Stebbins-Saint Michael Wind-Diesel Feasibility Study

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This report was prepared by V3 Energy, LLC under contract to Alaska Village Electric Cooperative, Inc. to assess the technical and economic feasibility of installing four Northern Power 100 Arctic model turbines or one EWT 52-900 turbine in the village of Stebbins to serve a combined Stebbins-St. Michael load. This analysis is part of a conceptual design report and final project design funded by the Renewable Energy Fund, which is administered by the Alaska Energy Authority.

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Introduction

Alaska Village Electric Cooperative (AVEC) is the electric utility for the City of Stebbins and the City of Saint Michael. 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 in 2014.

Stebbins and Saint Michael

Stebbins has a population of 585 people while Saint Michael has a population of 401 people (2010 census). Both villages are located on Saint Michael Island in Norton Sound, 125 miles southeast of Nome and 48 miles southwest of Unalakleet. The villages have a subarctic climate with maritime influences during the summer. Summer temperatures average 40° to 60 °F; winters average -4° to 16 °F. Extremes from -55° to 70 °F have been recorded. Annual precipitation averages 12 inches, with 38 inches of snow. Summers are rainy and fog is common. Norton Sound is typically ice free from early June to mid-November.

A fortified trading post called "Redoubt St. Michael" was built by the Russian-American Company at Saint Michael in 1833; it was the northernmost Russian settlement in Alaska. The Native village of "Tachik" stood to the northeast. When the Russians left Alaska in 1867, several of the post's traders remained. "Fort St. Michael," a U.S. military post, was established in 1897. During the gold rush of 1897, it was a major gateway to the interior via the Yukon River. As many as 10,000 persons were said to live in Saint Michael during the gold rush. Saint Michael was also a popular trading post for Eskimos to trade their goods for Western supplies. Centralization of many Yup'iks from the surrounding villages intensified after the measles epidemic of 1900 and the influenza epidemic of 1918. The village remained an important trans-shipment point until the Alaska Railroad was built. The city government was incorporated in 1969.

A federally-recognized tribe is located in Saint Michael, the Native Village of Saint Michael. In Stebbins, the analogous entity is the Stebbins Community Association. Stebbins' and Saint Michael's population is largely Yup'ik Eskimo and many residents are descendants of Russian traders. Seal, beluga whale, moose, caribou, fish, and berries are important staples. The sale and importation of alcohol is banned in both villages.

Stebbins and Saint Michael are accessible only be air and sea but are connected to each other with a 10.5 mile road. Both villages have airports and a seaplane base is available. Regular and charter flights are available from Nome and Unalakleet. Saint Michael is near the Yukon River Delta and has a good natural harbor but no dock. Lighterage service is provided on a frequent basis from Nome. Both villages receive at least one annual shipment of bulk cargo. At present Saint Michael and Stebbins are not connected electrically with a power distribution intertie, but a project to do so is planned for the near future. The electrical intertie will follow the road connecting the two villages.

Note: Information above obtained from Alaska Community Database Community Information Summaries at www.commerce.state.ak.us/dca/commdb/CF_CIS.htm.

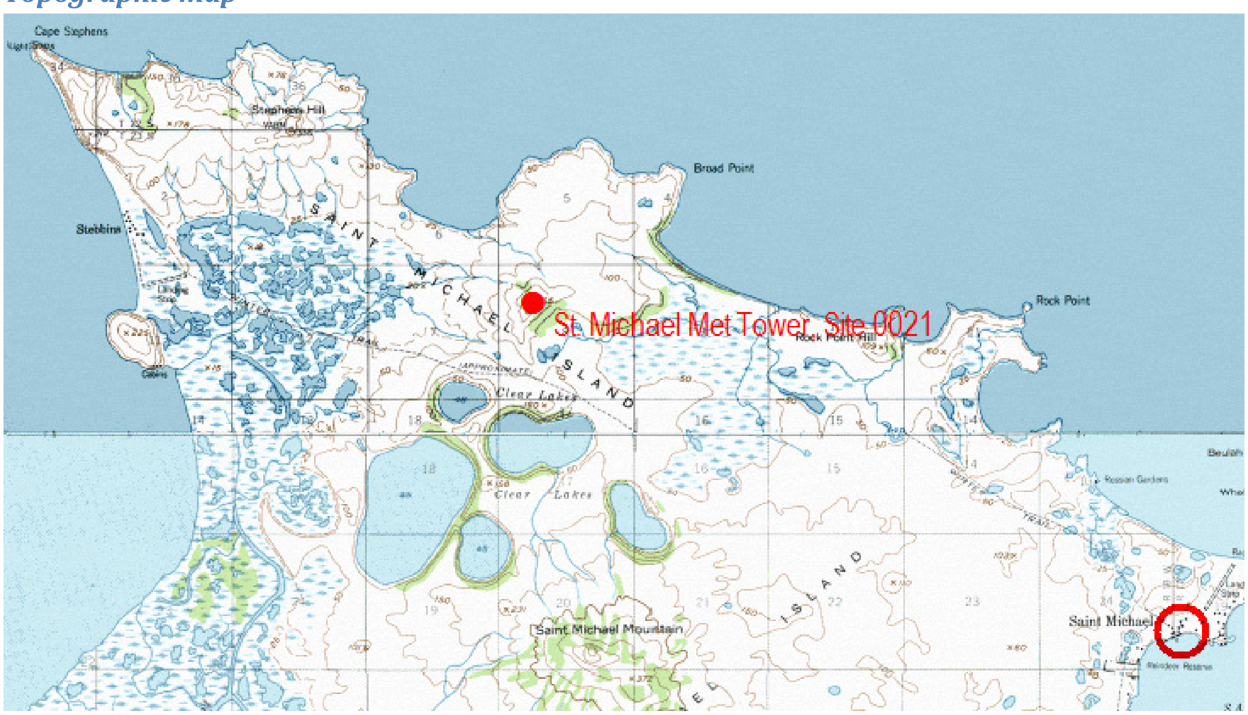
Saint Michael Wind Resource

A met tower was installed on an extinct cinder cone located on Saint Michael Native Corporation land near the road that connects Saint Michael to the village of Stebbins to the west. The site is large enough to accommodate two to three wind turbines, but current land use planning by the corporation reserves the site area (the cinder cone) for mining of lava basalt for construction activities. Although the site is not at present near electrical distribution lines, near-term plans call for construction of an intertie adjacent to the road between Saint Michael and Stebbins.

Saint Michael met tower data synopsis

Data dates	July 21, 2010 to September 19, 2011 (14 months)
Wind power class	Low Class 5 (excellent)
Power density mean, 28.4 m	435 W/m^2
Wind speed mean, 28.4 m	6.73 m/s
Max. 10-min wind speed average	24.7 m/s
Maximum 2-sec. wind gust	29.8 m/s (Feb. 2011)
Weibull distribution parameters	k = 2.03, c = 7.70 m/s
Wind shear power law exponent	0.116 (low)
Roughness class	0.60 (snow surface)
IEC 61400-1, 3rd ed. classification	Class III-c
Turbulence intensity, mean	0.081 (at 15 m/s)
Calm wind frequency, 28.4 m	26% (wind speeds <4 m/s)

Topographic map



Google Earth image

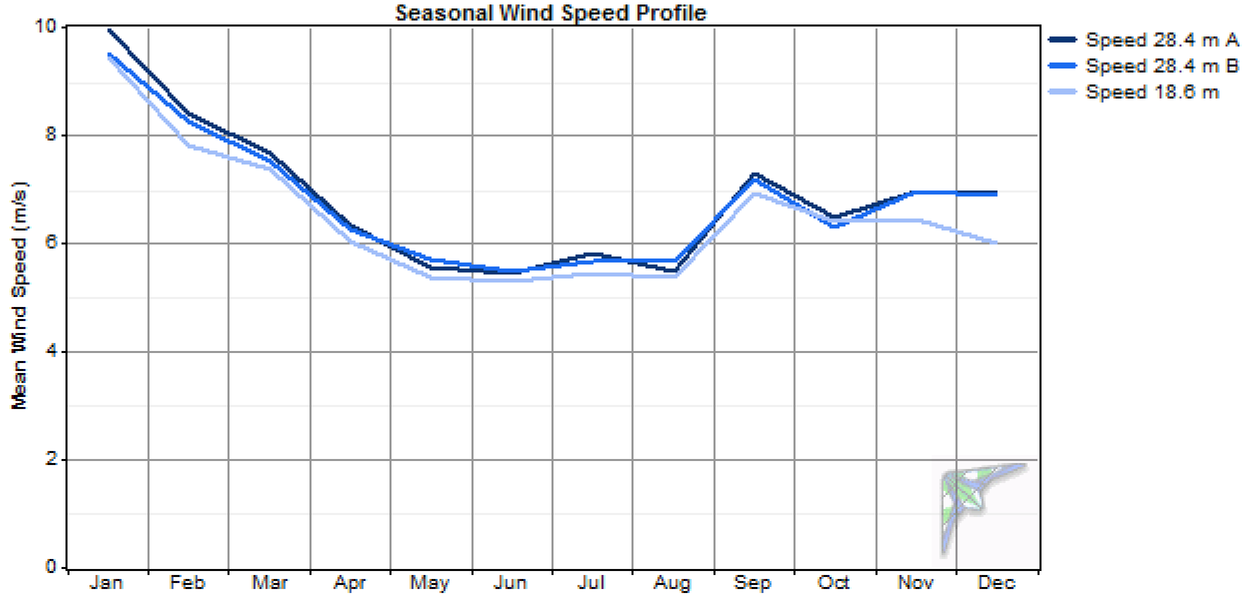
Measured Wind Speeds

Anemometer data collected from the met tower, from the perspectives of mean wind speed and mean wind power density, indicates an excellent wind resource. Note that cold temperatures contributed to a higher wind power density than otherwise might have been expected for the mean wind speeds.

Anemometer data summary

Variable	Speed 28.4 m A	Speed 28.4 m B	Speed 18.6 m
Measurement height (m)	28.4	28.4	18.6
Mean wind speed (m/s)	6.73	6.71	6.39
MMM wind speed (m/s)	6.85	6.78	6.49
Max 10-min wind speed (m/s)	24.6	24.7	22.7
Max gust wind speed (m/s)	29.8	29.8	29.1
Weibull k	1.84	1.82	1.82
Weibull c (m/s)	7.58	7.56	7.19
Mean power density (W/m²)	412	414	361
MMM power density (W/m²)	435	428	376
Mean energy content (kWh/m²/yr)	3,606	3,629	3,166
MMM energy content (kWh/m²/yr)	3,812	3,752	3,296
Energy pattern factor	2.12	2.16	2.17
Frequency of calms (%)	0.0	0.0	0.0
1-hr autocorrelation coefficient	0.934	0.931	0.934
Diurnal pattern strength	0.022	0.023	0.027
Hour of peak wind speed	19	19	16

Time series graph



Temperature and Density

Saint Michael experiences cool summers and cold winters with resulting higher than standard air density. Calculated air density during the met tower test period exceeds standard air density at 80 meters elevation (1.216 Kg/m^3) by 4.5 percent.

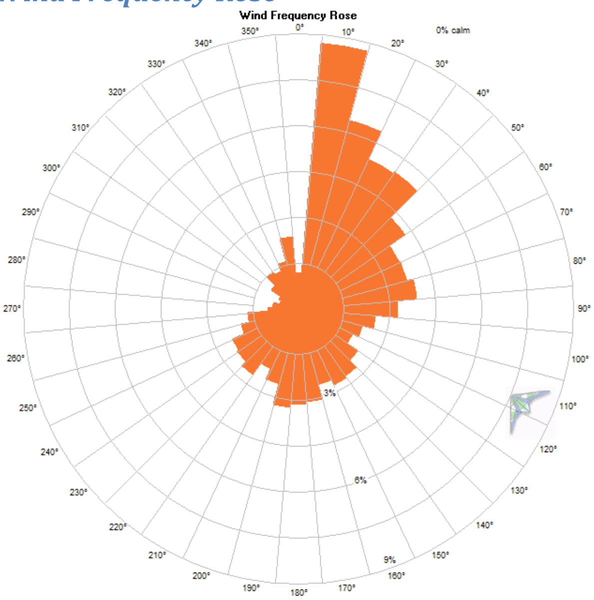
Temperature and density table

	Temperature			Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-8.0	-27.3	4.8	1.313	1.251	1.414
Feb	-10.6	-30.2	2.9	1.325	1.259	1.431
Mar	-7.2	-18.6	5.3	1.307	1.248	1.366
Apr	-4.4	-21.0	10.0	1.294	1.228	1.379
May	6.1	-4.9	21.4	1.245	1.180	1.296
Jun	12.7	5.8	22.1	1.216	1.177	1.246
Jul	13.1	6.2	22.9	1.214	1.172	1.244
Aug	13.8	7.6	24.6	1.215	1.168	1.259
Sep	10.7	1.4	20.1	1.224	1.185	1.266
Oct	2.4	-4.8	9.3	1.261	1.231	1.295
Nov	-3.2	-14.3	7.1	1.288	1.240	1.343
Dec	-13.4	-25.0	0.5	1.339	1.270	1.401
Annual	1.0	-30.2	24.6	1.270	1.168	1.431

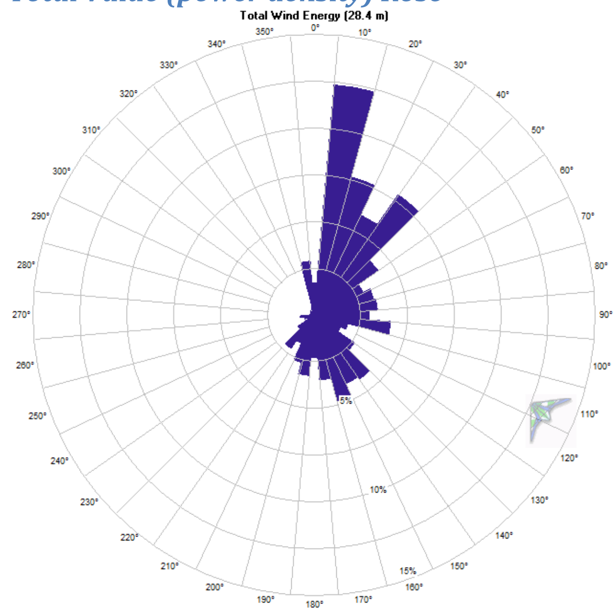
Wind Roses

Wind frequency rose data indicates highly directional winds principally from the north-northeast with easterly and southerly winds to a lesser extent. The mean value rose indicates that southeasterly winds, when they do occur, are of high energy and hence are storm winds. The wind energy rose indicates that for wind turbine operations the majority of power-producing winds will be north-northeast to northeast. Calm frequency (percent of time that winds at the 30 meter level are less than 4 m/s) was 26 percent during the met tower test period.

Wind Frequency Rose



Total Value (power density) Rose



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 a control system and demand-management strategy is required.

Categories of wind-diesel penetration levels

Penetration	Penetration Level		Operating characteristics and system requirements
	Instantaneous	Average	
Low	0% to 50%	Less than 20%	Diesel generator(s) run full time at greater than minimum loading level. Requires minimal changes to existing diesel control system. All wind energy generated supplies the village electric load; wind turbines function as “negative load” with respect to diesel generator governor response.
Medium	0% to 100+%	20% to 50%	Diesel generator(s) run full time at greater than minimum loading level. Requires control system capable of automatic generator start, stop and paralleling. To control system frequency during periods of high wind power input, system requires fast acting secondary load controller matched to a secondary load such as an electric boiler

Penetration	Penetration Level		Operating characteristics and system requirements
	Instantaneous	Average	
			augmenting a generator heat recovery loop. At high wind power levels, secondary (thermal) loads are dispatched to absorb energy not used by the primary (electric) load. Without secondary loads, wind turbines must be curtailed to control frequency.
High (Diesels-off Capable)	0% to 150+%	Greater than 50%	Diesel generator(s) can be turned off during periods of high wind power levels. Requires sophisticated new control system, significant wind turbine capacity, secondary (thermal) load, energy storage such as batteries or a flywheel, and possibly additional components such as demand-managed devices.

Power-producing Equipment

HOMER energy modeling software was used to analyze the new Stebbins powerplant presently under construction serving a combined Stebbins and Saint Michael load which will be realized when an electrical intertie connecting the two villages is complete. HOMER software 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. It is a static energy balance model, however, and is not designed to model the dynamic stability of a wind-diesel power system, although it will provide a warning that renewable energy input is potential sufficient to result in system instability.

Diesel Power Plant

Electric power (comprised of the diesel power plant and the electric power distribution system) in Stebbins is provided by AVEC. The new powerplant will be comprised of four identically rated and configured Caterpillar 3456 diesel generators.

New Stebbins powerplant diesel generators

Generator	Electrical Capacity	Diesel Engine Model
1	450 kW	Caterpillar 3456
2	450 kW	Caterpillar 3456
3	450 kW	Caterpillar 3456
4	450 kW	Caterpillar 3456

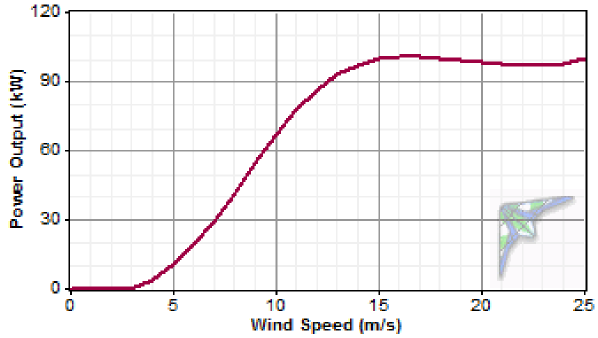
Wind Turbines

This project proposes to install four Northern Power Systems Northern Power 100 ARCTIC turbines for 400 kW installed wind capacity or one EWT 52-900 (or possibly a model 54-900 if the IEC classification of the site is determined to be Class III) for 900 kW installed wind capacity.

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.

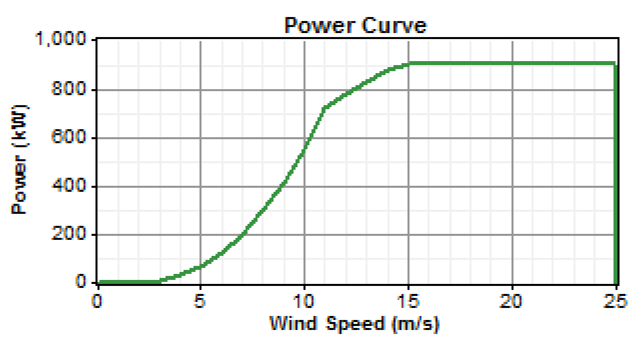
Northern Power 100 ARCTIC power curve



Emergya Wind Technologies EWT 52-900

The EWT 52-900 is an IEC Class II-A wind turbine rated at 5900 kW, equipped with a direct drive, permanent magnet, synchronous generator, a 52 rotor diameter (or 54 meter for IEC Class III conditions), and 40, 50 or 75 meter high towers. The turbine is pitch-controlled, variable speed, and can be equipped with an arctic package enabling continuous operation at temperatures down to -40° C. Three EWT-900 wind turbines are operational in Alaska, one in Delta Junction and two in Kotzebue. The EWT 52-900 wind turbine is manufactured in Amersfoort, The Netherlands, with North American representation in Bloomington, Minnesota. More information can be found at http://www.ewtinternational.com/?id=4 . The turbine power curve is shown below.

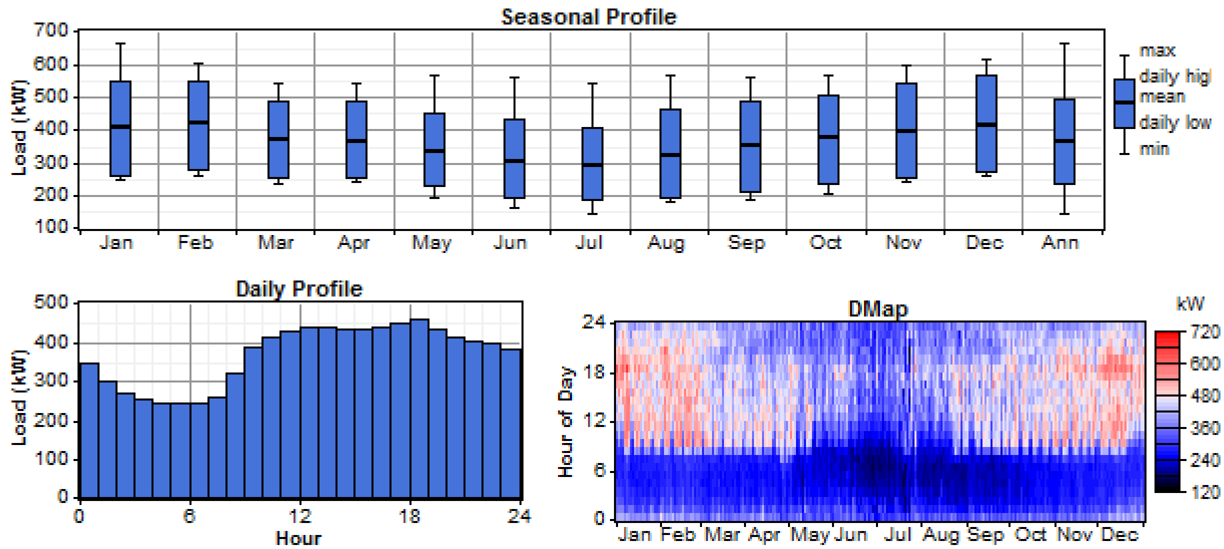
EWT 52-900 power curve



Electric Load

Stebbins and Saint Michael load data, collected from December 2010 to December 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 a January 1 to December 31 hourly list for export to HOMER software. The resulting load is shown graphically below. Average load is 367 kW with a 662 kW peak load and an average daily load demand of 8,806 kWh.

Electric load



Thermal Load

The new Stebbins power plant will include recovered heat to serve thermal loads which will include the village water plant. The thermal load was described by Brian Gray of Alaska Energy and Engineering, Inc. in the table below and incorporated into the Homer model.

Stebbins thermal load (planned)

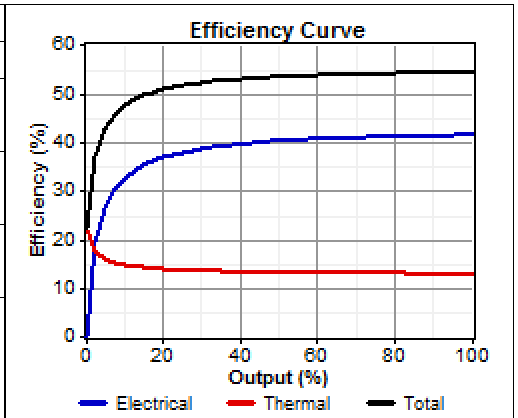
Month	Max Avg Temp, °F	Min Avg Load, kW	Mean Temp, °F	Mean Load, kW	Min Avg Temp, °F	Max Avg Load, kW
Jan	9.9	323	3.1	363	-3.7	403
Feb	10.3	321	2.9	364	-5.1	411
Mar	16.9	282	8.2	333	-0.5	384
Apr	29.3	209	21	258	12.7	307
May	45.8	113	38.1	158	30.4	203
Jun	54.6	61	48	100	41.4	138
Jul	61	23	54.3	63	47.6	102
Aug	59.8	30	52.9	71	46.1	111
Sep	51.2	81	43.9	124	36.7	166
Oct	33	188	26.9	223	20.8	259
Nov	19.1	269	13.2	304	7.3	338
Dec	8.4	332	1.8	370	-4.8	409

Diesel Generators

The HOMER model was constructed with the four new Stebbins generators that will eventually power both Stebbins and Saint Michaels once the intertie is complete. For cost modeling purposes, AEA assumes a generator O&M cost of $0.020/kWh. For HOMER modeling purposes, this was converted to $2.25/operating hour for each diesel generator (based on the combined power plant modeled average electrical load of 367 kW). Other diesel generator information pertinent to the HOMER model is shown below. Cat 3456 fuel curve information from Alaska Energy Authority was used in the Homer model.

Diesel generator HOMER modeling information

Diesel generator	Caterpillar 3456
Power output (kW)	450
Intercept coeff. (L/hr/kW rated)	0.007307
Slope (L/hr/kW output)	0.2382
Minimum electric load (%)	11.0% (50 kW)
Heat recovery ratio (percent of waste heat that can serve the thermal load)	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

Because the Stebbins met tower has not been operational long enough to predict annual turbine energy production at the Stebbins sites, WAsP (Wind Atlas and Application Program) software was used to predict the wind regime at the sites using the Saint Michael met tower as wind atlas reference. WAsP is PC-based software for predicting wind climates, wind resources and power production from wind turbines and wind farms.

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.

Turbine Site Options

The Stebbins met tower area was chosen as a potential wind turbine site because it is a particularly convenient location for construction and was believed to have good wind energy potential (see pin location on Google Earth image below). The road connecting Stebbins to Saint Michael passes through the site area, and the electrical intertie will be located on an easement alongside the road, making connection to the turbines relatively inexpensive.

Six months of data from the Stebbins met tower, however, indicates a less than expected wind resource at the Stebbins met tower site compared to the Saint Michael met tower data, as seen in the comparison table below.

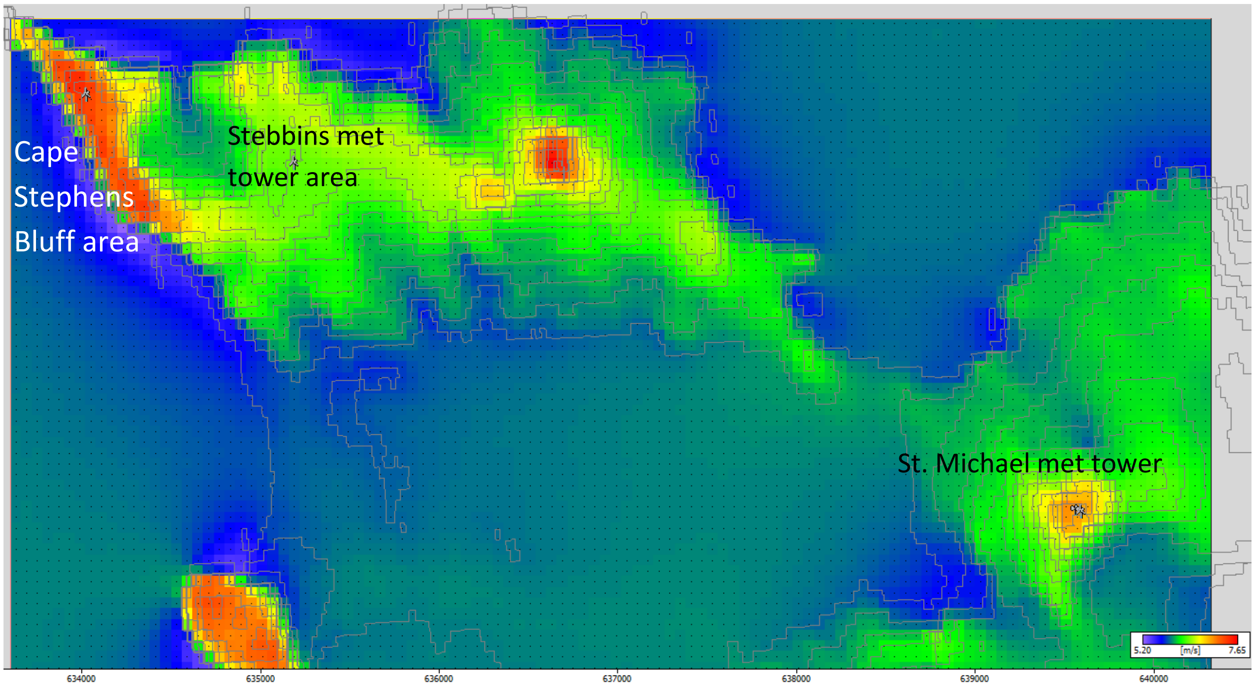
Saint Michael/Stebbins met tower data comparison

	Wind Speed 30 m (m/s)			Northern Power 100 CF (%)		
	St. Michael	Stebbins	Difference (%)	St. Michael	Stebbins	Difference (%)
Jan	9.95	7.14	-28.2	54.8	35.1	-35.9
Feb	8.41	8.22	-2.3	40.2	43.1	7.2
Mar	7.67	6.61	-13.8	38.1	31.4	-17.6
Apr	6.35	5.41	-14.8	24.5	19.5	-20.4
May	5.55	4.19	-24.5	19.9	9.4	-52.8
Jun	5.44	4.31	-20.8	18.6	11.8	-36.6
Jul	5.82	4.30	-26.2	21.7	10.2	-53.0
Aug	5.49			19.7		
Sep	7.28			32.3		
Oct	6.49			28.1		
Nov	6.96			33.6		
Dec	6.91			30.6		
Annual	6.86			30.2		

Notes
Stebbins: January and July are one-half months' data each
Turbine CF at 85% availability
Time periods DO NOT overlap

WAsP modeling of the Stebbins met tower site area with the Saint Michael met tower as the reference point validates the early data returns for the Stebbins met tower, as shown in the WAsP wind speed map below. On review of this map, however, it was noticed that the Cape Stephens bluff area due west of the Stebbins met tower site shows considerable promise for wind power development.

WAsP wind speed resource map



Due to WAsP modeling results that indicate a superior wind resource at the Cape Stephens bluff area, two possible Stebbins wind sites have been identified: the Stebbins met tower site area, referred to as Stebbins Site 1; and the bluff area of Cape Stephens to the west, referred to as Stebbins Site 2. Again, with the Saint Michael met tower as the reference, WAsP software predicts the highest turbine energy production at the Alternate 2 site; higher even that at the St. Michael met tower itself, as shown in the table below. These modeling results will be updated when one year of data from the Stebbins met tower is available. Modeling with Stebbins met tower data will refine the energy production estimates, but relative differences between the alternate sites are unlikely to change significantly.

WAsP comparative prediction of Stebbins sites, one turbine

Location	Wind Speed (annual mean), (m/s)	Power Density, (annual mean), (W/m^2)	NP 100 Annual Energy Production, AEP, (MWh/yr)	NP 100 Capacity Factor at 100% avail., (%)
St. Michael met site	6.95	462	293.0	33.4
Stebbins met site (Stebbins Site 1)	6.36	355	253.7	29.0
Bluff area (Stebbins Site 2)	7.35	547	320.5	36.6

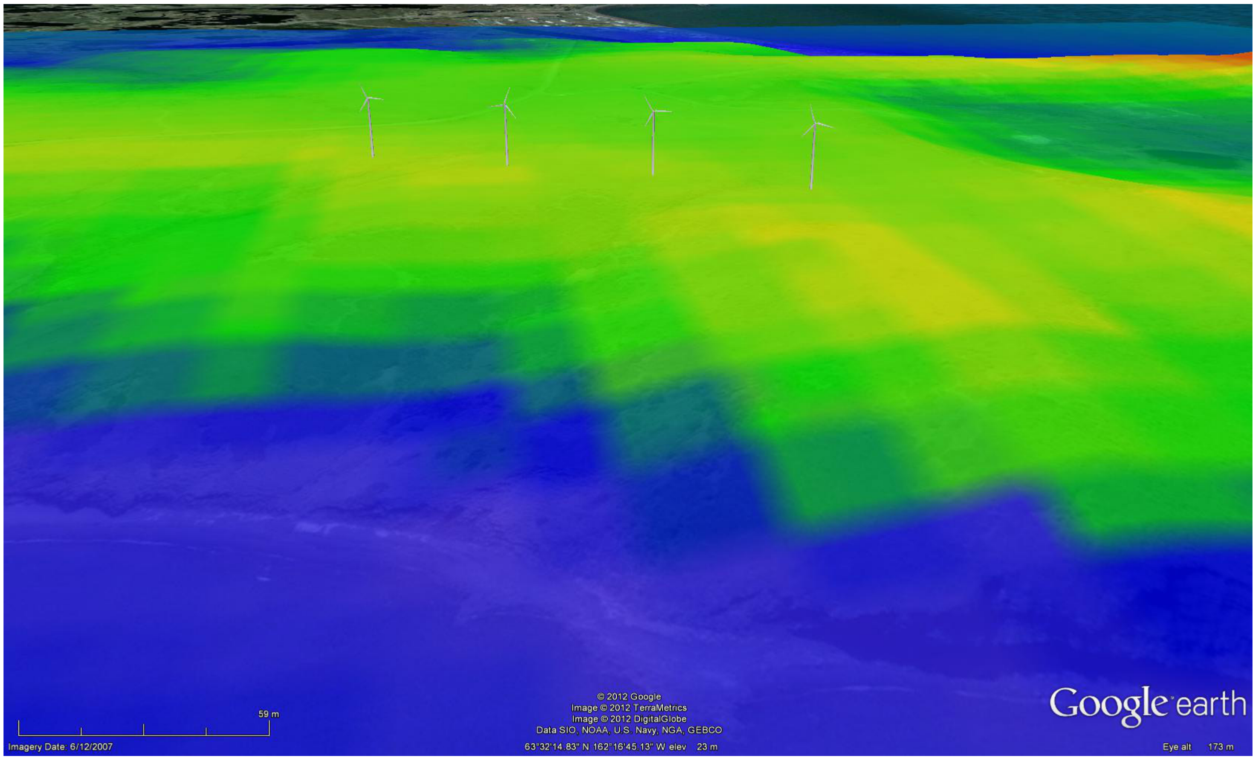
Alternate Sites 1 and 2

Stebbins Site 1: Stebbins met tower area

As noted earlier in this report, two alternate turbine configurations are considered: installation of four Northern Power 100 ARCTIC turbines or one EWT 52-900 turbine. These alternatives would have considerably different effects in that the combined 400 kW capacity of the Northern Power turbines is less than half the potential capacity of the 900 kW EWT turbine. Nine hundred kW of wind capacity may be excessive initially, especially until the intertie connected Stebbins to Saint Michael is completed, but turbine output can be limited via pitch control to as low as 250 kW maximum output.

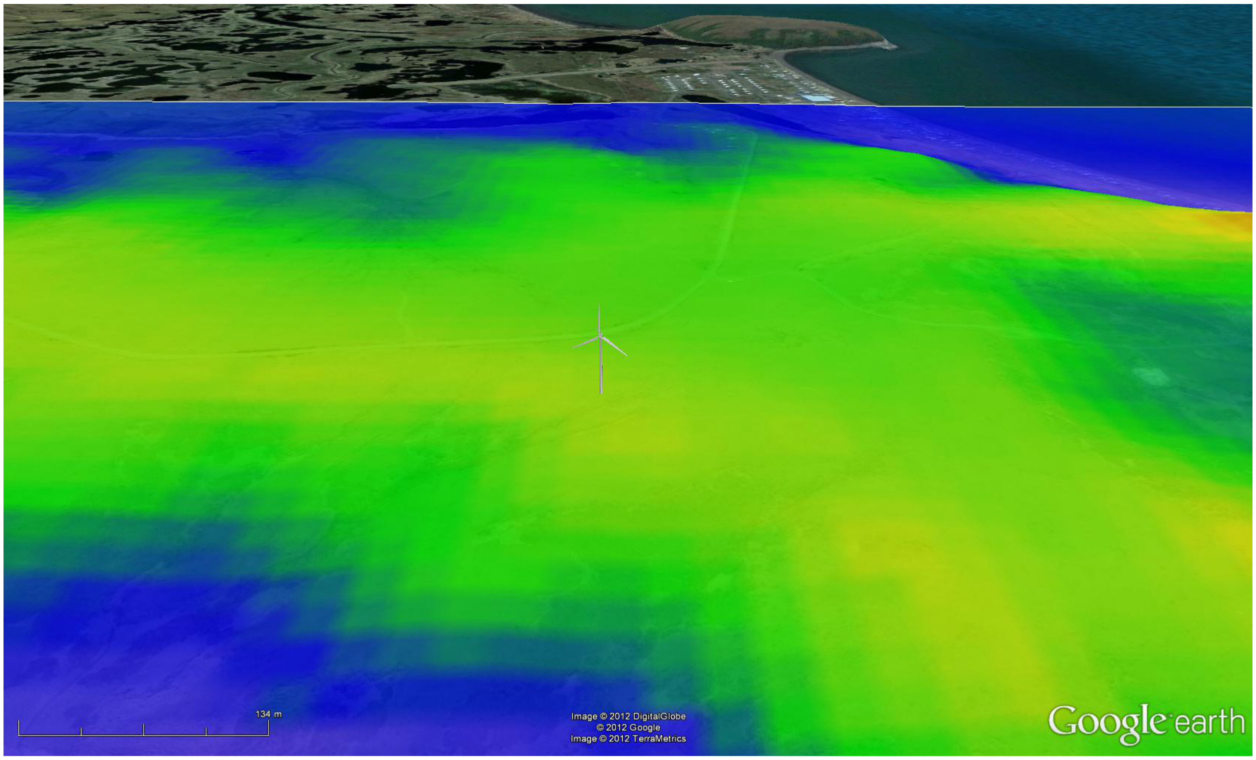
Turbine siting options for Stebbins Site 1 will be refined during the design process, but WAsP modeling with the Saint Michael met tower as a reference site indicates that turbines should be located on the northern edge of the plateau to catch upslope winds from the ocean. This effect is shown in the WAsP/Google Earth graphic below which indicates in yellow the higher wind speeds expected on northern edge of the plateau area. For this reason, the four Northern Power 100 turbines are located at or near the plateau edge, as is the EWT 52-900 turbine. The following image shows the Northern Power turbines on site without the WAsP wind speed overlay.

WAsP wind speed overlay Alt. Site 1 (Northern Power 100 ARCTIC turbines)



Northern Power 100 ARCTIC turbine layout at Stebbins Site 1

WAsP wind speed overlay Alt. Site 1 (EWT 52-900 turbine)

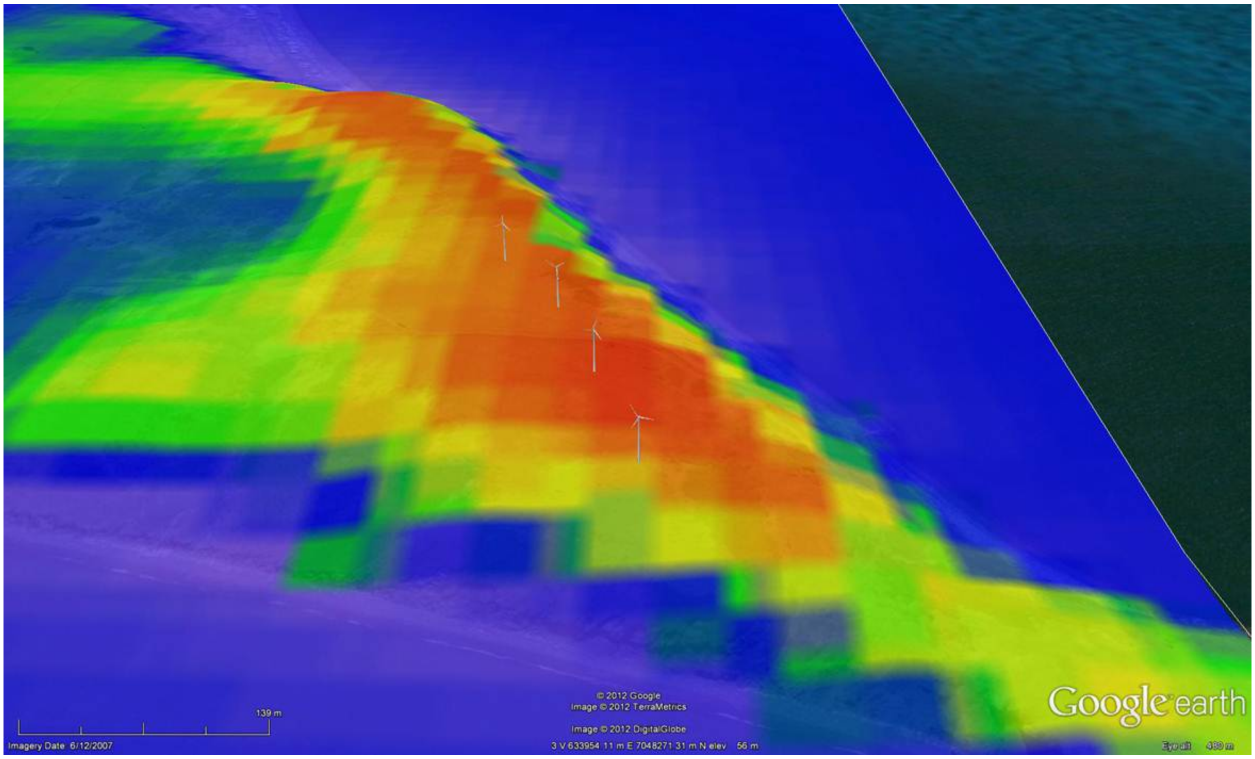


EWT 52-900 turbine layout at Stebbins Site 1

Stebbins Site 2: Cape Stephens Bluff Area

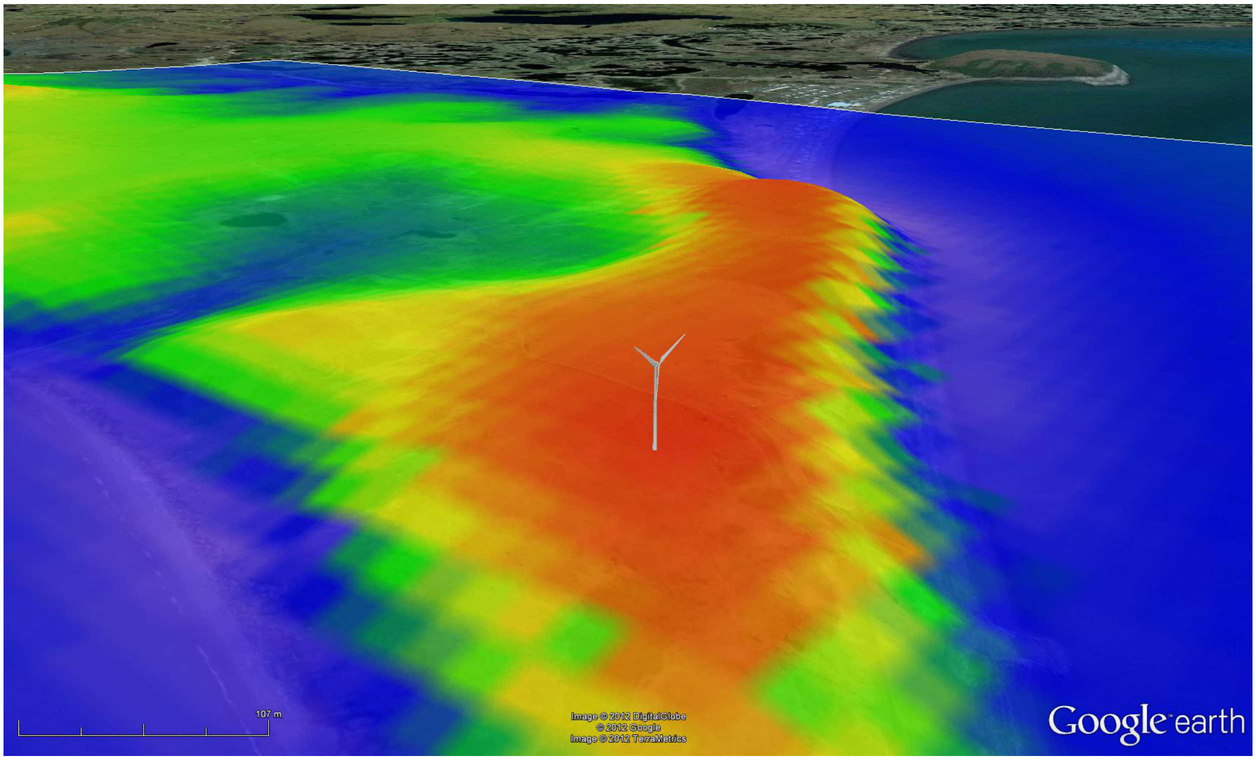
Given the significantly higher wind speeds at the Cape Stephens bluff area, Stebbins Site 2 will likely become the primary wind site during the design process. As noted with Stebbins Site 1, turbine siting options for Stebbins Site 2 will be refined during the design process and WAsP modeling updated with the nearby Stebbins met tower data when available. WAsP modeling indicates, however, that turbines should be located at or near the top of the bluff to make best use of the prevailing northeasterly winds.

WAsP wind speed overlay Alt. Site 2 (Northern Power turbines shown)



Northern Power 100 ARCTIC turbine layout at Stebbins Site 2

WAsP wind speed overlay Alt. Site 2 (EWT 52-900 turbine)



EWT 52-900 turbine layout at Stebbins Site 2

Wind Farm Modeling Results

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 single turbines, such as the EWT 52-900 at Alternate Sites 1 or 2, WAsP calculates gross AEP. Net AEP is identical to the gross as there is no wake loss to consider.

The following tables presents the WAsP software analysis of energy production and capacity factor performance of the Northern Power 100 in a four turbine array and one EWT 52-900 wind turbine at 100% turbine availability (percent of time that the turbine is on-line and available for energy production). Both wind turbines perform well in the Stebbins wind regime with good capacity factors and annual energy productions.

Note that for both turbines the standard (atmospheric conditions) power curve was compensated to the measured mean annual site air density of 1.272 kg/m^3. For the stall-controlled Northern Power 100, power output (for each m/s wind speed step) is multiplied by the ratio of site air density to standard air density of 1.225 kg kg/m^3. For the pitch-controlled EWT 52-900, the algorithm is similar but the density ratio is raised to the one-third power.

Site	Northern Power 100 Arctic			EWT 52-900
	Gross AEP (MWh/yr)	Net AEP (MWh/yr)	Wake Loss (%)	Gross AEP (MWh/yr)
Alt. Site 1 (met tower area)	1,093	1,081	1.08	2,568

Site	Northern Power 100 Arctic			EWT 52-900
	Gross AEP (MWh/yr)	Net AEP (MWh/yr)	Wake Loss (%)	Gross AEP (MWh/yr)
Alt. Site 2 (bluff area)	1,313	1,298	1.15	3,047

Economic Analysis

Installation of four Northern Power 100 ARCTIC wind turbines and one EWT 52-900 wind turbine in medium-to-high penetration mode without electrical storage are evaluated to demonstrate the economic benefit of the project options. Note that in the analyses turbines are 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

Wind Turbine Costs

Project capital and installation costs for the four alternatives (two different turbines at two possible sites) were obtained from HDL, Inc. and are copied below for information. Details regarding HDL's cost estimates are available from them.

Project cost estimates

Site	Four NP 100 ARCTIC turbines	One EWT52/54-900 turbine
Alt. Site 1 (Stebbins met tower area)	$4,220,500	$4,875,224
Alt. Site 2 (Cape Stephens bluff area)	$4,327,350	$5,000,725

Fuel Cost

A fuel price of $4.69/gallon ($1.24/Liter) was chosen for the initial HOMER analysis by reference to *Alaska Fuel Price Projections 2012-2035*, prepared for Alaska Energy Authority by the Institute for Social and Economic Research (ISER), dated July, 2012. The $4.69/gallon price reflects the average value of all fuel prices between the 2014 (assumed project start year) fuel price of $4.25/gallon and the 2033 (20 year project end year) fuel price of $5.14/gallon using the medium price projection analysis with social cost of carbon included (see ISER spreadsheet for Renewable Energy Fund Round 6 analysis).

By comparison, the fuel price for Stebbins (without social cost of carbon) reported to Regulatory Commission of Alaska for the 2011 PCE report is $3.24/gallon ($0.856/Liter).

Fuel cost table

Cost Scenario	2014 (/gal)	2033 (/gal)	Average (/gallon)	Average (/Liter)
Medium	$4.25	$5.14	$4.69	$1.24

Modeling Assumptions

As previously noted in this report, HOMER energy modeling software was used to analyze a combined Stebbins and Saint Michael 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.

Modeling assumptions are detailed in the table below. Many assumptions, such as project life, discount rate, operations and maintenance (O&M) costs, etc. are AEA default values. Other assumptions, such as diesel overhaul cost and time between overhaul are based on general rural Alaska power generation experience.

The base or comparison scenario is new Stebbins power plant presently under construction that will be equipped with four identically configured Caterpillar 3456 diesel engines with 450 kW generators. Although the existing Stebbins does not have a heat recovery loop to offset thermal loads in the village, the new powerplant will have this capability. With that in mind, the base, or comparison, scenario is the new power plant operating in diesel mode with functional heat recovery serving the thermal load defined previously in the report.

Note that wind turbines installed at either of the Stebbins will operate in parallel with the diesel generators. Excess energy will serve thermal loads via a secondary load controller and electric boiler. Installation cost of wind turbines assumes construction of three phase power distribution to the selected site, plus civil, permitting, integration and other related project costs.

Homer modeling assumptions

Economic Assumptions	
Project life	20 years (2014 to 2033)
Discount rate	3%
System fixed O&M cost	$600,000/year (independent of diesel O&M costs)
Operating Reserves	
Load in current time step	10%
Wind power output	50%
Fuel Properties (both types)	
Heating value	43.2 MJ/kg (18,600 BTU/lb.)
Density	820 kg/m^3 (6.85 lb./gal)
Price	$4.69/gal ($1.24/Liter)
Diesel Generators	
Generator capital cost	$0 (new generators already funded)
O&M cost	$2.25/hour (approximately $0.02/kWh)
Time between overhauls	15,000 hours (run time)
Overhaul cost	None assumed
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	100% and 80%
Northern Power 100 ARCTIC project cost (4 turbines)	$4,220,500 (Alt. Site 1) $4,327,350 (Alt. Site 2)
EWT 52-900 (or 54-900) (1 turbine)	$4,875,224 (Alt. Site 1) $5,000,725 (Alt. Site 2)
O&M cost	$0.0469/kWh for NP 100 ARCTIC (equates to $12,325/year) and $0.018/kWh for EWT 52-900 (equates to $42,573/year); both assume 30% CF. Note that the EWT 52-900 the AEA

	default O&M rate for an urban wind turbine was chosen even though this would be a rural application. This decision was based on the utility scale of the EWT turbine and the excessively high annual cost if the rural rate were chosen.
Wind speed	Saint Michael met tower: 6.84 m/s at 28.4 m level of met tower 7.07 m/s at 37 m, extrapolated 7.38 m/s at 50 m, extrapolated Stebbins Site 1 (Stebbins met tower area): 6.64 m/s at 37 m, 100% turbine availability 5.90 m/s at 37 m, 80% turbine availability Stebbins Site 2 (Cape Stephens bluff area): 7.40 m/s, 100% turbine availability 6.50 m/s, 80% turbine availability
Density adjustment	1.272 kg/m^3 (1.270 kg/m^3 measured at St. Michael met tower); note that standard density is 1.225 kg/m^3
Energy Loads	
Electric	8.80 MWh/day average combined Stebbins-Saint Michael power plant load
Thermal	5.44 MWh/day average new Stebbins thermal load (once on-line)

Stebbins Site 1, 100% Wind Turbine Availability

6.64 m/s wind speed at 37 meters

EWT 52-900	NP 100 Arctic	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Wind Fraction	Diesel (L)	Heating oil (L)	Total fuel use (gal)	Avoided fuel (gal)	Excess thermal (%)	B/C Ratio
1		$4,875,224	1,338,195	$24,784,186	0.425	0.38	430,221	113,672	143,697	100,013	18.1	1.063
		$0	1,771,015	$26,348,230	0.458	0.00	795,813	126,629	243,710	-	0.0	1.000
	4	$4,220,500	1,544,609	$27,200,374	0.476	0.20	551,272	151,604	185,700	58,010	2.6	0.969

Stebbins Site 1, 80% Wind Turbine Availability

5.90 m/s wind speed at 37 meters

EWT 52-900	NP 100 Arctic	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Wind Fraction	Diesel (L)	Heating oil (L)	Total fuel use (gal)	Avoided fuel (gal)	Excess thermal (%)	B/C Ratio
1		$4,875,224	1,417,374	$25,962,162	0.45	0.31	484,222	122,719	160,354	100,013	11.9	1.015
		$0	1,771,015	$26,348,230	0.458	0.00	795,813	126,629	243,710	-	0.0	1.000
	4	$4,220,500	1,597,108	$27,981,426	0.492	0.16	596,304	148,400	196,751	46,959	2.6	0.942

Stebbins Site 2, 100% Wind Turbine Availability

7.40 m/s wind speed at 37 meters

EWT 52-900	NP 100 Arctic	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Wind Fraction	Diesel (L)	Heating oil (L)	Total fuel use (gal)	Avoided fuel (gal)	Excess thermal (%)	B/C Ratio
1		$4,997,105	1,265,821	$23,829,318	0.405	0.45	382,778	103,608	128,504	100,013	25.4	1.106
		$0	1,771,015	$26,348,230	0.458	0.00	795,813	126,629	243,710	-	0.0	1.000
	4	$4,304,910	1,493,810	$26,529,032	0.462	0.24	508,102	154,177	174,975	68,735	2.7	0.993

Stebbins Site 2, 80% Wind Turbine Availability

6.50m/s wind speed at 37 meters

EWT 52-900	NP 100 Arctic	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Wind Fraction	Diesel (L)	Heating oil (L)	Total fuel use (gal)	Avoided fuel (gal)	Excess thermal (%)	B/C Ratio
1		$4,997,105	1,352,388	$25,117,220	0.432	0.37	439,784	115,404	146,681	100,013	16.8	1.049
		$0	1,771,015	$26,348,230	0.458	0.00	795,813	126,629	243,710	-	0.0	1.000
	4	$4,304,910	1,554,466	$27,431,442	0.481	0.19	559,655	151,042	187,767	55,943	2.6	0.961

Conclusion and Recommendations

WAsP and Homer modeling indicate that the wind resource in Stebbins, particularly at Stebbins Site 2, the Cape Stephens bluff area, would be highly productive for wind turbine operations. Both turbine configurations modeled – four Northern Power 100 ARCTIC turbines and one EWT 52-900 turbine – would be suitable and result in good benefit-to-cost ratios. To be considered during design, but it is likely that the economic evaluation of the project can be improved with addition of short-term electrical storage to allow the diesel engines to operate at lower loading levels, or even longer term electrical storage to “bank” excess instantaneous wind energy.

In addition to the Northern Power and EWT turbines, it is possible that other wind turbines, particularly remanufactured turbines that offer equivalent installed wind capacity for a lower cost, would be suitable for this project. This could be explored during project design.

Appendix A: WAsP modeling report of four Northern Power 100 ARCTIC turbines at Stebbins Site 1

Stebbins NW100 wind farm, Alternate Site 1

Produced on 8/29/2012 at 3:40:43 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP version: 10.02.0010.

Summary results

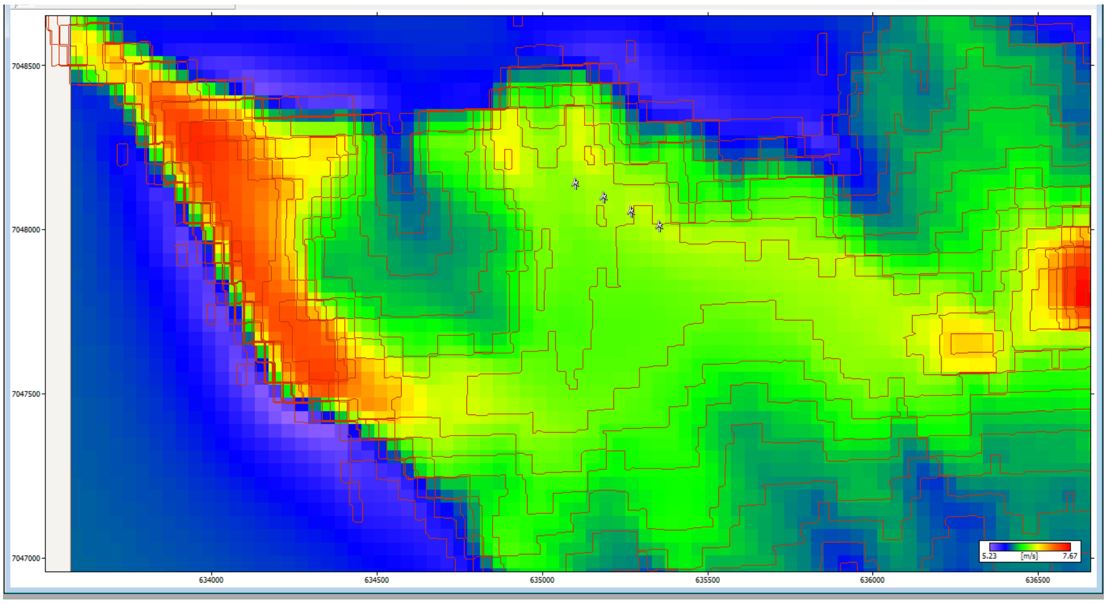
Parameter	Total	Average	Minimum	Maximum
Net AEP [MWh]	1081.482	270.371	266.189	275.148
Gross AEP [MWh]	1093.322	273.330	269.961	275.844
Wake loss [%]	1.08	-	-	-

Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
Steb NW 1	(635104, 7048126)	NWP 100	42.74428	37	266.189	1.4
Steb NW 2	(635188, 7048083)	NWP 100	44.22528	37	269.387	1.45
Steb NW 3	(635272, 7048040)	NWP 100	44.80402	37	270.759	1.24
Steb NW 4	(635356, 7047997)	NWP 100	45	37	275.148	0.25

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
Steb NW 1	(635104, 7048126)	37	7.3	1.73	6.48	389	0.8	0.4
Steb NW 2	(635188, 7048083)	37	7.3	1.72	6.53	398	0.7	0.3
Steb NW 3	(635272, 7048040)	37	7.3	1.72	6.54	402	0.8	0.4
Steb NW 4	(635356, 7047997)	37	7.4	1.72	6.56	407	0.8	0.4



Appendix B: WAsP modeling report of one EWT 52-900 turbine at Stebbins Site 1

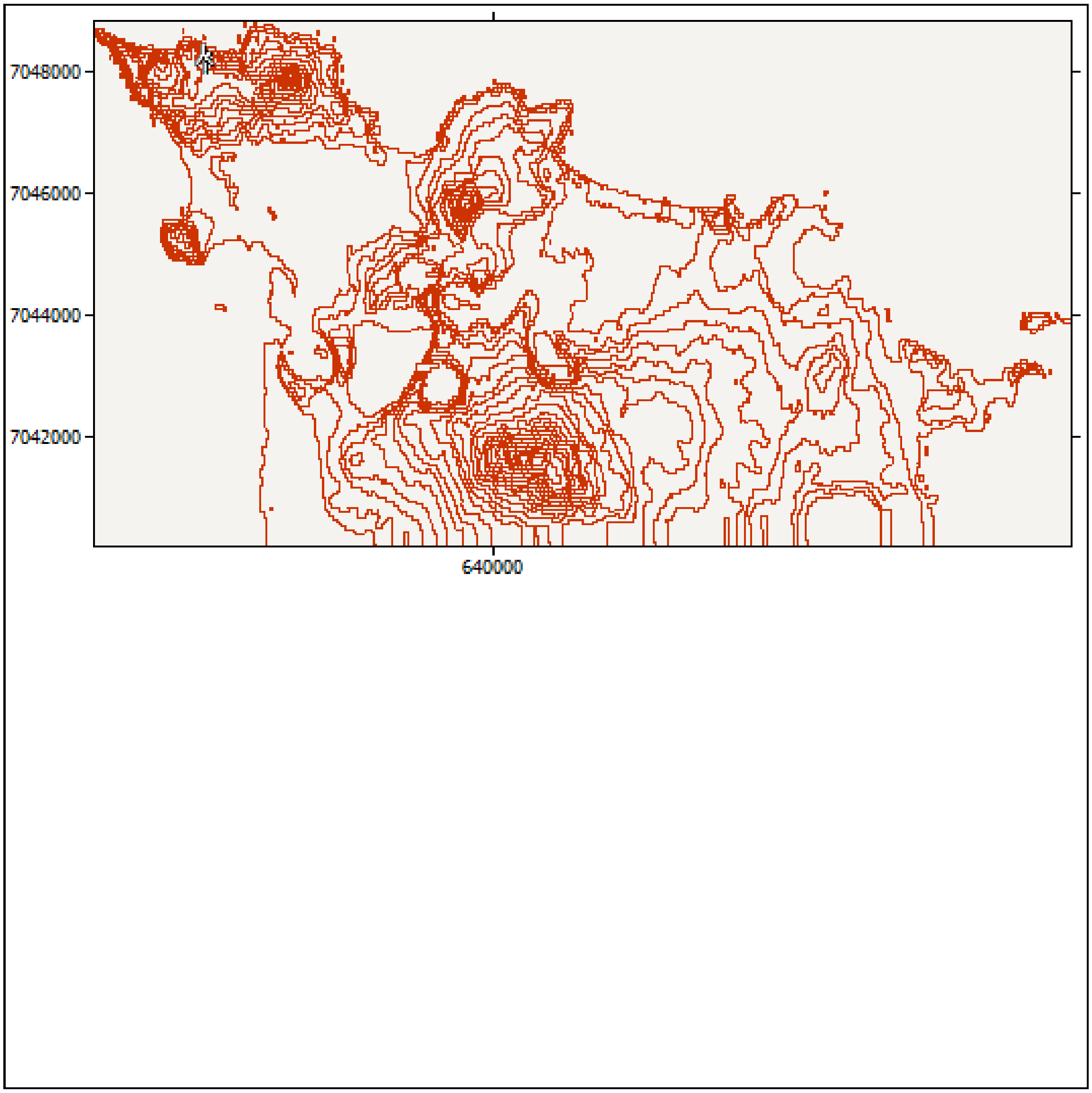
'EWT Site, met tower' Turbine site

Produced on 9/10/2012 at 2:09:29 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP Version: 10.02.0010

Site information

Location in the map

The turbine is located at co-ordinates (635329,7047997) in a map called 'Stebbins-St Michael'. The site elevation is 45.0 m a.s.l.



Site effects

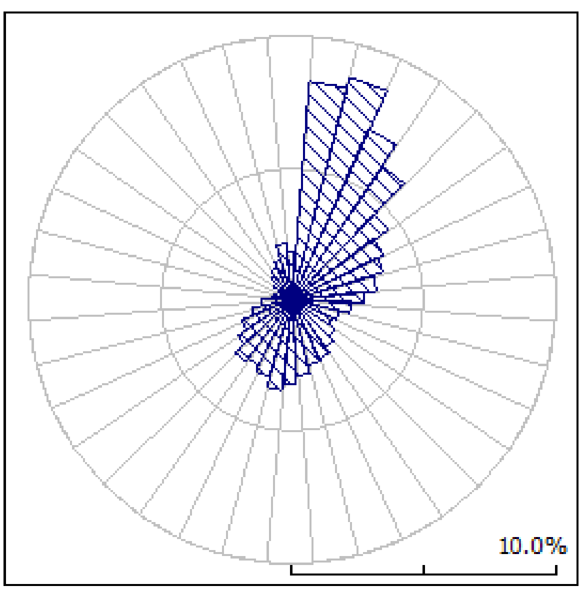
Sector	Angle [°]	Or.Spd [%]	Or.Tur [°]	Obs.Spd [%]	Rgh.Spd [%]	Rix [%]
1	0	10.11	1.9	0.00	0.00	0.3
2	10	11.09	1.1	0.00	0.00	0.2
3	20	11.57	0.3	0.00	0.00	0.3
4	30	11.49	-0.6	0.00	0.00	0.2
5	40	10.86	-1.4	0.00	0.00	0.2
6	50	9.74	-2.0	0.00	0.00	0.7
7	60	8.27	-2.5	0.00	0.00	0.8

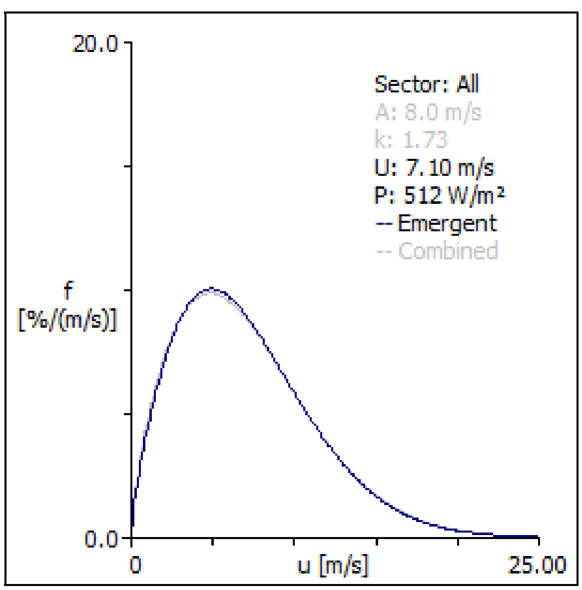
8	70	6.61	-2.6	0.00	0.00	0.7
9	80	4.95	-2.4	0.00	0.00	0.1
10	90	3.50	-2.0	0.00	0.00	0.0
11	100	2.45	-1.2	0.00	0.00	0.8
12	110	1.93	-0.3	0.00	0.00	0.1
13	120	2.02	0.6	0.00	0.00	0.1
14	130	2.70	1.5	0.00	0.00	0.1
15	140	3.89	2.1	0.00	0.00	0.0
16	150	5.42	2.5	0.00	0.00	0.0
17	160	7.10	2.6	0.00	0.00	0.0
18	170	8.73	2.4	0.00	0.00	0.0
19	180	10.11	1.9	0.00	0.00	0.6
20	190	11.09	1.1	0.00	0.00	3.6
21	200	11.57	0.3	0.00	0.00	0.9
22	210	11.49	-0.6	0.00	0.00	0.5
23	220	10.86	-1.4	0.00	0.00	0.5
24	230	9.74	-2.0	0.00	0.00	0.8
25	240	8.27	-2.5	0.00	0.00	1.2
26	250	6.61	-2.6	0.00	0.00	2.2
27	260	4.95	-2.4	0.00	0.00	2.4
28	270	3.50	-2.0	0.00	0.00	2.2
29	280	2.45	-1.2	0.00	0.00	2.1
30	290	1.93	-0.3	0.00	0.00	2.5
31	300	2.02	0.6	0.00	0.00	0.4
32	310	2.70	1.5	0.00	0.00	0.8
33	320	3.89	2.1	0.00	0.00	0.6
34	330	5.42	2.5	0.00	0.00	0.5
35	340	7.10	2.6	0.00	0.00	0.6
36	350	8.73	2.4	0.00	0.00	0.2

The all-sector RIX (ruggedness index) for the site is 0.8%

The predicted wind climate at the turbine site

-	Total	Wind at maximum power density distribution
Mean wind speed	7.10 m/s	12.43 m/s
Mean power density	512 W/m²	42 (W/m²)/(m/s)

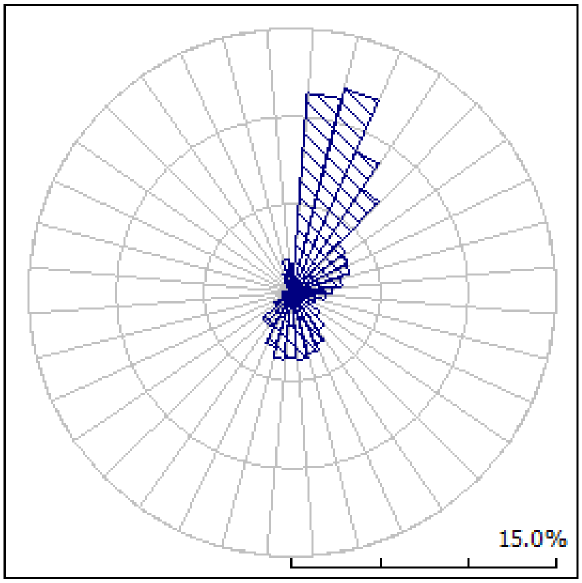


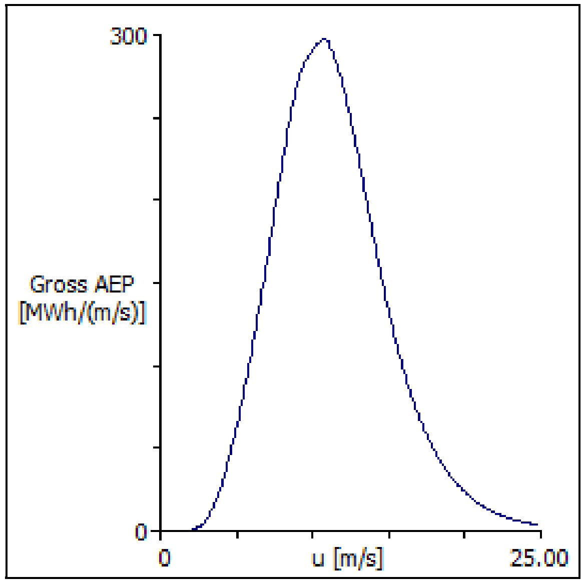


Results

Site	Location [m]	Turbine	Height [m]	Net AEP [GWh]	Wake loss [%]
EWT Site, met tower	(635329.2,7047997.0)	EWT52-900	50	2.568	0.0

The combined (omnidirectional) Weibull distribution predicts a gross AEP of 2.583 GWh and the emergent (sum of sectors) distribution predicts a gross AEP of 2.568 GWh. (The difference is 0.57%)





Project parameters

The site is in a project called Project 1.

Here is a list of all the parameters with non-default values:

- Default number of rose sectors: 36.00 (default is 12.00)
- Air density: 1.273 (default is 1.225)

Data origins information

The map was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\AVEC\Stebbins-St Michael\WAsP\Stebbins-St Michael.map', on a computer called 'V3ENERGYACER-PC'. The map file data were last modified on the 7/20/2012 at 4:27:07 PM

There is no information about the origin of the wind atlas file.

The wind turbine generator was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\Wind Turbines\WAsP turbine curves\EWT52-900, 50 m.wtg', on a computer called 'V3ENERGYACER-PC'. The wind turbine generator file were last modified on the 8/31/2012 at 1:12:58 PM

Appendix C: WAsP modeling report of four Northern Power 100 ARCTIC turbines at Stebbins Site 2

Stebbins NW100 wind farm, Alternate Site 2

Produced on 8/29/2012 at 4:03:16 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]	1297.965	324.491	317.096	332.191
Gross AEP [MWh]	1313.033	328.258	320.962	337.261
Wake loss [%]	1.15	-	-	-

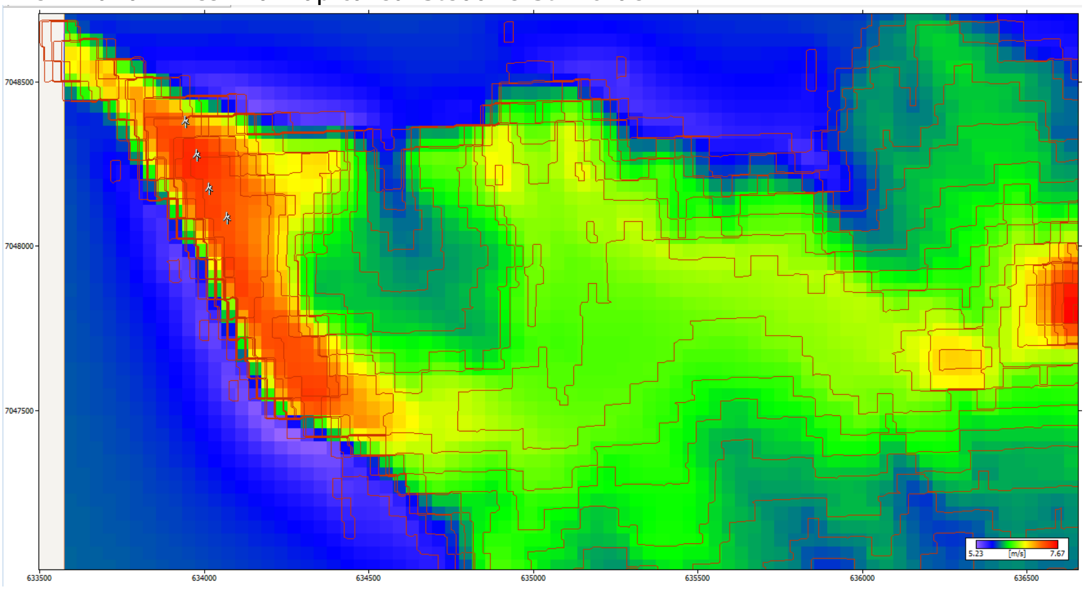
Site results

Site	Location [m]	Turbine	Elevation [m a.s.l.]	Height [m a.g.l.]	Net AEP [MWh]	Wake loss [%]
Steb NW-1	(633945, 7048363)	NWP 100	47.15633	37	317.096	1.2
Steb NW-2	(633981, 7048261)	NWP 100	60.09665	37	332.191	1.5
Steb NW-3	(634017, 7048160)	NWP 100	60.46437	37	325.465	1.4
Steb NW-4	(634073, 7048071)	NWP 100	61.44584	37	323.213	0.46

Site wind climates

Site	Location [m]	Height [m a.g.l.]	A [m/s]	k	U [m/s]	E [W/m²]	RIX [%]	dRIX [%]
Steb NW-1	(633945, 7048363)	37	8.1	1.71	7.22	546	0.9	0.4
Steb NW-2	(633981, 7048261)	37	8.4	1.72	7.48	602	0.8	0.4
Steb NW-3	(634017, 7048160)	37	8.3	1.72	7.36	571	0.9	0.4
Steb NW-4	(634073, 7048071)	37	8.2	1.73	7.28	550	1.0	0.5

The wind farm lies in a map called 'Stebbins-St Michael'.



Appendix D: WAsP modeling report of one EWT 52-900 turbine at Stebbins Site 2

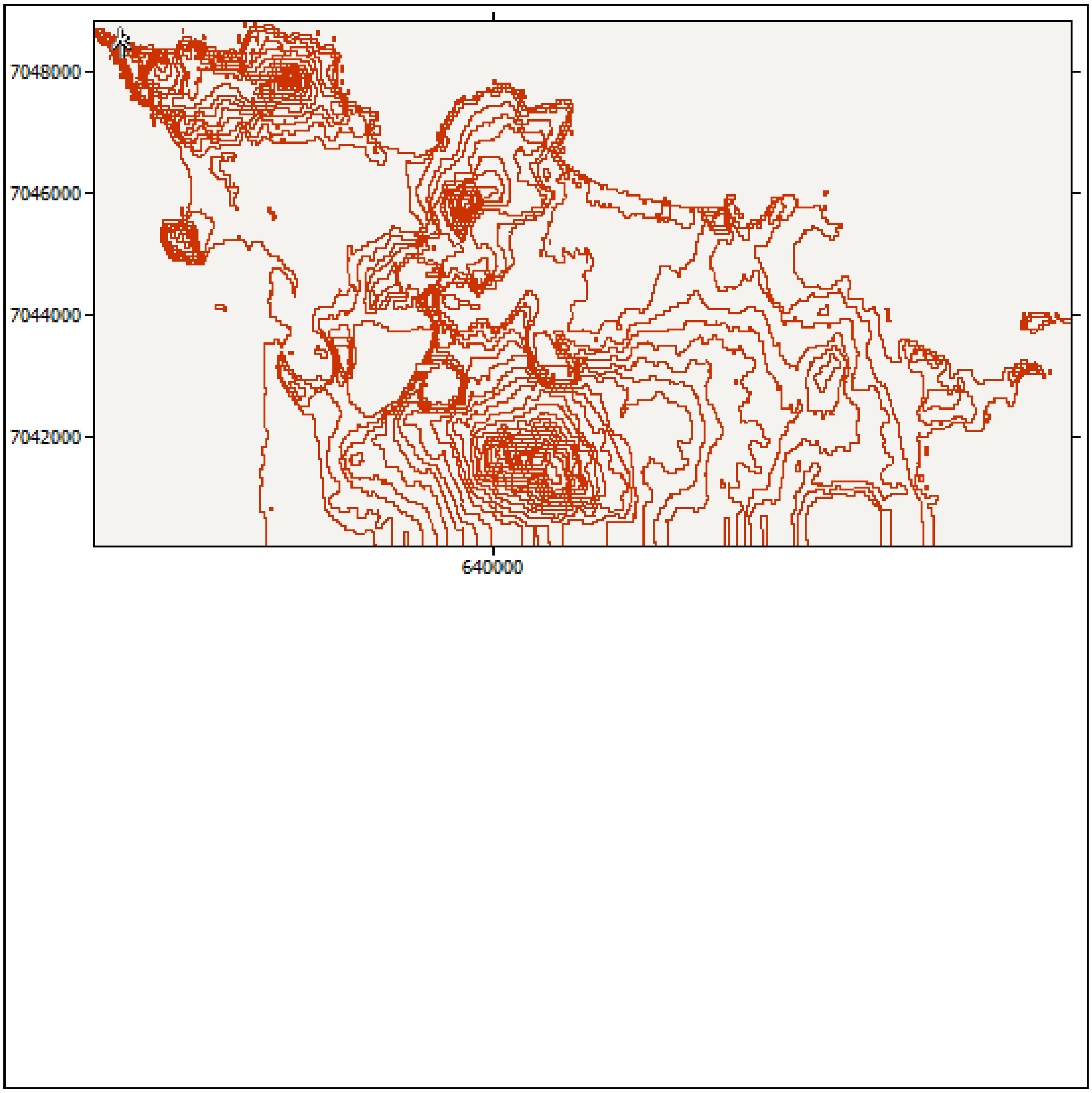
'EWT Site, Alt Site 2' Turbine site

Produced on 9/10/2012 at 5:05:31 PM by licenced user: Douglas J. Vaught, V3 Energy, USA using WAsP Version: 10.02.0010

Site information

Location in the map

The turbine is located at co-ordinates (633967,7048272) in a map called 'Stebbins-St Michael'. The site elevation is 59.1 m a.s.l.



Site effects

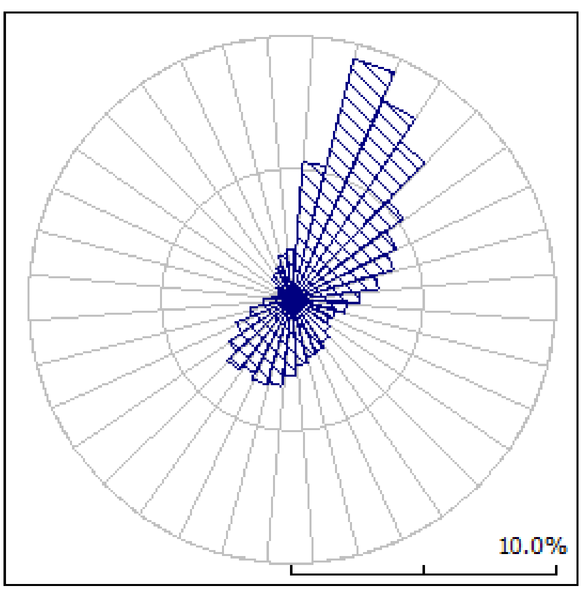
Sector	Angle [°]	Or.Spd [%]	Or.Tur [°]	Obs.Spd [%]	Rgh.Spd [%]	Rix [%]
1	0	18.96	5.8	0.00	0.00	0.4
2	10	22.93	5.2	0.00	0.00	0.4
3	20	26.22	4.0	0.00	0.00	0.6
4	30	28.52	2.4	0.00	0.00	0.5
5	40	29.59	0.6	0.00	0.00	0.5
6	50	29.34	-1.3	0.00	0.00	0.6
7	60	27.80	-3.0	0.00	0.00	0.9

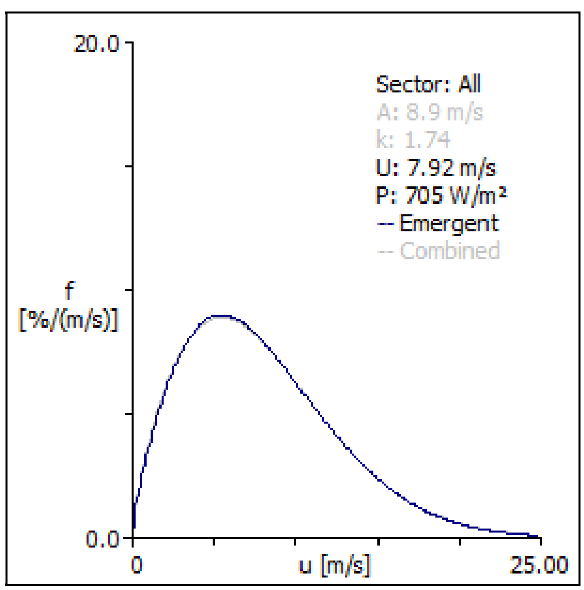
8	70	25.10	-4.5	0.00	0.00	0.6
9	80	21.51	-5.5	0.00	0.00	2.0
10	90	17.40	-5.9	0.00	0.00	1.1
11	100	13.24	-5.6	0.00	0.00	1.1
12	110	9.55	-4.6	0.00	0.00	0.4
13	120	6.85	-2.9	0.00	0.00	0.3
14	130	5.55	-0.7	0.00	0.00	0.2
15	140	5.85	1.6	0.00	0.00	0.6
16	150	7.71	3.6	0.00	0.00	1.6
17	160	10.84	5.0	0.00	0.00	2.5
18	170	14.76	5.8	0.00	0.00	3.5
19	180	18.96	5.8	0.00	0.00	0.3
20	190	22.93	5.2	0.00	0.00	0.8
21	200	26.22	4.0	0.00	0.00	1.1
22	210	28.52	2.4	0.00	0.00	0.9
23	220	29.59	0.6	0.00	0.00	1.1
24	230	29.34	-1.3	0.00	0.00	1.1
25	240	27.80	-3.0	0.00	0.00	1.1
26	250	25.10	-4.5	0.00	0.00	0.8
27	260	21.51	-5.5	0.00	0.00	0.9
28	270	17.40	-5.9	0.00	0.00	0.7
29	280	13.24	-5.6	0.00	0.00	0.5
30	290	9.55	-4.6	0.00	0.00	0.5
31	300	6.85	-2.9	0.00	0.00	1.0
32	310	5.55	-0.7	0.00	0.00	1.3
33	320	5.85	1.6	0.00	0.00	1.5
34	330	7.71	3.6	0.00	0.00	0.8
35	340	10.84	5.0	0.00	0.00	0.5
36	350	14.76	5.8	0.00	0.00	0.4

The all-sector RIX (ruggedness index) for the site is 0.9%

The predicted wind climate at the turbine site

-	Total	Wind at maximum power density distribution
Mean wind speed	7.92 m/s	13.80 m/s
Mean power density	705 W/m²	53 (W/m²)/(m/s)

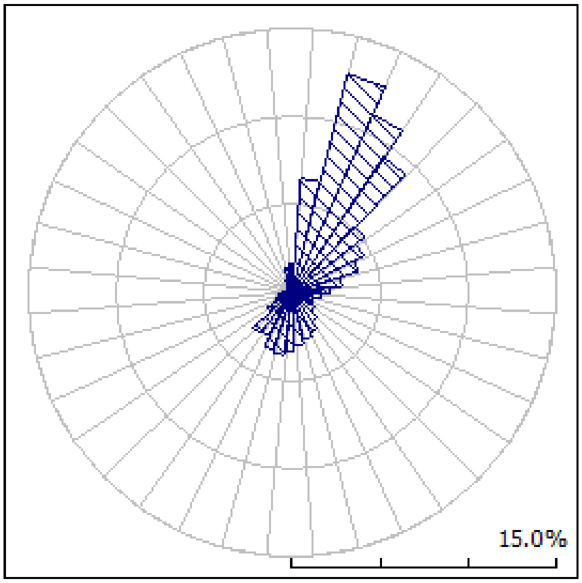


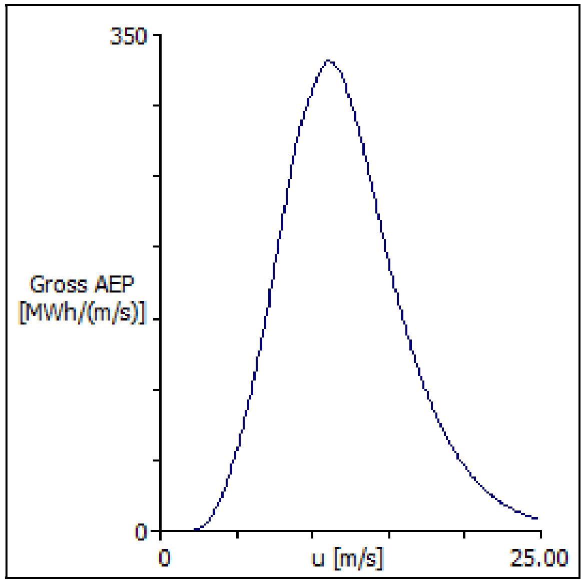


Results

Site	Location [m]	Turbine	Height [m]	Net AEP [GWh]	Wake loss [%]
EWT Site, Alt Site 2	(633967, 7048272)	EWT52-900	50	3.047	0.0

The combined (omnidirectional) Weibull distribution predicts a gross AEP of 3.054 GWh and the emergent (sum of sectors) distribution predicts a gross AEP of 3.047 GWh. (The difference is 0.22%)





Project parameters

The site is in a project called Project 1.

Here is a list of all the parameters with non-default values:

- Default number of rose sectors: 36.00 (default is 12.00)
- Air density: 1.273 (default is 1.225)

Data origins information

The map was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\AVEC\Stebbins-St Michael\WAsP\Stebbins-St Michael.map', on a computer called 'V3ENERGYACER-PC'. The map file data were last modified on the 7/20/2012 at 4:27:07 PM

There is no information about the origin of the wind atlas file.

The wind turbine generator was imported by 'Doug' from a file called 'C:\Users\Doug\Documents\Wind Turbines\WAsP turbine curves\EWT52-900, 50 m.wtg', on a computer called 'V3ENERGYACER-PC'. The wind turbine generator file were last modified on the 8/31/2012 at 1:12:58 PM

Appendix E: Homer System Report of four Northern Power 100 ARCTIC turbines at Stebbins Site 1

System Report - St Michael-Stebbins

Sensitivity case

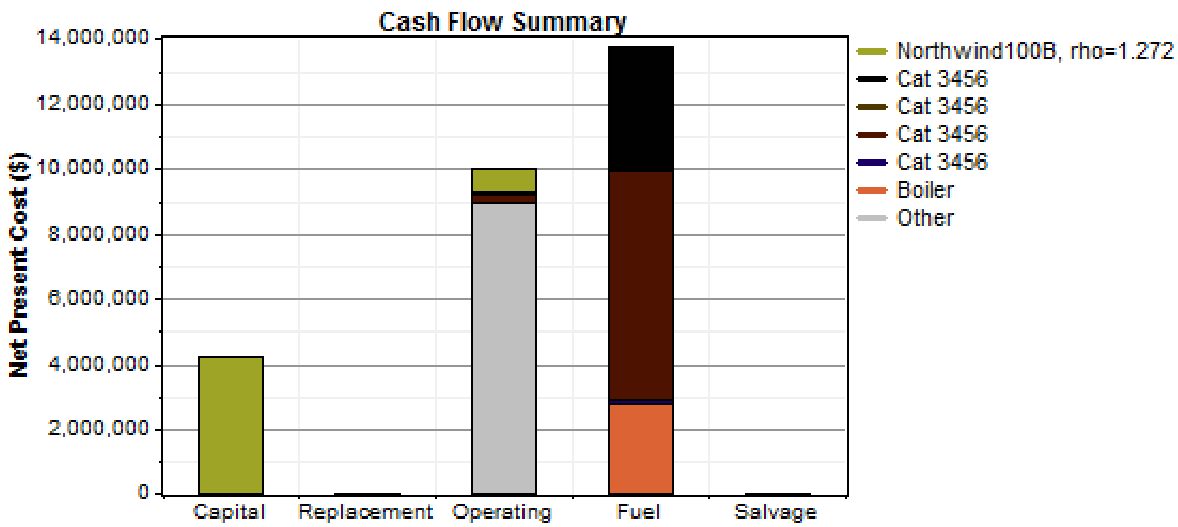
Wind Data Scaled Average:	5.9 m/s
EWT 52-900, rho=1.272 Capital Cost Multiplier:	1
Northwind100B, rho=1.272 Capital Cost Multiplier:	1
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %

System architecture

Wind turbine	4 Northwind100B, rho=1.272
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW

Cost summary

Total net present cost	$ 27,981,426
Levelized cost of energy	$ 0.492/kWh
Operating cost	$ 1,597,108/yr



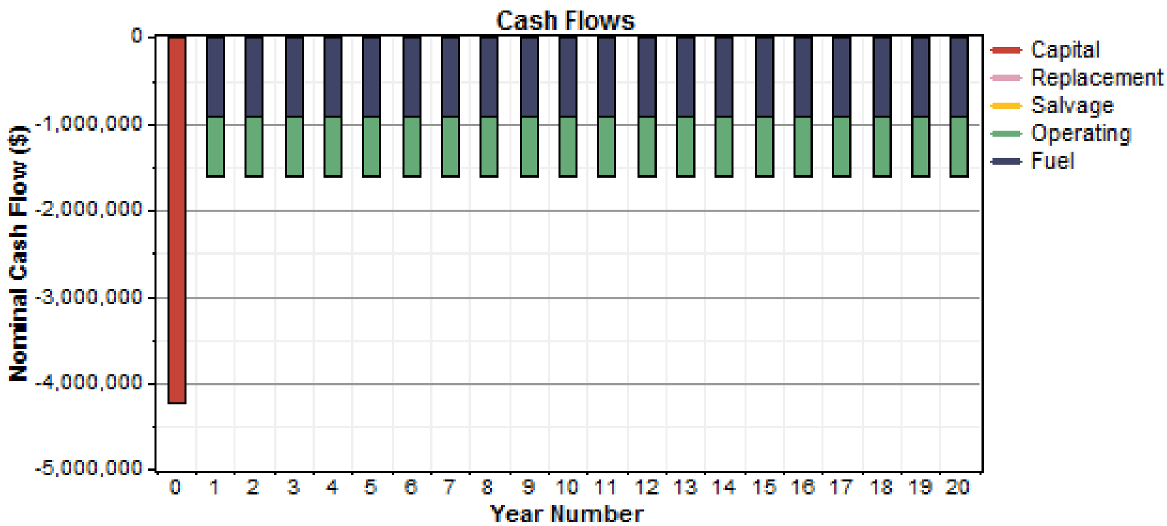
Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Northwind100B, rho=1.272	4,220,500	0	733,460	0	0	4,953,960
Cat 3456	0	0	70,397	3,813,348	0	3,883,744
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	273,251	7,052,573	0	7,325,825
Cat 3456	0	0	18,980	134,749	0	153,729
Boiler	0	0	0	2,737,693	0	2,737,693

Other	0	0	8,926,488	0	0	8,926,488
System	4,220,500	0	10,022,574	13,738,363	0	27,981,434

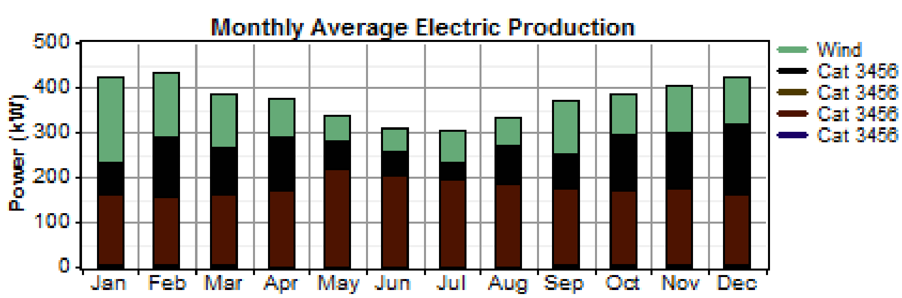
Annualized Costs

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
Northwind100B, rho=1.272	283,684	0	49,300	0	0	332,984
Cat 3456	0	0	4,732	256,317	0	261,049
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	18,367	474,044	0	492,411
Cat 3456	0	0	1,276	9,057	0	10,333
Boiler	0	0	0	184,016	0	184,016
Other	0	0	600,000	0	0	600,000
System	283,684	0	673,674	923,434	0	1,880,792



Electrical

Component	Production (kWh/yr)	Fraction
Wind turbines	868,099	27%
Cat 3456	838,755	26%
Cat 3456	0	0%
Cat 3456	1,533,883	47%
Cat 3456	28,067	1%
Total	3,268,803	100%

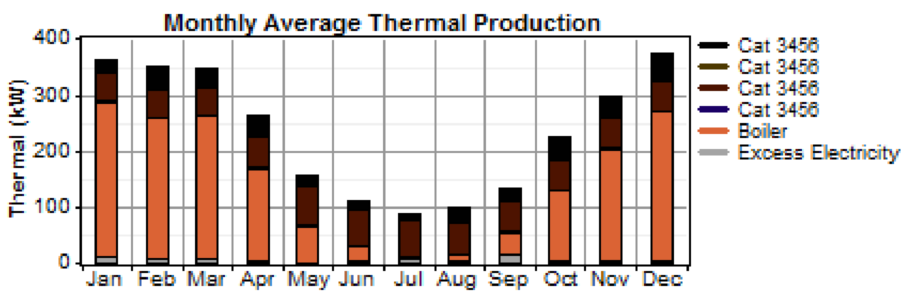


Load	Consumption	Fraction
	(kWh/yr)	
AC primary load	3,214,180	100%
Total	3,214,180	100%

Quantity	Value	Units
Excess electricity	54,607	kWh/yr
Unmet load	0.00768	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.157	

Thermal

Component	Production	Fraction
	(kWh/yr)	
Cat 3456	262,951	13%
Cat 3456	490,155	24%
Cat 3456	9,637	0%
Boiler	1,221,105	60%
Excess electricity	54,607	3%
Total	2,038,455	100%



Load	Consumption	Fraction
	(kWh/yr)	
Thermal load	1,986,697	100%
Total	1,986,697	100%

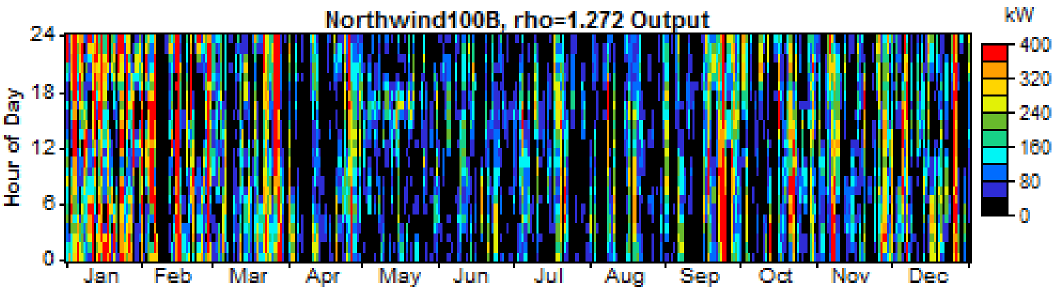
Quantity	Value	Units
Excess thermal energy	51,758	kWh/yr

AC Wind Turbine: Northwind100B, rho=1.272

Variable	Value	Units
Total rated capacity	400	kW
Mean output	99.1	kW
Capacity factor	24.8	%
Total production	868,099	kWh/yr

Variable	Value	Units
Minimum output	0.00	kW

Maximum output	395	kW
Wind penetration	27.0	%
Hours of operation	6,904	hr/yr
Levelized cost	0.384	$/kWh

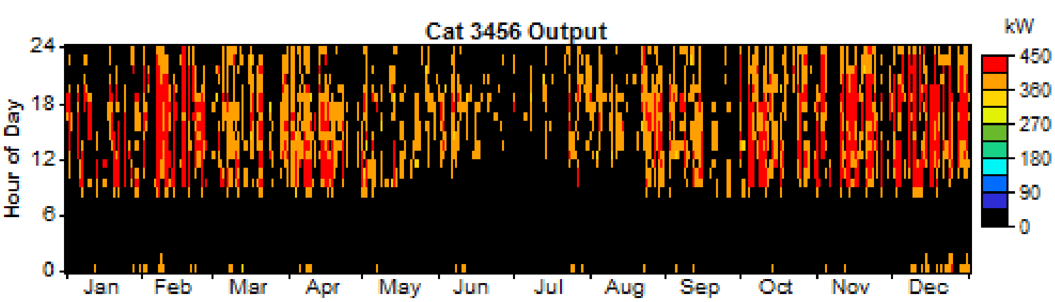


Cat 3456

Quantity	Value	Units
Hours of operation	2,103	hr/yr
Number of starts	482	starts/yr
Operational life	11.9	yr
Capacity factor	21.3	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	838,755	kWh/yr
Mean electrical output	399	kW
Min. electrical output	359	kW
Max. electrical output	450	kW
Thermal production	262,951	kWh/yr
Mean thermal output	125	kW
Min. thermal output	113	kW
Max. thermal output	140	kW

Quantity	Value	Units
Fuel consumption	206,707	L/yr
Specific fuel consumption	0.246	L/kWh
Fuel energy input	2,033,998	kWh/yr
Mean electrical efficiency	41.2	%
Mean total efficiency	54.2	%

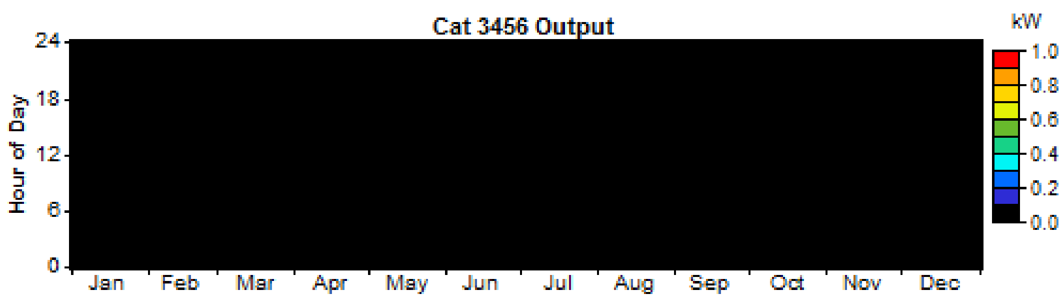


Cat 3456

Quantity	Value	Units
Hours of operation	0	hr/yr
Number of starts	0	starts/yr
Operational life	1,000	yr
Capacity factor	0.00	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	0.00	kWh/yr
Mean electrical output	0.00	kW
Min. electrical output	0.00	kW
Max. electrical output	0.00	kW
Thermal production	0.00	kWh/yr
Mean thermal output	0.00	kW
Min. thermal output	0.00	kW
Max. thermal output	0.00	kW

Quantity	Value	Units
Fuel consumption	0	L/yr
Specific fuel consumption	0.000	L/kWh
Fuel energy input	0	kWh/yr
Mean electrical efficiency	0.0	%
Mean total efficiency	0.0	%



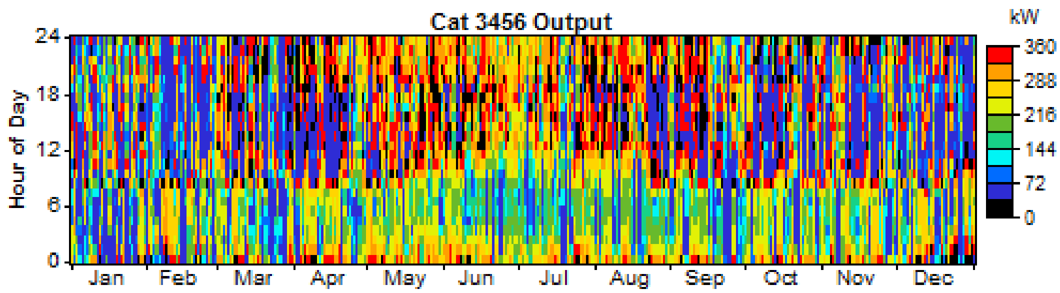
Cat 3456

Quantity	Value	Units
Hours of operation	8,163	hr/yr
Number of starts	396	starts/yr
Operational life	3.06	yr
Capacity factor	38.9	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	1,533,883	kWh/yr

Mean electrical output	188	kW
Min. electrical output	49.5	kW
Max. electrical output	359	kW
Thermal production	490,155	kWh/yr
Mean thermal output	60.0	kW
Min. thermal output	17.0	kW
Max. thermal output	113	kW

Quantity	Value	Units
Fuel consumption	382,293	L/yr
Specific fuel consumption	0.249	L/kWh
Fuel energy input	3,761,766	kWh/yr
Mean electrical efficiency	40.8	%
Mean total efficiency	53.8	%



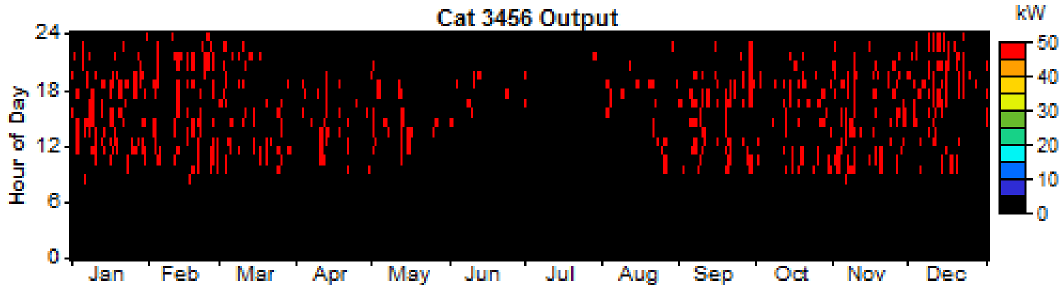
Cat 3456

Quantity	Value	Units
Hours of operation	567	hr/yr
Number of starts	368	starts/yr
Operational life	44.1	yr
Capacity factor	0.712	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	28,067	kWh/yr
Mean electrical output	49.5	kW
Min. electrical output	49.5	kW
Max. electrical output	49.5	kW
Thermal production	9,637	kWh/yr
Mean thermal output	17.0	kW
Min. thermal output	17.0	kW
Max. thermal output	17.0	kW

Quantity	Value	Units
Fuel consumption	7,304	L/yr
Specific fuel consumption	0.260	L/kWh

Fuel energy input	71,873	kWh/yr
Mean electrical efficiency	39.0	%
Mean total efficiency	52.5	%



Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,962,912
Carbon monoxide	3,876
Unburned hydocarbons	429
Particulate matter	292
Sulfur dioxide	3,957
Nitrogen oxides	34,586

Appendix F: Homer System Report of one EWT 52-900 turbine at Stebbins Site 1

System Report - St Michael-Stebbins

Sensitivity case

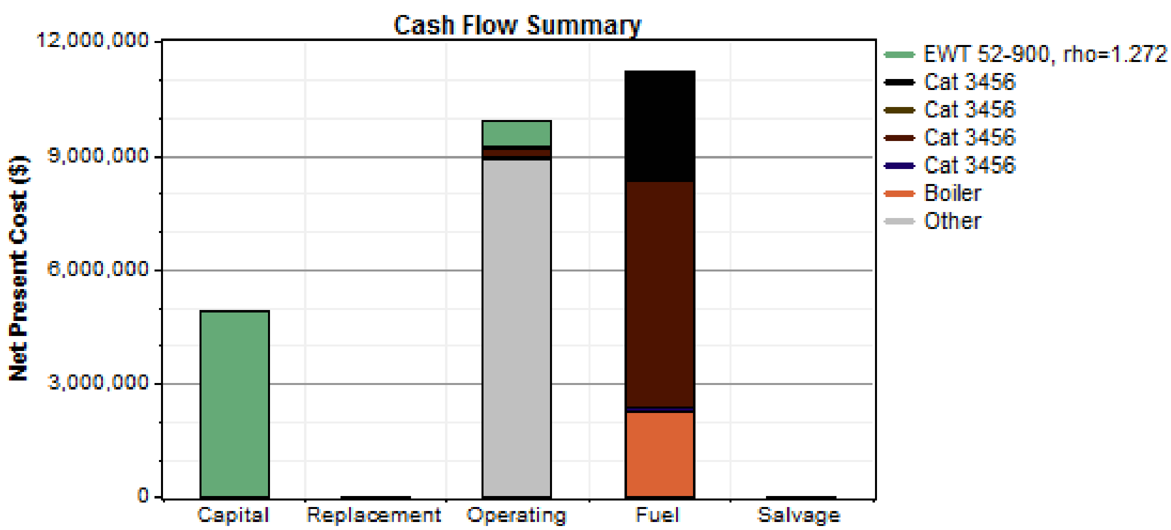
Wind Data Scaled Average:	5.9 m/s
EWT 52-900, rho=1.272 Capital Cost Multiplier:	1
Northwind100B, rho=1.272 Capital Cost Multiplier:	1
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %
Cat 3456 Heat Recovery Ratio:	22 %

System architecture

Wind turbine	1 EWT 52-900, rho=1.272
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW

Cost summary

Total net present cost	$ 25,962,162
Levelized cost of energy	$ 0.450/kWh
Operating cost	$ 1,417,374/yr



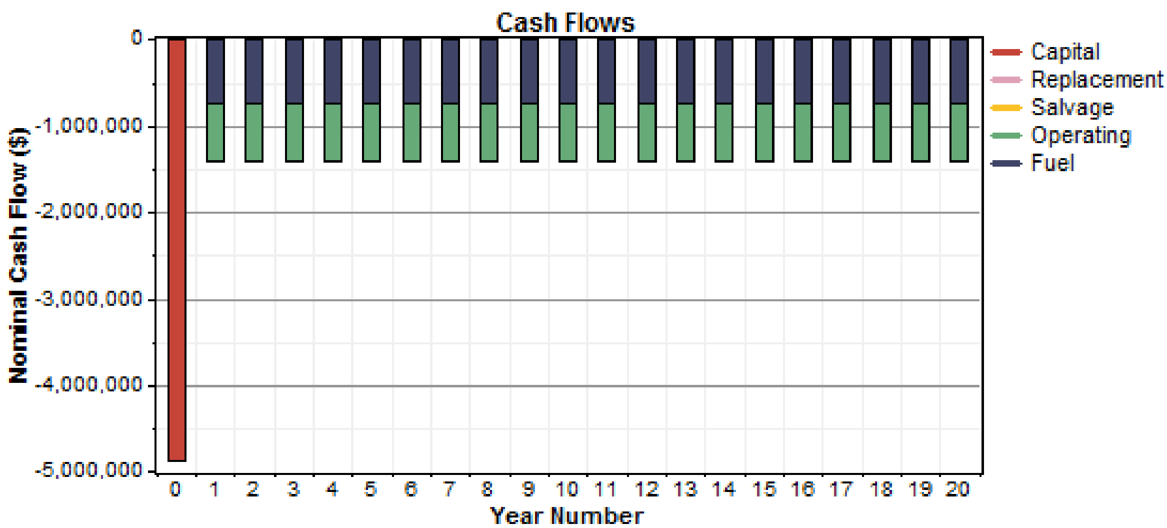
Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
EWT 52-900, rho=1.272	4,875,224	0	633,379	0	0	5,508,603
Cat 3456	0	0	53,124	2,873,506	0	2,926,631
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	262,640	5,957,029	0	6,219,669
Cat 3456	0	0	14,427	102,428	0	116,855
Boiler	0	0	0	2,263,924	0	2,263,924

Other	0	0	8,926,488	0	0	8,926,488
System	4,875,224	0	9,890,058	11,196,886	0	25,962,166

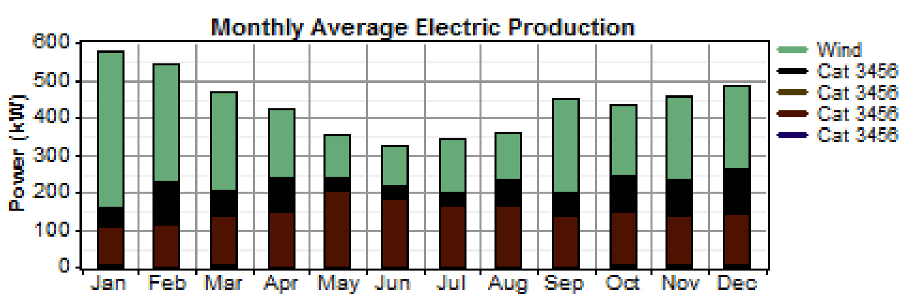
Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
EWT 52-900, rho=1.272	327,692	0	42,573	0	0	370,265
Cat 3456	0	0	3,571	193,145	0	196,716
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	17,654	400,406	0	418,059
Cat 3456	0	0	970	6,885	0	7,855
Boiler	0	0	0	152,171	0	152,171
Other	0	0	600,000	0	0	600,000
System	327,692	0	664,767	752,607	0	1,745,066



Electrical

Component	Production	Fraction
	(kWh/yr)	
Wind turbine	1,861,484	49%
Cat 3456	632,005	17%
Cat 3456	0	0%
Cat 3456	1,292,753	34%
Cat 3456	21,335	1%
Total	3,807,576	100%

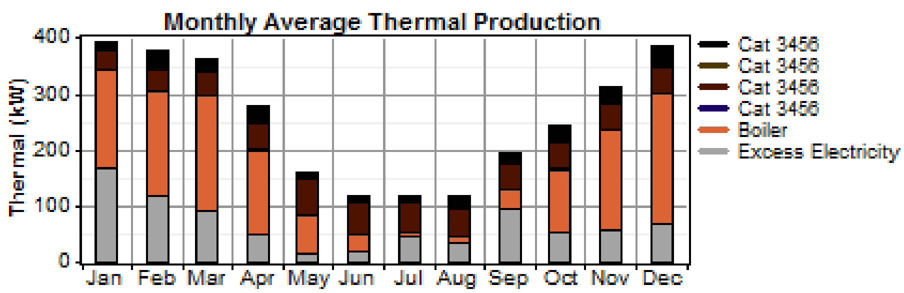


Load	Consumption	Fraction
	(kWh/yr)	
AC primary load	3,214,180	100%
Total	3,214,180	100%

Quantity	Value	Units
Excess electricity	593,384	kWh/yr
Unmet load	0.00789	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.312	

Thermal

Component	Production	Fraction
	(kWh/yr)	
Cat 3456	198,151	9%
Cat 3456	414,650	19%
Cat 3456	7,326	0%
Boiler	1,009,788	45%
Excess electricity	593,384	27%
Total	2,223,299	100%



Load	Consumption	Fraction
	(kWh/yr)	
Thermal load	1,986,697	100%
Total	1,986,697	100%

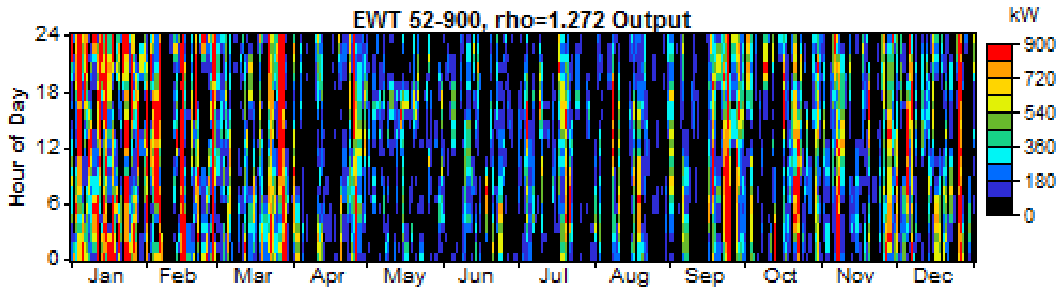
Quantity	Value	Units
Excess thermal energy	236,602	kWh/yr

AC Wind Turbine: EWT 52-900, rho=1.272

Variable	Value	Units
Total rated capacity	900	kW
Mean output	212	kW
Capacity factor	23.6	%
Total production	1,861,484	kWh/yr

Variable	Value	Units
Minimum output	0.00	kW

Maximum output	889	kW
Wind penetration	57.9	%
Hours of operation	8,032	hr/yr
Levelized cost	0.199	$/kWh

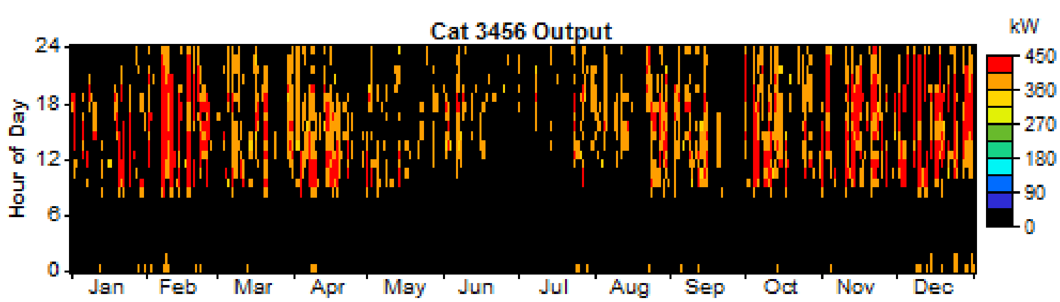


Cat 3456

Quantity	Value	Units
Hours of operation	1,587	hr/yr
Number of starts	386	starts/yr
Operational life	15.8	yr
Capacity factor	16.0	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	632,005	kWh/yr
Mean electrical output	398	kW
Min. electrical output	359	kW
Max. electrical output	450	kW
Thermal production	198,151	kWh/yr
Mean thermal output	125	kW
Min. thermal output	113	kW
Max. thermal output	140	kW

Quantity	Value	Units
Fuel consumption	155,762	L/yr
Specific fuel consumption	0.246	L/kWh
Fuel energy input	1,532,697	kWh/yr
Mean electrical efficiency	41.2	%
Mean total efficiency	54.2	%

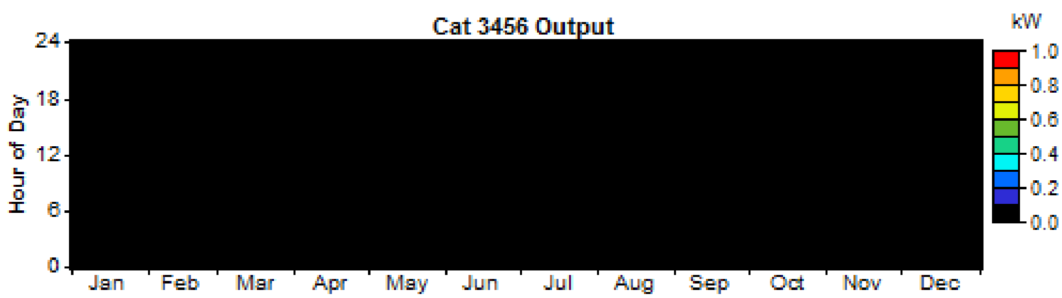


Cat 3456

Quantity	Value	Units
Hours of operation	0	hr/yr
Number of starts	0	starts/yr
Operational life	1,000	yr
Capacity factor	0.00	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	0.00	kWh/yr
Mean electrical output	0.00	kW
Min. electrical output	0.00	kW
Max. electrical output	0.00	kW
Thermal production	0.00	kWh/yr
Mean thermal output	0.00	kW
Min. thermal output	0.00	kW
Max. thermal output	0.00	kW

Quantity	Value	Units
Fuel consumption	0	L/yr
Specific fuel consumption	0.000	L/kWh
Fuel energy input	0	kWh/yr
Mean electrical efficiency	0.0	%
Mean total efficiency	0.0	%



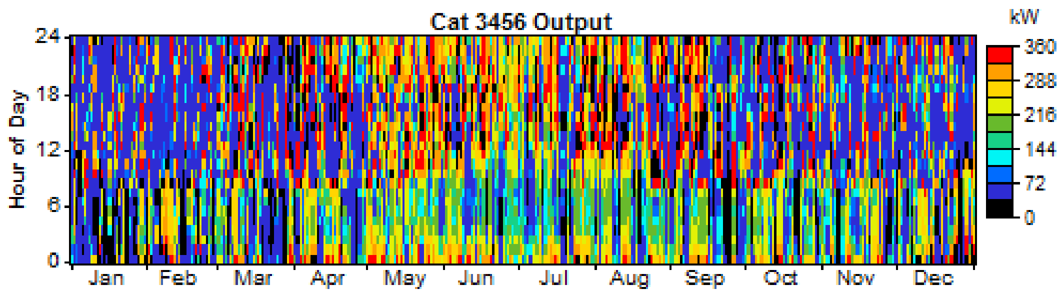
Cat 3456

Quantity	Value	Units
Hours of operation	7,846	hr/yr
Number of starts	414	starts/yr
Operational life	3.19	yr
Capacity factor	32.8	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	1,292,753	kWh/yr

Mean electrical output	165	kW
Min. electrical output	49.5	kW
Max. electrical output	359	kW
Thermal production	414,650	kWh/yr
Mean thermal output	52.8	kW
Min. thermal output	17.0	kW
Max. thermal output	113	kW

Quantity	Value	Units
Fuel consumption	322,908	L/yr
Specific fuel consumption	0.250	L/kWh
Fuel energy input	3,177,414	kWh/yr
Mean electrical efficiency	40.7	%
Mean total efficiency	53.7	%



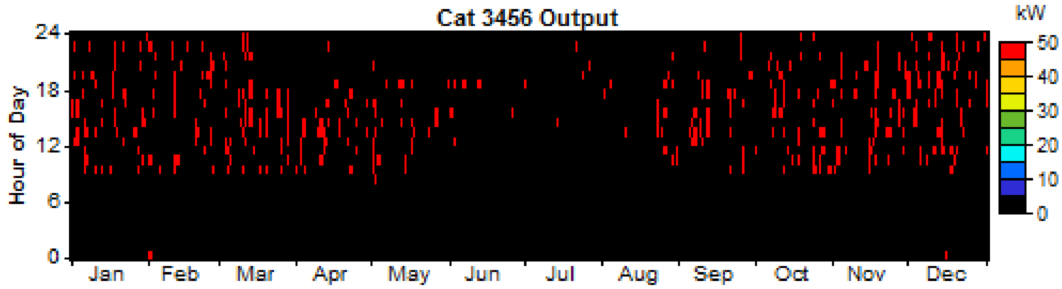
Cat 3456

Quantity	Value	Units
Hours of operation	431	hr/yr
Number of starts	305	starts/yr
Operational life	58.0	yr
Capacity factor	0.541	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	21,335	kWh/yr
Mean electrical output	49.5	kW
Min. electrical output	49.5	kW
Max. electrical output	49.5	kW
Thermal production	7,326	kWh/yr
Mean thermal output	17.0	kW
Min. thermal output	17.0	kW
Max. thermal output	17.0	kW

Quantity	Value	Units
Fuel consumption	5,552	L/yr
Specific fuel consumption	0.260	L/kWh

Fuel energy input	54,634	kWh/yr
Mean electrical efficiency	39.0	%
Mean total efficiency	52.5	%



Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,599,813
Carbon monoxide	3,147
Unburned hydocarbons	349
Particulate matter	237
Sulfur dioxide	3,225
Nitrogen oxides	28,085

Appendix G: Homer System Report of four Northern Power 100 ARCTIC turbines at Stebbins Site 2

System Report - St Michael-Stebbins

Sensitivity case

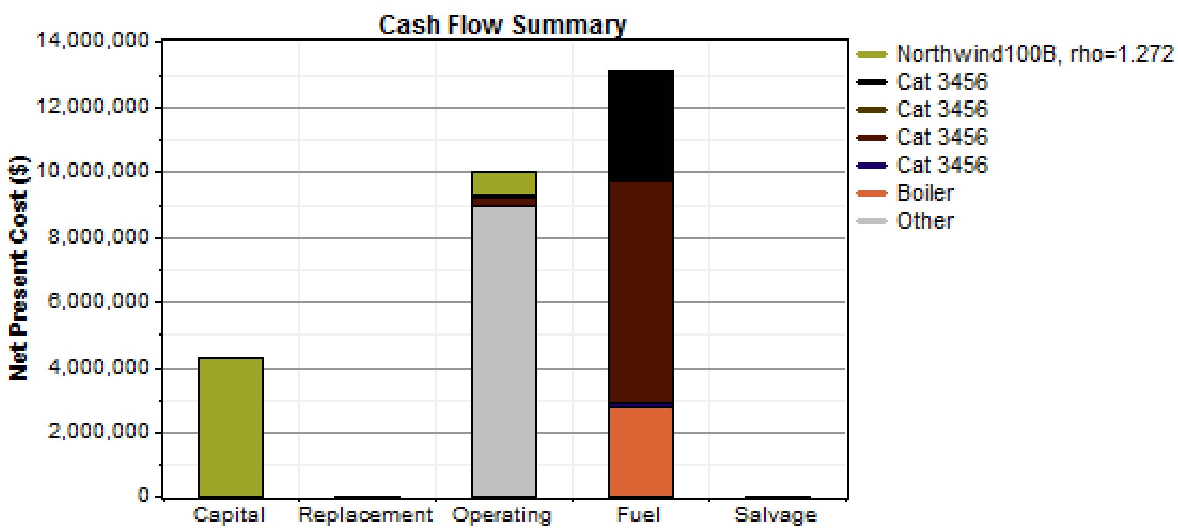
Wind Data Scaled Average:	6.5	m/s
EWT 52-900, rho=1.272 Capital Cost Multiplier:	1.02	
Northwind100B, rho=1.272 Capital Cost Multiplier:	1.02	
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%

System architecture

Wind turbine	4 Northwind100B, rho=1.272
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW

Cost summary

Total net present cost	$ 27,431,442
Levelized cost of energy	$ 0.481/kWh
Operating cost	$ 1,554,466/yr



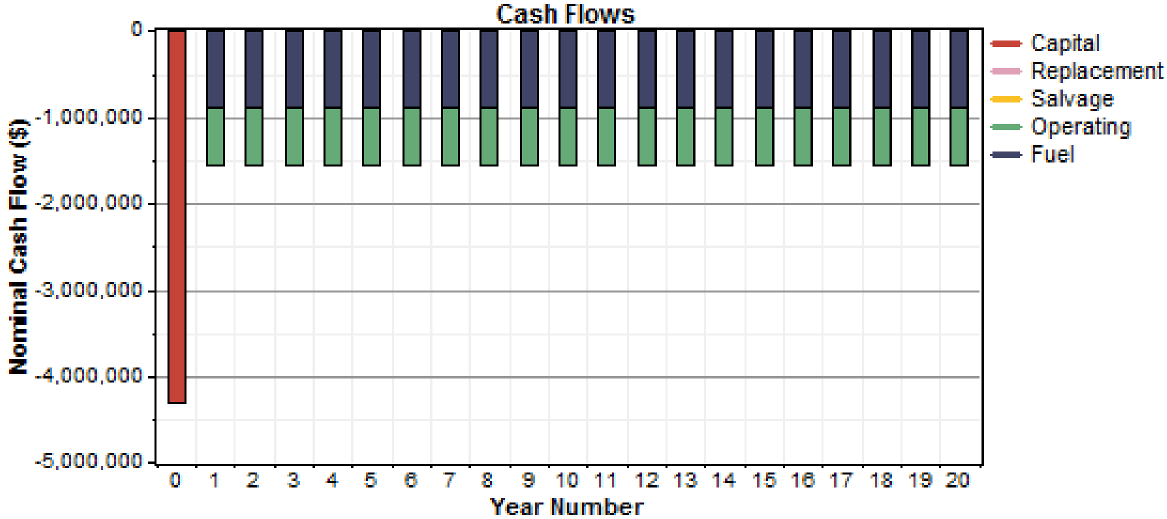
Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Northwind100B, rho=1.272	4,304,910	0	733,460	0	0	5,038,370
Cat 3456	0	0	61,961	3,352,907	0	3,414,867
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	275,795	6,844,977	0	7,120,772
Cat 3456	0	0	17,842	126,668	0	144,510
Boiler	0	0	0	2,786,443	0	2,786,443

Other	0	0	8,926,488	0	0	8,926,488
System	4,304,910	0	10,015,545	13,110,994	0	27,431,448

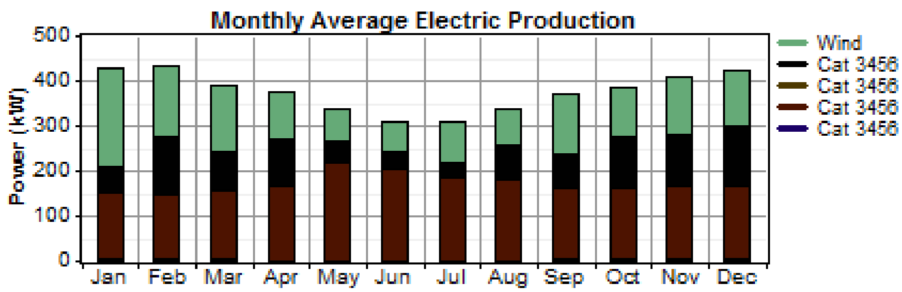
Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
Northwind100B, rho=1.272	289,358	0	49,300	0	0	338,658
Cat 3456	0	0	4,165	225,368	0	229,533
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	18,538	460,090	0	478,628
Cat 3456	0	0	1,199	8,514	0	9,713
Boiler	0	0	0	187,293	0	187,293
Other	0	0	600,000	0	0	600,000
System	289,358	0	673,202	881,265	0	1,843,824



Electrical

Component	Production	Fraction
	(kWh/yr)	
Wind turbines	1,042,057	32%
Cat 3456	737,454	22%
Cat 3456	0	0%
Cat 3456	1,487,776	45%
Cat 3456	26,384	1%
Total	3,293,671	100%

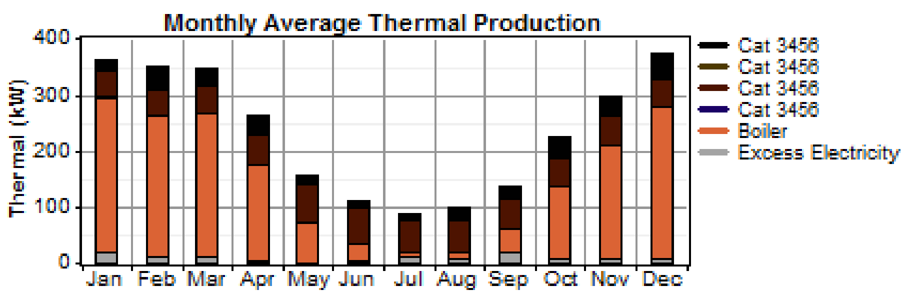


Load	Consumption	Fraction
	(kWh/yr)	
AC primary load	3,214,180	100%
Total	3,214,180	100%

Quantity	Value	Units
Excess electricity	79,478	kWh/yr
Unmet load	0.00861	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.190	

Thermal

Component	Production	Fraction
	(kWh/yr)	
Cat 3456	231,207	11%
Cat 3456	475,937	23%
Cat 3456	9,059	0%
Boiler	1,242,849	61%
Excess electricity	79,478	4%
Total	2,038,529	100%



Load	Consumption	Fraction
	(kWh/yr)	
Thermal load	1,986,697	100%
Total	1,986,697	100%

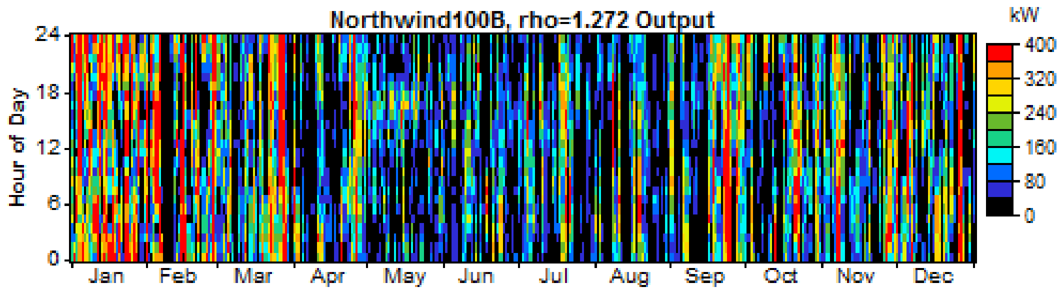
Quantity	Value	Units
Excess thermal energy	51,832	kWh/yr

AC Wind Turbine: Northwind100B, rho=1.272

Variable	Value	Units
Total rated capacity	400	kW
Mean output	119	kW
Capacity factor	29.7	%
Total production	1,042,057	kWh/yr

Variable	Value	Units
Minimum output	0.00	kW

Maximum output	395	kW
Wind penetration	32.4	%
Hours of operation	7,230	hr/yr
Levelized cost	0.325	$/kWh

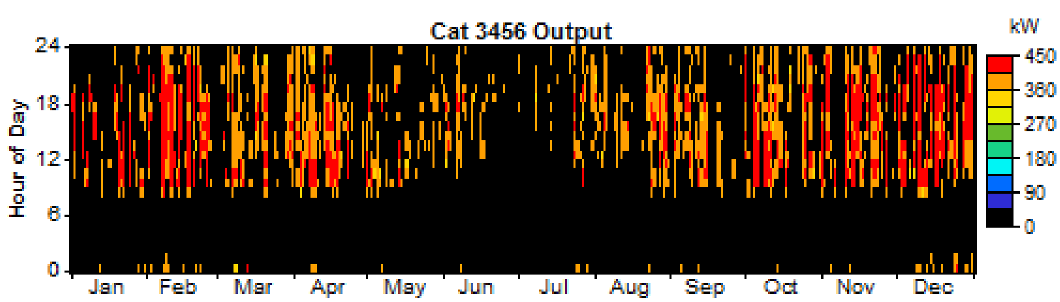


Cat 3456

Quantity	Value	Units
Hours of operation	1,851	hr/yr
Number of starts	426	starts/yr
Operational life	13.5	yr
Capacity factor	18.7	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	737,454	kWh/yr
Mean electrical output	398	kW
Min. electrical output	359	kW
Max. electrical output	450	kW
Thermal production	231,207	kWh/yr
Mean thermal output	125	kW
Min. thermal output	113	kW
Max. thermal output	140	kW

Quantity	Value	Units
Fuel consumption	181,748	L/yr
Specific fuel consumption	0.246	L/kWh
Fuel energy input	1,788,404	kWh/yr
Mean electrical efficiency	41.2	%
Mean total efficiency	54.2	%

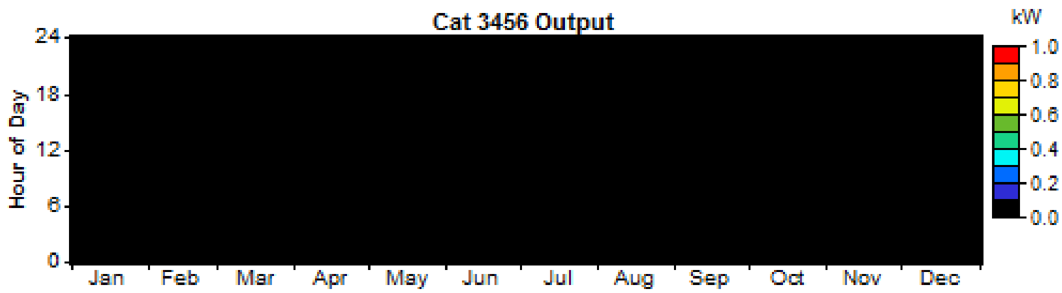


Cat 3456

Quantity	Value	Units
Hours of operation	0	hr/yr
Number of starts	0	starts/yr
Operational life	1,000	yr
Capacity factor	0.00	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	0.00	kWh/yr
Mean electrical output	0.00	kW
Min. electrical output	0.00	kW
Max. electrical output	0.00	kW
Thermal production	0.00	kWh/yr
Mean thermal output	0.00	kW
Min. thermal output	0.00	kW
Max. thermal output	0.00	kW

Quantity	Value	Units
Fuel consumption	0	L/yr
Specific fuel consumption	0.000	L/kWh
Fuel energy input	0	kWh/yr
Mean electrical efficiency	0.0	%
Mean total efficiency	0.0	%



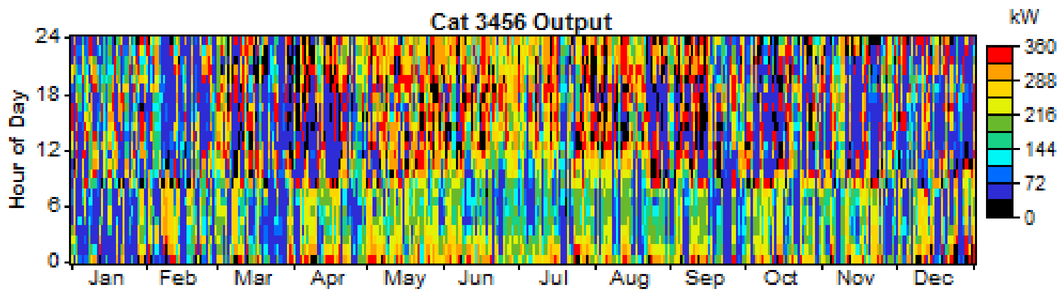
Cat 3456

Quantity	Value	Units
Hours of operation	8,239	hr/yr
Number of starts	342	starts/yr
Operational life	3.03	yr
Capacity factor	37.7	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	1,487,776	kWh/yr

Mean electrical output	181	kW
Min. electrical output	49.5	kW
Max. electrical output	359	kW
Thermal production	475,937	kWh/yr
Mean thermal output	57.8	kW
Min. thermal output	17.0	kW
Max. thermal output	113	kW

Quantity	Value	Units
Fuel consumption	371,040	L/yr
Specific fuel consumption	0.249	L/kWh
Fuel energy input	3,651,036	kWh/yr
Mean electrical efficiency	40.7	%
Mean total efficiency	53.8	%



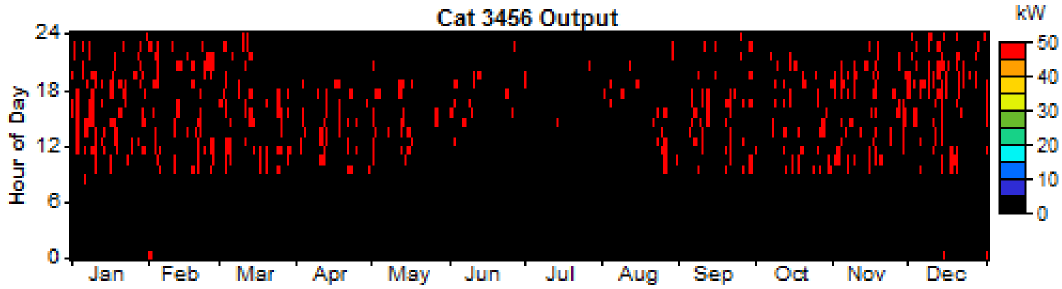
Cat 3456

Quantity	Value	Units
Hours of operation	533	hr/yr
Number of starts	345	starts/yr
Operational life	46.9	yr
Capacity factor	0.669	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	26,384	kWh/yr
Mean electrical output	49.5	kW
Min. electrical output	49.5	kW
Max. electrical output	49.5	kW
Thermal production	9,059	kWh/yr
Mean thermal output	17.0	kW
Min. thermal output	17.0	kW
Max. thermal output	17.0	kW

Quantity	Value	Units
Fuel consumption	6,866	L/yr
Specific fuel consumption	0.260	L/kWh

Fuel energy input	67,564	kWh/yr
Mean electrical efficiency	39.0	%
Mean total efficiency	52.5	%



Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,873,393
Carbon monoxide	3,638
Unburned hydocarbons	403
Particulate matter	274
Sulfur dioxide	3,777
Nitrogen oxides	32,460

Appendix H: Homer System Report of one EWT 52-900 turbine at Stebbins Site 2

System Report - St Michael-Stebbins

Sensitivity case

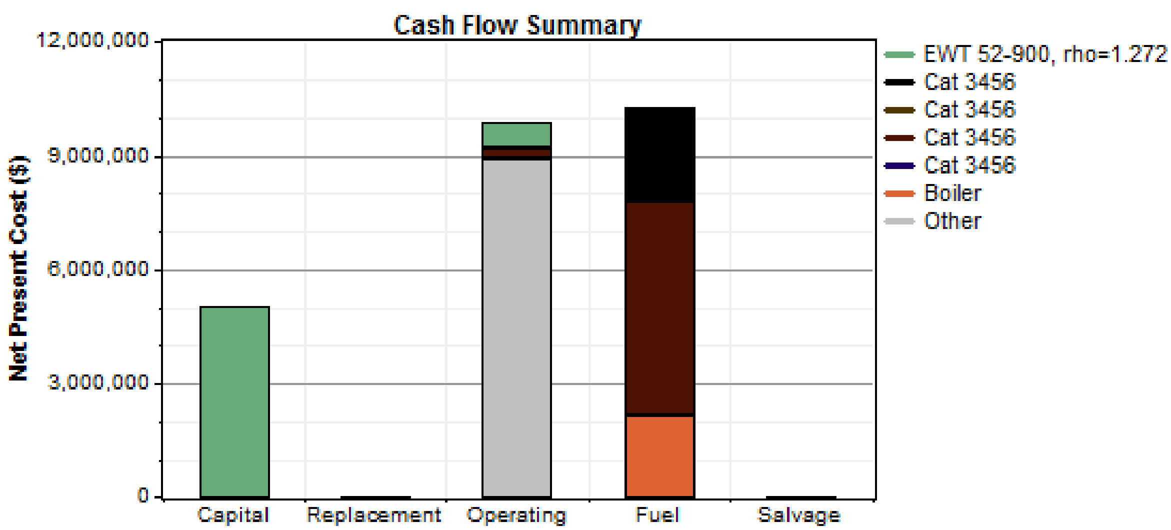
Wind Data Scaled Average:	6.5	m/s
EWT 52-900, rho=1.272 Capital Cost Multiplier:	1.02	
Northwind100B, rho=1.272 Capital Cost Multiplier:	1.02	
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%
Cat 3456 Heat Recovery Ratio:	22	%

System architecture

Wind turbine	1 EWT 52-900, rho=1.272
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW
Cat 3456	450 kW

Cost summary

Total net present cost	$ 25,117,220
Levelized cost of energy	$ 0.432/kWh
Operating cost	$ 1,352,388/yr



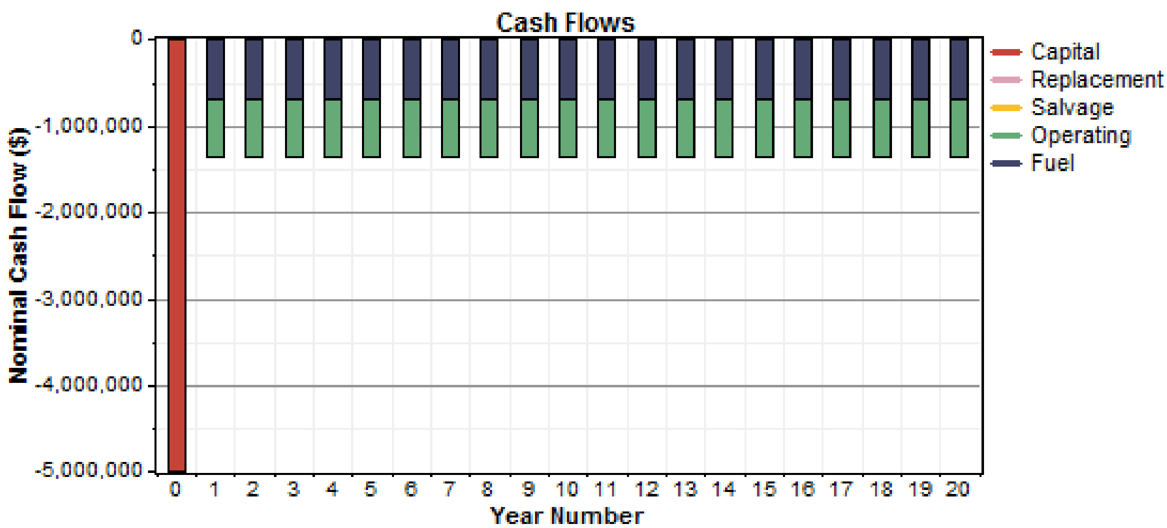
Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
EWT 52-900, rho=1.272	4,997,105	0	633,379	0	0	5,630,484
Cat 3456	0	0	45,960	2,484,351	0	2,530,311
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	259,192	5,536,841	0	5,796,032
Cat 3456	0	0	12,955	91,971	0	104,926
Boiler	0	0	0	2,128,988	0	2,128,988

Other	0	0	8,926,488	0	0	8,926,488
System	4,997,105	0	9,877,973	10,242,150	0	25,117,226

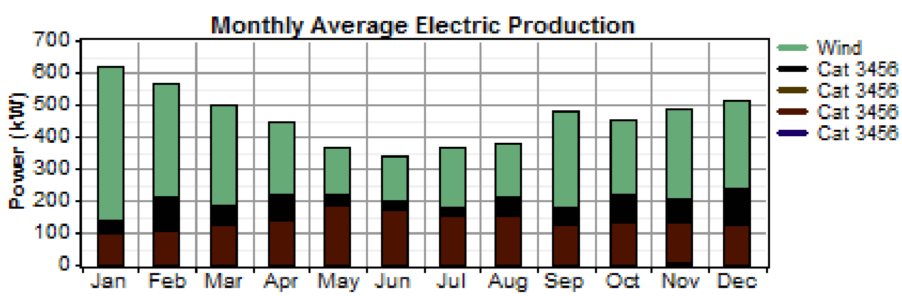
Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
EWT 52-900, rho=1.272	335,884	0	42,573	0	0	378,457
Cat 3456	0	0	3,089	166,987	0	170,077
Cat 3456	0	0	0	0	0	0
Cat 3456	0	0	17,422	372,163	0	389,584
Cat 3456	0	0	871	6,182	0	7,053
Boiler	0	0	0	143,101	0	143,101
Other	0	0	600,000	0	0	600,000
System	335,884	0	663,955	688,433	0	1,688,272



Electrical

Component	Production	Fraction
	(kWh/yr)	
Wind turbine	2,255,650	56%
Cat 3456	546,401	14%
Cat 3456	0	0%
Cat 3456	1,200,218	30%
Cat 3456	19,157	0%
Total	4,021,426	100%

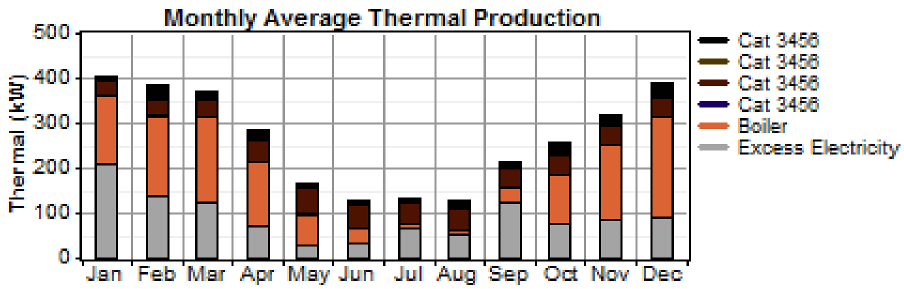


Load	Consumption	Fraction
	(kWh/yr)	
AC primary load	3,214,180	100%
Total	3,214,180	100%

Quantity	Value	Units
Excess electricity	807,227	kWh/yr
Unmet load	0.00716	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.370	

Thermal

Component	Production	Fraction
	(kWh/yr)	
Cat 3456	171,319	7%
Cat 3456	385,704	17%
Cat 3456	6,578	0%
Boiler	949,602	41%
Excess electricity	807,227	35%
Total	2,320,430	100%



Load	Consumption	Fraction
	(kWh/yr)	
Thermal load	1,986,697	100%
Total	1,986,697	100%

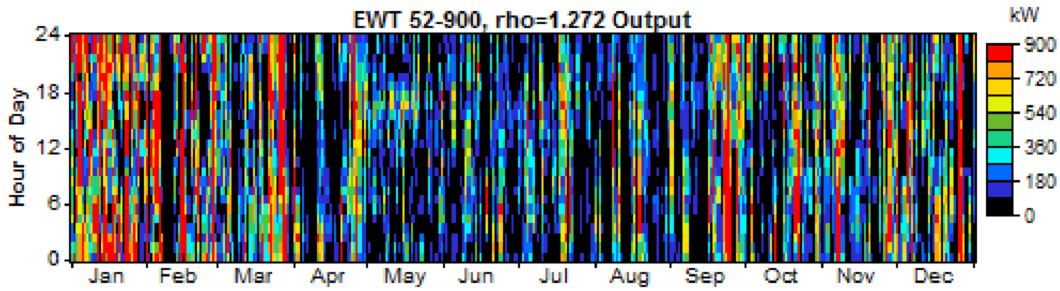
Quantity	Value	Units
Excess thermal energy	333,733	kWh/yr

AC Wind Turbine: EWT 52-900, rho=1.272

Variable	Value	Units
Total rated capacity	900	kW
Mean output	257	kW
Capacity factor	28.6	%
Total production	2,255,650	kWh/yr

Variable	Value	Units
Minimum output	0.00	kW

Maximum output	889	kW
Wind penetration	70.2	%
Hours of operation	8,149	hr/yr
Levelized cost	0.168	$/kWh

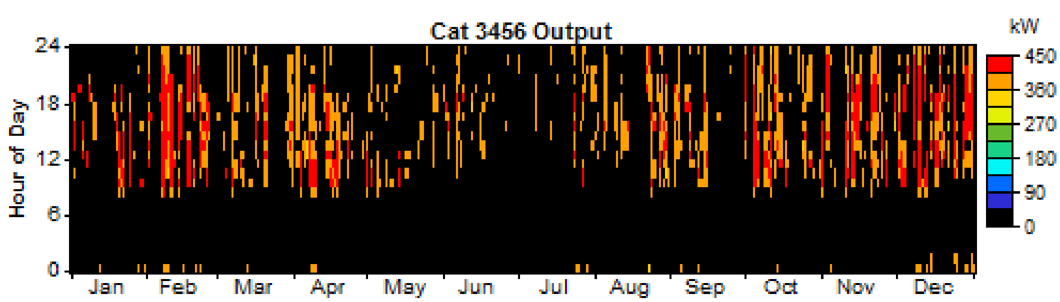


Cat 3456

Quantity	Value	Units
Hours of operation	1,373	hr/yr
Number of starts	343	starts/yr
Operational life	18.2	yr
Capacity factor	13.9	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	546,401	kWh/yr
Mean electrical output	398	kW
Min. electrical output	359	kW
Max. electrical output	450	kW
Thermal production	171,319	kWh/yr
Mean thermal output	125	kW
Min. thermal output	113	kW
Max. thermal output	140	kW

Quantity	Value	Units
Fuel consumption	134,667	L/yr
Specific fuel consumption	0.246	L/kWh
Fuel energy input	1,325,126	kWh/yr
Mean electrical efficiency	41.2	%
Mean total efficiency	54.2	%

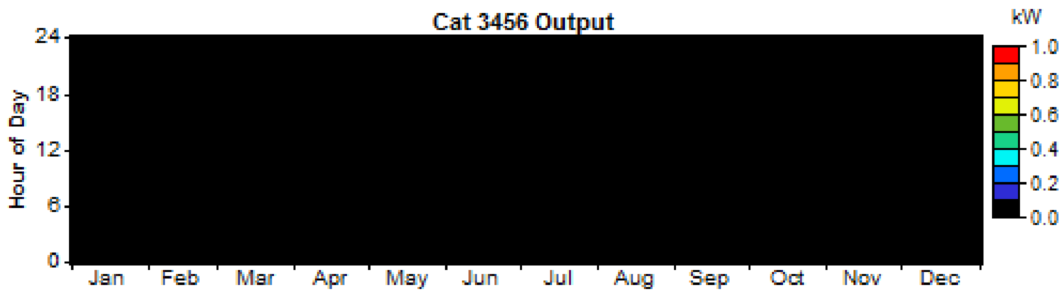


Cat 3456

Quantity	Value	Units
Hours of operation	0	hr/yr
Number of starts	0	starts/yr
Operational life	1,000	yr
Capacity factor	0.00	%
Fixed generation cost	6.33	$/hr
Marginal generation cost	0.295	$/kWhyr

Quantity	Value	Units
Electrical production	0.00	kWh/yr
Mean electrical output	0.00	kW
Min. electrical output	0.00	kW
Max. electrical output	0.00	kW
Thermal production	0.00	kWh/yr
Mean thermal output	0.00	kW
Min. thermal output	0.00	kW
Max. thermal output	0.00	kW

Quantity	Value	Units
Fuel consumption	0	L/yr
Specific fuel consumption	0.000	L/kWh
Fuel energy input	0	kWh/yr
Mean electrical efficiency	0.0	%
Mean total efficiency	0.0	%



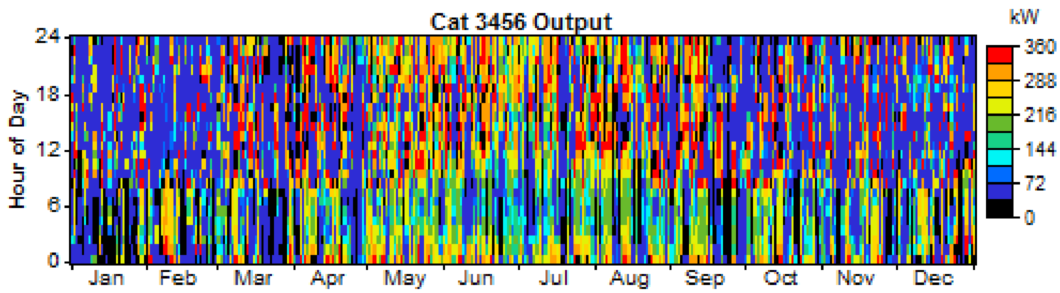
Cat 3456

Quantity	Value	Units
Hours of operation	7,743	hr/yr
Number of starts	413	starts/yr
Operational life	3.23	yr
Capacity factor	30.4	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	1,200,218	kWh/yr

Mean electrical output	155	kW
Min. electrical output	49.5	kW
Max. electrical output	359	kW
Thermal production	385,704	kWh/yr
Mean thermal output	49.8	kW
Min. thermal output	17.0	kW
Max. thermal output	113	kW

Quantity	Value	Units
Fuel consumption	300,131	L/yr
Specific fuel consumption	0.250	L/kWh
Fuel energy input	2,953,290	kWh/yr
Mean electrical efficiency	40.6	%
Mean total efficiency	53.7	%



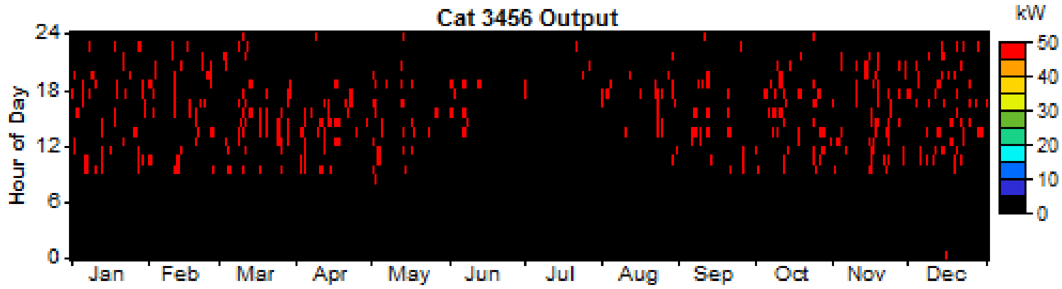
Cat 3456

Quantity	Value	Units
Hours of operation	387	hr/yr
Number of starts	294	starts/yr
Operational life	64.6	yr
Capacity factor	0.486	%
Fixed generation cost	3.17	$/hr
Marginal generation cost	0.304	$/kWhyr

Quantity	Value	Units
Electrical production	19,157	kWh/yr
Mean electrical output	49.5	kW
Min. electrical output	49.5	kW
Max. electrical output	49.5	kW
Thermal production	6,578	kWh/yr
Mean thermal output	17.0	kW
Min. thermal output	17.0	kW
Max. thermal output	17.0	kW

Quantity	Value	Units
Fuel consumption	4,985	L/yr
Specific fuel consumption	0.260	L/kWh

Fuel energy input	49,056	kWh/yr
Mean electrical efficiency	39.1	%
Mean total efficiency	52.5	%



Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,463,440
Carbon monoxide	2,859
Unburned hydocarbons	317
Particulate matter	215
Sulfur dioxide	2,950
Nitrogen oxides	25,507