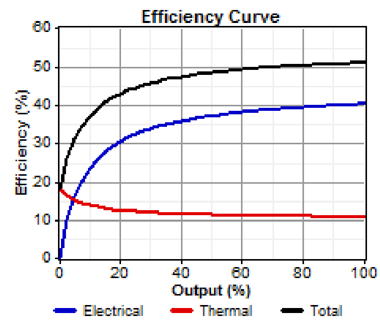
Diesel generator HOMER modeling information

Diesel generator	Cummins QSX15G9	Caterpillar 3508	Caterpillar 3512
Power output (kW)	499	611	908
Intercept coeff. (L/hr/kW rated)	.0222	0.0233	0.0203
Slope (L/hr/kW output)	0.215	0.238	0.233
Minimum electric load (%)	0% (0 kW)	0% (0 kW)	0% (0 kW)
Heat recovery ratio (% of waste heat that can serve the thermal load)	22	22	22

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

Slope – the marginal fuel consumption of the generator

Diesel generator efficiency curves

Fuel efficiency curve, QSX15G9	Fuel efficiency curve, Cat 3508	Fuel efficiency curve, Cat 3508
		

WAsP Modeling, Wind Turbine Layout

WAsP (Wind Atlas Analysis and Application Program) and is PC-based software for predicting wind climates, wind resources and power production from wind turbines and wind farms and was used to model the Pitka's Point terrain and wind turbine performance.

WAsP software calculates gross and net annual energy production (AEP) for turbines contained within wind farms, such as an array of two or more turbines in proximity to each other. For s single turbine array, WAsP calculates gross AEP. With one turbine, net AEP is identical to gross AEP as there is no wake loss to consider.

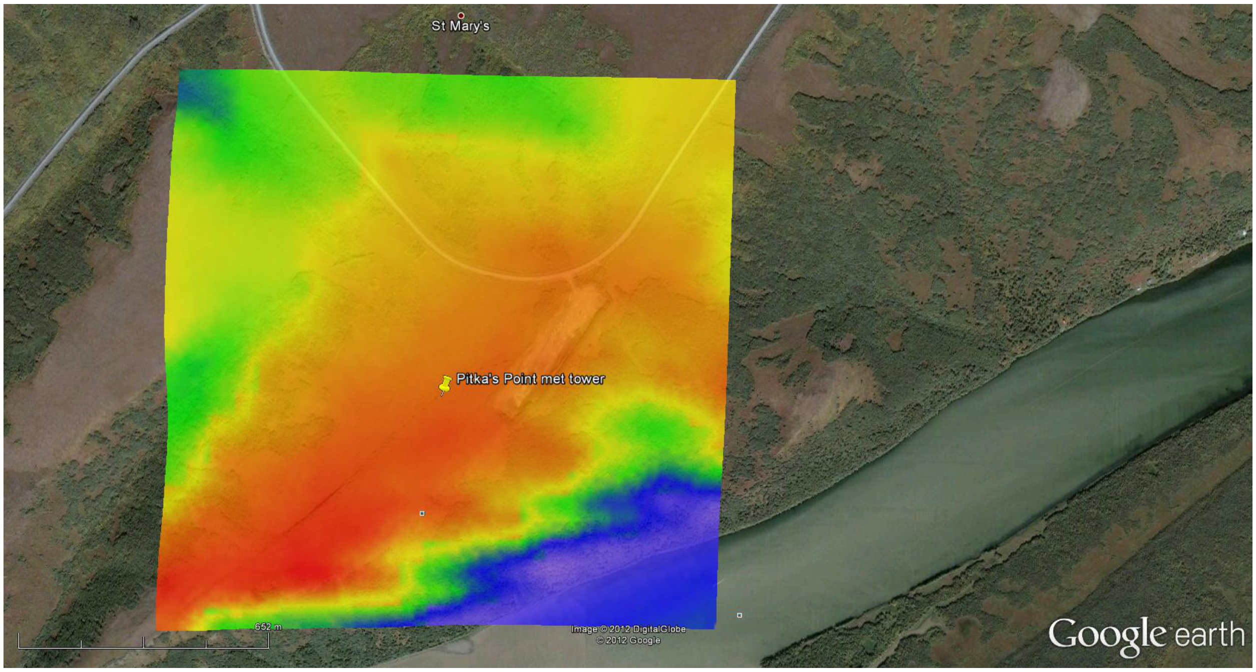
Orographic Modeling

WAsP modeling begins with import of a digital elevation map (DEM) of the subject site and surrounding area and conversion of coordinates to Universal Transverse Mercator (UTM). UTM is a geographic coordinate system that uses a two-dimensional Cartesian coordinate system to identify locations on the surface of Earth. UTM coordinates reference the meridian of its particular zone (60 longitudinal zones are further subdivided by 20 latitude bands) for the easting coordinate and distance from the equator for the northing coordinate. Units are meters. Elevations of the DEMs are converted to meters (if necessary) for import into WAsP software.

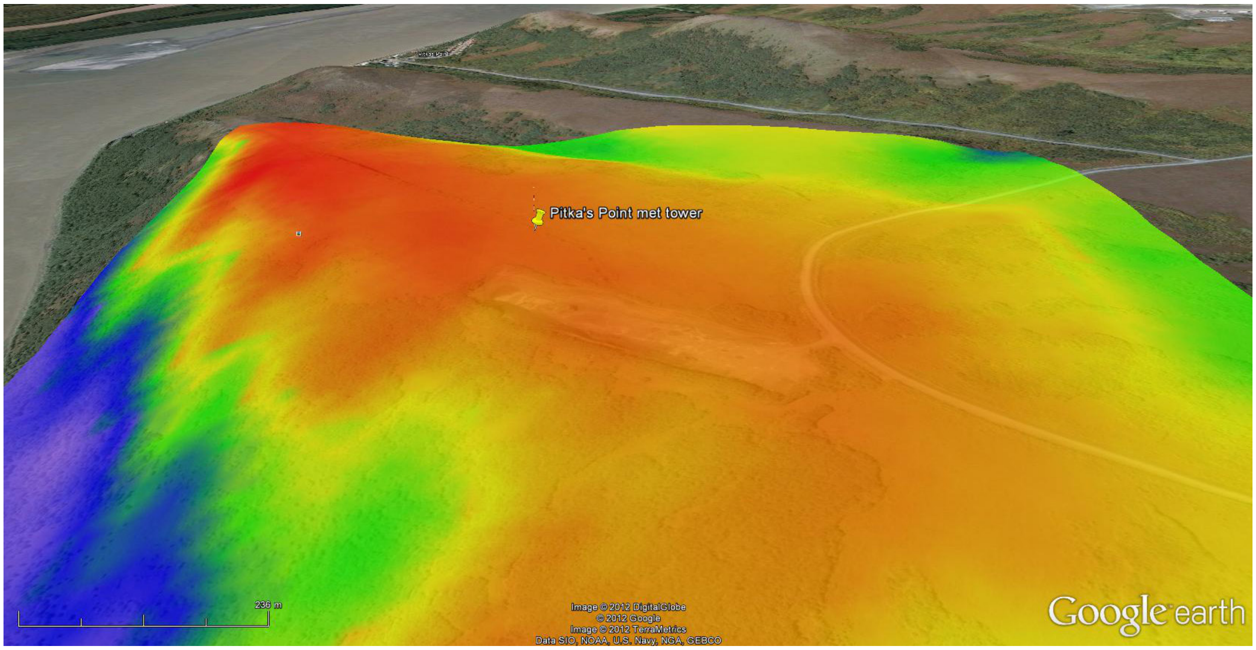
A met tower reference point is added to the digital elevation map, wind turbine locations identified, and a wind turbine(s) selected to perform the calculations. WAsP considers the orographic (terrain) effects on the wind (plus surface roughness and obstacles) and calculates how wind flow increases or decreases at each node of the DEM grid. The mathematical model has a number of limitations, including the assumption of overall wind regime of the turbine site is the same as the met tower reference site, prevailing weather conditions are stable over time, and the surrounding terrain at both sites is sufficiently gentle and smooth to ensure laminar, attached wind flow. WAsP software is not capable of modeling turbulent wind flow resulting from sharp terrain features such as mountain ridges, canyons, shear bluffs, etc.

Orographic modeling of wind across the site, with the Pitka's Point met tower as the reference site, indicates an outstanding wind resource on the top edge of the bluff, especially downhill from the met tower toward the Yukon River and the village of Pitka's Point.

Wind modeling of Pitka's Point site area, plan view



Wind modeling of Pitka's Point site area, view to west



Wind Turbine Project Site

The project site is Pitka's Point Native Corporation land on and near the location of the Pitka's Point met tower, with boundaries of the Pitka's Point/Saint Mary's Airport road to the north, a rock quarry to the east, the bluff and Lot 10 to the south, and a Native Allotment to the west. More specifically, AVEC has obtained site control on Lot 6 within these general boundaries for turbine siting. Site control of Lot 6 is adequate to site four NPS100 ARCTIC turbines.

It is important to note that winds at the project site, though robust as a Class 6 wind resource, are prone to rime icing conditions in winter. Rime icing is more problematic for wind turbine operations than freezing rain (clear ice) given its tenacity and longevity in certain climatic conditions. Anti-icing and/or de-icing features may be necessary to sustain availability during the winter months.

Northern Power 100 ARCTIC Turbine Layout

Using WAsP software, locations for four NPS100 ARCTIC wind turbines were selected that have high gross energy production, but at the same time result in minimal array loss, thus yielding a high net energy production. Site constraints necessitated that the turbines be located on the southern boundary of the available lot but yet maintain sufficient offset from the quarry to accommodate its possibly future expansion.

NPS 100 ARCTIC Turbine Layout

Turbine	UTM (easting, northing)
Pitkas 1	Zone 3V 591490, 6879581
Pitkas 2	Zone 3V 591616, 6879581
Pitkas 3	Zone 3V 591564, 6879490
Pitkas 4	Zone 3V 591690, 6879490

WAsP Modeling Results for Northern Power 100 ARCTIC Array

The following table presents the WAsP software analysis of energy production and capacity factor performance of the NPS100 ARCTIC turbines in a four turbine array at 100% turbine availability (percent of time that the turbine is on-line and available for energy production). The turbines perform very well in the Pitka's Point wind regime with excellent annual energy production and minimal array wake loss. WAsP modeling results are included in Appendix B of this report.

Note that the standard (atmospheric conditions) power curve was compensated to the measured mean annual site air density of 1.273 kg/m^3. For the stall-controlled NPS100 ARCTIC, power output (for each m/s wind speed step) of the standard power curve was multiplied by the ratio of site air density to standard air density of 1.225 kg kg/m^3 and capped at a maximum 100 kW output.

WAsP model results, fourNPS100 ARCTIC turbine array, 100% availability

Parameter	Total (MWh/yr)	Average Each (MWh/yr)	Minimum Each (MWh/yr)	Maximum Each (MWh/yr)
Net AEP	1,384	346.0	339.5	358.8
Gross AEP	1,420	355.2	348.2	365.8
Wake loss	2.59 %	-	-	-

NPS100 ARCTIC turbine layout, view to north

NPS100 ARCTIC turbine layout, view to southwest

Alternate Turbine Layout

Using WAsP software, locations for five NPS100 ARCTIC wind turbines (four planned plus a possible future fifth turbine) were selected that have similar high gross energy production and minimal array loss as the first layout, but allow for electrical distribution line routing that will not cross the access road (a problem noted by AVEC Engineering with respect to the layout above). As with the layout above, site constraints necessitated that the turbines be located on the southern boundary of the available lot but yet maintain sufficient offset from the quarry to accommodate its possibly future expansion.

NPS 100 ARCTIC alternate layout

Turbine	UTM (easting, northing)
Pitkas 1	Zone 3V 591490, 6879499
Pitkas 2	Zone 3V 591595, 6879499
Pitkas 3	Zone 3V 591700, 6879499
Pitkas 4	Zone 3V 591543, 6879580
Pitkas 5 (future)	Zone 3V 591648, 6879580

WAsP Modeling Results for Alternate Northern Power 100 ARCTIC Array

The following table presents the WAsP software analysis of energy production and capacity factor performance of the NPS100 ARCTIC turbines in a four turbine array at 100% turbine availability (percent of time that the turbine is on-line and available for energy production). As with the layout above, the turbines perform very well in the Pitka's Point wind regime with excellent annual energy production and minimal array wake loss. WAsP modeling results are included in Appendix C of this report.

Annual energy production alternate four turbine array, 100% availability

Parameter	Total (MWh/yr)	Average Each (MWh/yr)	Minimum Each (MWh/yr)	Maximum Each (MWh/yr)
Net AEP	1,391	347.7	341.7	361.9
Gross AEP	1,430	357.4	348.2	365.8
Wake loss	2.69 %	-	-	-

Northern Power 100 turbines, view to north

Economic Analysis

Homer software was used to model static energy balance of the Saint Mary's electrical and thermal power system at one hour increments of time. Wind turbines are modeled as connected to the electrical distribution system with first priority to serve the electrical load and second priority to serve the thermal load via a secondary load controller and electric boiler.

Project Capital Cost

Capital and installation costs of four NPS100 ARCTIC wind turbines to serve the village of St. Mary's, including distribution system extension is $4,749,528. This cost estimate was developed by CRW Engineering, Inc. for AVEC's Renewable Energy Fund Round 7 construction project proposal. Pitka's Point Native Corporation is making an in-kind contribution of $33,000 for the project site; hence total cost for this project is $4,782,528.

Fuel Cost

A fuel price of $5.27/gallon ($1.39/Liter) was chosen for the initial HOMER analysis by reference to *Alaska Fuel Price Projections 2013-2035*, dated June 30, 2013, which was prepared for the Alaska Energy Authority by the Institute for Social and Economic Research (ISER), and the *2013_06_R7Prototype_final_07012013* Excel spreadsheet, also written by ISER. The $5.27/gallon price reflects the average value of all fuel prices between the 2015 (the assumed project start year) fuel price of $4.47/gallon and the 2034 (20 year project end year) fuel price of $6.45/gallon using the medium price projection analysis with an average social cost of carbon (SCC) of $0.61/gallon included.

By comparison, the fuel price for Saint Mary's (without social cost of carbon) reported to Regulatory Commission of Alaska for the 2012 PCE report is $3.26/gallon ($1.02/Liter), without inclusion of SCC. Assuming an SCC of $0.40/gallon (ISER *Prototype* spreadsheet, 2013 value), the 2012 Saint Mary's fuel price was $3.66/gallon ($1.13/Liter).

Heating fuel displacement by excess energy diverted to thermal loads is valued at $6.42/gallon ($1.70/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 SCC) plus $1.05/gallon, assuming heating oil displacement between 1,000 and 25,000 gallons per year.

Fuel cost table (SCC included)

ISER medium cost projection	2015 (/gal)	2034 (/gal)	Average (/gallon)	Average (/Liter)
Diesel fuel	$4.47	$6.45	$5.37	$1.42
Heating oil	$5.52	$7.50	$6.42	$1.70

Modeling Assumptions

HOMER energy modeling software was used to analyze the Saint Mary's power System. HOMER is a static energy model 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. Homer software is widely used in the State of Alaska to aid development of village wind-diesel power projects.

HOMER 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. The base or comparison scenario is the existing St. Mary's/Andreafsky powerplant with its present configuration of diesel generators. Also assumed in the base or comparison scenario is that excess powerplant heat serves the thermal load via a heat recovery loop.

Wind turbines constructed at the Pitka's Point site are assumed to operate in parallel with the diesel generators. Excess energy will serve thermal loads via a secondary load controller and electric boiler, but this SLC/boiler combination may not be part of the diesel generator recovered heat loop. Installation cost of four NPS100 ARCTIC wind turbines assumes a three-phase distribution line extension from the road to the wind turbine site plus a two-phase to three-phase upgrade of the distribution system from the line extension tie-in to an existing three-phase distribution point on the west side of the village of St. Mary's.

Homer and ISER modeling assumptions

Economic Assumptions	
Project cost	$4,782,528
Project life	20 years (2015 to 2034)
Discount rate	3% (reference: ISER 2013 *Prototype* spreadsheet)
Operating Reserves	
Load in current time step	10%
Wind power output	100% (Homer setting to force diesels 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)
Price (20 year average; ISER 2013, medium projection plus SCC)	$5.27/gal ($1.38/Liter)
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)
Price (20 year average; ISER 2013, medium projection plus SCC)	$6.32/gal ($1.66/Liter)
Diesel Generators	
Generator capital cost	$0 (new generators already funded)
O&M cost	$0.02/kWh (reference: ISER 2013 *Prototype* spreadsheet)
Minimum load	50 kW; based on AVEC's operational criteria of 50 kW minimum diesel loading with their wind-diesel systems
Schedule	Optimized
Wind Turbines	
Availability	80%
O&M cost	$0.049/kWh (reference: ISER 2013 *Prototype* spreadsheet)
Wind speed	7.69 m/s at 30 m, 100% turbine availability 6.75 m/s at 30 m, 80% turbine availability
Density adjustment	1.273 kg/m^3; note that standard air density is 1.225 kg/m^3; Homer wind resource elevation set at -350 meters to simulate the Pitka's Point air density
Energy Loads	
Electric	9.09 MWh/day average Saint Mary's electric load
Thermal	5.22 MWh/day average Saint Mary's thermal load

Economic Valuation

Homer software was used in this feasibility analysis to model the wind resource, wind turbine energy production, effect on the diesel engines when operated with wind turbines, and excess wind energy that could be used to serve thermal loads. Although Homer software is designed to evaluate economic valuation by ranking alternatives, including a base or "do nothing" alternative by net present cost, AEA economic valuation methodology differs in its assumptions of O&M costs, fuel cost for each year of the project life, and disposition of excess energy. Excess energy is valued in the ISER spreadsheet with an assumption that the powerplant is not co-generation. In other words, excess energy is valued without consideration of possible thermal production loss due to reduced diesel engine loading as would occur in a co-generation system configuration.

In an effort to align economic valuation of project alternatives with Alaska Energy Authority methods, this feasibility analysis uses AEA's economic evaluation methods. Although ISER developed the cost evaluation spreadsheet, AEA determined the assumptions and methods of the model. The model is updated every July in preparation for the next round of Renewable Energy Fund requests for proposals in the form of an explanation report and an Excel spreadsheet. The latest version of the spreadsheet has a file name of *2013_06-R7Prototype_final_07012013* and is available on ISER's website.

Project Economic Valuation

	Homer Model					ISER Model						
Turbine Type	Wind Capacity (kW)	Diesel Efficiency (kWh/gal)	Wind Energy (kWh/yr)	Excess Electricity (kWh/yr	Net Wind Energy (kWh/yr)	Project Capital Cost	Diesel Efficiency (kWh/gal)	NPV Benefits	NPV Capital Costs	NPV Net Benefit	B/C Ratio	Diesel and Heat Oil Displaced (gal/yr)
NPS100	400	15.1	1,147,750	55,398	1,092,352	$4,782,528	13.03	$5,757,260	$4,346,491	$1,410,769	1.32	85,250

Notes:
Wind energy at 80% availability
NPV benefits and capital costs at 3% discount rate; base year is 2012 (ISER spreadsheet)
Diesel efficiency for ISER cost model from 2012 PCE Report
Assumes excess wind energy to thermal loads not connected to recovered heat loop

Additional Information

Turbine Type	Hub Height (m)	No. Turbines	Diesel Fuel Displaced (gal/yr)	Wind Energy to Thermal (kWh/yr)	Heating Oil Equiv. (gal)	Wind Penetration (% electrical)	Wind Penetration (% thermal)
NPS100	37	4	83,834	55,398	1,416	34.6	2.9

Note: wind energy at 80% availability

Appendix A, WAsP Wind Farm Report, Pitka's Point Site, NP 100 Turbines

Pitka's Point, Alaska Wind Resource Report

Pitka's Point met tower, photo by Doug Vaught

April 25, 2012

Douglas Vaught, P.E.
V3 Energy, LLC
Eagle River, Alaska

Summary

The wind resource measured at the Pitka's Point met tower site is outstanding with measured wind power class 6 by measurement of wind power density and wind speed. Extensive wind resource analysis has been conducted in the Saint Mary's region, with met towers at a lower elevation site closer to the village of Saint Mary's and near Mountain Village in addition to the Pitka's Point met tower. Documented in another report, the wind resource measured at the nearby Saint Mary's met tower site is less robust than that measured at Pitka's Point and appears to experience similar icing problems. The Mountain Village wind resource classification appears to be between those measured at Pitka's Point and Saint Mary's. Considering the inland location of Saint Mary's/Pitka's Point, the wind resource measure at the Pitka's Point met tower site is highly unusual, and very favorable, with its combination of a high annual average wind speed, relatively low elevation, likely good geotechnical conditions, and proximity to existing roads and infrastructure.

Met tower data synopsis

Data dates	October 26, 2007 to February 12, 2009 (16 months)
Wind power class	Class 6 (excellent), based on wind power density
Wind power density mean, 38 m	558 W/m^2
Wind speed mean, 38 m	7.62 m/s (17.0 mph)
Max. 10-min wind speed	29.5 m/s
Maximum 2-sec. wind gust	26.3 m/s (81.2 mph), January 2008
Weibull distribution parameters	k = 1.93, c = 8.63 m/s
Wind shear power law exponent	0.176 (low)
Roughness class	2.09 (description: few trees)
IEC 61400-1, 3rd ed. classification	Class II-c (at 38 meters)
Turbulence intensity, mean (at 38 m)	0.076 (at 15 m/s)
Calm wind frequency (at 38 m)	20% (< 4 m/s) (16 mo. measurement period)

Test Site Location

A 40 meter NRG Systems, Inc. tubular-type meteorological (met) tower was installed on Pitka's Point Native Corporation land on the bluff immediately above the Yukon River with excellent exposure to northeasterly winds down the Andreafsky River, northerly winds from the mountains and southerly winds from the flat, tundra plains leading toward Bethel. The met tower site is near an active rock quarry and visual inspection of that quarry indicates the likelihood of excellent geotechnical conditions for wind turbine foundations. Also of advantage for the site is near proximity of the road connecting Saint Mary's to Pitka's Point, the airport and Mountain Village. A two-phase power distribution line (connecting the St. Mary's powerplant to Pitka's Point as one phase and to the airport as the second phase) routes on the south side of the road. This line could be upgraded to three-phase at minimal cost to connect wind turbines to the system.

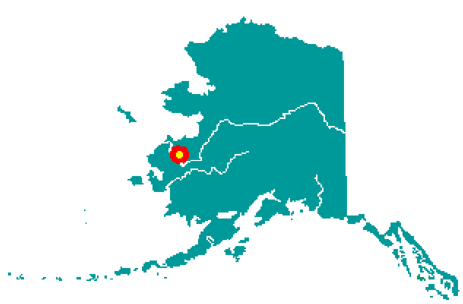


Photo of St. Mary's from Pitka's Point site, view to NE, Andreafsky River in background

Site information

Site number	0066
Latitude/longitude	N 62° 02.252" W 163° 14.820"
Time offset	-9 hours from GMT (Yukon/Alaska time zone)
Site elevation	177 meters (580 ft.)
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	Tubular tall tower, 8-inch diam., 40 meter height

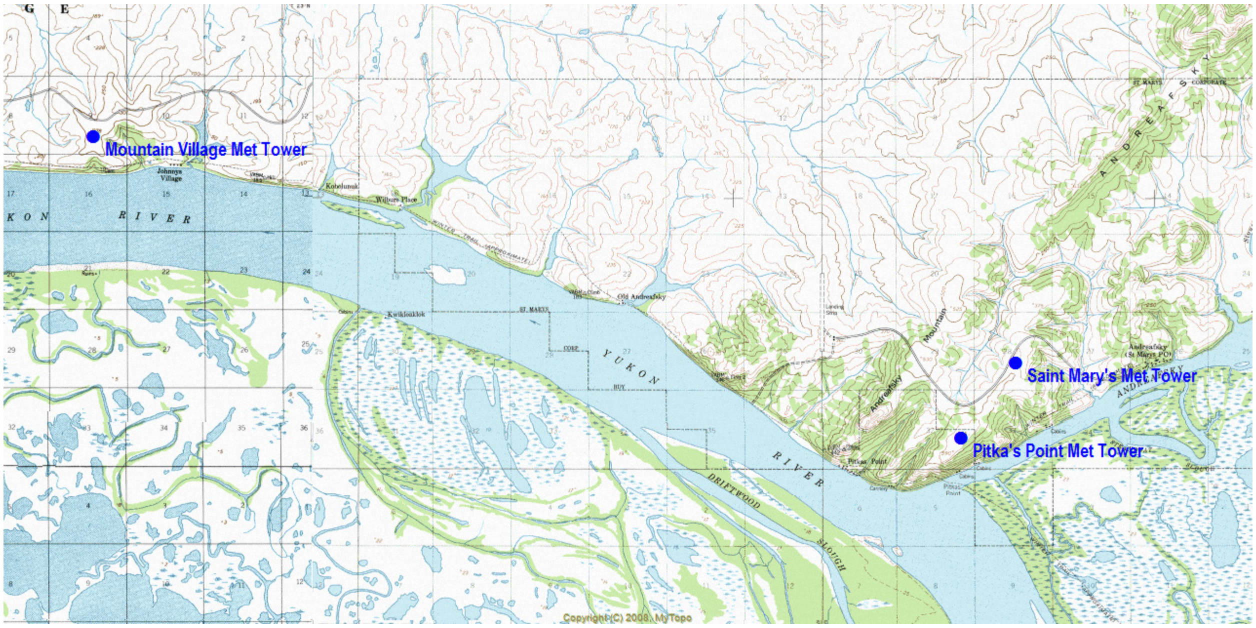
Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40C anemometer	38.0 m	0.765	0.35	NNE
2	NRG IceFree III anemometer	28.2 m	0.572	1.0	WNW
3	NRG #40C anemometer	28.8 m	0.765	0.35	NNE
4	NRG #40C anemometer	21.0 m	0.765	0.35	NNE
7	NRG #200P wind vane	38 m	0.351	260	080° T
8	NRG IceFree III wind vane	29 m	0.351	350	350° T

9	iPack Voltmeter		0.021	0	
10	NRG #110S Temp C	2 m	0.136	-86.383	N/A
12	RH-5 relative humidity	2 m	0.097	0	

Google Earth image, Pitka's Point and Saint Mary's

Topographic maps



Data Quality Control

Data was filtered to remove presumed icing events that yield false zero wind speed data and non-variant wind direction data. Data that met criteria listed below were automatically filtered. In addition, data was manually filtered for obvious icing that the automatic filter didn't catch, and invalid or low quality data for situations such as logger initialization and other situations.

- Anemometer icing – data filtered if temperature < 1°C, speed SD = 0, and speed changes < 0.25 m/s for minimum 2 hours
- Vane icing – data filtered if temperature < 1°C and vane SD = 0 for minimum of 2 hours
- Tower shading of 29 meter and 28 meter (IceFree) paired anemometers – refer to graphic below

Because the met tower site is a known rime icing environment, it was thought that installation of a heated anemometer and wind vane would result in much better data recovery than from standard non-heated sensors, but that did not prove entirely true. As one can see in the table below, data loss due to icing was actually higher from the IceFree anemometer than the standard anemometers, although data loss due to icing from the IceFree wind vane is not quite half that from the standard vane. It is not clear why data recovery from the heated anemometer was so poor. One possible explanation is excessive voltage drop from the power line tie-in to the sensor on the met tower. Another explanation is simply the difficult nature of the rime icing environment at the site.

Note also that all data was lost for the period from December 27, 2008 to January 7, 2009. The tower itself collapsed during a severe rime icing event on February 12, 2009, although temperature and relative humidity data collection continued for two additional weeks until March 1, 2009. The February 12 ice storm also resulted in the collapse of the nearby St. Mary's met tower. The St. Mary's met tower was replaced in order to continue that study but with more than one year of Pitka's Point data obtained, it was decided not to replace the Pitka's Point met tower.

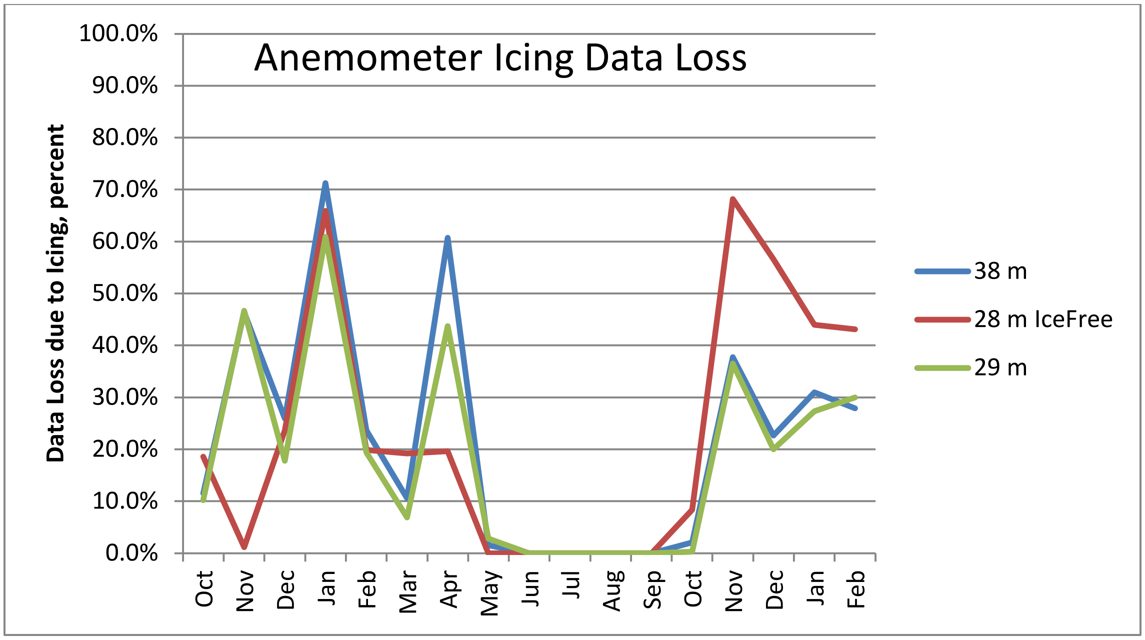
Sensor data recovery table

Sensor	Possible Records	Valid Records	<Unflagged data>	Icing	Invalid	Low quality	Tower shading	Recovery Rate (%)
Speed 38 m	74,016	52,519	52,519	15,962	2,702	0	0	70.96
Speed 28 m IceFree	74,016	47,014	47,014	17,676	2,706	648	6,252	63.52
Speed 29 m	74,016	51,775	51,775	14,605	2,702	0	4,294	69.95
Speed 21 m	74,016	54,025	54,025	13,971	2,702	0	0	72.99
Direction 38 m	74,016	51,528	51,528	17,608	2,772	0	0	69.62
Direction 29 m IceFree	74,016	58,876	58,876	9,803	2,772	0	0	79.54
iPack Voltmeter	74,016	69,122	69,122	0	245	0	0	93.39
Temperature	74,016	68,694	68,694	0	673	0	0	92.81
RH-5 Relative Humid. (installed on 1/8/2009)	74,016	7,344	7,344	0	62,023	0	0	9.92

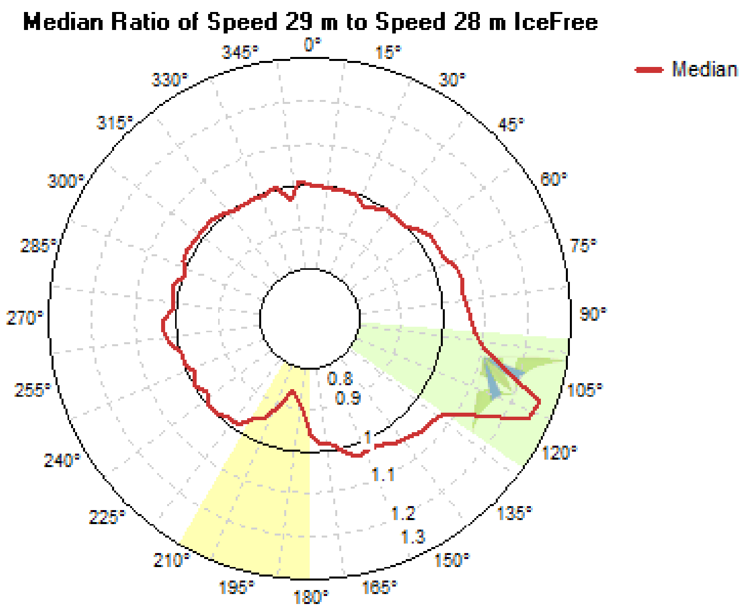
Sensor data recovery rate by month

		anemometers				vanes	
Year	Month	38 m	28 m IceFree	29 m	21 m	38 m	29 m IceFree
2007	Oct	86.9	75.4	88.3	88.3	79.2	28.1
2007	Nov	53.7	82.9	51.9	54.0	44.5	100.0
2007	Dec	74.1	69.3	80.1	82.7	77.5	79.0
2008	Jan	28.7	23.8	27.6	43.2	54.8	72.5
2008	Feb	76.3	73.5	79.2	78.5	65.8	86.7
2008	Mar	89.5	78.0	92.7	96.6	77.7	89.6
2008	Apr	39.3	71.1	49.1	42.4	66.9	76.5
2008	May	98.5	85.5	89.5	97.3	96.3	98.2
2008	Jun	100.0	89.8	89.3	100.0	100.0	100.0
2008	Jul	100.0	93.6	93.7	100.0	100.0	100.0
2008	Aug	100.0	92.6	97.0	100.0	100.0	100.0
2008	Sep	100.0	89.6	99.0	100.0	96.7	100.0
2008	Oct	97.9	88.2	98.3	97.9	93.8	95.6
2008	Nov	62.3	28.1	58.0	56.4	54.9	79.0
2008	Dec	65.4	31.9	65.5	64.6	46.6	72.6
2009	Jan	53.6	36.7	50.1	58.0	45.2	51.1
2009	Feb	40.9	22.7	42.3	42.3	37.9	36.6
2009	Mar	0.0	0.0	0.0	0.0	0.0	0.0
All Data		71.0	63.5	70.0	73.0	69.6	79.5

Data loss due to icing conditions



Tower shading filter plot



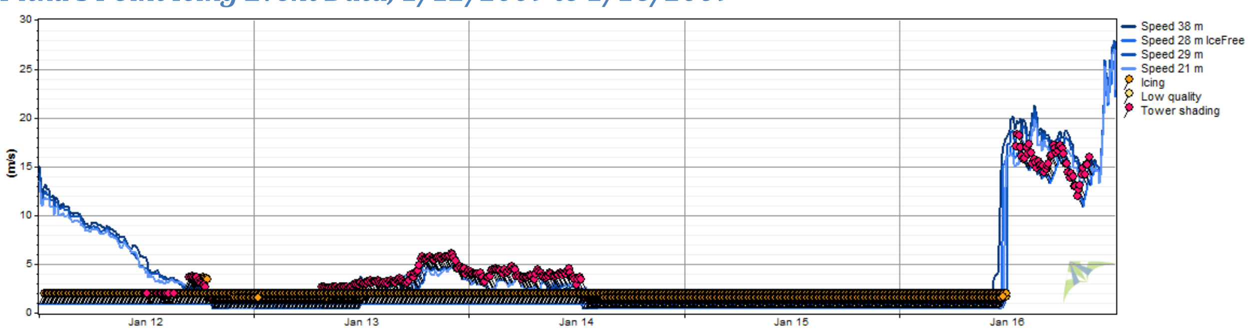
Documentation of Icing

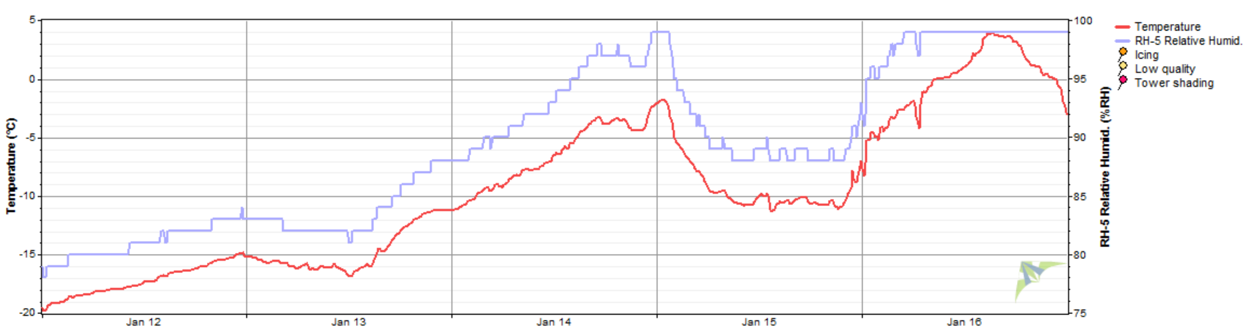
Rime icing is more problematic for wind turbine operations than freezing rain (clear ice) given its tenacity and longevity in certain climatic conditions. For this reason, wind power at the Pitka's Point site should be developed with consideration to the possible need for anti-icing and de-icing measures. These may include redundant control sensors, air-heated rotor blades, leading edge blade heaters, and active operational intervention during winter months to visually detect and de-ice the turbines.

An icing event leading to data recovery loss from the sensors is indicated in the January 15, 2009 photographs below, which clearly indicate the presence of icing conditions. This icing event is also shown in the data graphs of January 15 below. Note that temperature is below freezing, relative humidity is high, wind speed standard deviation equals zero, and the wind speeds are stopped at their offset values of 0.4 m/s. These conditions met the criteria of icing conditions and were automatically flagged by the wind analysis software.

Pitka's Point Icing Event Photographs, 1/15/2009

Pitka's Point Icing Event Data, 1/12/2009 to 1/16/2009





Wind Speed

Anemometer data obtained from the met tower, from the perspectives of both mean wind speed and mean wind power density, indicate an outstanding wind resource. Note that cold temperatures contributed to a higher wind power density than standard conditions would yield for the measured mean wind speeds.

Anemometer data summary

Variable	Speed 38 m	Speed 29 m	Speed 28 m IceFree	Speed 21 m
Measurement height (m)	38	28.8	28.2	21
Mean wind speed (m/s)	7.68	7.29	7.33	6.83
MoMM wind speed (m/s)	**7.62**	**7.24**	**7.33**	**6.78**
Median wind speed (m/s)	7.20	6.80	7.00	6.40
Max wind speed (m/s)	29.50	29.20	27.50	28.40
Weibull k	1.94	1.89	2.22	1.88
Weibull c (m/s)	8.64	8.20	8.26	7.68
Mean power density (W/m²)	573	502	441	414
MoMM power density (W/m²)	**559**	**490**	**441**	**404**
Mean energy content (kWh/m²/yr)	5,015	4,396	3,861	3,627
MoMM energy content (kWh/m²/yr)	**4,897**	**4,294**	**3,861**	**3,541**
Energy pattern factor	1.95	2.00	1.73	2.01
Frequency of calms (%) (< 4 m/s)	20.4	21.9	17.6	24.7
MoMM = mean of monthly means				

Time Series

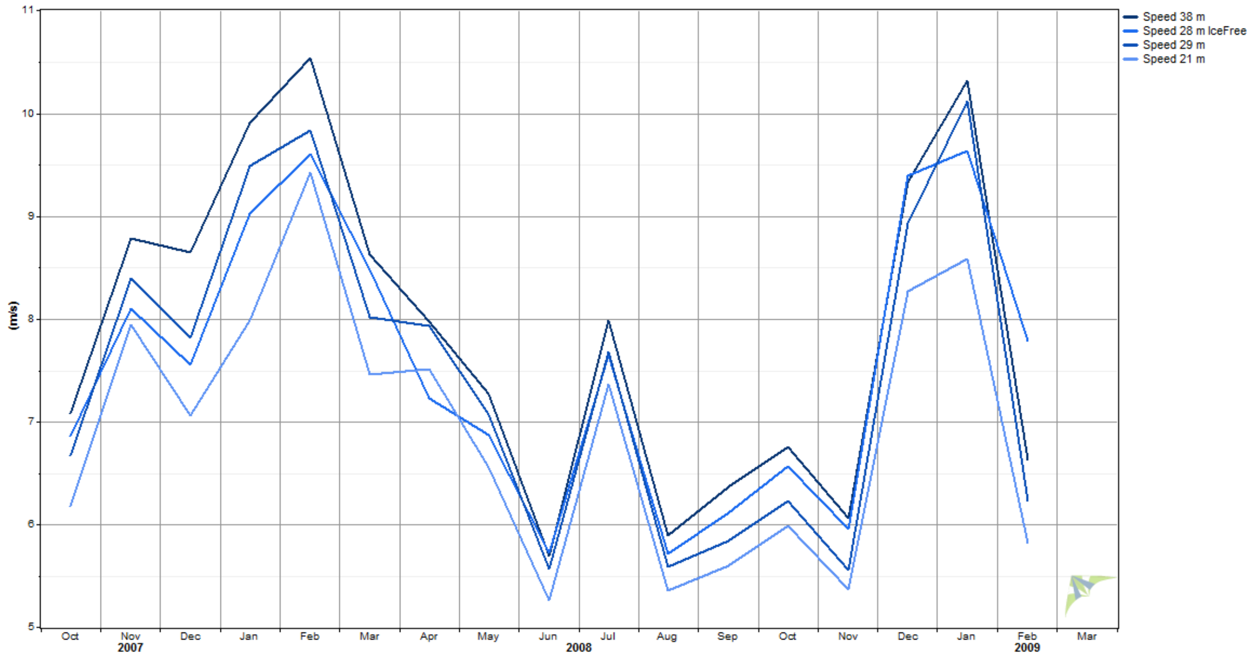
Time series calculations indicate high mean wind speeds during the winter months with more moderate, but still relatively high, mean wind speeds during summer months. This correlates well with the Saint Mary's/Andreafsky/Pitka's Point village load profile where winter months see high demand for electricity and heat and the summer months have lower demand for electricity and heat. The daily wind profiles indicate relatively even wind speeds throughout the day with slightly higher wind speeds during night hours.

38 m anemometer data summary

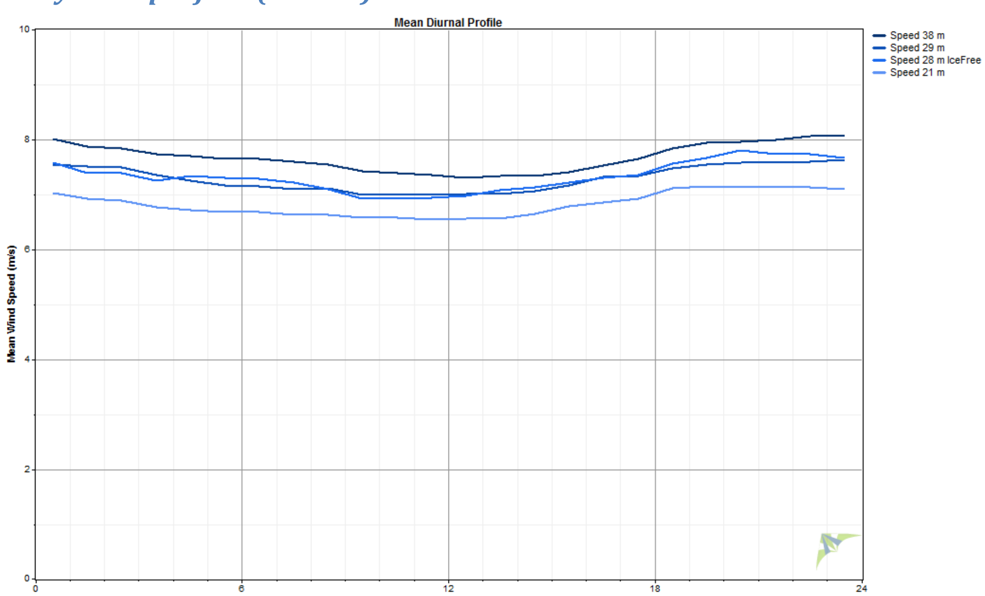
Month	Mean (m/s)	Median (m/s)	Max 10-min avg (m/s)	Max gust (2 sec) (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Jan	10.17	10.70	29.5	35.9	5.34	1.97	11.45
Feb	9.21	9.20	20.1	23.3	4.07	2.41	10.36
Mar	8.62	8.50	21.8	26.3	4.33	2.07	9.71
Apr	7.98	7.80	16.9	20.6	2.83	3.05	8.90
May	7.27	6.90	21.8	27.1	3.67	2.06	8.19
Jun	5.70	5.80	13.2	15.3	2.62	2.28	6.40

Jul	7.98	7.70	21.7	26.3	3.33	2.55	8.99
Aug	5.89	5.70	15.3	17.9	2.95	2.05	6.62
Sep	6.37	6.70	12.5	16.8	2.44	2.85	7.11
Oct	6.80	6.60	20.1	24.8	3.81	1.80	7.62
Nov	7.32	6.40	24.1	29.8	4.48	1.72	8.23
Dec	8.97	8.90	22.9	27.5	4.69	1.95	10.07
Annual	7.62	7.20	29.5	35.9	4.09	1.94	8.64

Monthly time series, mean wind speeds



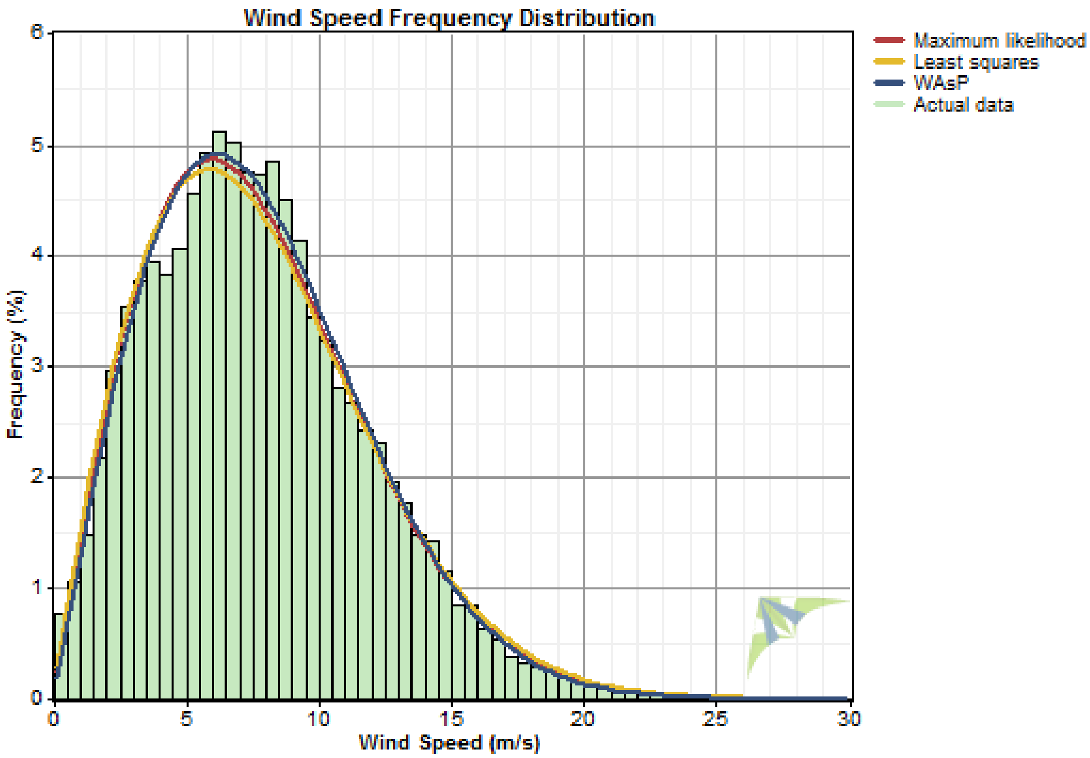
Daily wind profiles (annual)



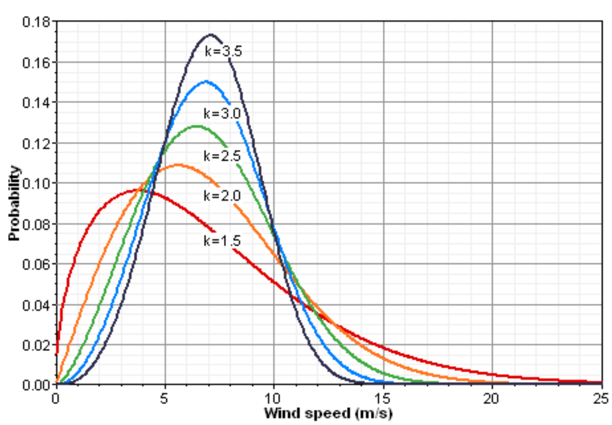
Probability Distribution Function

The probability distribution function (PDF), or histogram, of the Pitka's Point met tower site wind speed indicates a shape curve dominated by moderate wind speeds and is reflective of a "normal" shape curve, known as the Rayleigh distribution (Weibull k = 2.0), which is defined as the standard wind distribution for wind power analysis. As seen below in the wind speed distribution of the 38 meter anemometer, the most frequently occurring wind speeds are between 5 and 10 m/s with very few wind events exceeding 25 m/s (the cutout speed of most wind turbines; see following wind speed statistical table).

PDF of 38 m anemometer (17months' data)



Weibull k shape curve table



Weibull values table, 38 m anemometer

Algorithm	Weibull k	Weibull c (m/s)	Mean (m/s)	Proportion Above 7.678 m/s	Power Density (W/m2)	R Squared
Maximum likelihood	1.940	8.644	7.666	0.452	543.6	0.990
Least squares	1.898	8.692	7.713	0.454	566.8	0.988
WAsP	1.998	8.725	7.732	0.461	541.3	0.990
Actual data			7.678	0.461	541.3	

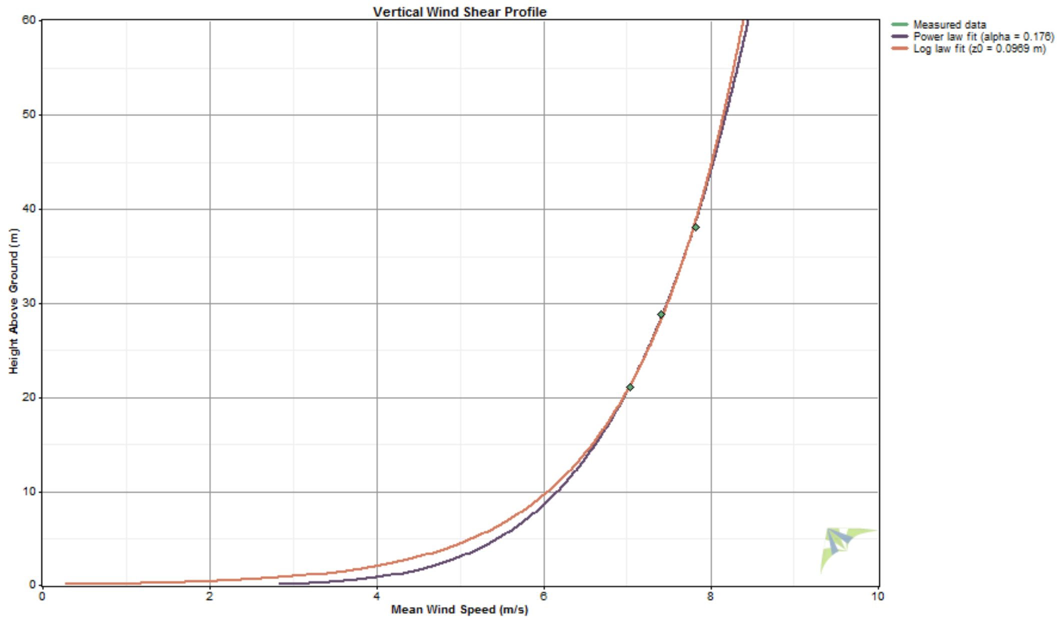
Occurrence by wind speed bin (38 m anemometer)

Bin Endpoints (m/s)		Occurrences			Bin Endpoints (m/s)		Occurrences		
Lower	Upper	No.	Percent	Cumul.	Lower	Upper	No.	Percent	Cumul.
0	1	955	1.82%	1.82%	15	16	893	1.70%	96.52%
1	2	1,918	3.65%	5.47%	16	17	615	1.17%	97.69%
2	3	3,409	6.49%	11.96%	17	18	373	0.71%	98.40%
3	4	4,050	7.71%	19.67%	18	19	306	0.58%	98.98%
4	5	4,141	7.88%	27.56%	19	20	181	0.34%	99.33%
5	6	4,982	9.49%	37.04%	20	21	133	0.25%	99.58%
6	7	5,320	10.13%	47.17%	21	22	93	0.18%	99.76%
7	8	4,975	9.47%	56.65%	22	23	58	0.11%	99.87%
8	9	4,911	9.35%	66.00%	23	24	29	0.06%	99.92%
9	10	3,976	7.57%	73.57%	24	25	11	0.02%	99.94%
10	11	3,177	6.05%	79.62%	25	26	7	0.01%	99.96%
11	12	2,681	5.10%	84.72%	26	27	11	0.02%	99.98%
12	13	2,246	4.28%	89.00%	27	28	5	0.01%	99.99%
13	14	1,707	3.25%	92.25%	28	29	5	0.01%	100.00%
14	15	1,349	2.57%	94.82%	29	30	2	0.00%	100.00%

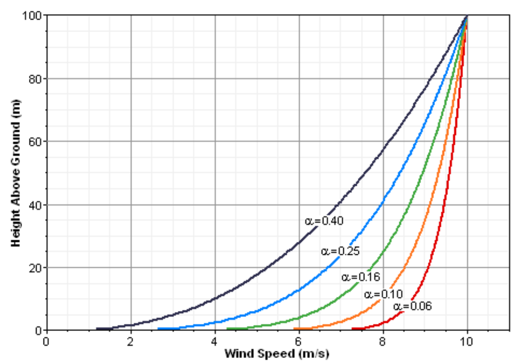
Wind Shear and Roughness

Wind shear at the Pitka's Point met tower site was calculated with the three standard (non-heated) anemometers installed on the met tower. The calculated power law exponent of 0.176 indicates relatively low shear at the site. Calculated surface roughness at the site is 0.11 m (the height above ground where wind speed would be zero) for a roughness class of 2.08 (description: few trees).

Vertical wind shear profile



Comparative wind shear profiles



Wind shear by direction sector table

Direction Sector	Time Steps	Mean Wind Speed (m/s) Speed 38 m	Speed 29 m	Speed 21 m	Best-Fit Power Law Exp	Surface Roughness (m)
345° - 15°	7,444	8.55	8.02	7.61	0.197	0.1777
15° - 45°	5,176	7.53	7.08	6.63	0.214	0.2655
45° - 75°	7,501	9.62	9.06	8.66	0.176	0.0973
75° - 105°	5,627	8.93	8.30	7.57	0.280	0.7842
105° - 135°	3,004	7.71	7.38	7.00	0.165	0.0645
135° - 165°	2,779	8.28	8.04	7.71	0.121	0.0070
165° - 195°	2,364	7.42	7.21	6.95	0.111	0.0035
195° - 225°	456	3.83	3.57	3.35	0.224	0.3280
225° - 255°	1,636	4.73	4.45	4.27	0.172	0.0857
255° - 285°	1,478	4.86	4.59	4.42	0.161	0.0572

285° - 315°	2,821	6.24	6.00	5.88	0.098	0.0011
315° - 345°	4,845	6.92	6.54	6.38	0.136	0.0189

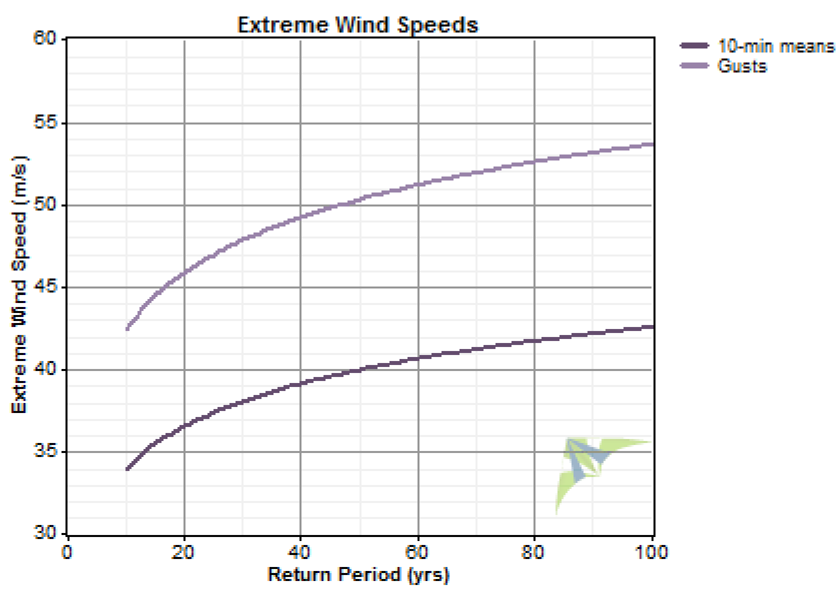
Extreme Winds

A modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, was used to predict extreme winds at the Pitka's Point met tower site. Sixteen months of data though are minimal at best and hence results should be viewed with caution. Nevertheless, with data available the predicted Vref (maximum ten-minute average wind speed) in a 50 year return period (in other words, predicted to occur once every 50 years) is 41.6 m/s. This result classifies the site as Class II by International Electrotechnical Commission 61400-1, 3rd edition (IEC3) criteria. IEC extreme wind probability classification is one criteria – with turbulence the other – that describes a site with respect to suitability for particular wind turbine models. Note that the IEC3 Class II extreme wind classification, which clearly applies to the Pitka's Point met tower site, indicates relatively energetic winds and turbines installed at this location should be IEC3 Class II rated.

Site extreme wind probability table, 38 m data

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
3	29.2	35.5	I	50.0
10	35.4	43.1	II	42.5
20	37.0	45.0	III	37.5
30	39.6	48.2	S	designer-specified
50	41.6	50.6		
100	44.2	53.8		
average gust factor:	1.22			

Extreme wind graph, by annual method



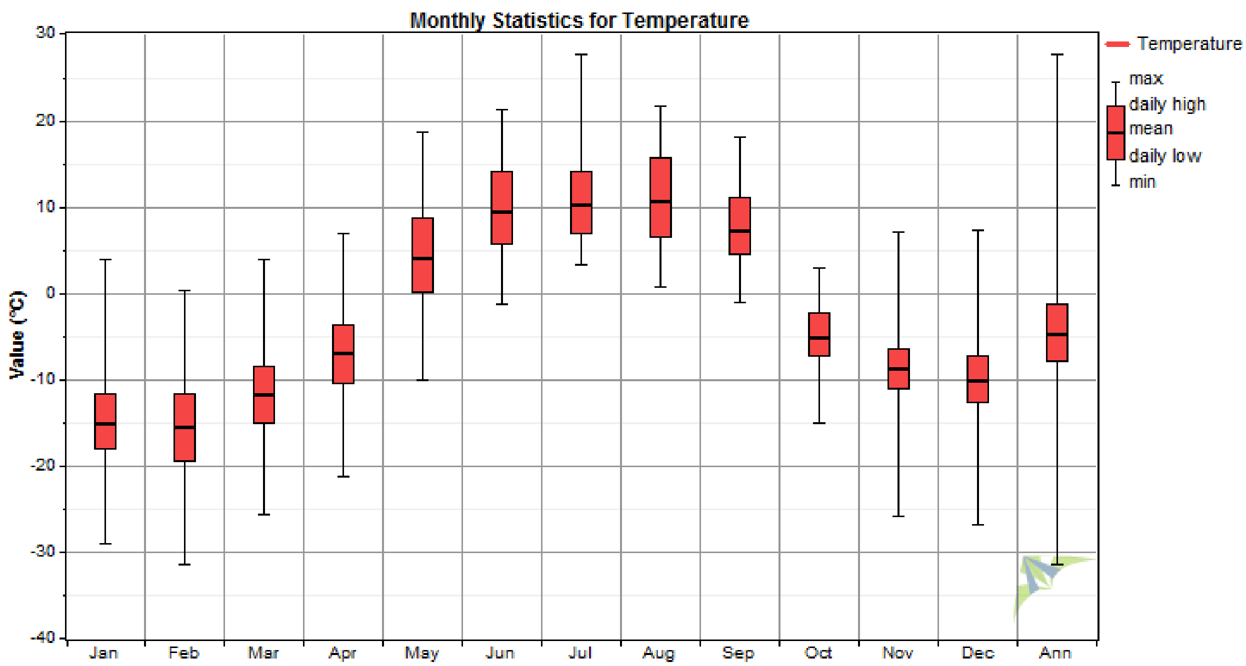
Temperature, Density, and Relative Humidity

The Pitka's Point met tower site experiences cool summers and cold winters with resulting higher than standard air density. Calculated mean-of-monthly-mean (or annual) air density during the met tower test period exceeds the 1.204 kg/m^3 standard air density for a 177 meter elevation by 5.7 percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

Temperature and density table

	Temperature						Air Density		
Month	Mean (°F)	Min (°F)	Max (°F)	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	4.7	-20.2	39.0	-15.1	-29.0	3.9	1.325	1.204	1.416
Feb	4.1	-24.7	32.4	-15.5	-31.5	0.2	1.343	1.264	1.430
Mar	11.0	-14.3	38.8	-11.7	-25.7	3.8	1.275	1.204	1.397
Apr	19.5	-6.3	44.2	-7.0	-21.3	6.8	1.299	1.235	1.372
May	39.4	13.8	65.5	4.1	-10.1	18.6	1.247	1.185	1.314
Jun	49.2	29.5	70.2	9.5	-1.4	21.2	1.223	1.174	1.272
Jul	50.5	37.9	81.9	10.3	3.3	27.7	1.220	1.149	1.250
Aug	51.3	33.1	70.9	10.7	0.6	21.6	1.218	1.173	1.263
Sep	45.1	30.0	64.6	7.3	-1.1	18.1	1.233	1.187	1.270
Oct	22.7	5.0	37.2	-5.2	-15.0	2.9	1.290	1.252	1.339
Nov	16.3	-14.6	44.6	-8.7	-25.9	7.0	1.308	1.234	1.398
Dec	13.9	-16.2	45.0	-10.1	-26.8	7.2	1.307	1.204	1.403
Annual	27.4	-24.7	81.9	-2.5	-31.5	27.7	1.273	1.149	1.430

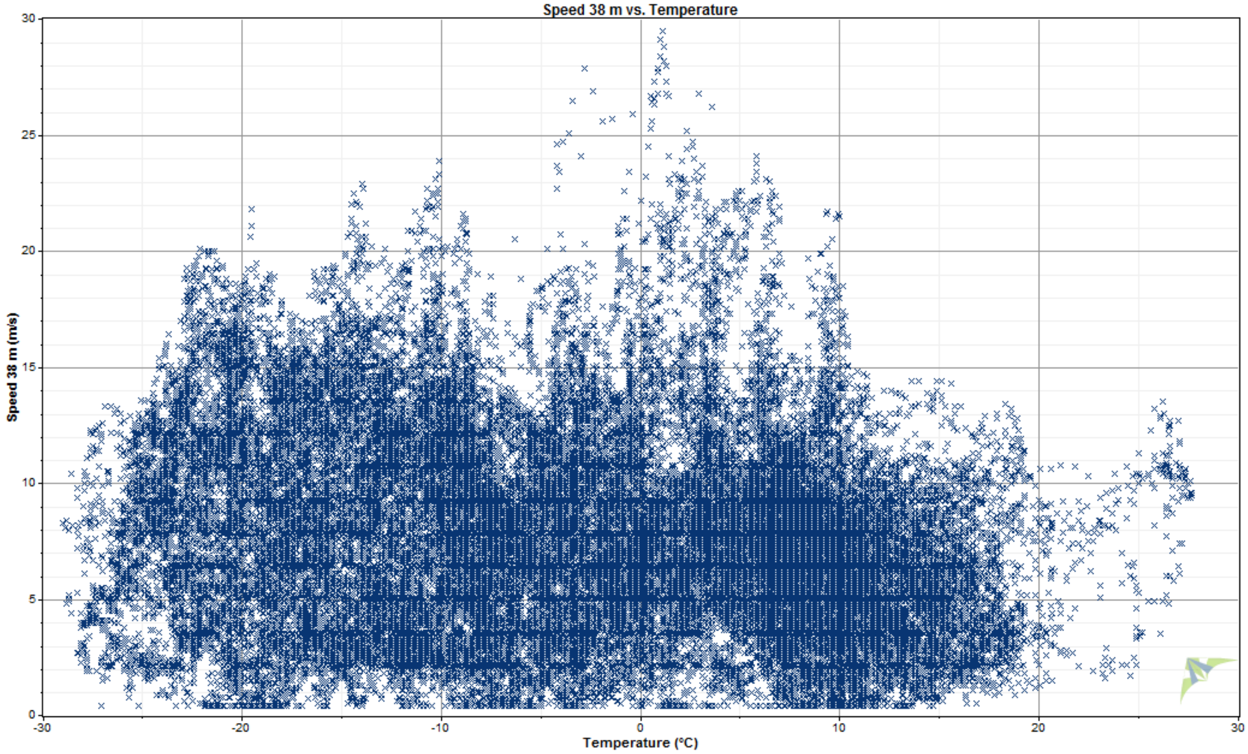
Pitka's Point temperature boxplot graph



Wind Speed Scatterplot

The wind speed versus temperature scatterplot below indicates cold temperatures at the Pitka's Point met tower site with a preponderance of below freezing temperatures. During the met tower test periods, temperatures were often below -20° C (-4° F), the minimum operating temperature for most standard-environment wind turbines. Note that arctic-capable (ratings to -40°C) wind turbines would be required at Pitka's Point.

Wind speed/temperature

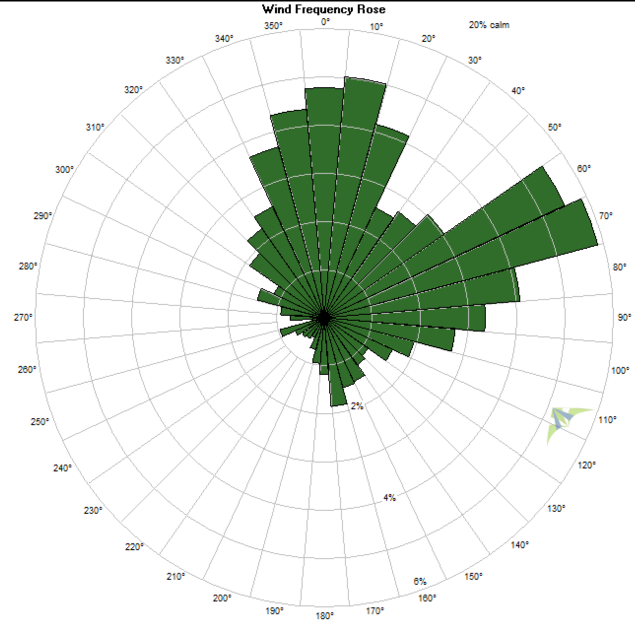


Wind Direction

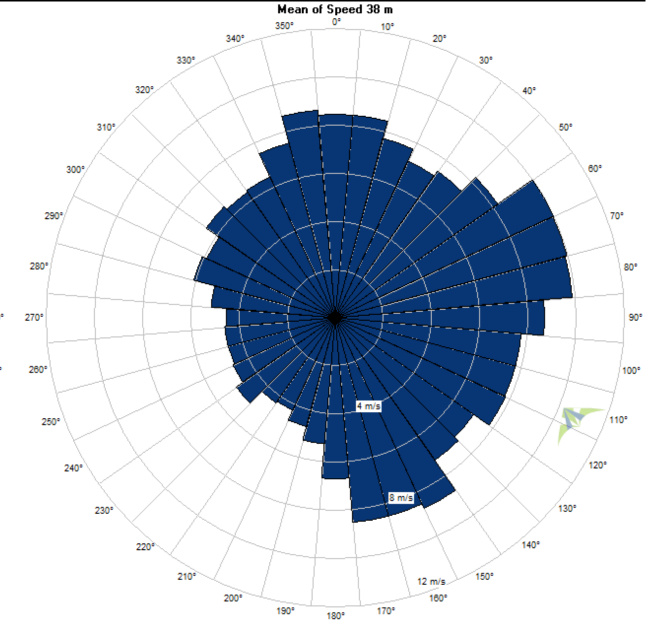
Wind frequency rose data indicates that winds at the Pitka's Point met tower site are primarily bi-directional, with northerly and east-northeasterly winds predominating. The mean value rose indicates that east-northeasterly winds are of higher intensity than northerly winds, but interesting, the infrequent south-southeasterly winds, when they do occur, are highly energetic and likely indicative of storm winds.

Calm frequency (the percent of time that winds at the 38 meter level are less than 4 m/s, a typical cut-in speed of larger wind turbines) was a very low 20 percent during the 16 month test period.

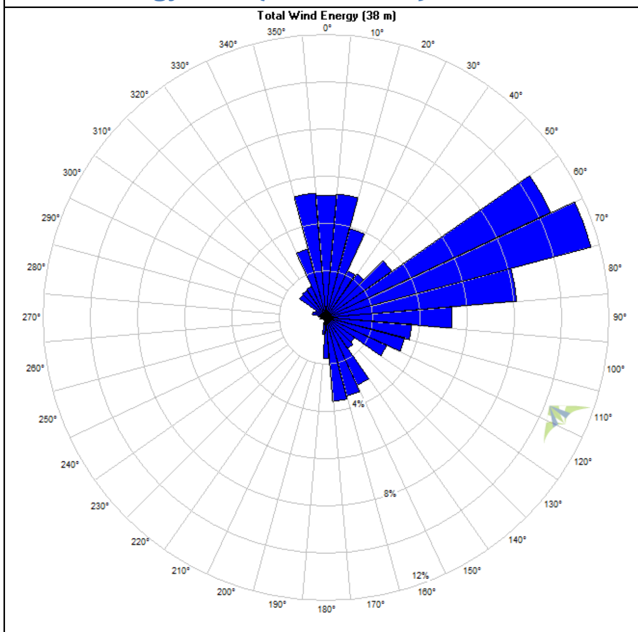
Wind frequency rose (38 m vane)



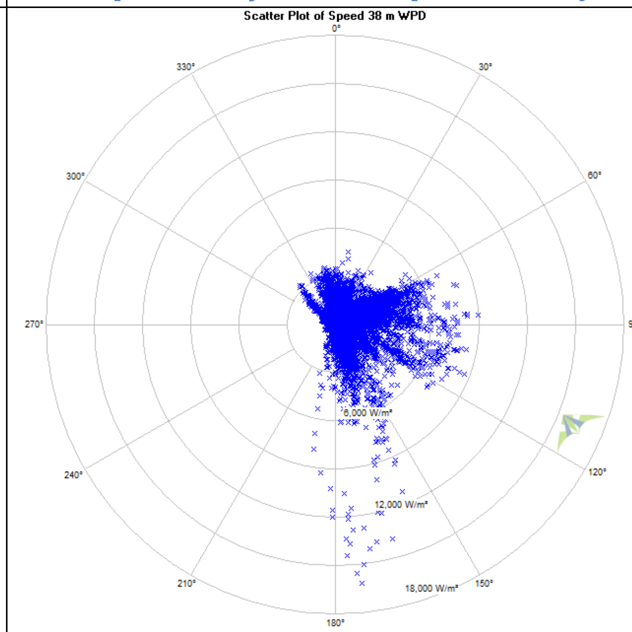
Mean value rose (38 m anem.)



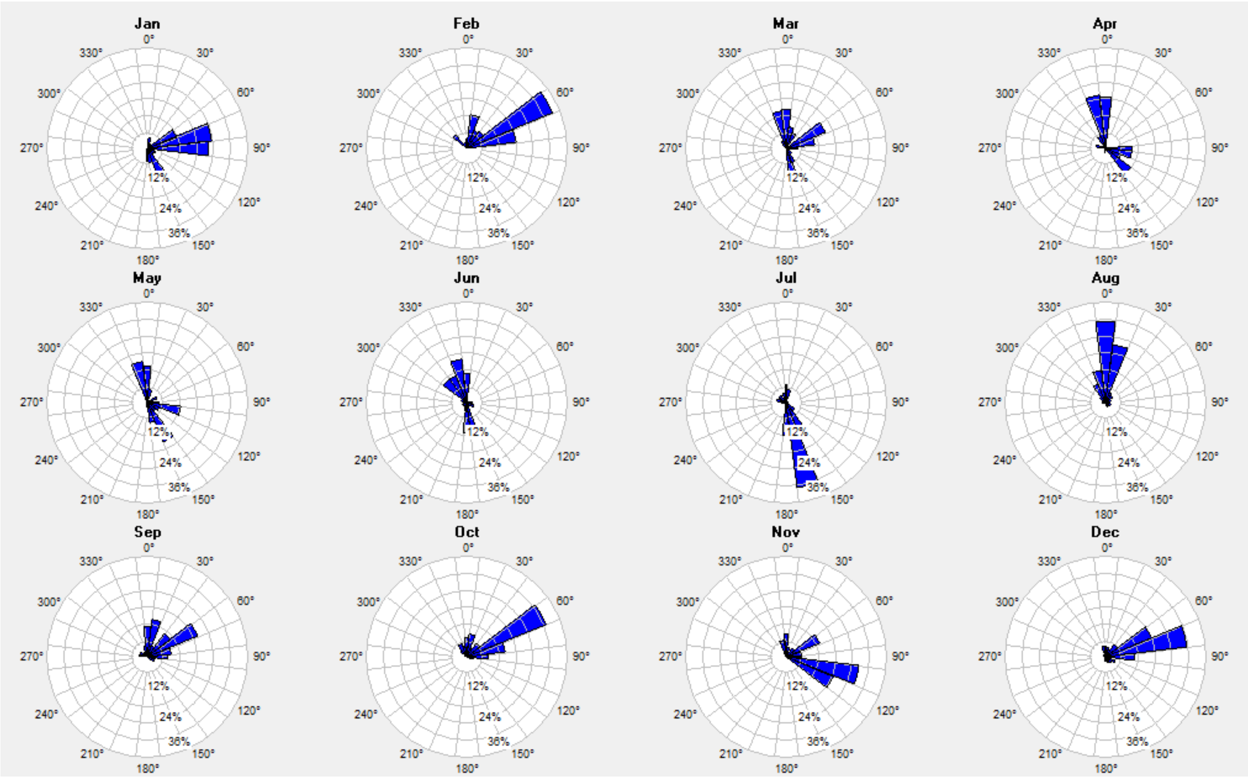
Wind energy rose (38 m anem.)



Scatterplot rose of 38 m wind power density



Wind density (38 meter height) roses by month (common scale)



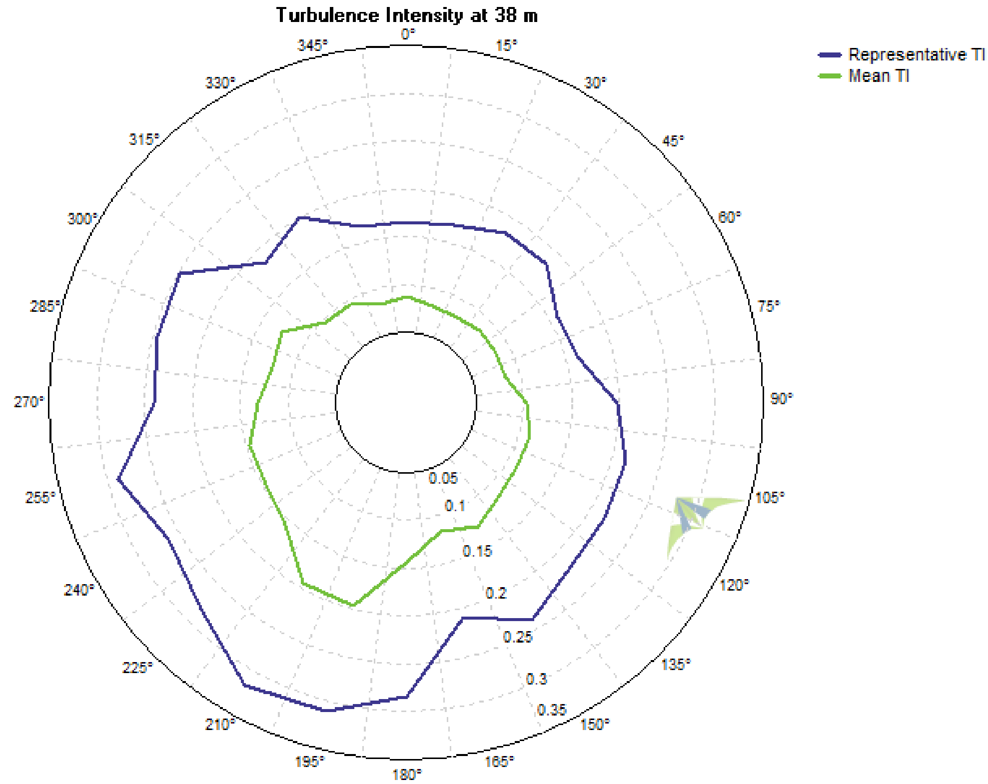
Turbulence

The turbulence intensity (TI) is acceptable with a mean turbulence intensity of 0.076 and a representative turbulence intensity of 0.105 at 15 m/s wind speed, indicating quite smooth air for wind turbine operations. This equates to an International Electrotechnical Commission (IEC) 3rd Edition (2005) turbulence category C, which is the lowest defined category. These data are shown in the turbulence intensity graph below. As seen, representative TI (90th percentile of the turbulence intensity values, assuming a normal distribution) at 15 m/s is well under IEC Category C criteria at the Pitka's Point met tower site.

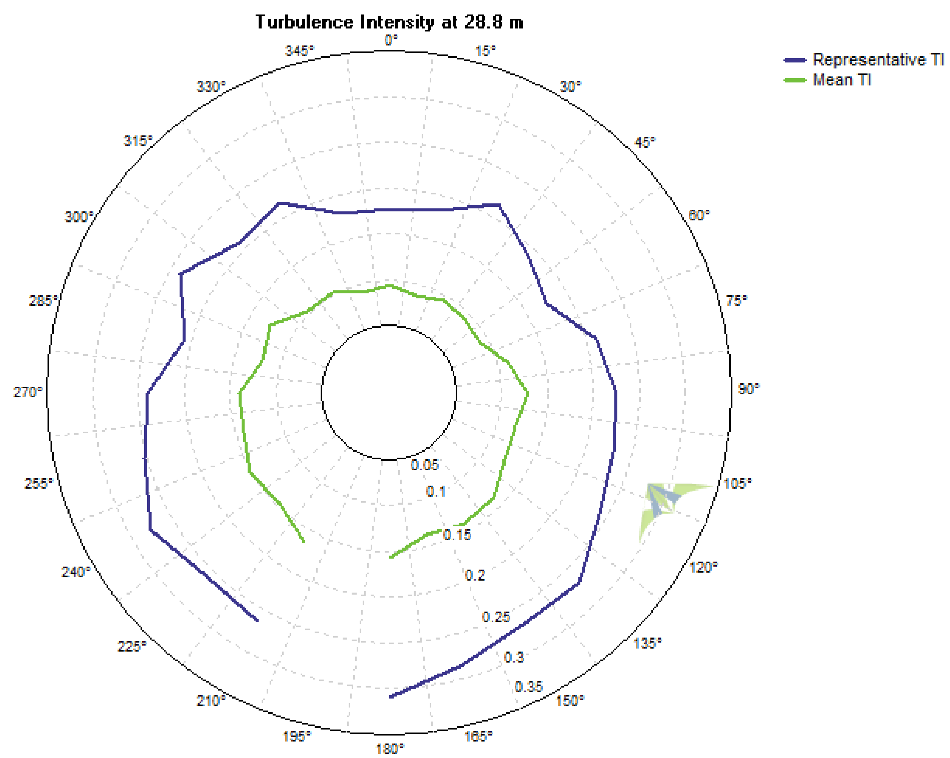
Turbulence synopsis

	38 m anem.			29 m anem.			Legend	
Sector	Mean TI at 15 m/s	Repres. TI at 15 m/s	IEC3 Category	Mean TI at 15 m/s	Repres. TI at 15 m/s	IEC3 Category	IEC3 Categ.	Mean TI at 15 m/s
all	0.076	0.105	C	0.088	0.117	C	S	>0.16
315° to 045°	0.060	0.084	C	0.067	0.094	C	A	0.14-0.16
045° to 135°	0.079	0.105	C	0.093	0.119	C	B	0.12-0.14
135° to 225°	0.089	0.119	C	0.093	0.117	C	C	0-0.12
045° to 135°	0.074	0.099	C	0.071	0.084	C		

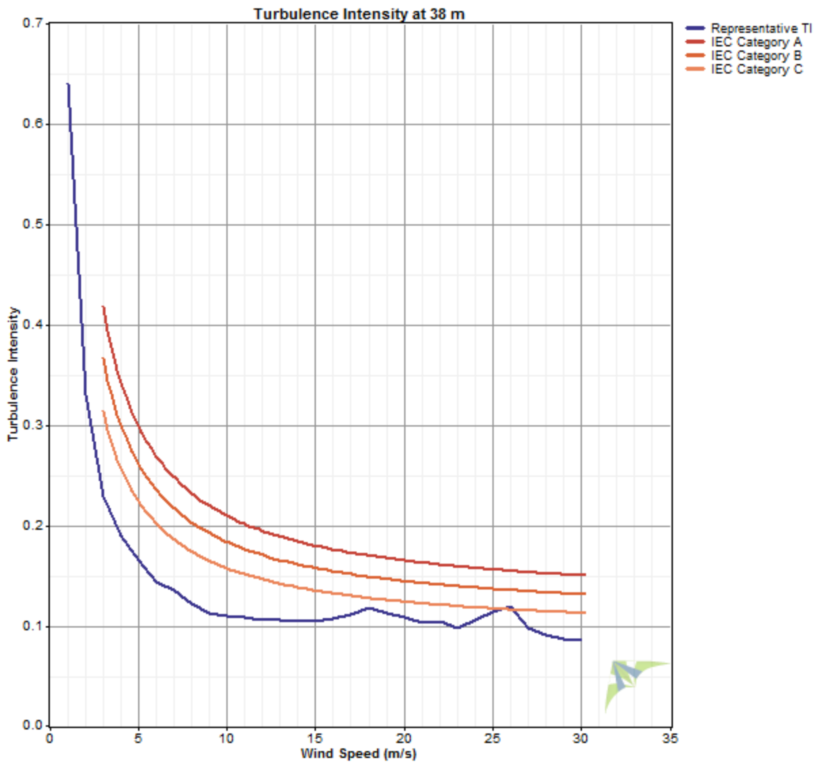
Turbulence rose, 38 m anemometer, 38 m vane



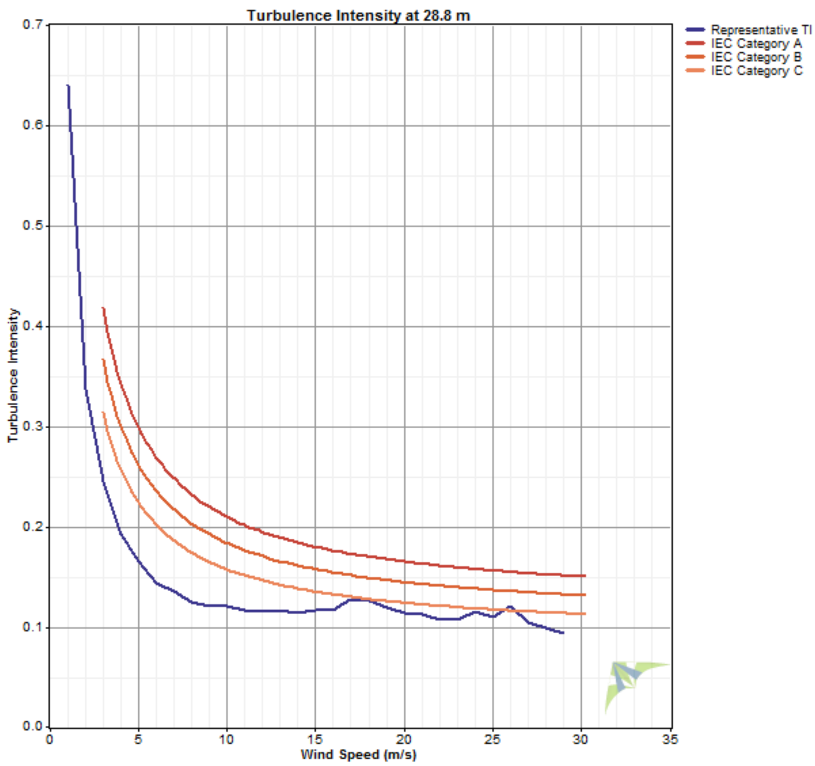
Turbulence rose, 29 m anemometer, 29 m vane



Turbulence intensity, 38 m, all direction sectors



Turbulence intensity, 29 m, all direction sectors



Turbulence table, 38 m data, all sectors

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	1,336	0.403	0.185	0.640	1.833
2	1.5	2.5	2,692	0.197	0.105	0.331	1.111
3	2.5	3.5	3,834	0.139	0.070	0.228	0.600
4	3.5	4.5	4,076	0.114	0.059	0.190	0.917
5	4.5	5.5	4,528	0.100	0.051	0.165	0.827
6	5.5	6.5	5,278	0.091	0.041	0.144	0.364
7	6.5	7.5	5,126	0.085	0.039	0.135	1.169
8	7.5	8.5	5,027	0.079	0.034	0.122	0.637
9	8.5	9.5	4,538	0.073	0.030	0.112	0.449
10	9.5	10.5	3,503	0.074	0.028	0.110	0.255
11	10.5	11.5	2,881	0.074	0.026	0.108	0.229
12	11.5	12.5	2,488	0.074	0.024	0.105	0.271
13	12.5	13.5	1,966	0.075	0.023	0.105	0.197
14	13.5	14.5	1,519	0.075	0.022	0.104	0.191
15	14.5	15.5	1,054	0.076	0.022	0.105	0.241
16	15.5	16.5	777	0.079	0.022	0.107	0.177
17	16.5	17.5	484	0.082	0.022	0.111	0.163
18	17.5	18.5	322	0.089	0.023	0.118	0.203
19	18.5	19.5	260	0.086	0.020	0.112	0.144
20	19.5	20.5	148	0.085	0.018	0.109	0.138
21	20.5	21.5	113	0.088	0.012	0.103	0.130
22	21.5	22.5	75	0.087	0.013	0.104	0.112
23	22.5	23.5	49	0.085	0.010	0.098	0.107
24	23.5	24.5	11	0.092	0.010	0.105	0.105
25	24.5	25.5	8	0.097	0.014	0.114	0.127
26	25.5	26.5	7	0.089	0.024	0.119	0.137
27	26.5	27.5	10	0.081	0.013	0.098	0.104
28	27.5	28.5	7	0.075	0.013	0.091	0.100
29	28.5	29.5	2	0.071	0.013	0.087	0.080
30	29.5	30.5	1	0.085	0.000	0.085	0.085

Appendix B, WAsP Turbine Site Report, NPS100 ARCTIC Layout

Pitka's Point 'Turbine cluster 5' wind farm

Produced on 8/18/2013 at 7:16:33 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0010.

Summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	1384.010	346.002	339.467	358.841
Gross AEP [MWh]	1420.792	355.198	348.148	365.825
Wake loss [%]	2.59	-	-	-

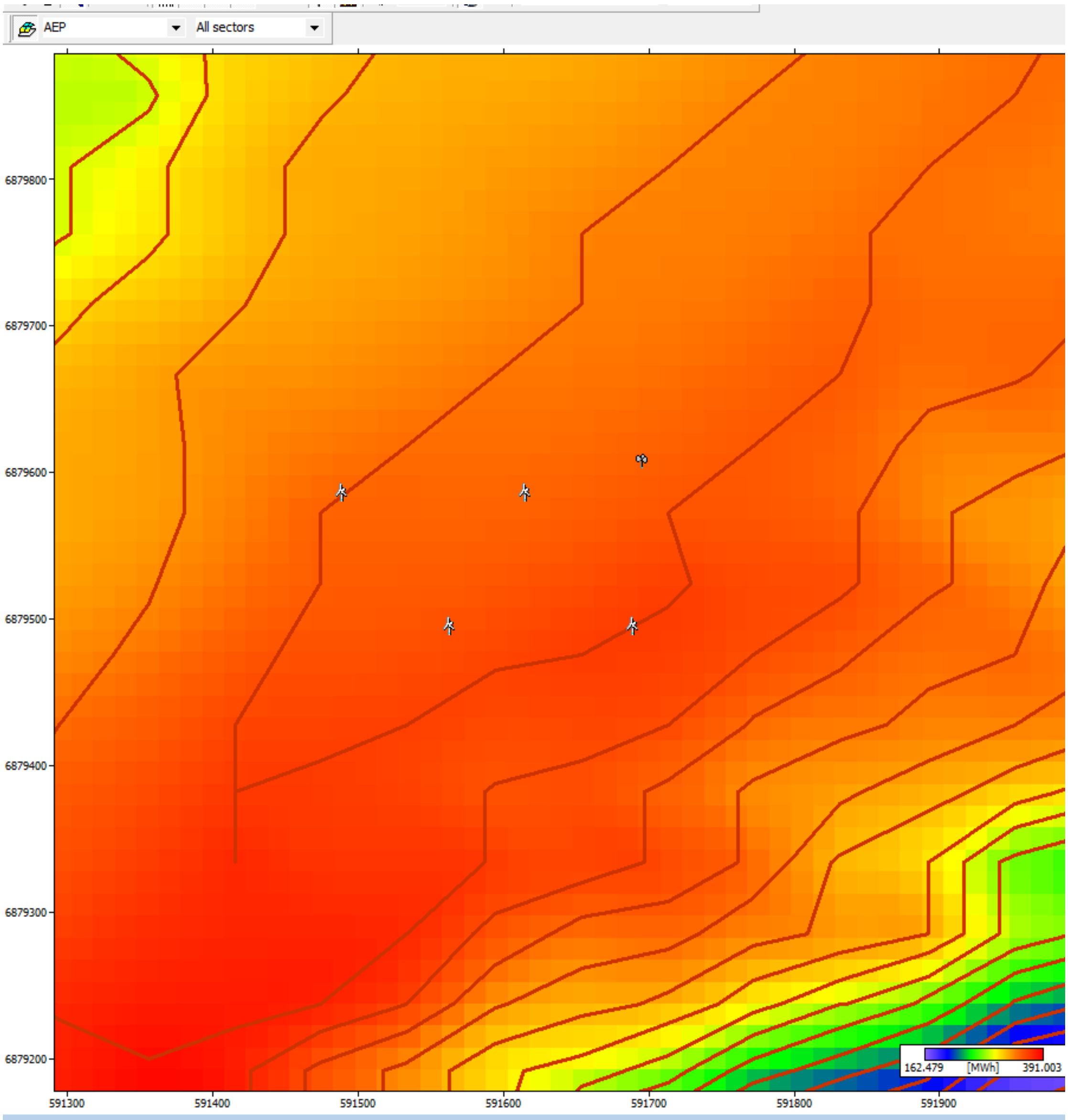
Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
Pitkas 1	(591490, 6879581)	NPS100-21	170	38	339.467	2.49
Pitkas 2	(591616, 6879581)	NPS100-21	170	38	342.907	1.73
Pitkas 3	(591564, 6879490)	NPS100-21	170	38	342.794	4.22
Pitkas 4	(591690, 6879490)	NPS100-21	169.3152	38	358.841	1.91

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
Pitkas 1	(591490, 6879581)	38	8.5	1.98	7.53	527	3.5	0.3
Pitkas 2	(591616, 6879581)	38	8.5	1.99	7.54	526	3.6	0.3
Pitkas 3	(591564, 6879490)	38	8.6	1.99	7.66	552	3.8	0.5
Pitkas 4	(591690, 6879490)	38	8.8	1.99	7.77	577	3.6	0.4

The wind farm lies in a map called 'KWIGUKutmDV'.



The wind farm is in a project called 'Pitkas Point REF 7'
A wind atlas called 'Wind atlas 2' was used to calculate the predicted wind climates

Data origins information

The map was imported by 'User' from a file called 'C:\Users\User\Documents\WindConsultLLC\Alaska\MAPS\KWIGUKutmDV.map', on a computer called 'SERVER'. The map file data were last modified on the 2/7/2012 at 6:08:37 PM

There is no information about the origin of the wind atlas associated with this wind farm.

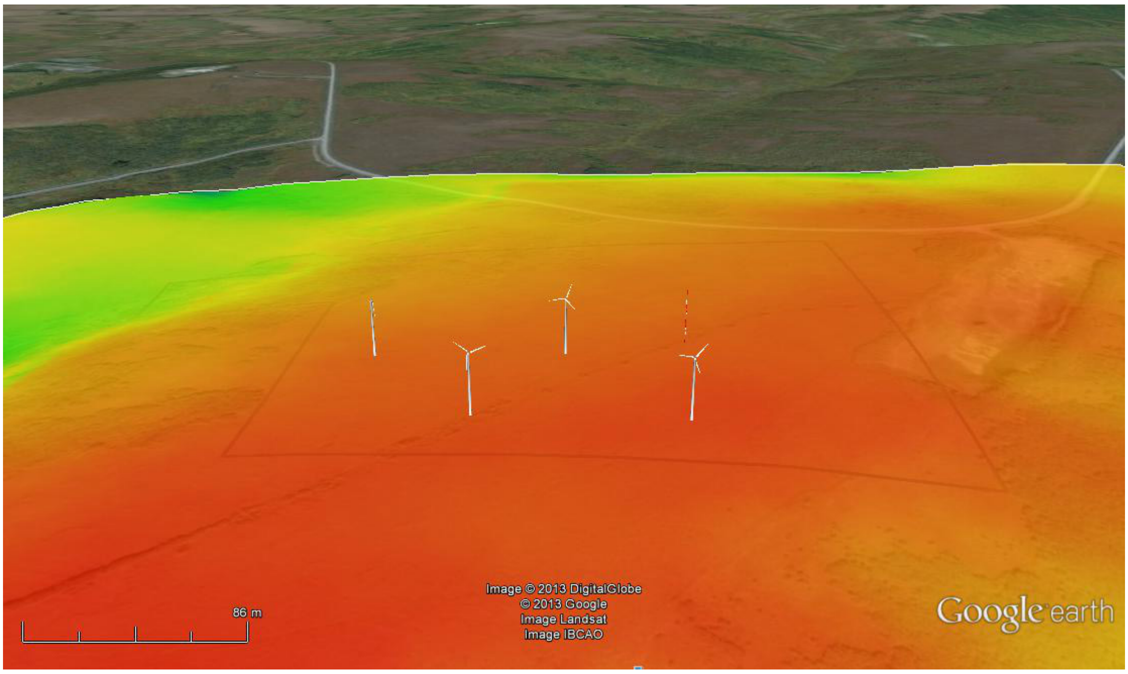
The wind turbine generator associated with this wind farm was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\Wind Turbines\WAsP turbine curves\NW100B_21, 37 meter.wtg', on a computer called 'V3ENERGYACER-PC'. The wind turbine generator file was last modified on the 8/10/2013 at 5:45:29 PM

Project parameters

The wind farm is in a project called Pitkas Point REF 7.

Here is a list of all the parameters with non-default values:
Air density: 1.281 (default is 1.225)

Google Earth Overlays



Appendix C, WAsP Turbine Site Report, Alternate NPS100 ARCTIC Layout

'8-24-13 iteration' wind farm

Produced on 8/24/2013 at 12:01:04 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0010.

Summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	1711.923	342.385	335.662	355.510
Gross AEP [MWh]	1780.054	356.011	348.232	365.776
Wake loss [%]	3.83	-	-	-

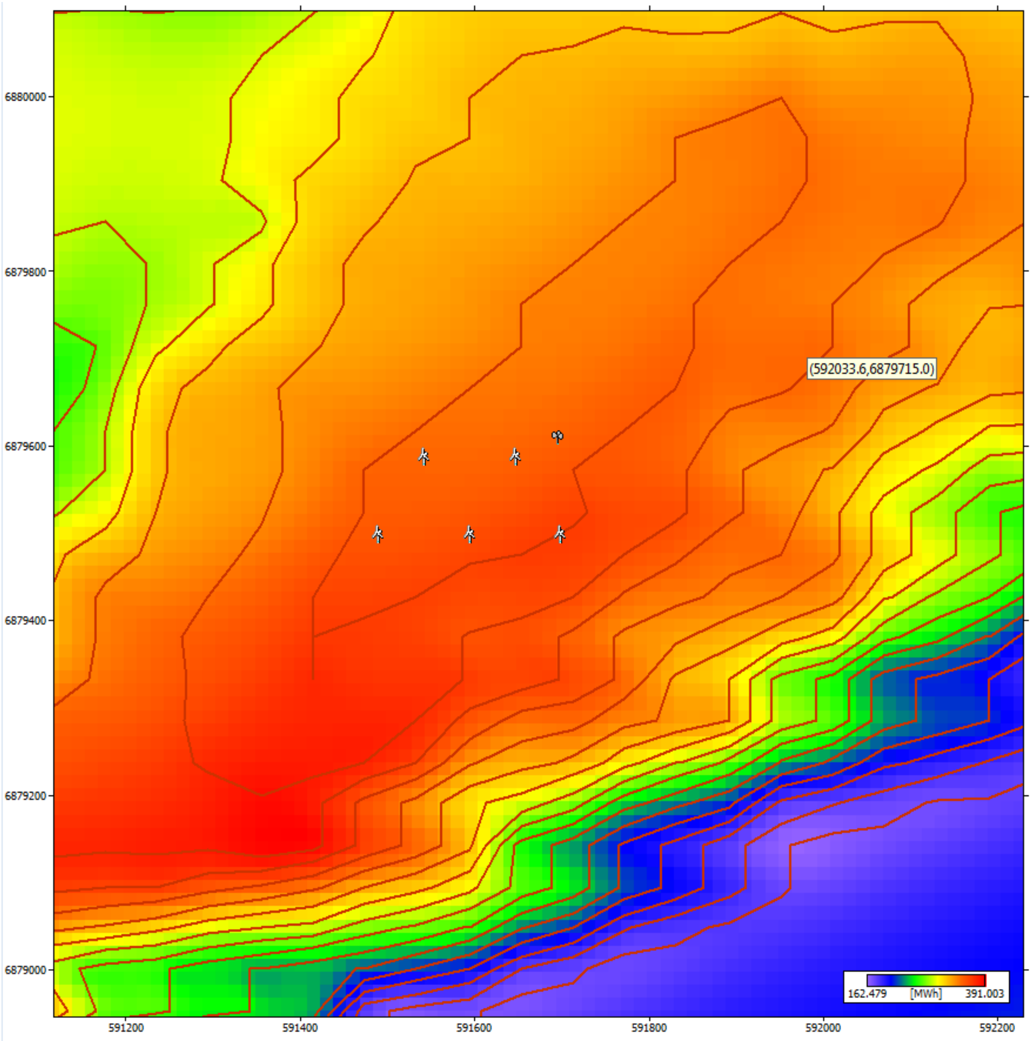
Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
Pitkas 1	(591490, 6879490)	NPS100-21	170	38	338.589	4.81
Pitkas 2	(591595, 6879490)	NPS100-21	170	38	339.526	5.63
Pitkas 3	(591700, 6879490)	NPS100-21	168.5835	38	355.510	2.81
Pitkas 4	(591543, 6879580)	NPS100-21	170	38	335.662	3.61
Pitkas 5	(591648, 6879580)	NPS100-21	170	38	342.636	2.26

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
Pitkas 1	(591490, 6879490)	38	8.6	1.99	7.63	548	3.8	0.5
Pitkas 2	(591595, 6879490)	38	8.7	1.99	7.68	558	3.7	0.4
Pitkas 3	(591700, 6879490)	38	8.8	1.99	7.77	576	3.6	0.4
Pitkas 4	(591543, 6879580)	38	8.5	1.99	7.53	526	3.5	0.2
Pitkas 5	(591648, 6879580)	38	8.5	1.99	7.56	531	3.5	0.3

The wind farm lies in a map called 'KWIGUKutmDV'.



The wind farm is in a project called 'Pitkas Point REF 7'
A wind atlas called 'Wind atlas 2' was used to calculate the predicted wind climates

Data origins information

The map was imported by 'User' from a file called 'C:\Users\User\Documents\WindConsultLLC\Alaska\MAPS\KWIGUKutmDV.map', on a computer called 'SERVER'. The map file data were last modified on the 2/7/2012 at 6:08:37 PM

There is no information about the origin of the wind atlas associated with this wind farm.

The wind turbine generator associated with this wind farm was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\Wind Turbines\WAsP turbine curves\NW100B_21, 37 meter.wtg', on a computer called 'V3ENERGYACER-PC'. The wind turbine generator file was last modified on the 8/10/2013 at 5:45:29 PM

Project parameters

The wind farm is in a project called Pitkas Point REF 7.

Here is a list of all the parameters with non-default values:
Air density: 1.281 (default is 1.225)