New Stuyahok, Alaska
Wind-Diesel Analysis

Google Earth image of New Stuyahok

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Introduction

Alaska Village Electric Cooperative (AVEC) is the electric utility for the City of New Stuyahok, Alaska. AVEC was awarded a grant from the Alaska Energy Authority (AEA) to complete conceptual design work for installation of wind turbines with planned construction in 2017. With anticipated completion in summer 2016 of the electrical intertie connecting New Stuyahok to Ekwok, the two villages are modeled as a combined village for this report.

Village of New Stuyahok

New Stuyahok is located on the Nushagak River, about 12 miles upriver from the village of Ekwok and 52 miles northeast of Dillingham. It is a southern Yupik Eskimo village with Russian Orthodox influences.

Residents practice a fishing and subsistence lifestyle. The village is constructed at two elevations, one 25 feet above river level and one about 40 feet above river level.

The present location is the third site that villagers can remember. The village moved downriver to the Mulchatna area from the "Old Village" in 1918. During the 1920s and 30s, the village was engaged in herding reindeer for the U.S. government. However, by 1942 the herd had dwindled to nothing, the village had been subjected to flooding, and the site was too far inland to receive barge service. So the village moved downriver again to its present location.

Stuyahok appropriately means "going downriver place." The first school was built in 1961. A post office was also established that year. An airstrip was built soon thereafter, and the 1960s saw a 40% increase in the village population. The city was incorporated in 1972. A 2014 population estimate by the State Department of Labor indicates 499 residents in the village.

Village of Ekwok

Ekwok means "end of the bluff" and is the oldest continuously-occupied Yupik Eskimo village on the Nushagak River. During the 1800s, the settlement was used in the spring and summer as a fish camp and in the fall as a base for berry picking. By 1923, it was the largest settlement along the river. In 1930, a BIA school was constructed. Mail was delivered by dog sled from Dillingham until a post office opened in Ekwok in 1941. Many of the earliest homes in Ekwok were located in a low flat area near the riverbank. After a severe flood in the early 1960s, villagers relocated to the current location on higher ground. The city was incorporated in 1974. A 2014 population estimate by the State Department of Labor indicates 119 residents in the village.

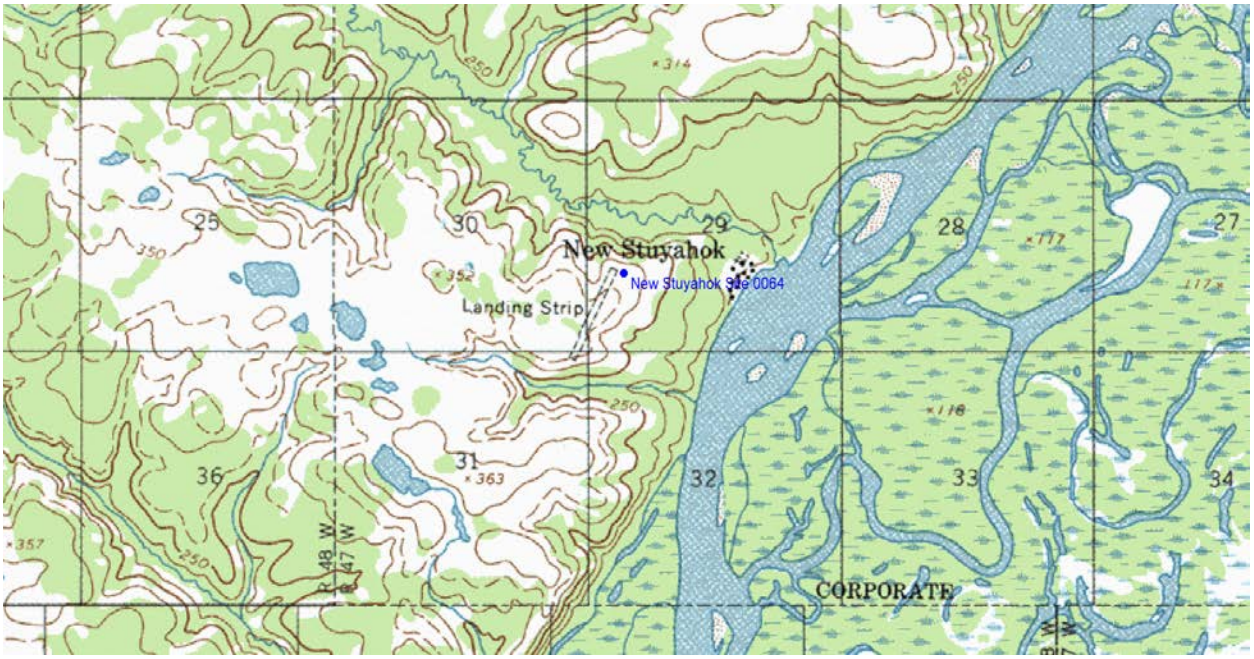
Wind Resource

New Stuyahok has been monitored for wind resource twice: from 2003 to 2005 in the meadow near the apron of the old airport (Site 0064), and from 2012 to 2014 at the north end of the runway of the old airport (Site 1064). Because the proposed project site is nearest the first met tower study, data from it is referenced in this report.

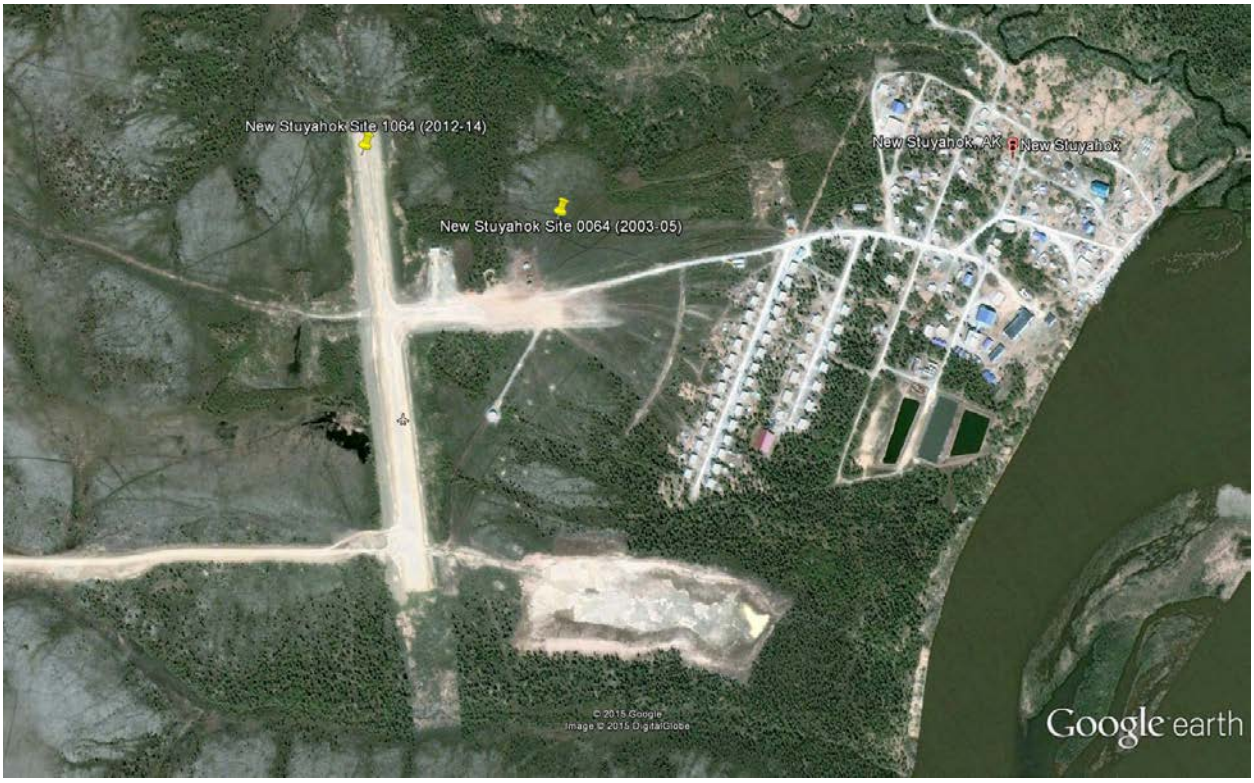
New Stuyahok met tower data synopsis

Data start date	10/10/2003
Data end date	7/7/2005
Wind power class (by WPD)	Class 2 (marginal)
Wind speed average (30 meters)	5.46 m/s measured
Wind power density (30 meters)	232 W/m^2
Weibull distribution parameters	k = 1.76, c = 6.3 m/s
Roughness Class	4.39 (suburban)
Power law exponent	0.38 (high wind shear)
Frequency of calms (4.0 m/s threshold)	36%
Mean Turbulence Intensity	0.151 (IEC 61400-1 3rd ed. turbulence category A)

Topographic map of New Stuyahok



Google Earth image of New Stuyahok (view to north)



Google Earth image (view to west)

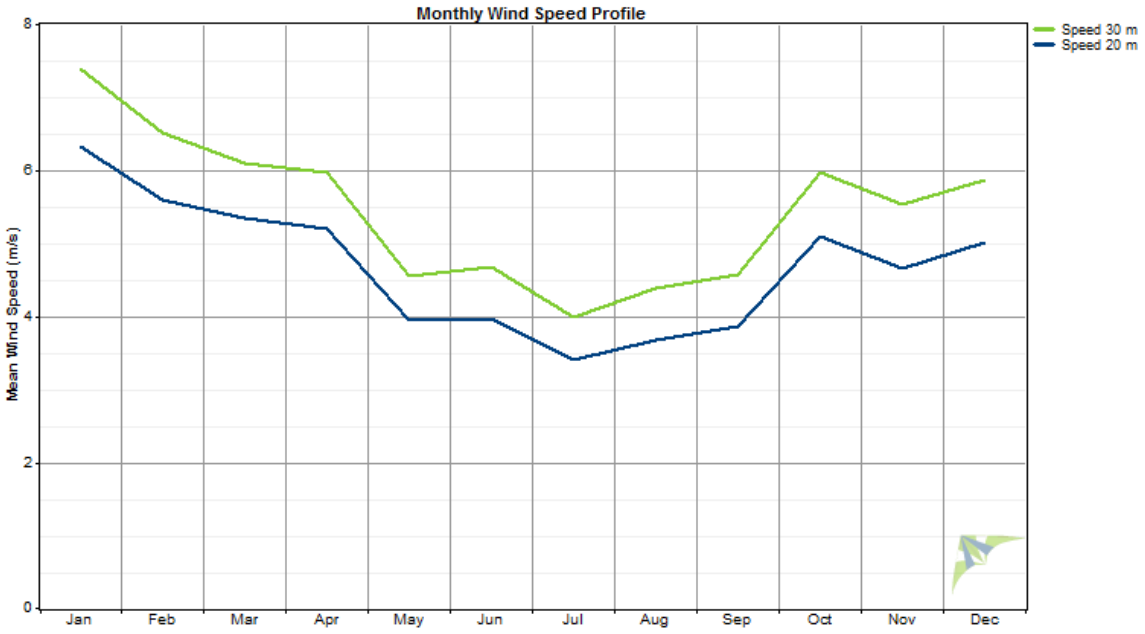
Measured Wind Speeds

Measured wind speeds in New Stuyahok are fair for wind power development, provided a wind turbine optimized for lower wind speeds is selected.

Wind Speed Sensor Summary

	30 m anemometer					20 m anemometer		
Month	Mean (m/s)	Max (m/s)	SD (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)
Jan	7.44	19.5	3.10	2.54	8.36	6.43	16.8	2.81
Feb	6.52	20.9	3.58	1.90	7.35	5.59	17.6	3.12
Mar	6.06	21.3	3.34	1.88	6.81	5.31	18.1	2.94
Apr	5.97	20.0	3.51	1.76	6.71	5.19	17.3	3.08
May	4.56	19.5	3.08	1.52	5.07	3.95	15.9	2.59
Jun	4.68	17.6	2.94	1.63	5.23	3.98	14.4	2.44
Jul	3.98	15.9	2.22	1.89	4.49	3.40	12.9	1.92
Aug	4.38	14.6	2.49	1.84	4.93	3.68	12.6	2.16
Sep	4.58	13.1	2.76	1.68	5.12	3.87	11.5	2.51
Oct	5.99	20.7	2.98	2.08	6.74	5.11	17.0	2.64
Nov	5.58	21.9	3.09	1.87	6.29	4.69	18.7	2.74
Dec	5.85	20.9	3.31	1.83	6.58	4.99	19.0	2.98
All data	**5.46**	21.9	3.26	1.77	6.29	**4.67**	19.0	2.87

New Stuyahok Site 0064 wind speed graph



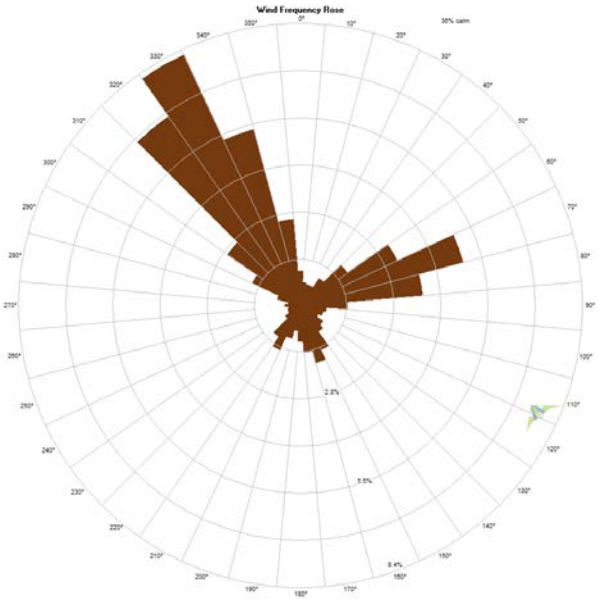
Wind Roses

Winds at the New Stuyahok met tower test site are primarily northerly with occasional southerly winds. The power density rose indicates, however, that power producing winds at the site are predominately

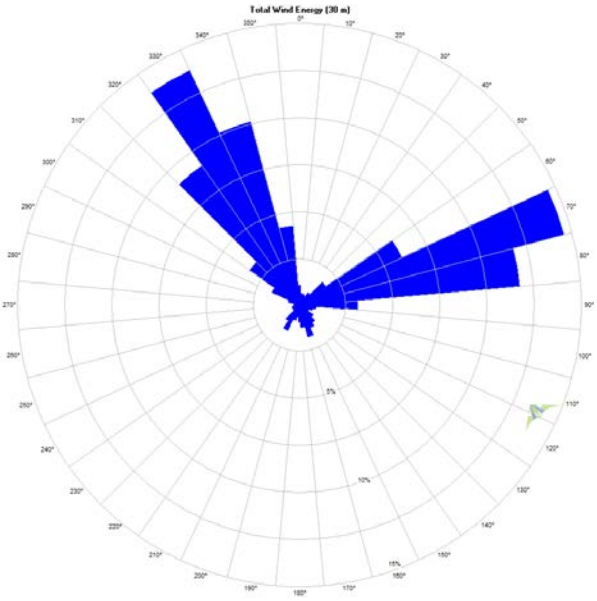
north-northeast and to a lesser extent south-southeast. Ideally, multiple wind turbines should oriented on an east-west axis to avoid turbine shadowing.

Note that a wind threshold of 4.0 m/s was selected for the definition of calm winds. With this threshold, the New Stuyahok 0064 (2003 to 2005) met tower site experienced 36 percent calm conditions during the test period.

Wind Frequency Rose



Total Value (power density) Rose



Temperature and Density

Over the reporting period, New Stuyahok had an average temperature of 1.7° C. The minimum recording temperature during the measurement period was -32.9° C and the maximum temperature was 28.5° C. Consequent to New Stuyahok's cool temperatures, the average air density of 1.275 kg/m^3 is approximately five percent higher than the standard air density of 1.217 kg/m^3 (at 14.5° C temperature and 100.46 kPa pressure at 70 m elevation).

Temperature and density table

	Temperature				Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-12.0	-31.1	2.7	7.37	1.341	1.269	1.446
Feb	-6.5	-32.9	5.5	9.02	1.314	1.256	1.457
Mar	-6.3	-29.9	6.6	7.72	1.313	1.251	1.439
Apr	-0.1	-24.1	16.0	6.93	1.283	1.210	1.405
May	8.5	-2.6	20.2	3.86	1.243	1.193	1.294
Jun	12.6	0.9	27.2	4.70	1.225	1.165	1.277
Jul	15.1	4.8	28.5	4.26	1.214	1.160	1.259
Aug	14.8	2.8	27.3	4.50	1.216	1.165	1.268
Sep	6.3	-4.9	17.2	4.57	1.253	1.205	1.305

Month	Temperature Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Air Density Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Oct	1.8	-11.5	11.3	4.43	1.273	1.230	1.338
Nov	-3.3	-23.5	8.4	7.24	1.298	1.243	1.402
Dec	-10.0	-31.5	3.9	8.32	1.331	1.263	1.448
All data	**1.7**	-32.9	28.5	11.11	**1.275**	1.160	1.457

Wind-Diesel Hybrid 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 very low, low, medium, 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 a control system and demand-management strategy is required.

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

Proposed System Configuration

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 wind turbines at the New Stuyahok project site would be configured at the medium penetration level.

Diesel Power Plant

Electric power (comprised of the diesel power plant and the electric power distribution system) in New Stuyahok is provided by AVEC with the following diesel configuration.

New Stuyahok power plant diesel generators

Generator	Electrical	Diesel Engine Model	Generator
1	499 kW	Cummins QSX15 G9	Newage NCI534F1
2	363 kW	Detroit Diesel S60K4 1800 rpm	Kato 6P4-1450
3	505 kW	Caterpillar 3456	Cat LC6

Wind Turbines

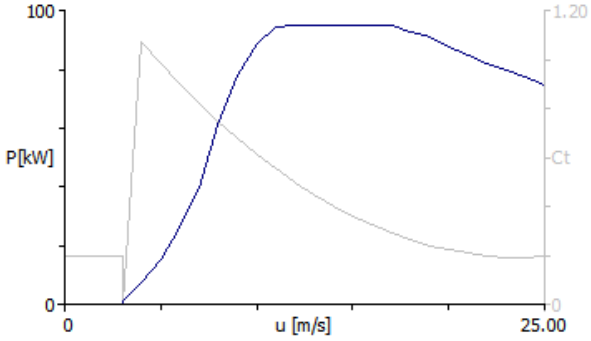
This report considers installation of two or three Northern Power Systems' NPS 100C-24 wind turbines for 190 kW or 385 kW installed wind capacity, and one Vestas V27 at 225 kW installed capacity, to serve the New Stuyahok and Ekwok combined loads.

Northern Power NPS 100C-24

The NPS 100C-24 is rated at 95 kW and is equipped with a permanent magnet, synchronous generator for direct drive (no gearbox) operation. The turbine has a 24.4 meter diameter rotor and will be equipped with a 23 meter tower for this installation. The turbine is stall-controlled and in the proposed version will be equipped with an arctic package enabling continuous operation at temperatures to -40° C. The NPS 100 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 NPS 100 wind turbine is manufactured in Barre, Vermont, USA. More information can be found at http://www.northernpower.com/. The power curve of the NPS 100C-24 is shown below.

Northern Power Systems 100 (A model) wind turbines, Toksook Bay, Alaska

NPS 100C-24 power and thrust curves

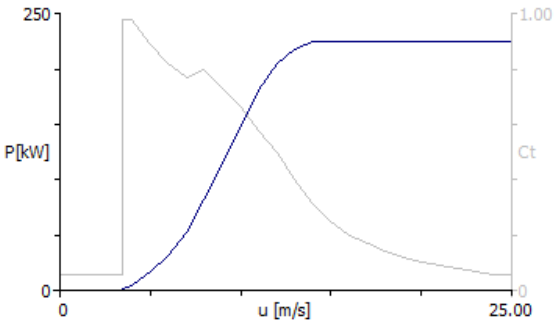


Vestas V27

The Vestas V27 was originally manufactured by Vestas Wind Systems A/S in Denmark and is no longer in production in Europe, although the turbine reported is presently manufactured under license in India. For many years the V27 was Vestas' workhorse wind turbine and many are still in operation worldwide. Present availability of the V27 in Alaska is as a remanufactured unit from Halus Power Systems in San Leandro, California. The V27 is pitch-regulated, has a synchronous (induction) double-wound generator, active yaw control, a 27 meter diameter rotor, is rated at 225 kW power output, and is available at a 32 meter hub height as a standard tower option. More information can be found at http://www.halus.com/.

Vestas V27 wind turbines, Saint Paul Island, Alaska

V27 power and thrust curves



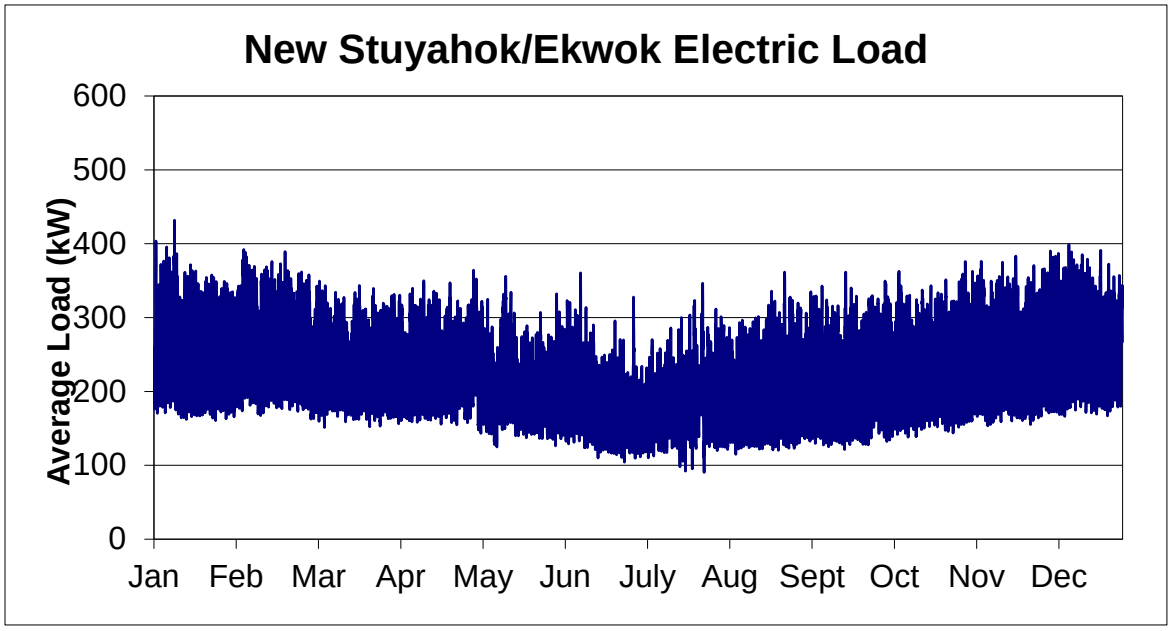
Load Demand

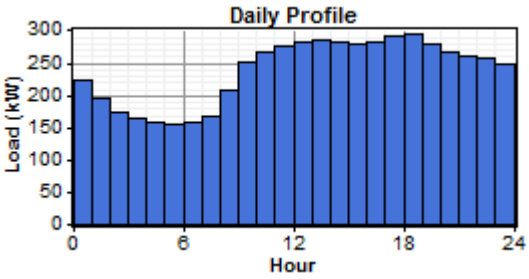
This analysis includes stand-alone electric and thermal load demand in New Stuyahok (including inclusion of Ekwok electric load with full operational status of the intertie).

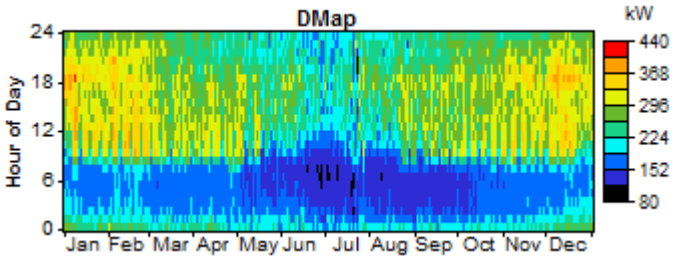
New Stuyahok Electric Load

New Stuyahok and Ekwok electric load was synthesized with the Alaska Village Electric Load Calculator developed by Mia Devine of AEA in 2005. Reference for the Calculator was AVEC's 2013 Annual Generation Report. Average combined load of the villages is 237 kW with a 432 kW peak and an average daily load demand of 5,686 kWh.

New Stuyahok electric load







Diesel Generators

The HOMER model was constructed with all three New Stuyahok generators. Information pertinent to the HOMER model is shown in the table below. Note that the New Stuyahok power plant is presently equipped with manual switchgear which would be upgraded to automated switchgear for a wind project. This would enable the diesel generators to automatically operate in parallel with wind turbines and each other. For the HOMER model, the diesel generators are allowed to operate at a no-load

condition (0 kW) to reflect AVEC's new grid-bridging wind-diesel control technology with ultra-capacitors.

Diesel generator HOMER modeling information

Diesel generator	Cummins QSX15G9	Detroit Diesel S60K4	Caterpillar 3456
Power output (kW)	499	363	505
Intercept coeff. (L/hr/kW rated)	0.04	0.04	0.04
Slope (L/hr/kW output)	0.22	0.22	0.22
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

WAsP Modeling, Wind Turbine Layouts

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 New Stuyahok 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

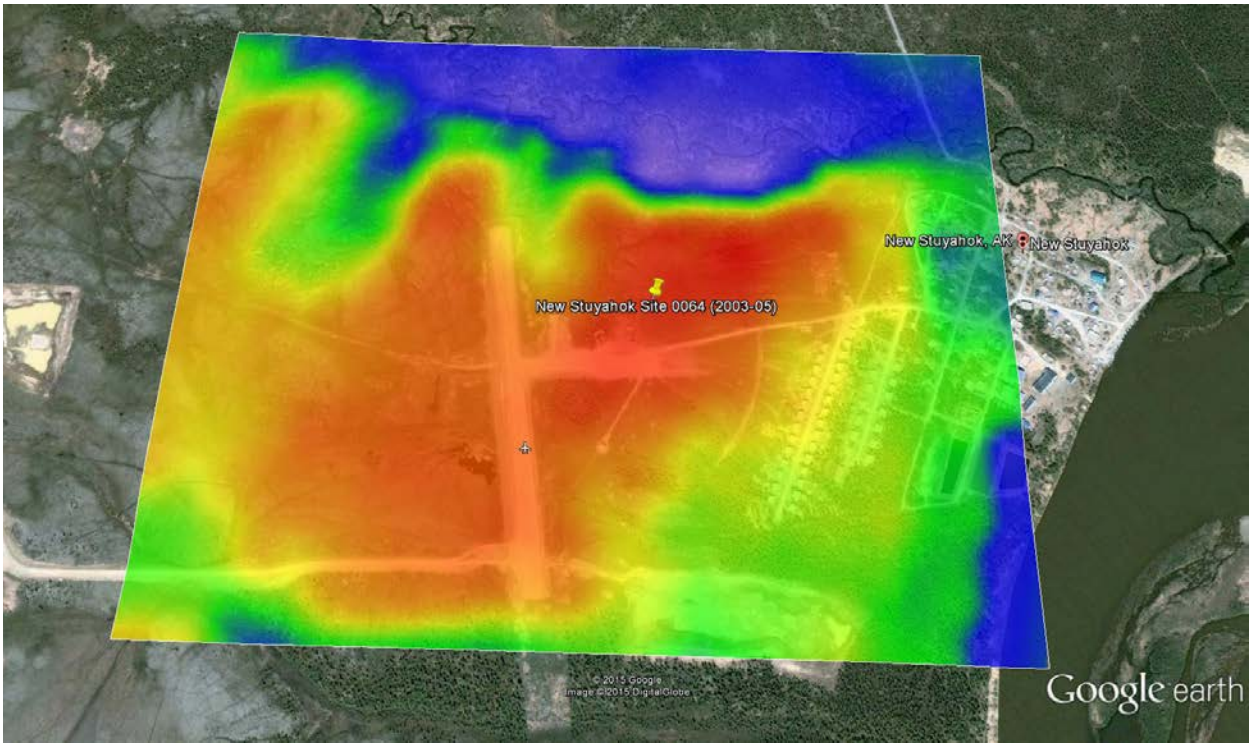
WAsP modeling begins with import of a digital elevation map (DEM) of the subject site and surrounding area and conversion of coordinates to Universal Transverse Mercator (UTM). UTM is a geographic coordinate system that uses a two-dimensional Cartesian coordinate system to identify locations on the surface 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 New Stuyahok Site 0064 met tower as the reference site, indicates a fair wind resource on the higher terrain west of the old airport, but a marginal wind resource on the north side of the meadow where the met tower had been located. Photos indicate that this meadow now hosts several structures, forcing the wind turbines to a less-than-optimal placement at a lower elevation toward the ravine north of the meadow.

Wind modeling of New Stuyahok site area, plan view



Wind Turbine Project Site

The project site is Native Corporation land north of the apron of the old airport and approximately 180 meters east of the north end of the old runway. New development on the site precludes placing wind turbines in a more desirable location nearer the airport access road, hence turbine placement is further north than ideal. This location, however, is a compromise that enables turbines to be located at this site area but with sufficient buffer from the new infrastructure.

Photograph of wind turbine site area, view to northeast

Wind Turbine Layout

Using WAsP software, three wind turbine layout arrangements were developed: three NPS 100C-24's, two NPS 100C-24's, and one Vestas V27. The wind turbines were aligned to minimize wake loss from the measured prevailing and secondary winds. Site constraints (i.e., new infrastructure) necessitated that the turbines be located beyond the north edge of the meadow in heavy brush and at lower elevation than more ideal terrain further south (nearer the airport access road).

NPS 100C-24 Three Turbine Array

Turbine	UTM (easting, northing)	Elevation
WTG 1	Zone 4V 594849, 6591764	74.3
WTG 2	Zone 4V 594913, 6591728	84.3
WTG 3	Zone 4V 594976, 6591691	87.5

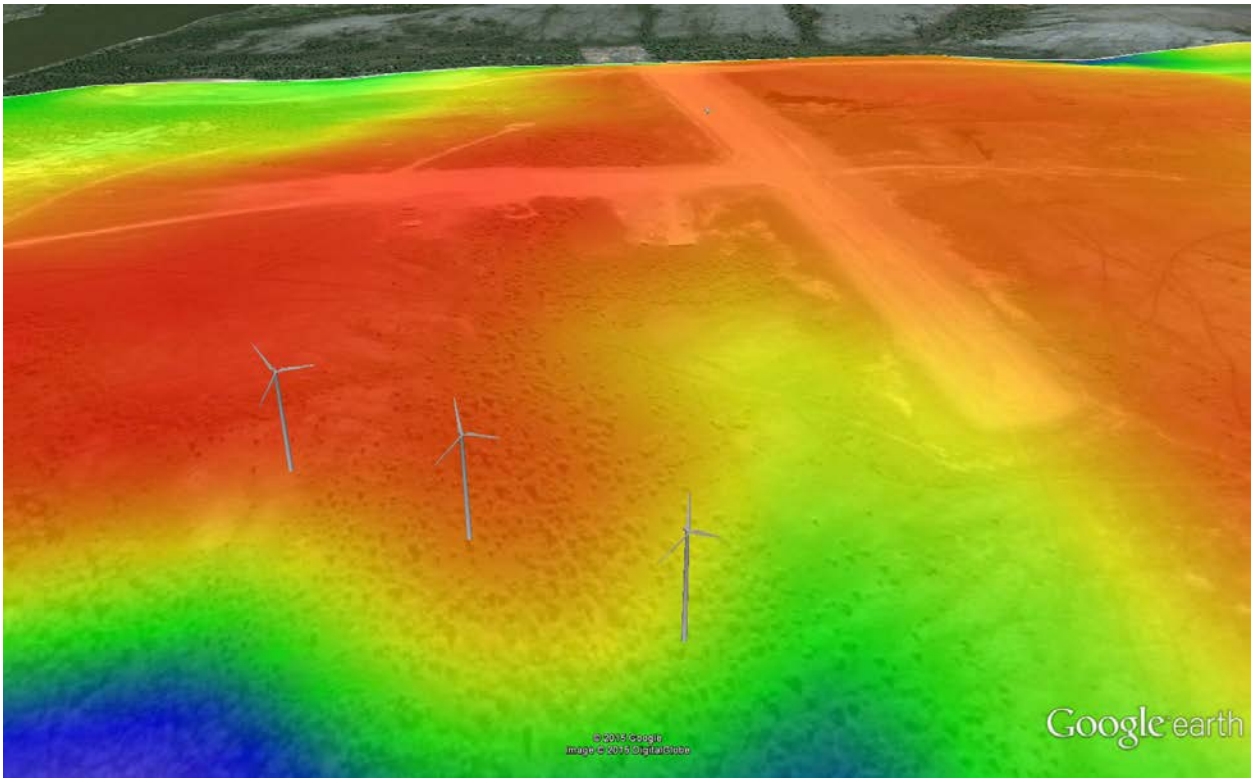
NPS 100C-24 Two Turbine Array

Turbine	UTM (easting, northing)	Elevation
WTG 1	Zone 4V 594913, 6591728	84.3
WTG 2	Zone 4V 594976, 6591691	87.5

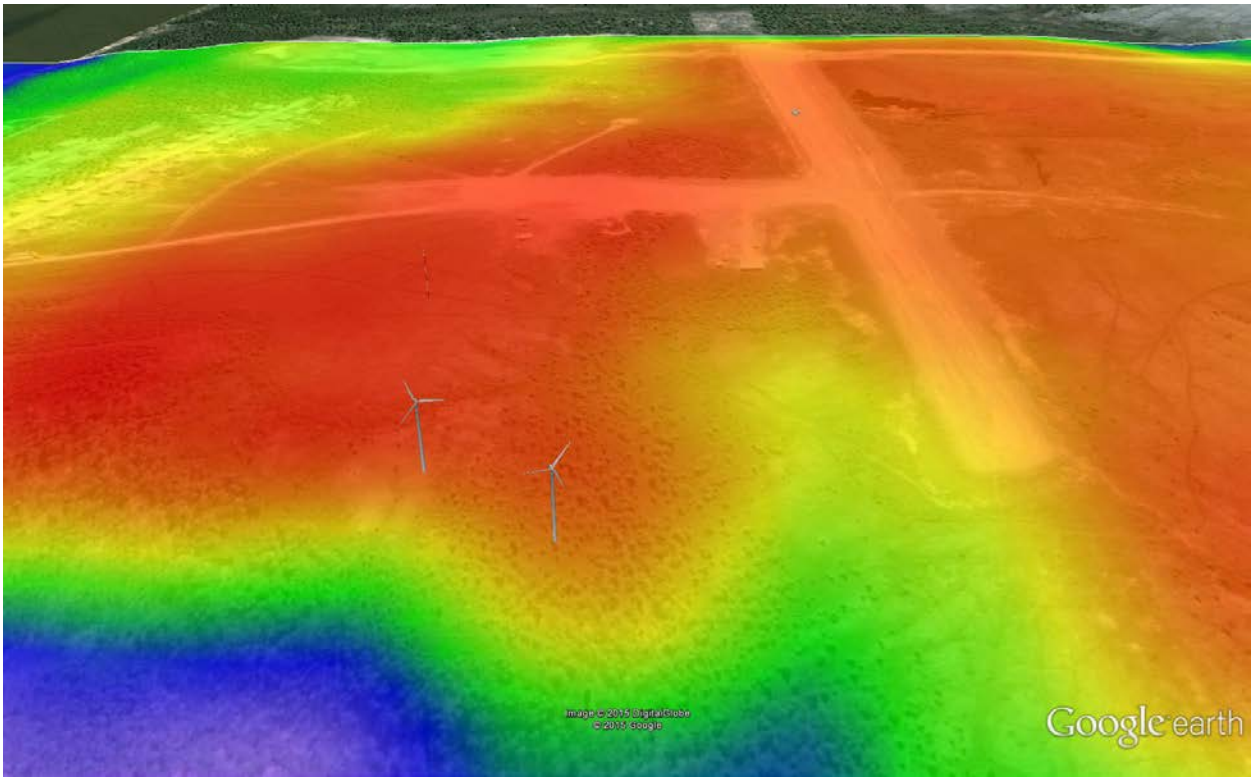
Vestas V27 One Turbine

Turbine	UTM (easting, northing)	Elevation
WTG 1	Zone 4V 594976, 6591691	87.5

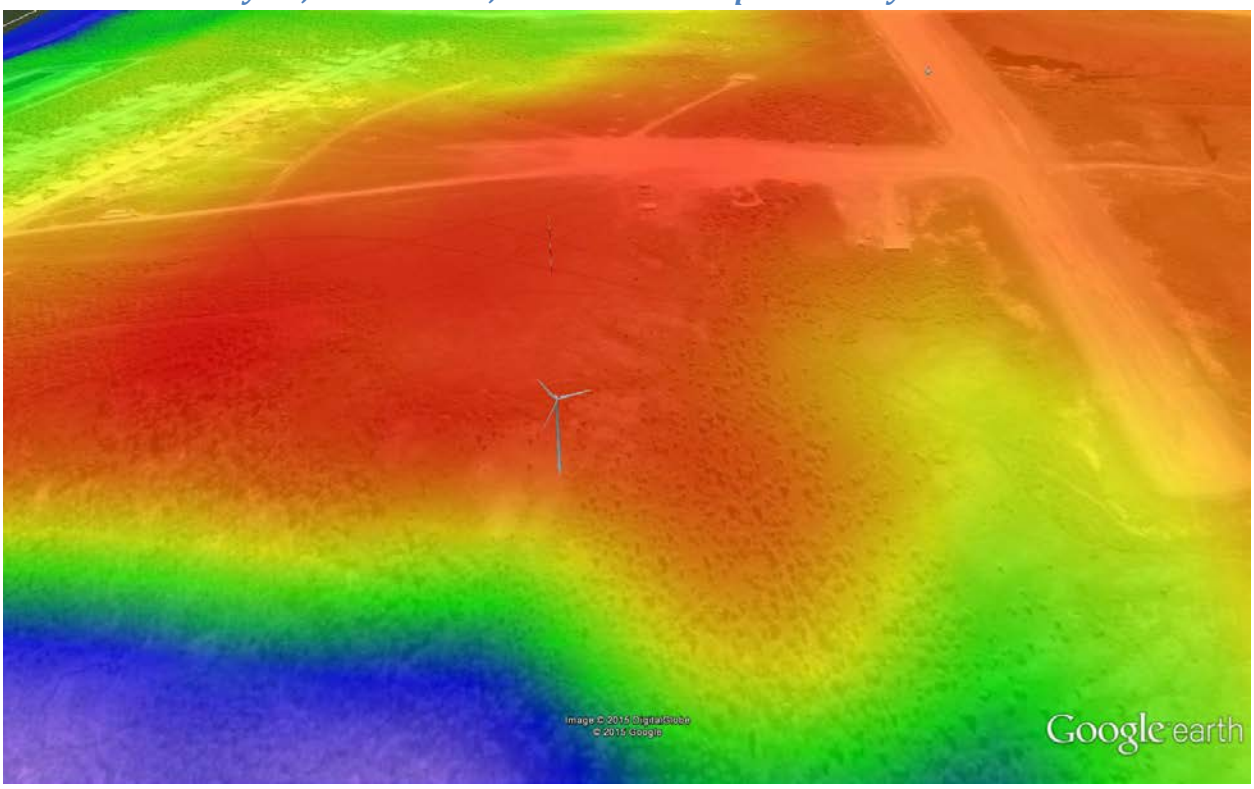
NPS 100C-24 three turbine layout, view to south, with WAsP wind speed overlay



NPS 100C-24 three turbine layout, view to south, with WAsP wind speed overlay



V27 one turbine layout, view to south, with WAsP wind speed overlay



WAsP Modeling Results for Turbine Array Options

The following tables present the WAsP software analysis of energy production of three and two NPS 100C-24 turbines, and one Vestas V27 turbine, all at 100% turbine availability (percent of time that the turbine is on-line and available for energy production with no energy production losses other than WAsP-calculated wake loss). The NPS 100C-24 wind turbine models relatively well in the New Stuyahok wind regime with acceptable annual energy production and minimal array wake loss. The Vestas V27 is less well optimized for the lower wind speeds at the project site, which is reflected in the modeling results.

NPS 100C-24 three turbine array, WAsP model results, 100% AEP

Parameter	Total (MWh/yr)	Mean Each (MWh/yr)	Minimum Each (MWh/yr)	Maximum Each (MWh/yr)
Gross AEP	745.7	248.6	227.7	263.9
Net AEP	717.1	239.0	224.3	252.3
Wake loss	3.83%	-	-	-

NPS 100C-24 two turbine array, WAsP model results, 100% AEP

Parameter	Total (MWh/yr)	Mean Each (MWh/yr)	Minimum Each (MWh/yr)	Maximum Each (MWh/yr)
Gross AEP	518.0	259.0	254.0	264.0
Net AEP	505.1	252.6	250.9	254.3
Wake loss	2.49%	-	-	-

Vestas V27 one turbine, WAsP model results, 100% AEP

Parameter	Total (MWh/yr)	Mean Each (MWh/yr)	Minimum Each (MWh/yr)	Maximum Each (MWh/yr)
Gross AEP	389.1	389.1	389.1	389.1
Net AEP	389.1	389.1	389.1	389.1
Wake loss	0.0%	-	-	-

Economic Analysis

Homer software was used to model static energy balance of the New Stuyahok electrical and thermal power system at ten minute 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 located at the community school.

Project Capital Cost

Capital and installation costs of wind turbines to serve the villages of New Stuyahok and Ekwok, including distribution system extension is shown in the table below. These cost estimates were developed by HDL for this conceptual design report.

Capital cost

Configuration	Capital cost (from HDL)	Cost/kW
3 Northern NPS100C-24	$5,114,100	$17,944
2 Northern NPS100C-24	$4,130,600	$21,740
1 Vestas V27	$3,625,700	$16,114

Fuel Cost

A fuel price of $5.07/gallon was chosen for the initial HOMER analysis by reference to the *2014_06-R8Prototype_AEA_Final_2014-08-07* Excel spreadsheet, written by ISER. The $4.83/gallon price reflects the average value of all fuel prices between the 2017 (the assumed project start year) fuel price of $4.53/gallon and the 2036 (20 year project end year) fuel price of $5.77/gallon using the medium price projection analysis with an average CO_2-equivalent allowance cost of $0.60/gallon included.

By comparison, the fuel price for New Stuyahok reported to Regulatory Commission of Alaska for the 2014 PCE report was $4.38/gallon, without inclusion of CO2-equivalent allowance. Assuming a CO_2-equivalent allowance of $0.42/gallon (ISER *Prototype* spreadsheet, 2013 value), the New Stuyahok 2014 diesel fuel price was $4.80/gallon.

Heating fuel displacement by diversion of excess energy to thermal loads is valued at $6.01/gallon as an average price for the 20 year project period. This price was determined by reference to the *2014_06-R8Prototype_AEA_Final_2014-08-07* Excel spreadsheet where heating oil is valued at the cost of diesel fuel (with CO_2-equivalent allowance) plus $0.94/gallon, assuming heating oil displacement between 1,000 and 25,000 gallons per year.

Fuel cost table (SCC included)

ISER medium cost projection	2017 (/gal)	2035 (/gal)	Average (/gallon)
Diesel fuel	$4.53	$5.77	$5.07
Heating oil	$5.47	$6.71	$6.01

Modeling Assumptions

HOMER energy modeling software was used to analyze the New Stuyahok 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 New Stuyahok power plant with its present configuration of diesel generators, which also will serve Ekwok by distribution intertie.

Wind turbines constructed at the New Stuyahok 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, although the SLC/boiler may not be part of the diesel generator recovered heat loop and could be operated as a remote node. Installation cost of the wind turbines assumes a three-phase distribution line extension from the road to the wind turbine site.

Homer and ISER modeling assumptions

Economic Assumptions	
Project life	20 years (2017 to 2036)
Discount rate	3% (reference: ISER 2014 R8*Prototype* spreadsheet)
Operating Reserves	
Load in current time step	10%
Wind power output	100% (Homer setting ensure diesels on operation)
Fuel Properties (no. 2 diesel for power plant)	
Heating value	46.8 MJ/kg (140,000 BTU/gal)
Density	830 kg/m^3 (6.93 lb./gal)
Price (20 year average; ISER 2014, medium projection plus SCC)	$5.07/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)
Price (20 year average; ISER 2014, medium projection plus SCC)	$6.01/gal
Diesel Generators	
Generator capital cost	$0 (new generators already funded)
O&M cost	$0.02/kWh (reference: ISER 2014 R8*Prototype* spreadsheet)
Minimum load	0 percent (grid-bridging control)
Efficiency (overall)	13.59 kWh/gal (2014 PCE Report)
Schedule	Optimized

Wind Turbines	
Net AEP	80%
O&M cost	$0.050/kWh (reference: ISER 2014 R8*Prototype* spreadsheet)
Wind speed	5.44 m/s at 30 m, measured at met tower
	5.55 m/s at 30 m, WAsP est. at met tower
	6.20 m/s at 37 m, WAsP avg of 3 NPS100s at site
	6.35 m/s at 37 m, WAsP avg of 2 NPS100s at site
	6.20 m/s at 32 m, WAsP calc at V27 site
Density adjustment	1.280 (from Site 0064 met tower data)
Energy Loads	
Electric	5.69 MWh/day average New Stuyahok and Ekwok electric load
Thermal	Not modeled

Model Results

HOMER energy modeling software was used to calculate wind turbine energy production and excess energy available (not demanded by the electrical load). Note that inclusion of wind turbines as a wind-diesel power system, even at lower penetration levels, can result in energy generation greater than electrical load demand. This is due to spinning reserve and minimum loading requirements of the diesel generators. Note that wind turbine energy production in these analyses is calculated at 80 percent of gross.

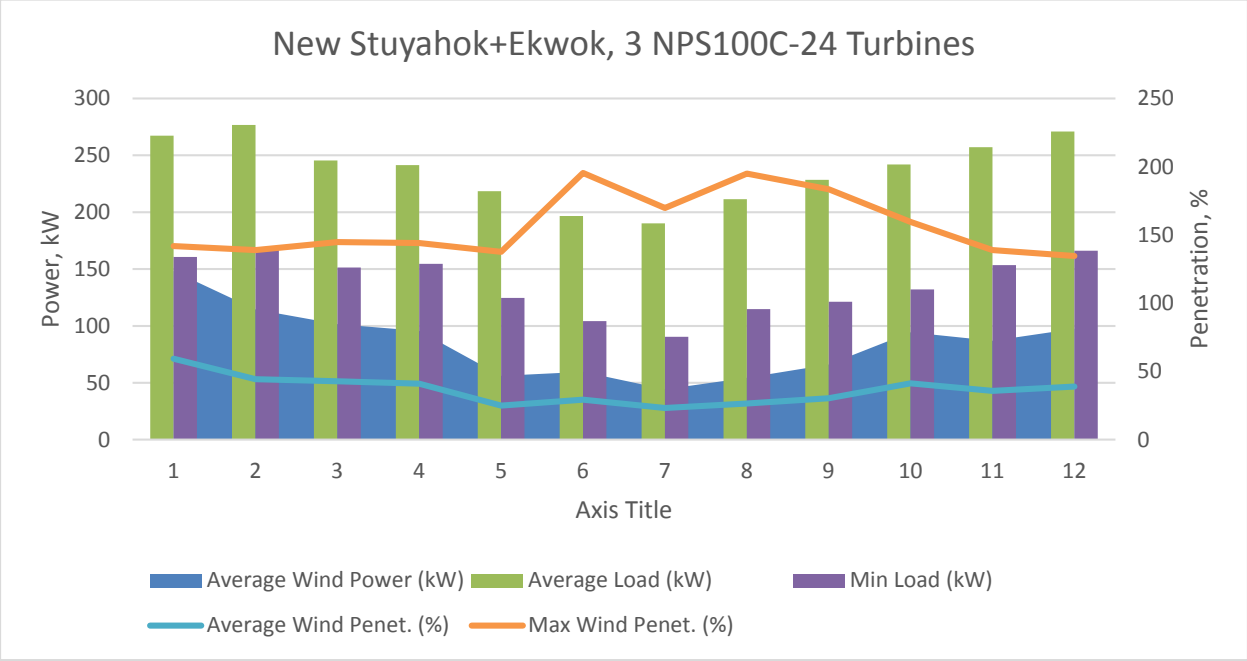
Northern Power NPS100C-24, three turbines

This configuration is three Northern Power NPS100C-24 wind turbines at a 37 meter hub height at the proposed wind site presented in the WAsP modeling section of this analysis report. The 10 minute averaging time simulation models wind energy production at 80 percent net (or 80 percent of annual gross) at the turbine site, not the met tower. Homer software predicts 36% average annual wind power penetration and 195% maximum instantaneous (10 minute) wind penetration.

Energy table, three NPS 100C-24 turbines, 80% net AEP

Month	Average Wind Power (kW)	Wind Energy (kWh)	Average Load (kW)	Min Load (kW)	Average Excess Power (kW)	Excess Energy (kWh)	Average Wind Penet. (%)	Max Wind Penet. (%)
1	148	110256	267	161	29	2803	59	142
2	114	76936	277	167	33	2036	44	139
3	102	75526	245	151	31	1544	43	145
4	96	68903	241	155	34	1760	41	144
5	56	41732	218	125	19	175	25	138
6	60	42915	197	104	39	638	29	195
7	44	33010	190	90	32	1021	23	170
8	54	40471	211	115	48	1292	26	195
9	66	47596	228	121	44	1763	30	183
10	94	70171	242	132	26	1073	41	160
11	87	62565	257	153	28	1188	36	139
12	97	72502	271	166	28	1504	39	135
Annual	85	742584	237	90	32	16798	36	195

Chart, three NPS 100C-24 turbines



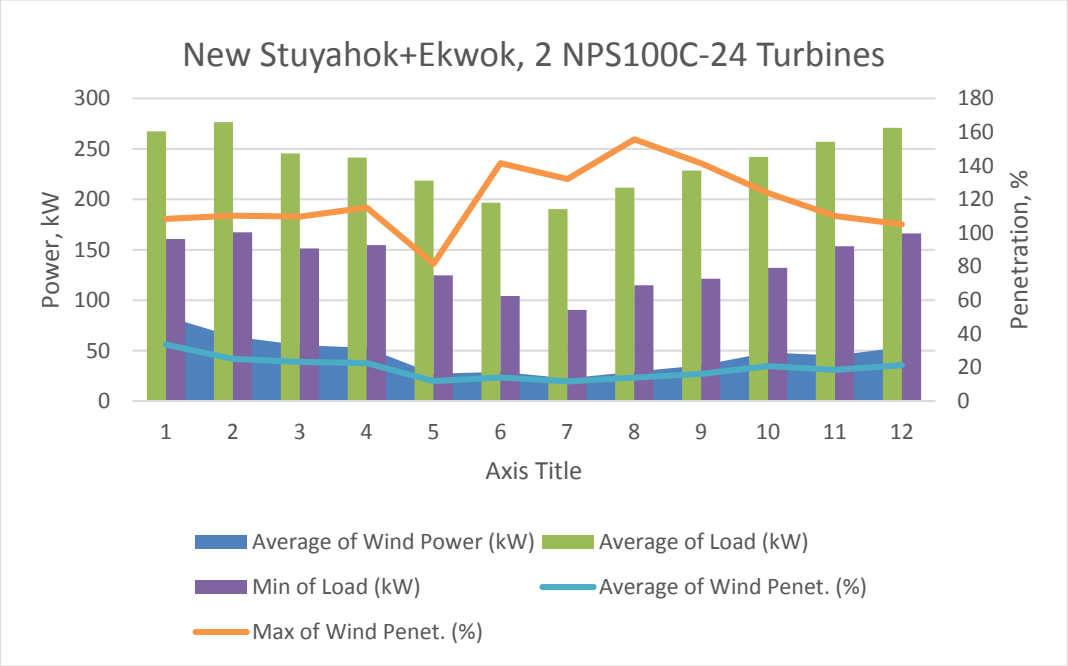
Northern Power NPS100C-24, two turbines

This configuration is two Northern Power NPS100C-24 wind turbines at a 37 meter hub height at the proposed wind site presented in the WAsP modeling section of this analysis report. The 10 minute averaging time simulation models wind energy production at 80 percent net (or 80 percent of annual gross) at the turbine site, not the met tower. Homer software predicts 25% average annual wind power penetration and 131% maximum instantaneous (10 minute) wind penetration.

Energy table, two NPS 100C-24 turbines, 80% net AEP

Month	Average Wind Power (kW)	Wind Energy (kWh)	Average Load (kW)	Min Load (kW)	Average Excess Power (kW)	Excess Energy (kWh)	Average Wind Penet. (%)	Max Wind Penet. (%)
1	102	76090	267	161	0	0	41	95
2	79	53356	277	167	0	0	31	93
3	71	52543	245	151	0	0	30	97
4	67	47943	241	155	0	0	29	96
5	40	29473	218	125	0	0	18	94
6	42	30266	197	104	14	59	21	131
7	31	23248	190	90	11	35	16	113
8	38	28277	211	115	20	160	19	130
9	46	33131	228	121	14	128	21	122
10	66	49135	242	132	7	10	29	106
11	61	43722	257	153	0	0	25	93
12	68	50364	271	166	0	0	27	90
Annual	59	517548	237	90	15	393	25	131

Chart, two NPS 100C-24 turbines



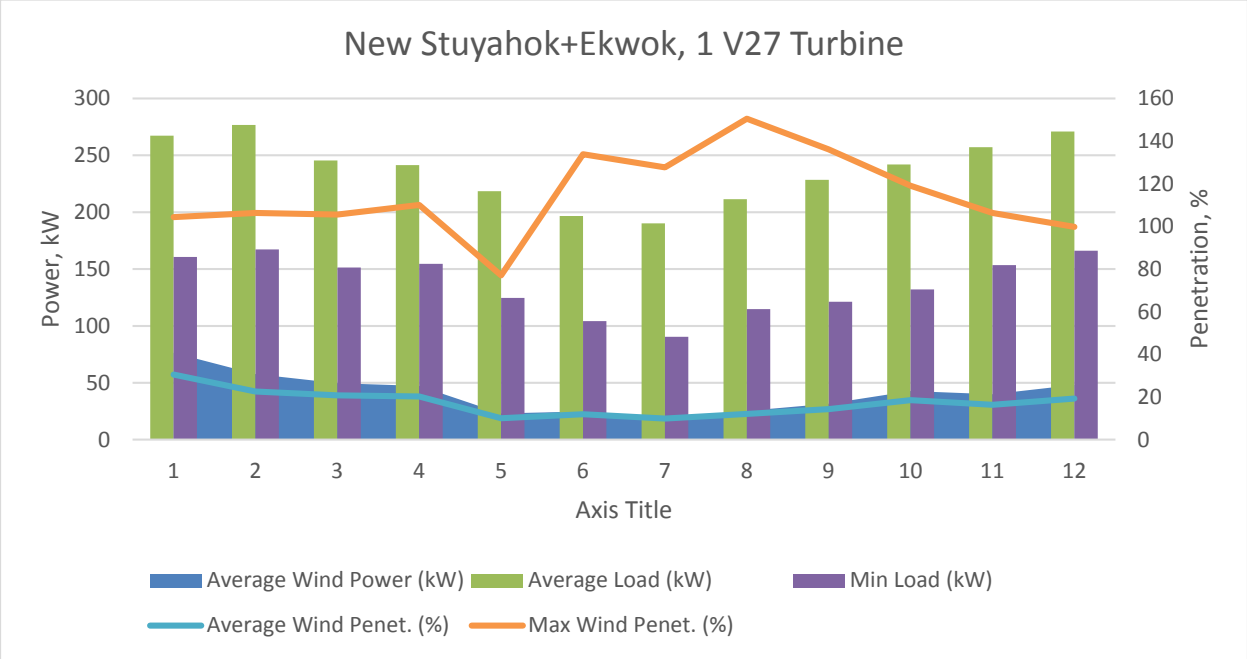
Vestas V27, one turbine

This configuration is one Vestas V27 wind turbine at a 32 meter hub height at the proposed wind site presented in the WAsP modeling section of this analysis report. The 10 minute averaging time simulation models wind energy production at 80 percent net (or 80 percent of annual gross) at the turbine site, not the met tower. Homer software predicts 17% average annual wind power penetration and 151% maximum instantaneous (10 minute) wind penetration.

Energy table, one V27 turbine, 80% net AEP

Month	Average Wind Power (kW)	Wind Energy (kWh)	Average Load (kW)	Min Load (kW)	Average Excess Power (kW)	Excess Energy (kWh)	Average Wind Penet. (%)	Max Wind Penet. (%)
1	76	56815	267	161	3	12	31	104
2	58	38739	277	167	5	27	23	106
3	50	36903	245	151	6	8	21	106
4	47	34027	241	155	8	30	20	110
5	23	17129	218	125	0	0	10	77
6	25	17817	197	104	21	17	12	134
7	19	14252	190	90	20	92	10	128
8	25	18872	211	115	30	164	12	151
9	32	22734	228	121	27	163	14	136
10	43	31850	242	132	13	22	19	119
11	40	28716	257	153	6	3	16	106
12	48	35737	271	166	0	0	19	100
Annual	40	353591	237	90	16	538	17	151

Chart, one V27 turbine



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 power plant 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 *2014_06-R8Prototype_AEA_Final_2014-08-07* and is available on AEA's website.

Project economic valuation

Turbine	No.	Capacity (kW)	(in $ millions) Project Cost	NPV Benefits	NPV Costs	B/C ratio	Diesel Fuel Saved (gal/yr)	Heat Oil Saved (gal/yr)	Petroleum Fuel Saved (gal/yr)
NPS 100C-24	3	300	5.11	3.37	4.54	0.74	53,406	364	53,770
	2	200	4.13	2.38	3.67	0.65	38,054	12	38,066

Turbine	No.	Capacity (kW)	(in $ millions) Project Cost	NPV Benefits	NPV Costs	B/C ratio	Diesel Fuel Saved (gal/yr)	Heat Oil Saved (gal/yr)	Petroleum Fuel Saved (gal/yr)
V27	1	225	3.63	1.63	3.22	0.51	25,979	12	25,991

Conclusion

New Stuyahok has a moderate wind resource for wind power development. Wind behavior at the met tower sites demonstrates low extreme wind probability but moderately high to high turbulence due to heavy brush to the north. Constraints limit the project site to the north side of the now developed meadow near the apron of the old airport, but ideally, a site less exposed to turbulence-inducing vegetation could be found.

All three modeled wind turbine configurations are medium penetration options and controllable with a secondary load controller/boiler configuration, either in a recovered heat loop or as a remote node. Economic benefit of the projects model as moderate. This is due to the modest wind resource at the selected wind turbine site and the high project construction costs.

Appendix A – NPS100C Three Turbine Array, WAsP Wind Farm Report

'New Stuyahok, three NPS100C's' wind farm

Produced on 4/23/2015 at 12:36:10 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0017.

Summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	690.481	230.160	215.930	243.064
Gross AEP [MWh]	718.119	239.373	219.240	254.133
Wake loss [%]	3.85	-	-	-

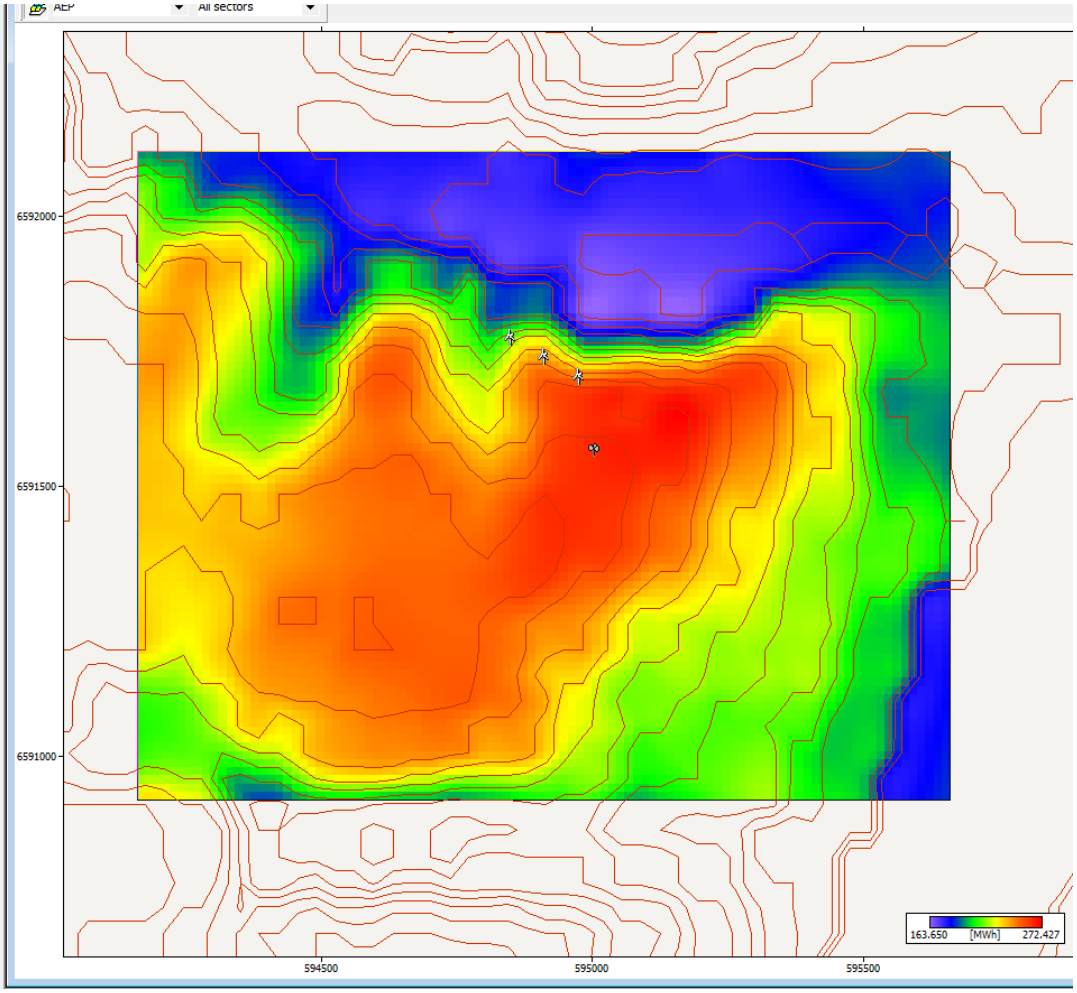
Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
WTG 1	(594849.5,6591764.0)	NPS100C-24	74.29062	37	215.930	1.51
WTG 2	(594913.0,6591728.0)	NPS100C-24	84.31248	37	231.487	5.42
WTG 3	(594976, 6591691)	NPS100C-24	87.49069	37	243.064	4.36

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
WTG 1	(594849.5,6591764.0)	37	5.9	1.81	5.26	190	0.9	-0.2
WTG 2	(594913.0,6591728.0)	37	6.3	1.80	5.57	227	1.2	0.1
WTG 3	(594976, 6591691)	37	6.4	1.85	5.66	231	1.1	-0.1

The wind farm lies in a map called 'New Stuyahok'.



The wind farm is in a project called 'New Stuyahok'
A wind atlas called 'Wind atlas 1' was used to calculate the predicted wind climates

Data origins information

The map was imported by 'Douglas' from a file called 'C:\Users\Douglas\Documents\AVEC\New Stuyahok - Site 0064\WAsP\New Stuyahok.map', on a computer called 'V3ENERGYGATEWAY'. The map file data were last modified on the 2/21/2014 at 5:03:23 AM

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 'Douglas' from a file called 'C:\Users\Douglas\Documents\Wind Turbines\WAsP turbine curves\NPS100C-24, 37 meter.wtg', on a computer called 'V3ENERGYGATEWAY'. The wind turbine generator file was last modified on the 8/28/2014 at 3:15:58 PM

Project parameters

The wind farm is in a project called New Stuyahok.

All of the parameters in the project are default values.

Appendix B – NPS100C Two Turbine Array, WAsP Wind Farm Report

'New Stuyahok, two NPS100's' wind farm

Produced on 7/9/2015 at 11:48:20 AM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0017.

Summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	505.129	252.565	250.870	254.260
Gross AEP [MWh]	518.041	259.020	254.081	263.960
Wake loss [%]	2.49	-	-	-

Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
WTG 2	(594913, 6591728)	NPS100C-24	84.21686	37	250.870	1.26
WTG 3	(594976, 6591691)	NPS100C-24	87.49069	37	254.260	3.67

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
WTG 2	(594913, 6591728)	37	6.3	1.80	5.57	237	1.2	0.1
WTG 3	(594976, 6591691)	37	6.4	1.85	5.66	241	1.1	-0.1

The wind farm lies in a map called 'New Stuyahok'.

Appendix C – V27 One Turbine, WAsP Wind Farm Report

'New Stuyahok, one V27' wind farm

Produced on 7/9/2015 at 12:15:09 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0017.

Summary results

Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	389.155	389.155	389.155	389.155
Gross AEP [MWh]	389.155	389.155	389.155	389.155
Wake loss [%]	0.0	-	-	-

Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
WTG 3	(594976, 6591691)	Vestas V27 (225 kW)	87.49069	32	389.155	0.0

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
WTG 3	(594976, 6591691)	32	6.2	1.81	5.54	231	1.1	-0.1

The wind farm lies in a map called 'New Stuyahok'.