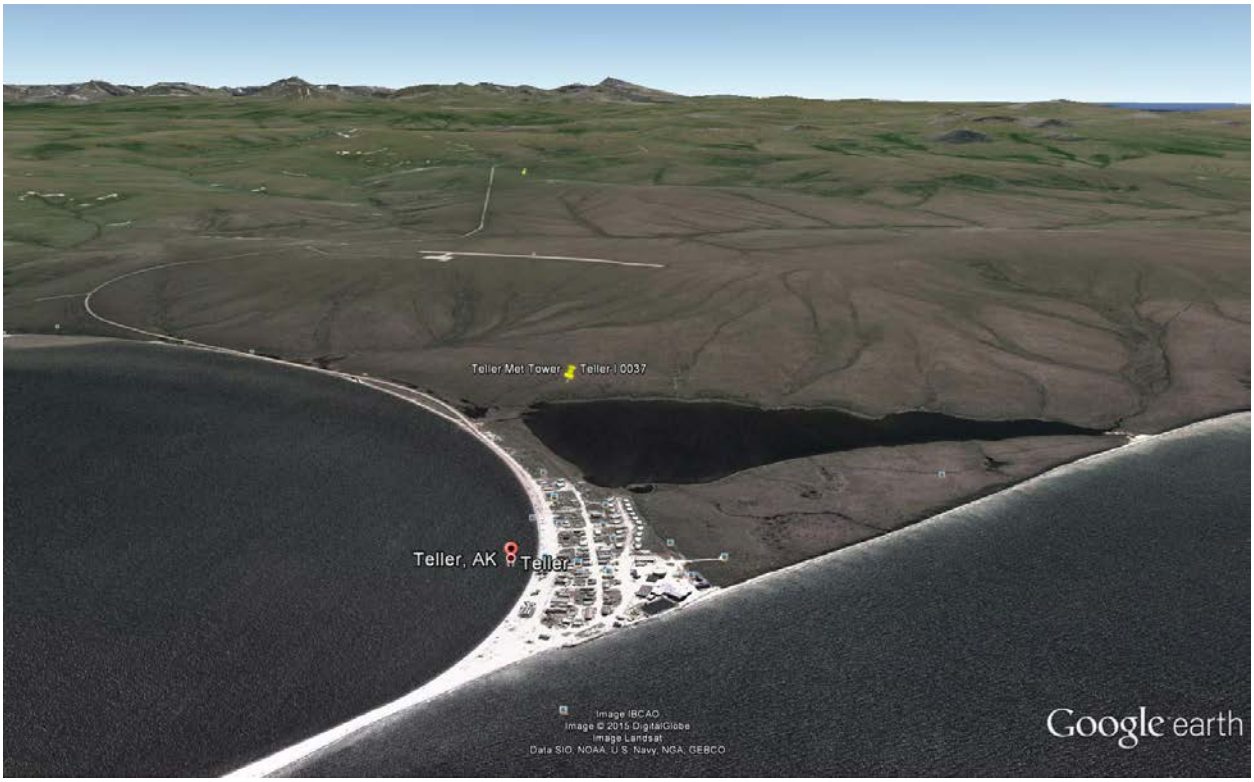
Teller, Alaska
Wind Resource Report



Teller, Google Earth image

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Contents

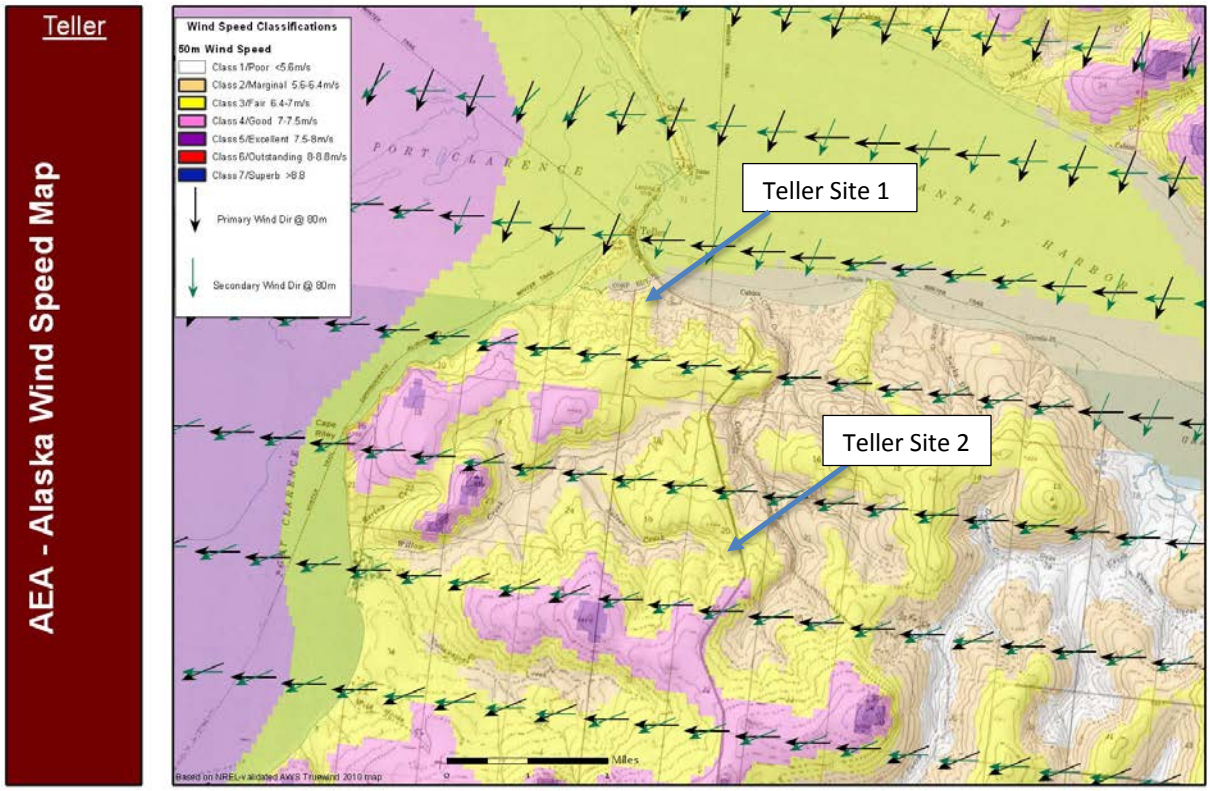
Summary

Alaska Village Electric Cooperative (AVEC), as the utility for Teller and nearby Brevig Mission, initiated a wind resource study in Teller in 2009 to identify a suitable site for wind turbines to supply Teller with wind energy. This initial effort focused on identifying a met tower site (referred to as Site 1) near Teller as project development construction costs would be relatively low and a project was presumed to be modest.

After installation of the Site 1 (also referred to as site 0037) met tower, AVEC began planning an overland electrical intertie to link Teller to the larger village of Brevig Mission located across the bay to the north. About this time, wind data collected from Site 1 indicated a lower-than-desired wind resource. Because an intertie with Brevig Mission would enable a larger wind power project, a site with a more robust wind resource was sought. A second met tower site (Site 2, or site 9037) was chosen south of the Teller airport.

The first met tower (at Site 1) was erected in November 2009 and was operational through September 2014. The Site 2 met tower was erected in May 2011 and was operational through September 2014.

AEA high resolution wind map, Teller



The high resolution wind map predicted a Class 2 to 3 wind resource at Site 1 and a Class 3 to 4 wind resource at Site 2. These predictions were verified with met tower data from both towers, which indicate Class 3 wind as Site 1 (site 0037) and Class 4 winds at Site 2 (site 9037). The tradeoff is that

although Site 2 (9037) has a superior wind resource to Site 1 (0037), it is further distance from Teller and development costs would be significantly higher.

Teller met towers, Site 1 (0037 and Site 2 (9037), Google Earth image, view east

Site 1 (0037), Near-Village

This met tower was erected in 2009 and decommissioned in 2014. It operated concurrently with the second met tower after it was installed in 2011.

Met Tower Location

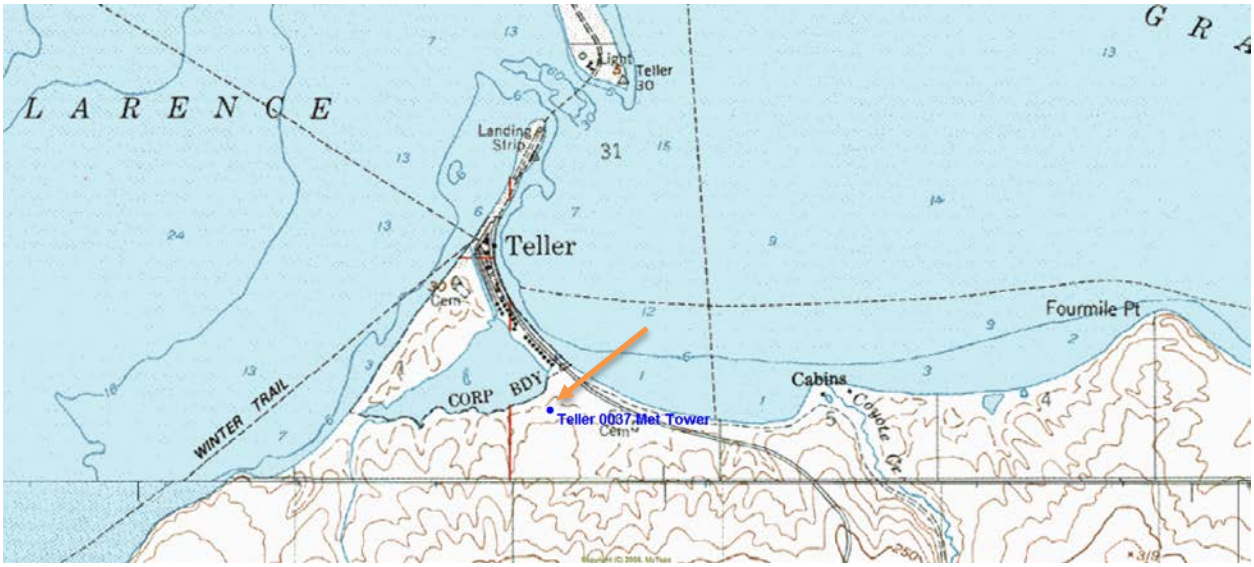
At the time of site selection, a wind project was anticipated to serve only Teller, hence the desire to identify a location with a presumed low cost of development and ease of access.

Data Synopsis

Data dates	Nov. 3, 2009 to Sept. 8, 2014 (Jan. 3, 2013 to Aug. 24, 2013 data missing)
Wind power class	Class 3 (fair); by wind power density
Wind power density mean, 26 m	272 W/m^2
Wind speed mean, 26 m	5.60 m/s (12.5 mph)
Max. 10-min avg. wind speed	28.4 m/s (63.5 mph)
Maximum 2-sec. wind gust	34.8 m/s (77.8 mph), Nov. 2013
Weibull distribution parameters	k = 1.63, c = 6.22 m/s
IEC 61400-1, 3rd ed. classification	Class III-C at 26 meters
Turbulence intensity, mean (at 40 m)	0.089 (at 15 m/s)
Calm wind frequency (at 26 m)	36% (< 4 m/s)

Teller met tower Site 1, Google Earth image, view north

Topographic map



Site information

Logger site number	0037
Site description	1,100 meters southeast of village center, near lagoon shore
Latitude/longitude	N 65° 15.257’; W 166° 21.237’”, WGS 84
Site elevation	22 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 152 mm diameter, installed at 26 meters

Tower sensor information

Note installation of all three anemometers at the top of the met tower, hence the inability to calculate wind shear power law coefficient and site roughness. Due to a missing tower section, also note that the met tower was installed at 26 meters height, not 30 meters as designed.

Sensor documentation

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	**25.6 m**	0.765	0.35	010° T
2	NRG #40 anemometer	**25.9 m**	0.765	0.35	182° T
3	NRG #40 anemometer	**26.2 m**	0.765	0.35	092° T
7	NRG #200P wind vane	26 m	0.351	357	002° T
9	NRG #110S Temp C	4.5 m	0.136	-86.383	east
12	Voltmeter	2 m	0.021	0	n/a

Photo, Site 1 met tower

STG photo

Data Quality Control

Data was filtered to remove presumed icing events that yield false zero wind speed data and non-variant wind direction data. Typically met tower data can be automatically filtered for icing, but icing events were so minimal that ice data was filtered by manual identification. Because all three anemometers were installed at the top of the tower, filtering for tower shadow was not accomplished. Note that the 8.5 months of missing data in 2013 are not included in the valid records column, resulting in lower recovery rate than represented only by icing data, which was extremely minimal.

Sensor data recovery table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Icing Records
Speed 25 m	m/s	25.6 m	251,268	220,942	87.9	976
Speed 26 m A	m/s	25.9 m	251,268	220,966	87.9	952
Speed 26 m B	m/s	26.2 m	251,268	220,885	87.9	1,033
Direction 26 m	°	26 m	251,268	219,326	87.3	2,592

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Icing Records
Temperature	°C		251,268	221,918	88.3	0

Wind Speed

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

Anemometer data summary

Variable	Speed 25 m	Speed 26 m A	Speed 26 m B
Measurement height (m)	25.6	25.9	26.2
Mean wind speed (m/s), raw data	5.48	5.57	5.50
Mean wind speed (m/s), filtered, icing	5.51	5.60	5.52
Median wind speed (m/s)	5.10	5.20	5.10
Max 10 min. avg. wind speed (m/s)	26.2	28.4	26.7
Max 2 second gust (m/s)	34.4	34.0	34.8
Weibull k	1.63	1.63	1.68
Weibull c (m/s)	6.11	6.22	6.16
Mean power density (W/m²)	255	272	253
Mean energy content (kWh/m²/yr)	2,231	2,380	2,214
Energy pattern factor	2.34	2.38	2.30
Frequency of calms (%)	35.9	35.7	36.3

Time Series

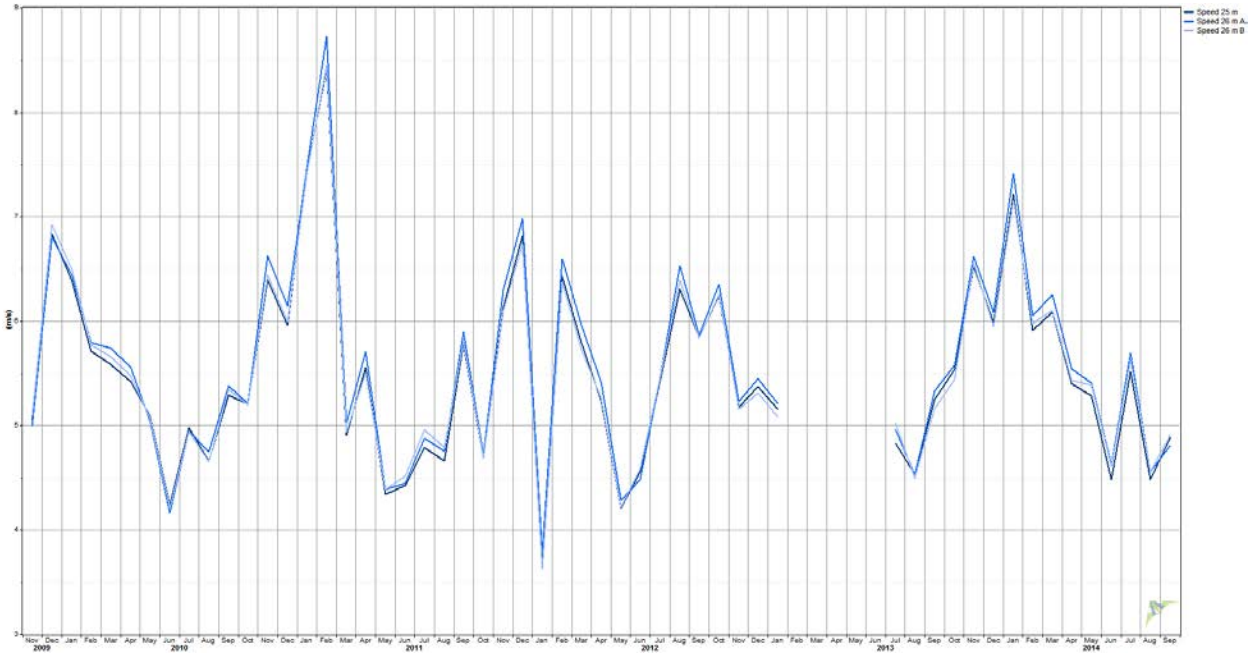
Time series calculations indicate higher wind speeds during the winter months with more moderate wind speeds during summer months, as one would expect. The daily wind profiles indicate relatively low diurnal variation with highest wind speeds during the afternoon hours.

26 m A anemometer data (filtered) summary

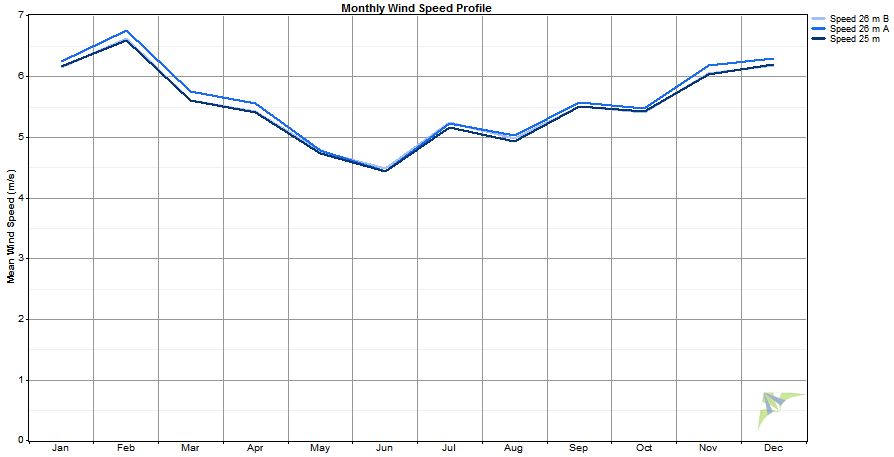
Month	Mean (m/s)	Median (m/s)	Max (m/s)	Gust (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Jan	6.25	5.90	23.1	28.7	3.82	1.61	6.93
Feb	6.76	6.20	28.4	34.0	4.33	1.60	7.53
Mar	5.75	5.50	19.2	23.7	3.26	1.75	6.41
Apr	5.56	5.10	22.2	26.8	3.37	1.67	6.20
May	4.78	4.50	21.6	24.8	2.78	1.69	5.32
Jun	4.43	4.40	13.5	16.4	2.49	1.70	4.91
Jul	5.23	4.90	21.9	26.8	3.14	1.63	5.79
Aug	5.03	4.70	22.1	30.2	2.99	1.67	5.59
Sep	5.57	5.20	20.6	25.6	3.14	1.77	6.22
Oct	5.46	5.20	22.8	28.7	2.99	1.83	6.11
Nov	6.17	5.40	26.5	31.8	4.04	1.57	6.87

Month	Mean (m/s)	Median (m/s)	Max (m/s)	Gust (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Dec	6.29	5.70	25.6	31.3	3.84	1.65	7.01
Annual	5.61	5.23	22.3	34.0	3.35	1.68	6.24

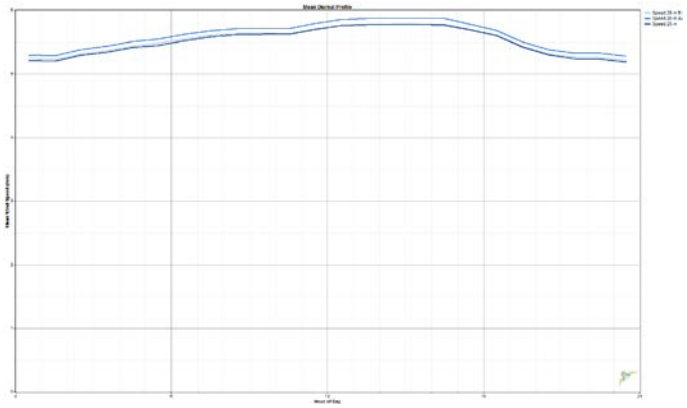
Monthly time series, mean wind speeds



Monthly time series, annualized, mean wind speeds



Daily wind profile

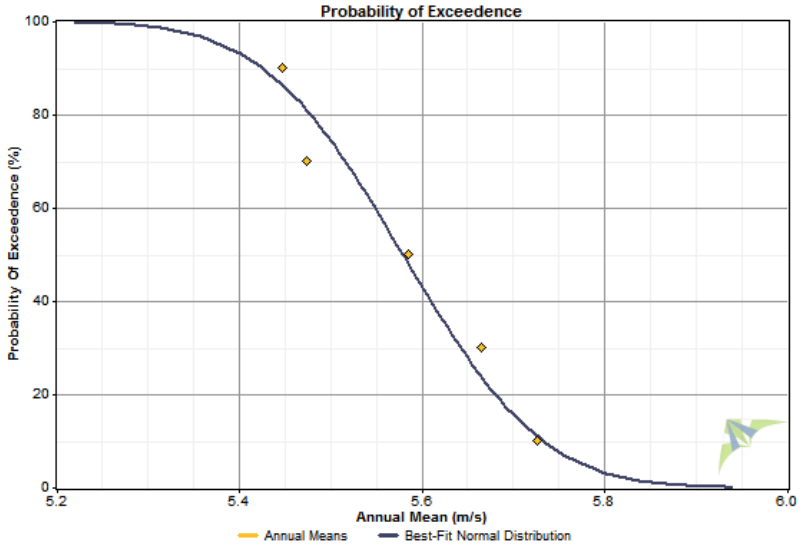


Probability of Exceedance

Probability of exceedance is an analysis of the distribution of annual mean wind speeds with estimates of the probability that the annual mean will exceed certain values.

Probability of exceedance table and graph, 26 m A anemometer (filtered)

%	Actual Dist. m/s	Normal Dist. m/s
P99		5.299
P95		5.379
P90		5.423
P75	5.447	5.496
P50	5.473	5.576
P25	5.665	5.656
P10		5.729
P5		5.772
P1		5.852



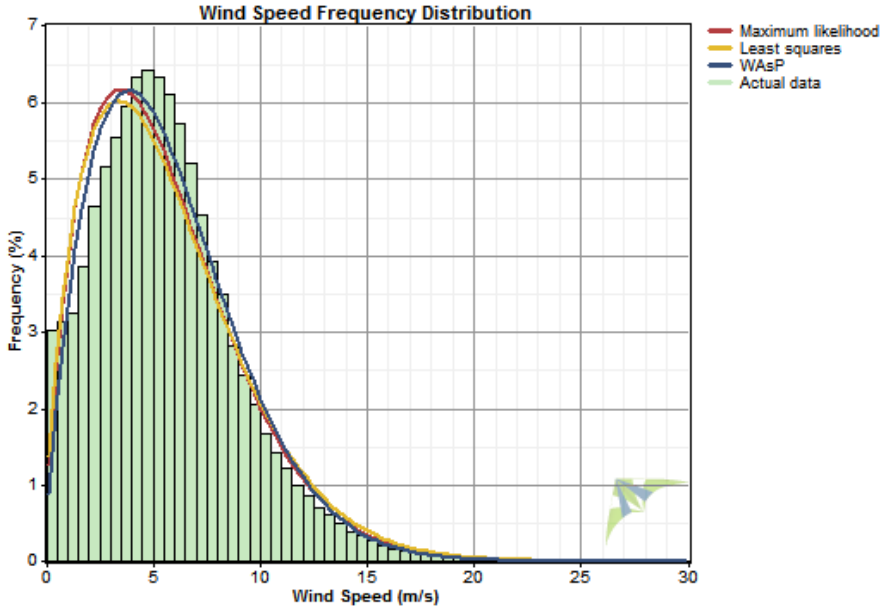
Probability Distribution Function

The probability distribution function (PDF), or histogram, of the Teller site 0037 wind speed reveals "normal" shape curve, the latter known as the Rayleigh distribution (Weibull k = 2.0). A Rayleigh distribution is the standard wind distribution for wind power analysis. As seen below for the 26 meter A anemometer, the most frequently occurring wind speeds are between 4 and 7 m/s with very few wind events exceeding 20 m/s.

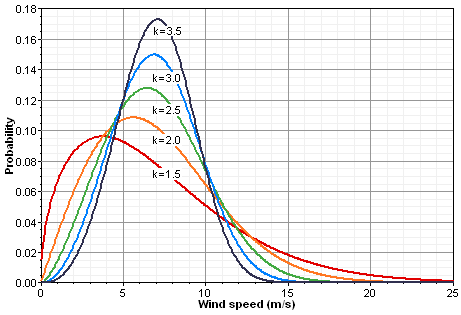
Weibull table, 26 m A anemometer (filtered)

Algorithm	Weibull k (-)	Weibull c (m/s)	Mean Speed (m/s)	Proportion Above 5.595 m/s	Power Density (W/m2)	R Squared (-)
Maximum likelihood	1.629	6.220	5.568	0.431	256	0.956
Least squares	1.593	6.318	5.666	0.439	278	0.954
WAsP	1.724	6.391	5.697	0.452	255	0.964
Actual data	(220,966 time steps)		5.595	0.452	255	

PDF of 26 m A anemometer



Weibull k shape curve table



Occurrence by wind speed bin (26 m A anemometer)

Bin Endpoints (m/s)		Occurrences			Bin Endpoints (m/s)		Occurrences		
Lower	Upper	No.	Percent	Cum. %	Lower	Upper	No.	Percent	Cum. %
0	1	14,335	6.5%	6.5%	15	16	809	0.4%	99.1%
1	2	16,110	7.3%	13.8%	16	17	635	0.3%	99.3%
2	3	21,819	9.9%	23.7%	17	18	460	0.2%	99.5%
3	4	25,258	11.4%	35.1%	18	19	331	0.1%	99.7%

Bin Endpoints (m/s)		Occurrences			Bin Endpoints (m/s)		Occurrences		
Lower	Upper	No.	Percent	Cum. %	Lower	Upper	No.	Percent	Cum. %
4	5	28,351	12.8%	47.9%	19	20	233	0.1%	99.8%
5	6	27,564	12.5%	60.4%	20	21	171	0.1%	99.9%
6	7	23,923	10.8%	71.2%	21	22	94	0.0%	99.9%
7	8	19,005	8.6%	79.9%	22	23	72	0.0%	100.0%
8	9	13,737	6.2%	86.1%	23	24	51	0.0%	100.0%
9	10	9,577	4.3%	90.4%	24	25	28	0.0%	100.0%
10	11	6,595	3.0%	93.4%	25	26	18	0.0%	100.0%
11	12	4,686	2.1%	95.5%	26	27	4	0.0%	100.0%
12	13	3,274	1.5%	97.0%	27	28	0	0.0%	100.0%
13	14	2,273	1.0%	98.0%	28	29	0	0.0%	100.0%
14	15	1,453	0.7%	98.7%	29	30	0	0.0%	100.0%

Wind Shear and Roughness

Because all three anemometers were installed at the top of the tower, vertical wind shear calculations are not possible. Given the open tundra terrain surrounding the met tower, however, a power law exponent of approximately 0.14 would be expected.

Extreme Winds

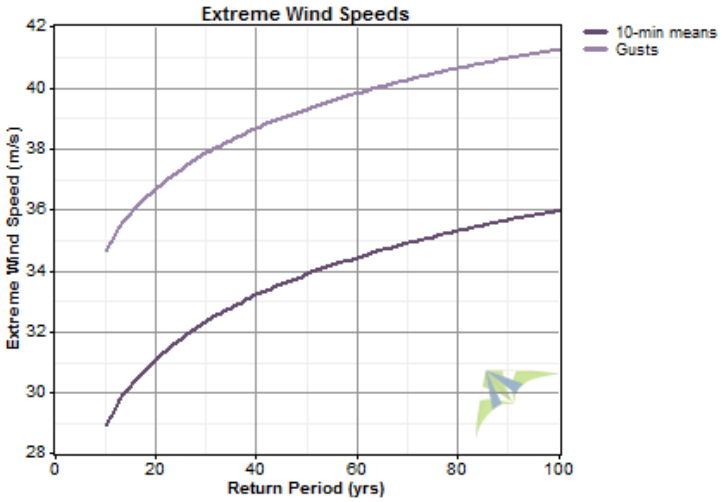
A modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, was used to predict extreme winds at the Teller Site 1 met tower site. The 26 meter A anemometer was chosen for this calculation as it recorded the highest wind speeds. With data available, the predicted Vref (maximum ten-minute average wind speed) in a 50 year return period (in other words, predicted to occur once every 50 years) is 33.9 m/s. This result classifies the site as Class III by International Electrotechnical Commission 61400-1, 3rd edition (IEC3) criteria.

IEC extreme wind probability classification is one criteria – turbulence is the other – that describes a site with respect to suitability for particular wind turbine models. Note that the IEC3 Class III extreme wind classification indicates relatively well behaved winds. All village and utility-scale wind turbines are designed for an IEC 61400-1 Class III wind regime and are potentially suitable for Teller.

Site extreme wind probability table, 26 m A data

	V_{ref}	Gust	IEC 61400-1, 3rd ed.	
Period (years)	(m/s)	(m/s)	Class	V_{ref}, m/s
20	31.1	36.7	I	50.0
30	31.8	37.3	II	42.5
50	33.9	39.3	III	37.5
100	36.0	41.3	S	designer-specified

Extreme wind graph, 26 m A level



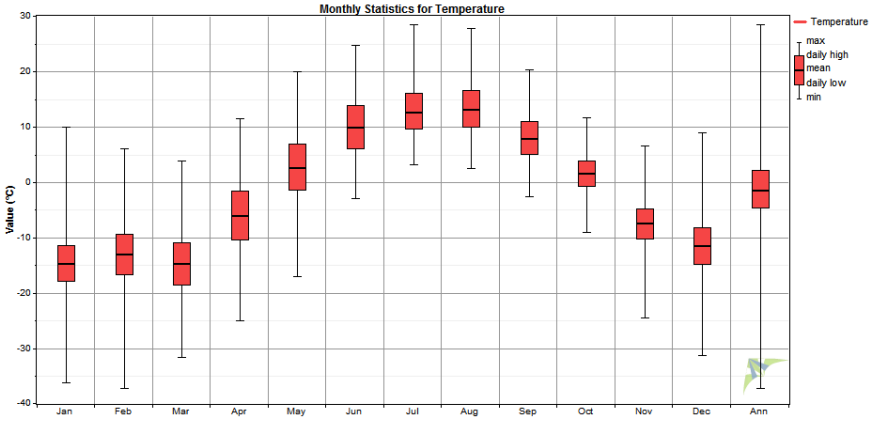
Temperature, Density, and Relative Humidity

Teller Site 1 experiences cool summers and cold winters with resulting higher than standard air density. Calculated mean-of-monthly-mean (or annual) air density during the met tower test period exceeds the 1.222 kg/m^3 standard air density for a 22 meter elevation by 5.5 percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

Temperature and density table

	Temperature			Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-14.7	-36.2	9.9	1.338	1.222	1.485
Feb	-13.0	-37.3	6.1	1.329	1.222	1.492
Mar	-14.7	-31.6	3.8	1.335	1.222	1.457
Apr	-6.0	-25.1	11.5	1.300	1.222	1.419
May	2.6	-17.0	19.9	1.266	1.201	1.374
Jun	9.9	-2.9	24.7	1.239	1.182	1.302
Jul	12.8	3.2	28.4	1.230	1.167	1.274
Aug	13.1	2.4	27.8	1.230	1.170	1.277
Sep	7.9	-2.6	20.4	1.252	1.199	1.301
Oct	1.7	-9.1	11.7	1.281	1.236	1.333
Nov	-7.4	-24.5	6.6	1.324	1.222	1.416
Dec	-11.4	-31.4	9.0	1.345	1.222	1.456
Annual	-1.6	-37.3	28.4	1.289	1.167	1.492
Temp °F	29.1	-35.1	83.1			

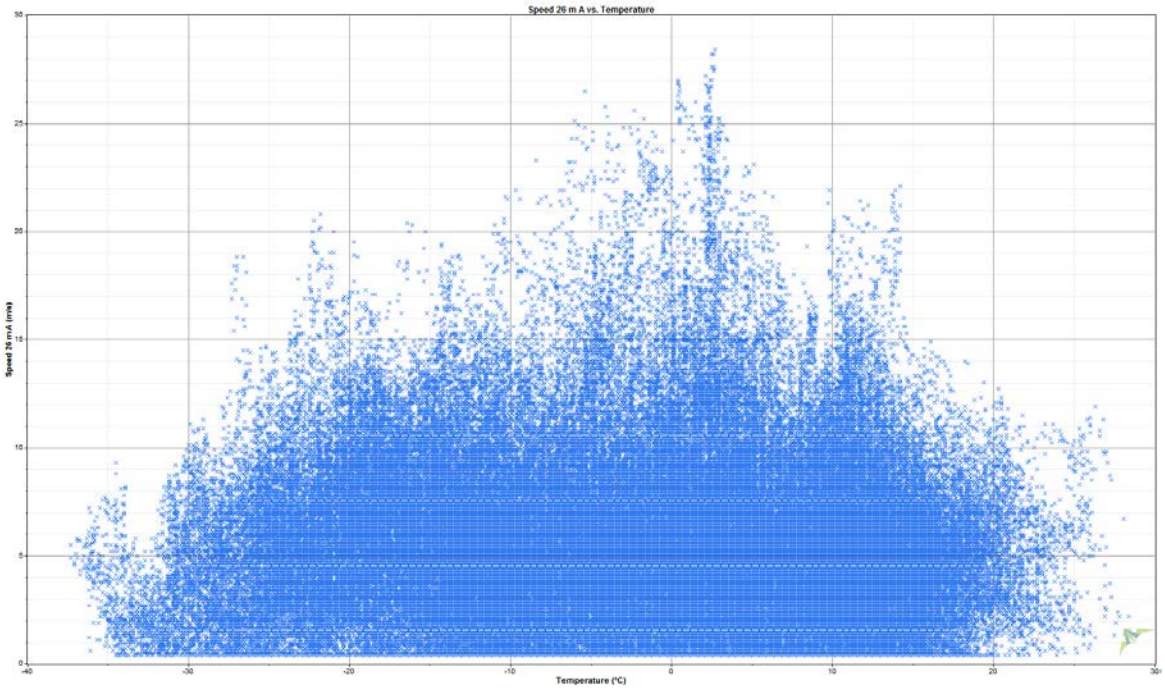
Temperature boxplot graph



Wind Speed Scatterplot

The wind speed versus temperature scatterplot below indicates cold temperatures at the Teller 0037 met tower site with a preponderance of below freezing temperatures. During the met tower test periods, temperatures were often below -20° C (-4° F), the minimum operating temperature for most standard-environment wind turbines. Note that arctic-capable (ratings to -40°C) wind turbines would be required at this site.

Wind speed/temperature



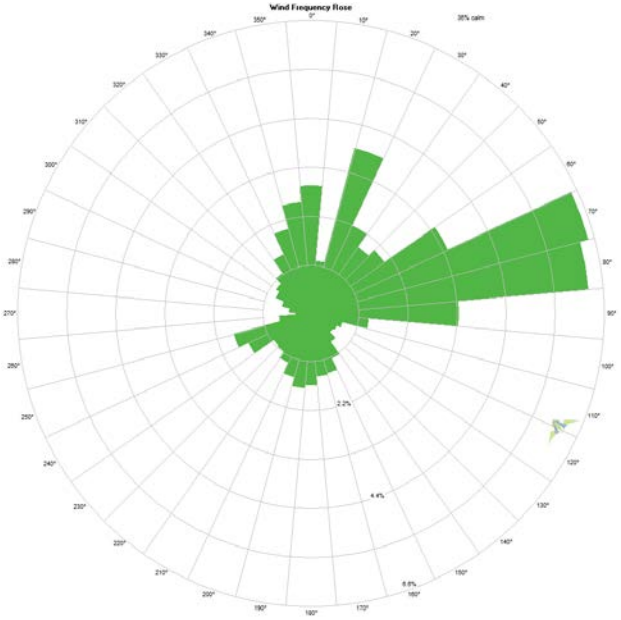
Wind Direction

Wind frequency rose data indicates that winds at the Teller 0037 met tower site are tri-directional, with predominately easterly winds and northerly and southerly winds to a lesser extent. The mean value rose indicates, however, that southerly winds are of the highest intensity, followed by northerly and

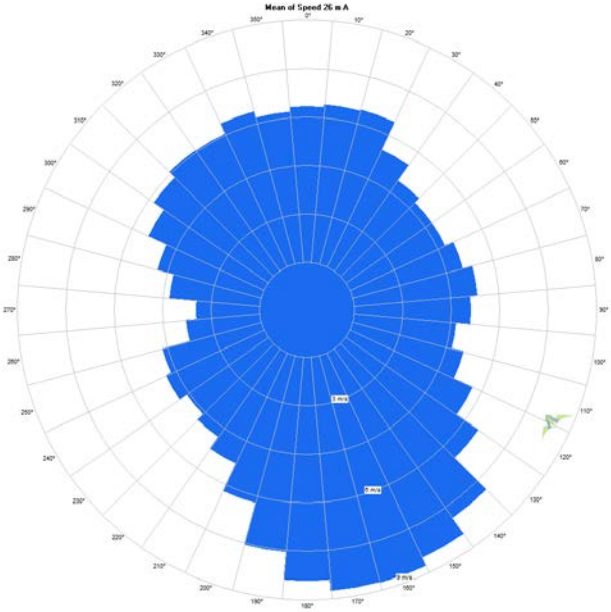
easterly winds in that order. Hence, the wind energy roses indicate that power-producing winds are northerly, easterly, and southerly.

Calm wind frequency (the percent of time that winds at the 26 meter level are less than 4 m/s, a typical cut-in speed of larger wind turbines) was a somewhat high 36 percent during the four year test period.

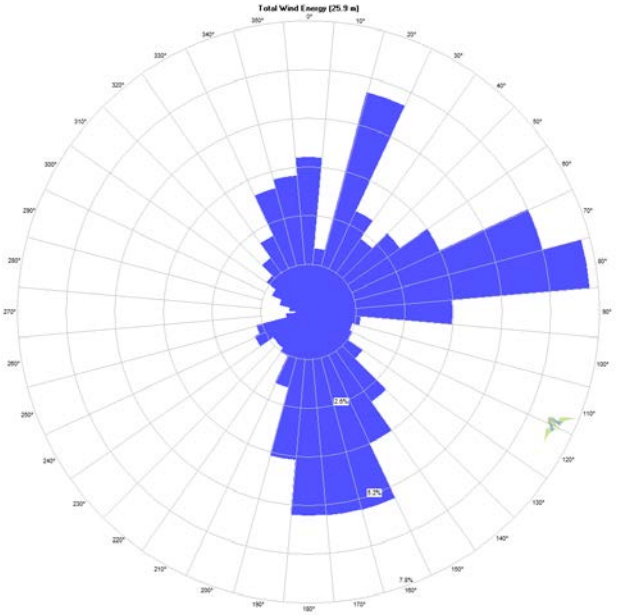
Wind frequency rose



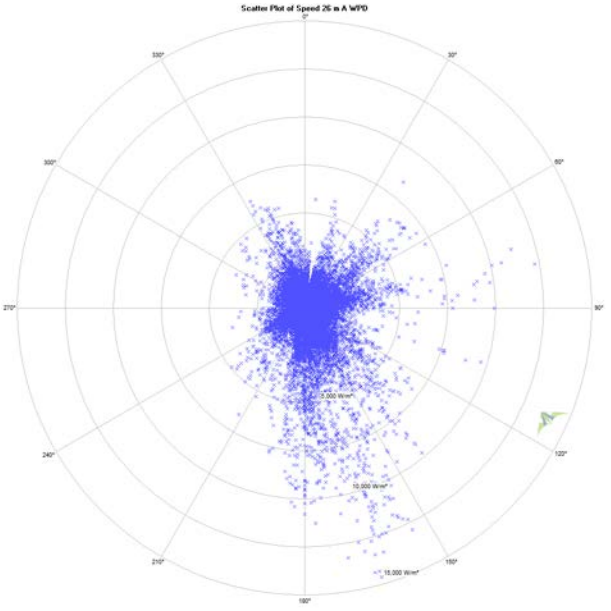
Mean value rose (26 m A anem.)



Total energy rose (26 m A anem.)



Scatterplot (26 m A anem.)



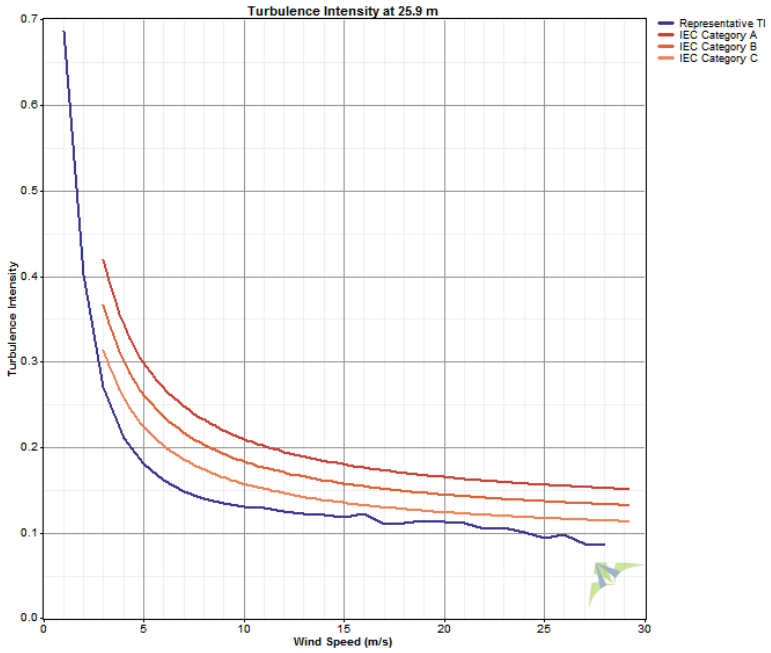
Turbulence

Site turbulence intensity (TI) is quite good with a mean turbulence intensity of 0.088 and a representative turbulence intensity of 0.118 at 15 m/s wind speed at 26 meters, indicating smooth air for wind turbine operations. This equates to an International Electrotechnical Commission (IEC) 3rd Edition (2005) turbulence category C, which is the lowest defined category. These data are shown in the turbulence intensity graph below. Representative TI (90th percentile of the turbulence intensity values, assuming a normal distribution) at 15 m/s is well under IEC Category C criteria at Teller Site 1.

Turbulence table, 26 m A anemometer, by sector

Bin Endpoints (°)							
Lower	Upper	Occurrences	Mean	Median	Min	Max	Std. Dev.
0	45	42,767	0.141	0.100	0.000	1.500	0.130
45	90	70,982	0.129	0.095	0.000	1.111	0.108
90	135	16,408	0.170	0.119	0.000	1.214	0.145
135	180	15,161	0.150	0.113	0.000	1.235	0.128
180	225	18,269	0.144	0.118	0.000	1.429	0.109
225	270	20,451	0.150	0.108	0.000	1.125	0.124
270	315	11,782	0.175	0.115	0.000	1.167	0.149
315	360	23,506	0.154	0.110	0.000	1.143	0.126

Turbulence intensity, 26 m A, all direction sectors



Teller Site 2 (9037), South of Airport

This met tower was installed in May, 2012, was the second met tower erected in Teller, and operated concurrently with the first met tower until both towers were decommissioned in September 2014.

Met Tower Location

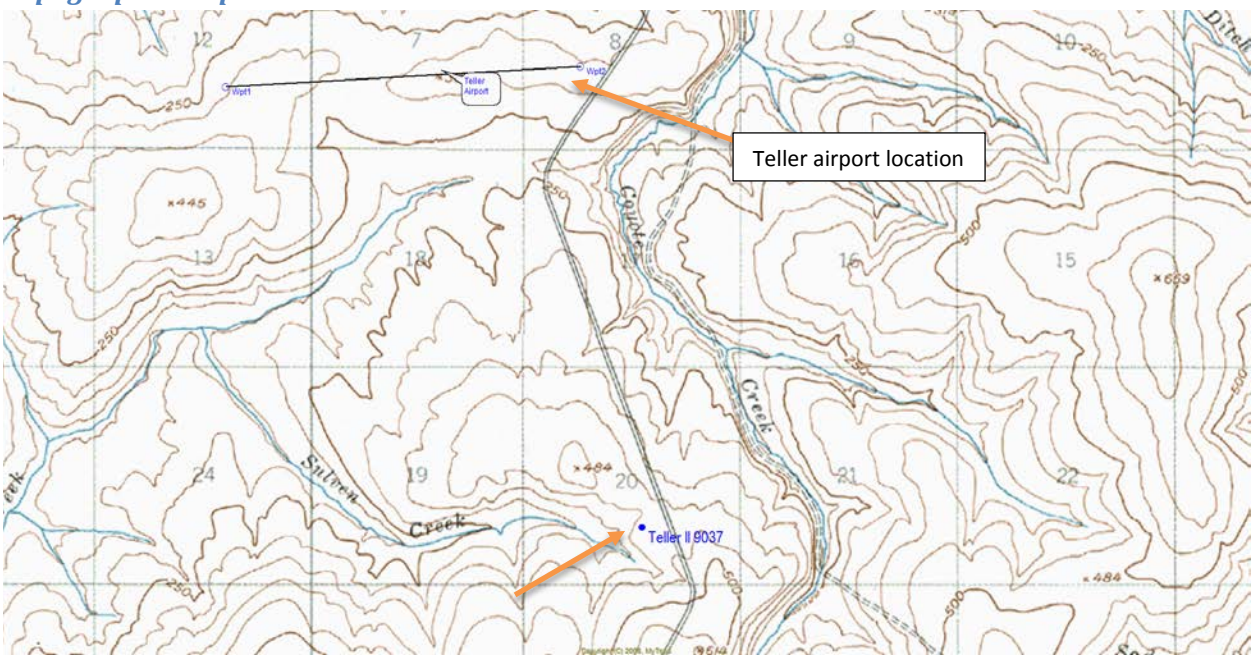
The Site 2 met tower location was chosen with consideration of anticipated higher wind speeds south of the airport and accessibility from the Nome-Teller road.

Data Synopsis

Data dates	May 11, 2012 to September 8, 2014 (28 months)
Wind power class	Class 4 (good)
Wind power density mean, 50 m	421 W/m^2
Wind speed mean, 50 m (filtered)	6.72 m/s (15.0 mph)
Max. 10-min avg. wind speed	28.0 m/s (62.6 mph)
Maximum 2-sec. wind gust	37.1 m/s (77.8 mph), Nov. 2013
Weibull distribution parameters	k = 1.76, c = 7.45 m/s
Wind shear power law exponent	0.141 (average)
Roughness class	0.99 (description: fallow field)
IEC 61400-1, 3rd ed. classification	Class II-C at 50 meters
Turbulence intensity, mean (at 50 m)	0.075 (at 15 m/s)
Calm wind frequency (at 26 m)	26% (< 4 m/s) (28 mo. measurement period)

Google Earth image, Teller met tower Site 2

Topographic map



Site information

Logger site number	9037
Site description	6.3 km SSE of Teller; 3.4 km south of airport access road
Latitude/longitude	N 65° 12.593’; W 166° 18.454’, WGS 84
Site elevation	124 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 50-meter tall tower, 203 mm diameter

Tower sensor information

Although a met tower commissioning sheet was not forwarded by the installation crew and perhaps not completed, sensor documentation as indicated on the met tower installation instruction form and keyed into the datalogger are presented below.

Sensor documentation

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	49 m	0.765	0.39	090° T
2	NRG #40 anemometer	49 m	0.764	0.37	270° T
3	NRG #40 anemometer	40 m	0.762	0.41	090° T
4	NRG #40 anemometer	32 m	0.763	0.40	090° T
5	NRG #40 anemometer	32 m	0.763	0.40	270° T
6	NRG #40 anemometer	24 m	0.767	0.38	090° T
7	NRG #200P wind vane	47 m	0.351	011	000° T
8	NRG #200P wind vane	39 m	0.351	011	000° T
9	NRG #110S temperature	4.5 m	0.136	-86.3	north
10	RH5X relative humidity	2 m	0.097	0.0	south

Channel	Sensor type	Height	Multiplier	Offset	Orientation
11	LI-200SZ pyranometer	4 m	1.32	0.0	180° T
12	Voltmeter	2 m	0.021	0.0	n/a

Photo, Site 2 (9037) met tower

AVEC photo

Data Quality Control

Data was filtered to remove presumed icing events that yield false zero wind speed data and non-variant wind direction data. Typically met tower data can be automatically filtered for icing, but icing events were so minimal that ice data was filtered by manual identification. Filtering for tower shadow was accomplished for the paired anemometers at 49 meters and 32 meters. Wind speed data loss due to icing was extremely minimal and surprising considering latitude and site elevation.

Sensor data recovery table

Label	Units	Possible Records	Valid Records	Recovery Rate (%)	Icing	Invalid	Tower Shading
Speed 49 m A	m/s	122,418	115,826	94.6	1,198	532	5,076
Speed 49 m B	m/s	122,418	100,579	82.2	1,041	532	20,436
Speed 40 m	m/s	122,418	120,835	98.7	1,196	532	0
Speed 32 m A	m/s	122,418	117,091	95.7	1,024	532	3,980
Speed 32 m B	m/s	122,418	101,904	83.2	927	532	19,220
Speed 24 m	m/s	122,418	121,067	98.9	959	532	0
Direction 47 m	°	122,418	119,553	97.7	2,476	529	0

Label	Units	Possible Records	Valid Records	Recovery Rate (%)	Icing	Invalid	Tower Shading
Direction 39 m	°	122,418	119,818	97.9	2,211	529	0
Temperature	°C	122,418	121,497	99.3	0	535	0
RH-5 Humidity %RH	%RH	122,418	121,383	99.2	0	649	0

Wind Speed

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

Anemometer data summary

Variable	Speed 49 m A	Speed 49 m B	Speed 40 m	Speed 32 m A	Speed 32 m B	Speed 24 m
Measurement height (m)	49	49	40	32	32	24
Mean wind speed (m/s) (raw)	6.55	6.42	6.38	6.18	6.12	5.89
Mean wind speed (m/s) (filtered)	6.66	6.51	6.36	6.25	6.23	5.87
MoMM wind speed (m/s) (filtered)	6.72	6.63	6.44	6.31	6.34	5.93
Max 10 min avg wind speed (m/s)	27.9	28	27.3	26	26.3	25.7
Max 2 sec gust wind speed (m/s)	36.7	37.1	35.5	35.1	35.5	35.3
Weibull k	1.77	1.62	1.73	1.77	1.68	1.69
Weibull c (m/s)	7.45	7.22	7.10	6.99	6.95	6.54
MoMM power density (W/m²)	412	426	368	341	360	292
MoMM energy content (kWh/m²/yr)	3,612	3,728	3,223	2,983	3,154	2,557
Energy pattern factor	2.13	2.30	2.17	2.13	2.21	2.19
Frequency of calms (%)	26.4	29.7	28.8	29.0	30.6	32.5

Time Series

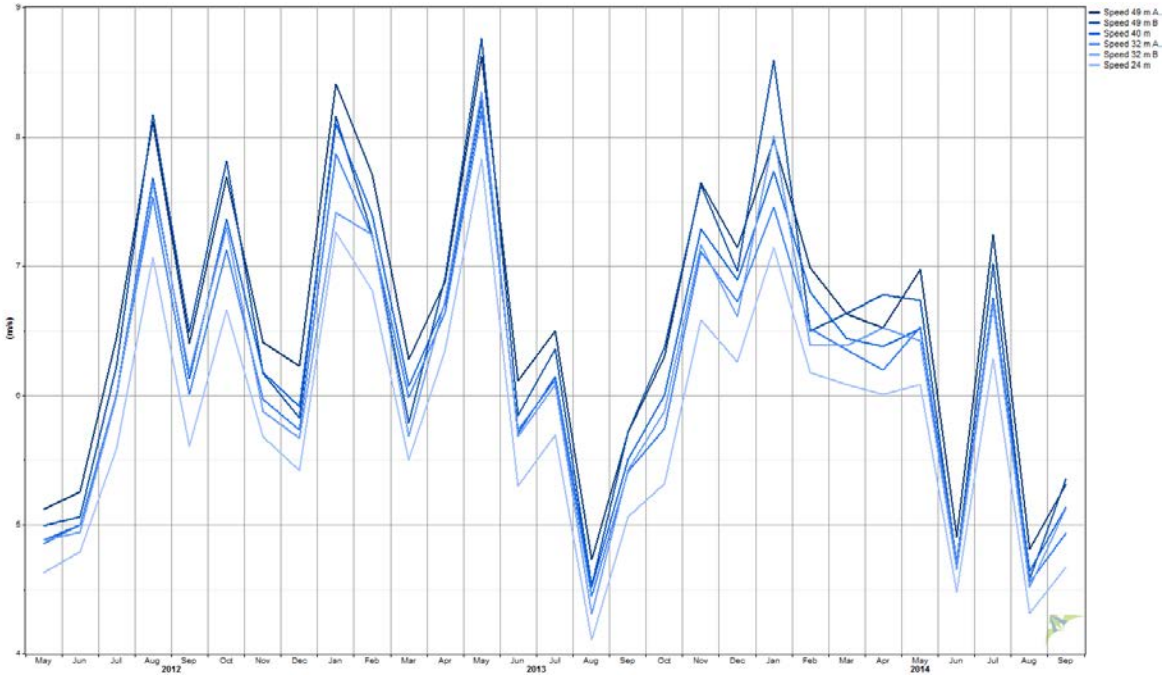
Time series calculations indicate higher wind speeds during the winter months with more moderate wind speeds during summer months, as one would expect. The daily wind profiles indicate moderate diurnal variation with highest wind speeds during the afternoon hours.

49 m A anemometer data (filtered) summary

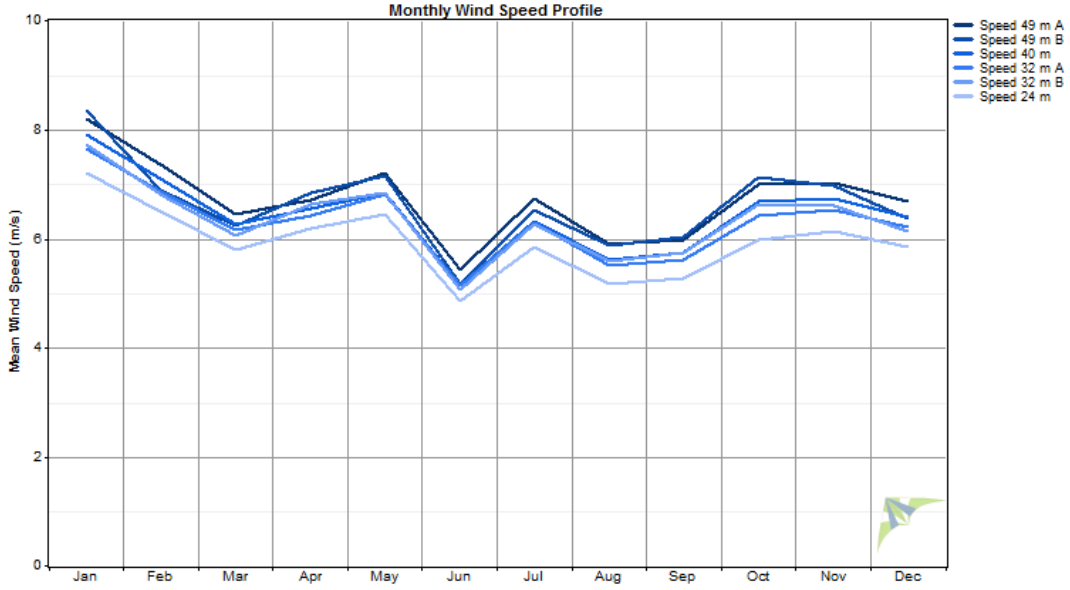
Month	Mean (m/s)	Median (m/s)	Max (m/s)	Gust (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Jan	8.19	7.90	23.2	28.3	4.05	2.07	9.20
Feb	7.35	7.00	25.7	27.5	3.68	2.03	8.25
Mar	6.45	6.20	19.5	23.3	3.45	1.89	7.23
Apr	6.70	6.10	22.8	26.4	3.72	1.86	7.53
May	7.22	6.40	20.7	24.9	4.33	1.68	8.05
Jun	5.43	5.20	22.0	25.6	3.11	1.75	6.07
Jul	6.74	6.10	24.0	28.0	3.99	1.72	7.53
Aug	5.89	5.20	27.9	32.9	3.85	1.58	6.56

Month	Mean (m/s)	Median (m/s)	Max (m/s)	Gust (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
Sep	5.98	5.50	16.0	20.6	3.11	1.97	6.71
Oct	6.99	6.60	19.7	25.3	3.61	1.98	7.86
Nov	7.02	6.30	27.8	36.7	4.39	1.62	7.82
Dec	6.68	6.60	18.7	21.8	3.41	1.96	7.48
Annual	6.72	6.26	22.3	36.7	3.73	1.84	7.52

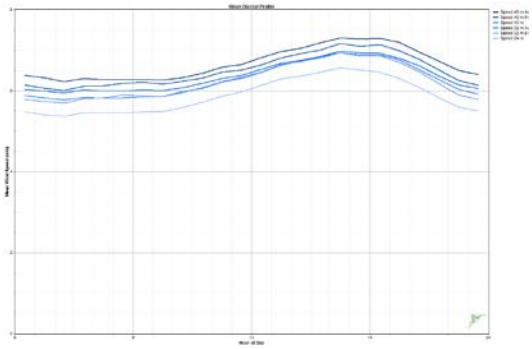
Monthly time series, mean wind speeds



Monthly time series, annualized, mean wind speeds



Daily wind profile



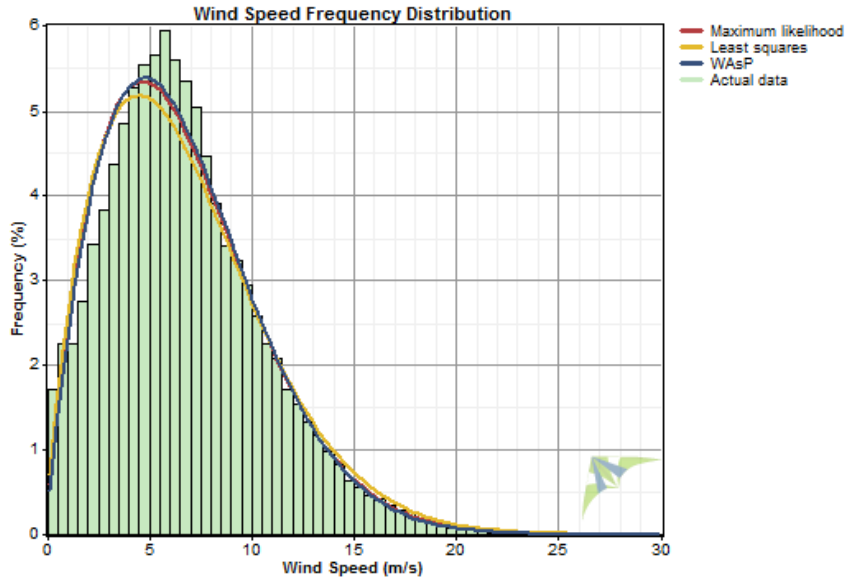
Probability Distribution Function

The probability distribution function (PDF), or histogram, of the Teller Site 2 (9037) wind speed reveals "normal" shape curve, the latter known as the Rayleigh distribution (Weibull k = 2.0). A Rayleigh distribution is the standard wind distribution for wind power analysis. As seen below for the 49 meter A anemometer, the most frequently occurring wind speeds are between 4 and 9 m/s with very few wind events exceeding 20 m/s (10 minute average).

Weibull table, 49 m A anemometer (filtered)

Algorithm	Weibull k (-)	Weibull c (m/s)	Mean Speed (m/s)	Proportion Above 5.595 m/s	Power Density (W/m2)	R Squared (-)
Maximum likelihood	1.769	7.453	6.633	0.441	390.3	0.974
Least squares	1.704	7.549	6.735	0.446	427.5	0.968
WAsP	1.800	7.476	6.648	0.444	385.2	0.976
Actual data	(115,826 time steps)		6.658	0.444	385.2	

PDF of 49 m A anemometer



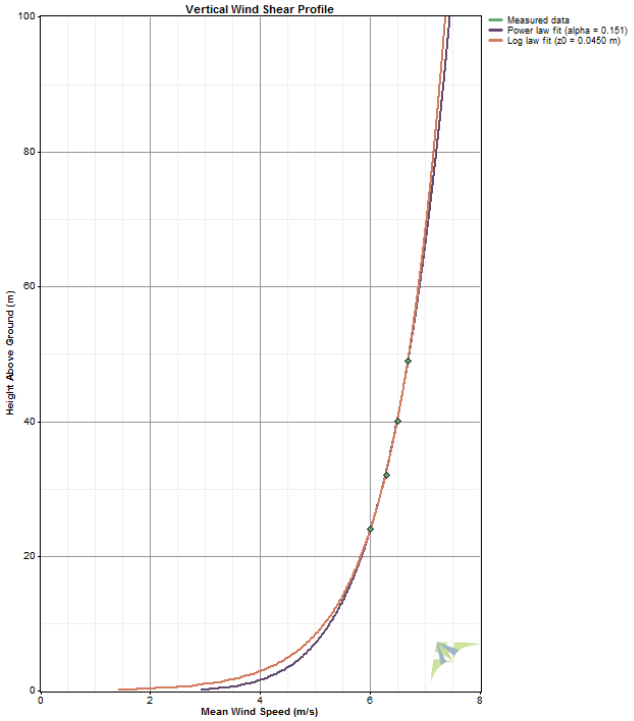
Occurrence by wind speed bin (49 m A anemometer)

Bin Endpoints (m/s)		Occurrences			Bin Endpoints (m/s)		Occurrences		
Lower	Upper	No.	Percent	Cum. %	Lower	Upper	No.	Percent	Cum. %
0	1	4,570	3.9%	3.9%	15	16	1,190	1.0%	97.8%
1	2	5,787	5.0%	8.9%	16	17	892	0.8%	98.6%
2	3	8,384	7.2%	16.2%	17	18	646	0.6%	99.2%
3	4	10,665	9.2%	25.4%	18	19	403	0.3%	99.5%
4	5	12,528	10.8%	36.2%	19	20	254	0.2%	99.7%
5	6	13,433	11.6%	47.8%	20	21	133	0.1%	99.8%
6	7	12,675	10.9%	58.7%	21	22	61	0.1%	99.9%
7	8	10,983	9.5%	68.2%	22	23	50	0.0%	99.9%
8	9	8,450	7.3%	75.5%	23	24	27	0.0%	100.0%
9	10	7,141	6.2%	81.7%	24	25	11	0.0%	100.0%
10	11	5,580	4.8%	86.5%	25	26	18	0.0%	100.0%
11	12	4,388	3.8%	90.3%	26	27	8	0.0%	100.0%
12	13	3,338	2.9%	93.2%	27	28	4	0.0%	100.0%
13	14	2,503	2.2%	95.3%	28	29	0	0.0%	100.0%
14	15	1,704	1.5%	96.8%	29	30	0	0.0%	100.0%

Wind Shear and Roughness

Considering only the four anemometers facing 090° T and filtering for icing and tower shadow, a power law exponent of 0.151 is calculated. This is an expected result for an open, tundra environment.

Vertical wind shear profile



Extreme Winds

A modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, was used to predict extreme winds at Teller Site 2. The 40 meter A anemometer was chosen for this calculation because it is nearest to the hub height of the Northern Power Systems NPS100 wind turbine. With data available, the predicted Vref (maximum ten-minute average wind speed) in a 50 year return period (in other words, predicted to occur once every 50 years) is 38.2 m/s. This result classifies the site as Class II by International Electrotechnical Commission 61400-1, 3rd edition (IEC3) criteria. IEC extreme wind probability classification is one criteria – with turbulence the other – that describes a site with respect to suitability for particular wind turbine models. Note that the IEC3 Class II extreme wind classification indicates relatively energetic winds and turbines installed at this location should be IEC3 Class II rated.

Site extreme wind probability table, 40 meter A data

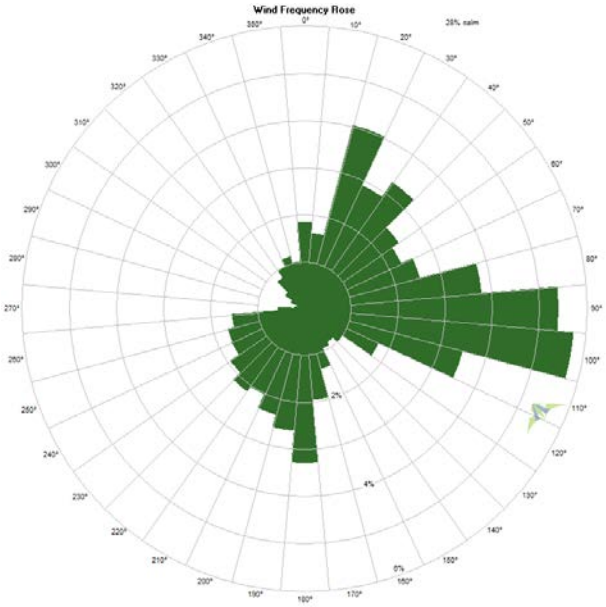
	V_{ref}	Gust	IEC 61400-1, 3rd ed.	
Period (years)	(m/s)	(m/s)	Class	V_{ref}, m/s
3	27.2	32.8	I	50.0
10	32.7	39.4	II	42.5
20	34.1	41.0	III	37.5
30	36.4	43.9	S	designer-specified
50	38.2	45.9		
100	40.5	48.8		
average gust factor:	1.20			

Wind Direction

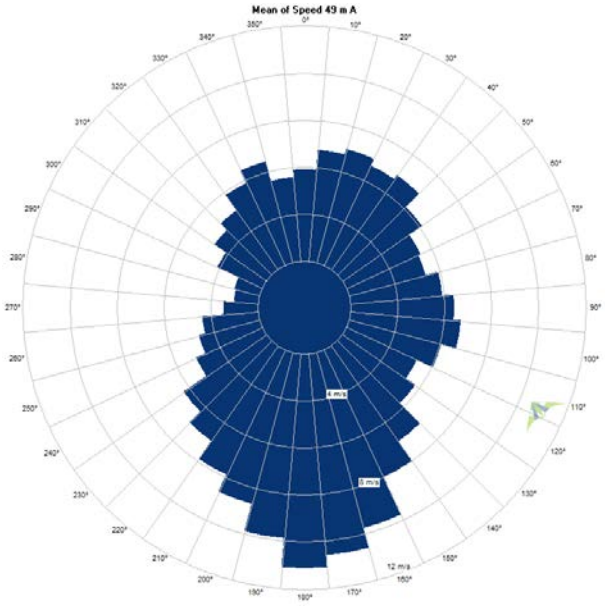
Wind frequency rose data indicates that winds at Site 2 (9037) are tri-directional, with predominately easterly winds and northerly and southerly winds to a lesser extent. The mean value rose indicates, however, that southerly winds are of the highest intensity, followed by northerly and easterly winds in that order. Hence, the wind energy roses indicate that power-producing winds are predominately southerly.

Calm wind frequency (the percent of time that winds at the 26 meter level are less than 4 m/s, a typical cut-in speed of larger wind turbines) was a moderate 26 percent during the 28 month test period.

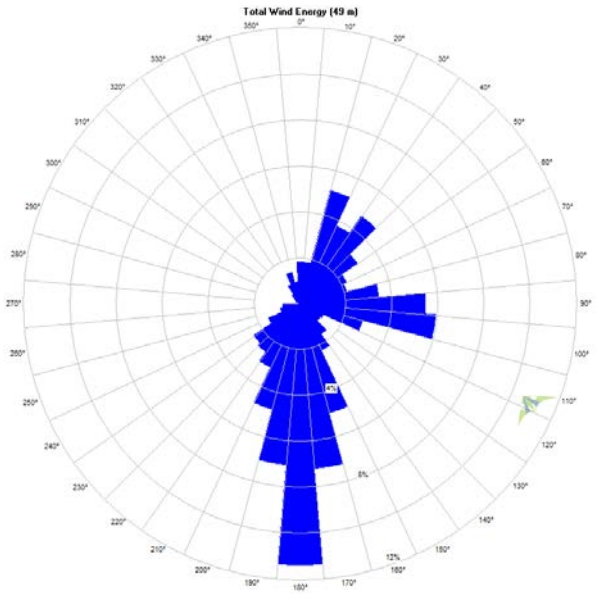
Wind frequency rose, 49 m A, 47 m vane



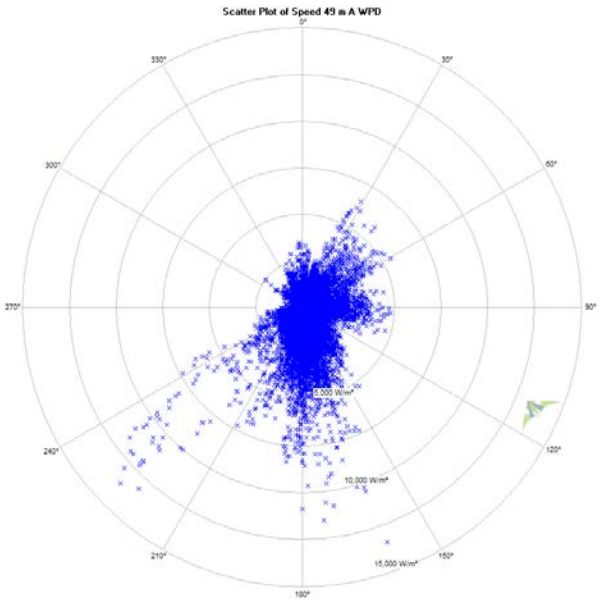
Mean value rose (49 m A anem.)



Total energy rose (49 m A anem.)



Scatterplot (49 m A anem.)



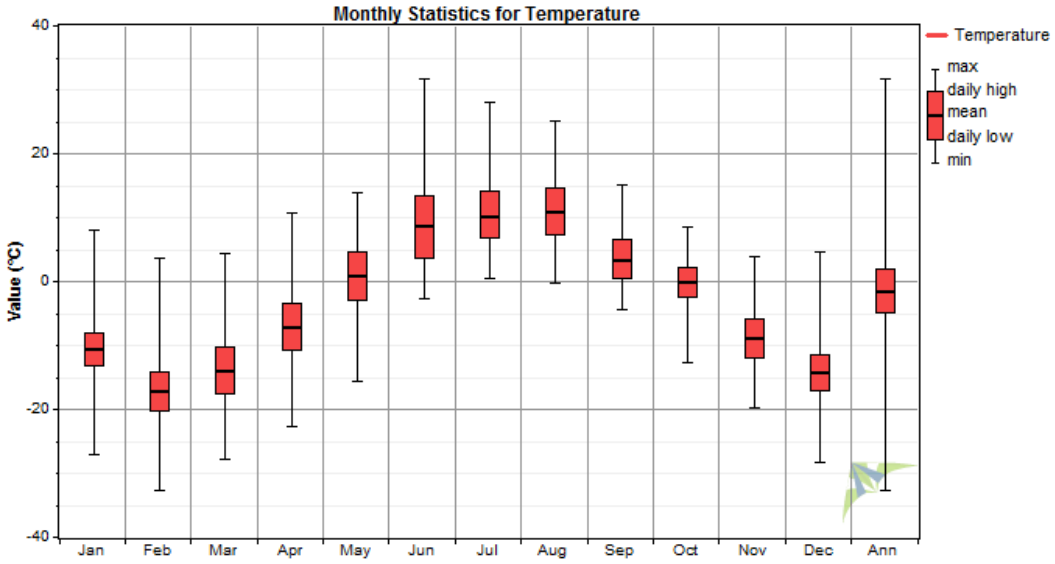
Temperature, Density, and Relative Humidity

Teller Site 2 experiences cool summers and cold winters with resulting higher than standard air density. Calculated mean-of-monthly-mean (or annual) air density during the met tower test period exceeds the 1.210 kg/m^3 standard air density for a 124 meter elevation by 6.6 percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

Temperature and density table

	Temperature			Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-10.6	-27.1	8.0	1.324	1.210	1.413
Feb	-17.2	-32.6	3.6	1.360	1.210	1.446
Mar	-13.9	-27.9	4.3	1.342	1.210	1.418
Apr	-7.1	-22.8	10.7	1.308	1.225	1.389
May	1.0	-15.6	14.0	1.269	1.211	1.350
Jun	8.8	-2.7	31.8	1.234	1.140	1.286
Jul	10.3	0.6	28.1	1.227	1.154	1.270
Aug	10.9	-0.3	25.0	1.224	1.166	1.274
Sep	3.4	-4.4	15.0	1.258	1.207	1.294
Oct	-0.1	-12.6	8.6	1.274	1.234	1.335
Nov	-8.7	-19.8	3.9	1.315	1.255	1.373
Dec	-14.2	-28.3	4.7	1.344	1.251	1.420
Annual	-3.1	-32.6	31.8	1.290	1.140	1.446
Temp °F	26.4	-26.7	89.2			

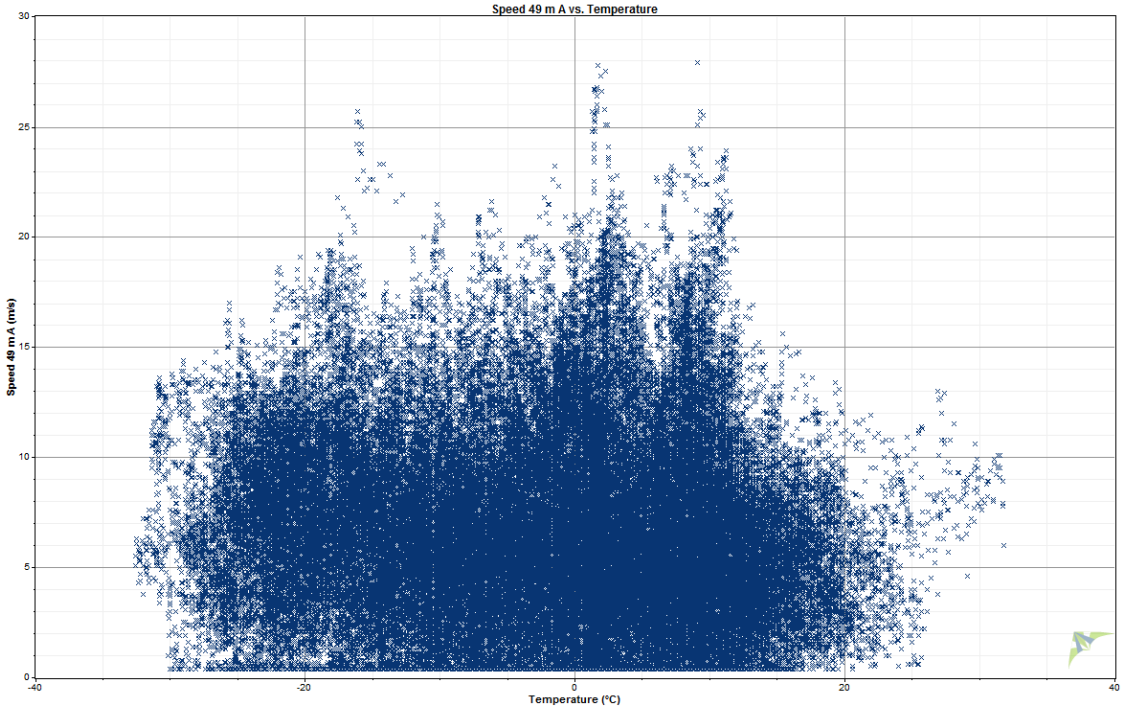
Temperature boxplot graph



Wind Speed Scatterplot

The wind speed versus temperature scatterplot below indicates cold temperatures at the Teller 9037 met tower site with a preponderance of below freezing temperatures. During the met tower test periods, temperatures were often below -20° C (-4° F), the minimum operating temperature for most standard-environment wind turbines. Note that arctic-capable (ratings to -40°C) wind turbines would be required at this site.

Wind speed/temperature



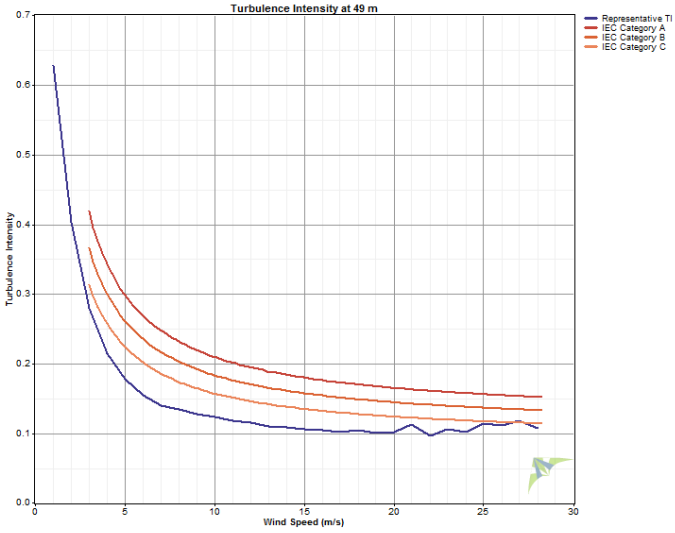
Turbulence

The turbulence intensity (TI) is very good with a mean turbulence intensity of 0.088 and a representative turbulence intensity of 0.074 at 15 m/s wind speed at 49 meters, indicating very smooth air for wind turbine operations. This equates to an International Electrotechnical Commission (IEC) 3rd Edition (2005) turbulence category C, which is the lowest defined category. These data are shown in the turbulence intensity graph below. As seen, representative TI (90th percentile of the turbulence intensity values, assuming a normal distribution) at 15 m/s is well under IEC Category C criteria at the Teller 9037 met tower site.

Turbulence table, 49 m A anemometer, by sector

Sector	Sector Midpoint (°)	Records In Sector	Mean TI	Standard Deviation of TI	Rep. TI	Peak TI
1	0	10,627	0.104	0.041	0.157	0.725
2	45	14,699	0.095	0.044	0.152	0.619
3	90	23,945	0.079	0.042	0.132	0.537
4	135	6,543	0.104	0.053	0.171	0.689
5	180	12,860	0.092	0.042	0.145	0.711
6	225	10,577	0.096	0.041	0.148	0.561
7	270	2,536	0.100	0.034	0.143	0.478
8	315	3,684	0.102	0.042	0.156	0.500

Turbulence intensity, 49 m A, all direction sectors



WAsP Analysis of Site 2 Area

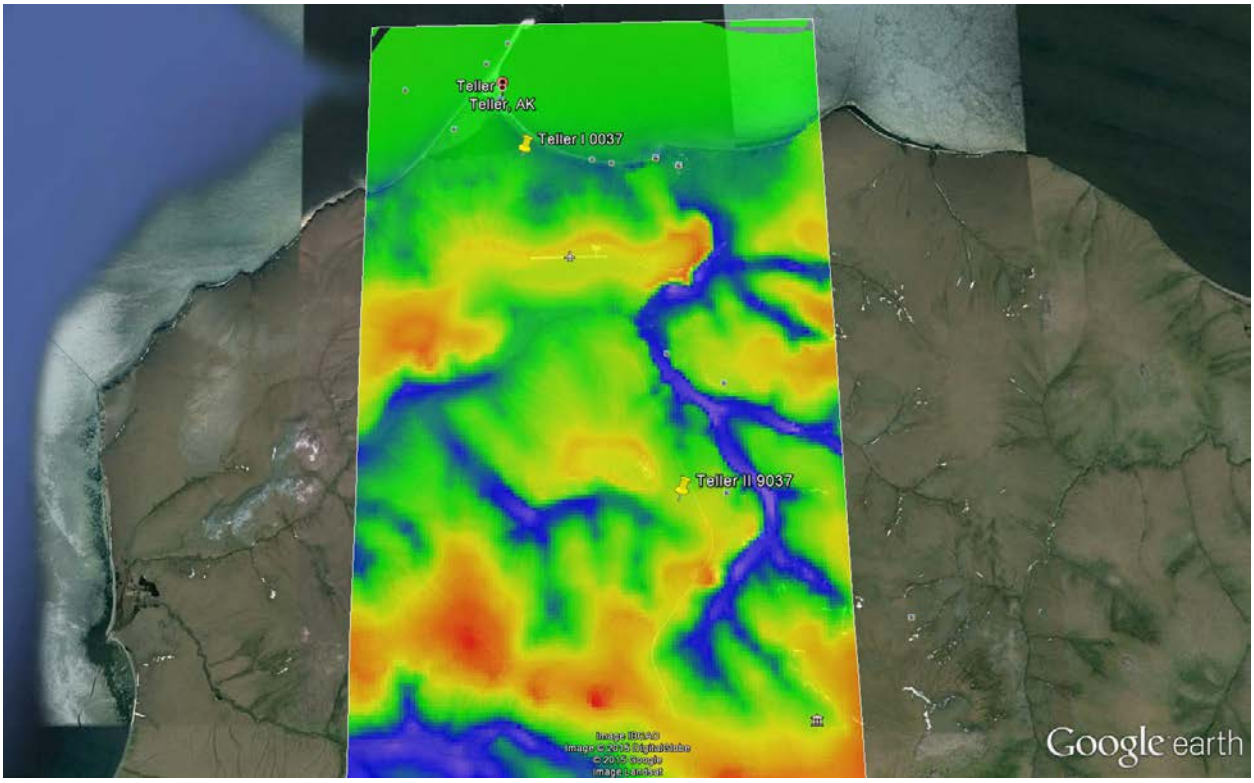
This section documents an analysis of the Teller wind resource at the Teller 2 (second) met tower site and surrounding vicinity using WAsP (Wind Atlas, Analysis and Application Program) software. The purpose of the analysis is to identify alternative sites for wind turbine construction in the Site 2 area. The criteria for this consideration is that an alternate site must be constructible. In general, and recognizing that the sites are a fair distance from Teller and that power distribution terminates at the airport, this means that a site must be relatively near the Teller-Nome Highway, not on Native Allotment land, and not likely to be opposed by the FAA in reference to airport operations. Additionally, soil conditions at the site are known or presumed suitable for turbine foundations.

The WAsP software analysis was accomplished by assessing the orographic effects of the wind as measured by the Teller Site 2 met tower. The terrain was modeled with high accuracy 1 arc-second digital elevation map (DEM) recently surveyed by USGS. Although the met tower was 50 meters high, an evaluation height of 37 meters was selected to predict annual energy production from the Northern Power Systems NPS100-24 wind turbine, a possible turbine choice for Teller.

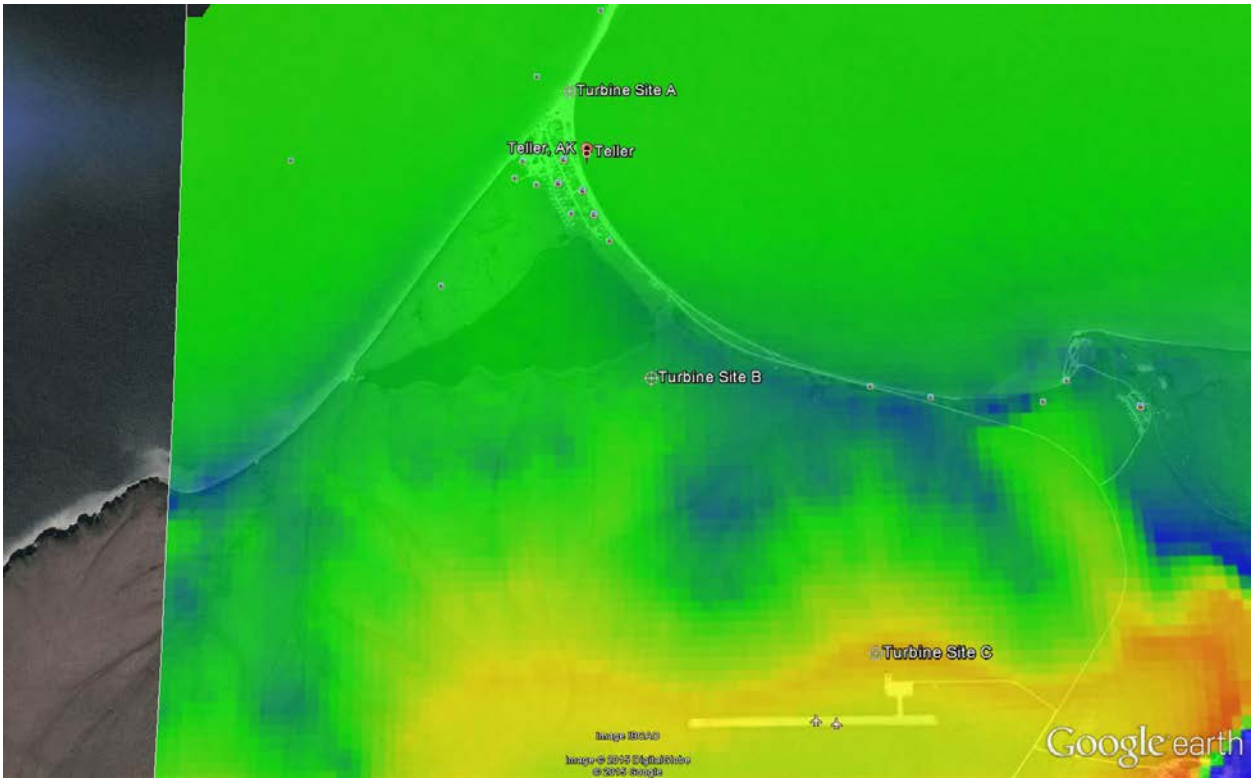
In WAsP, a resource area was created to visually display wind speed, wind power density, or other data of interest. This resource area included the village of Teller and the gravel spit to the north, Teller airport, the Site 2 met tower location and higher elevation terrain to the south. Six representative turbine locations were selected:

- Turbine Site A; on the gravel spit immediately north of Teller
- Turbine Site B; at Site 1 met tower
- Turbine Site C; immediately north of the airport tarmac
- Turbine Site D; near the Site 2 met tower
- Turbine Site E; at a gravel pit one kilometer south of the Site 2 met tower
- Turbine Site F; on higher terrain approximately 3.5 kilometers south of the Site 2 met tower

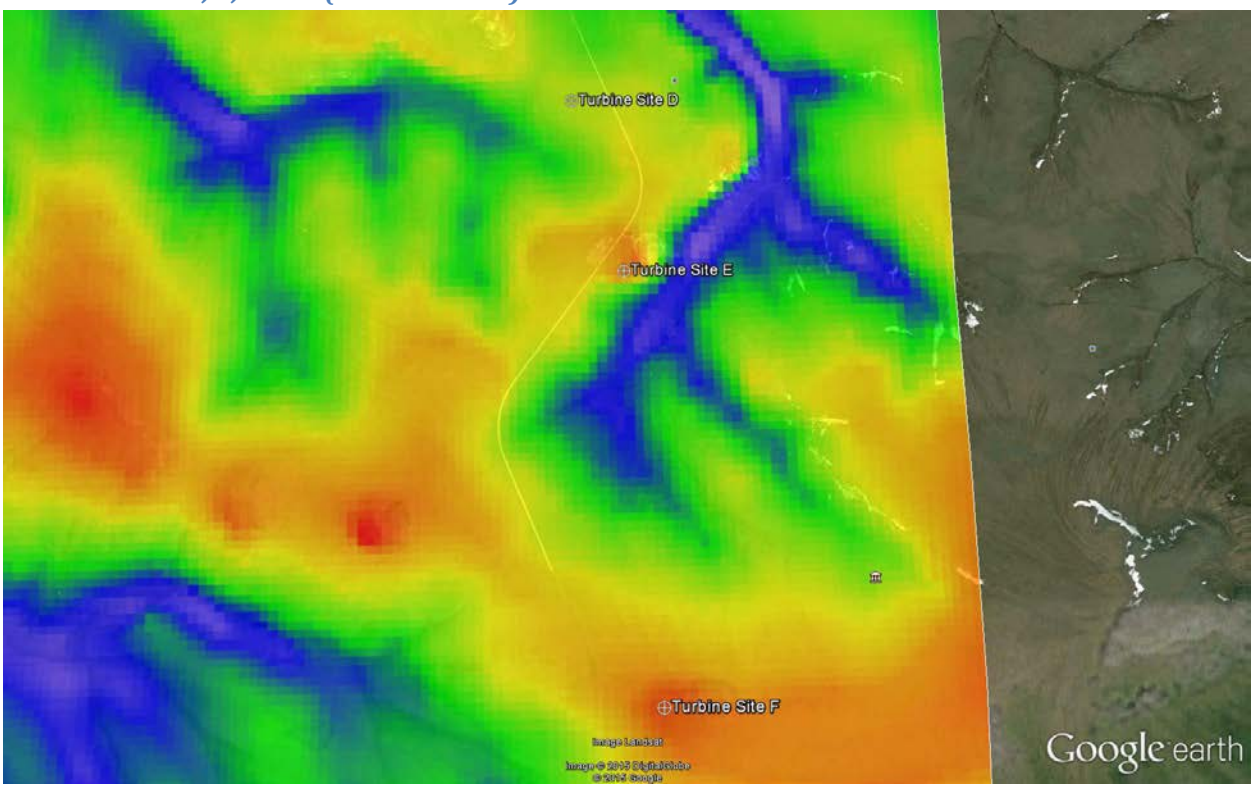
Overlay of WAsP-calculated wind speed on Google Earth image of Teller



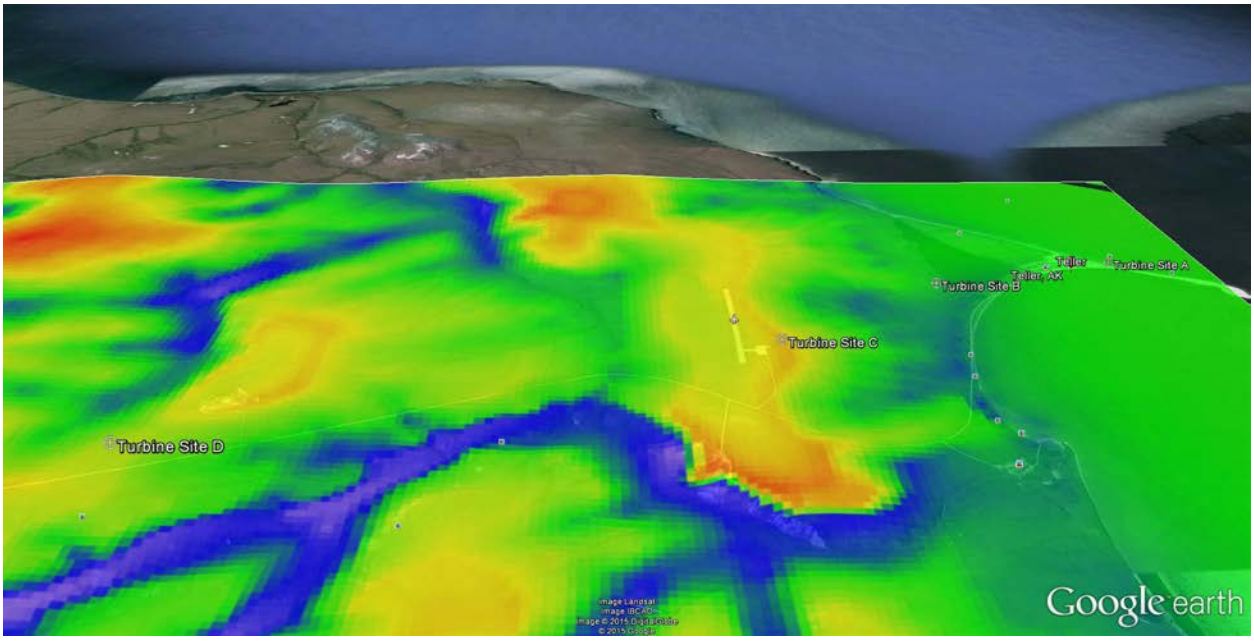
Turbine Sites A, B, and C (view to north)



Turbine Sites D, E, and F (view to north)



Turbine Sites A, B, C and D (view to west)



Wind speed comparison table (37 meter level, 100% net AEP)

Site Identifier	Location	Wind Speed (m/s)	Power Density (W/m^2)	NPS 100-24 AEP (MWh/yr)	NPS 100-24 Turbine CF (%)
Teller 2 Met Tower	Near landfill south of airport	6.47	339	n/a	n/a
Turbine Site A	On Teller gravel spit	6.16	291	262.8	30.0
Turbine Site B	At Site 1 met tower	6.07	275	257.2	29.4
Turbine Site C	Near airport tarmac	6.76	407	302.7	34.6
Turbine Site D	Near Site 2 met tower	6.51	343	289.5	33.0
Turbine Site E	Gravel pit 1 km south of Site 2 met tower	7.01	444	320.5	36.6
Turbine Site F	Higher terrain 3.5 km south of Site 2 met tower	7.29	502	338.5	38.6

WAsP Analysis Summary

The WAsP analysis indicates that with respect to wind resource, AVEC's optimal site option for wind turbines is Turbine Site F, the higher elevation terrain approximately 3.5 km south of the Teller II met tower and approx. 7.1 km south of the airport. Turbine Site E is also a good alternative to the Site 2 met tower area. If FAA permitting can be secured, a Turbine Site C (near the airport tarmac) would be excellent from a cost-of-development perspective. Note that energy estimates assume 100% net AEP. Actual energy production would be less with consideration of O&M, icing, array efficiency, and other production losses.