Remote Renewable Energy

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Abstract

A small scale hydro plant was to be placed in the Tuksuk Channel. The power generated by the channel would then be used to supply the surrounding region with electricity. It was determined that using the channel in this manner would not be feasible due to cost of transmission installation, lack of flow rate data for the river and tidal surges. A wind farm alternative proved more feasible and a more cost effect option. The windfarms would have an estimated payback period of seven years.

Contents

Contents

Introduction

The project was commissioned by Dr. Metzger, a Civil Engineer at the University of Alaska Anchorage. The project was to design a transmission system for a small scale hydrokinetic generator located in the Tuksuk Channel on the Seward Peninsula, Alaska. The transmission system was to supply two small communities, Teller and Brevig Mission. In addition to serving the communities general needs, additional power was to be supplied to a graphite mine at the Lost River and to a gravel mine at Windy Cove. The distance between Teller and the gravel mine was 9.6 miles. The distance between the graphite mine and the Tuksuk Channel was 17.5 miles using an undersea cable; compared to 18.6 miles using traditional overland lines. For the gravel mine, the undersea and overland routes from the generation sites were 36.7 miles and 39.8 miles, respectively [1].

After contacting the United States Geological Survey (USGS), the Alaska Weather Service, the Alaska River Service and the National Oceanic and Atmospheric Administration (NOAA), it was concluded that there was no flow data on the channel. Several other issues were raised courtesy of Christian Zimmerman of the USGS who noted that high tidal surges would affect the ability of the hydrokinetic generator to properly produce power [2]. The load was insufficient to justify the capital cost and maintenance costs for a traditional transmission line system. After a discussion with the project advisor, Dr. Radian Belu, an Electrical Engineer at the University of Alaska Anchorage, it was determined that the original implementation was unfeasible and an alternative was proposed.

The alternative to the hydrokinetic generator was determined to be a wind turbine as the region is prosperous with winds. The wind data, which included wind speed data for various years, was found and analyzed from Teller's airport weather station with aid from the Alaskan Weather Service [3].

Methodology

Three factors must be determined when designing a given transmission line system. These factors include the load, the available generation and the distance. The following Figure A1, which includes load data for Teller, was provided from the Alaska Village Electrical Cooperative (AVEC).

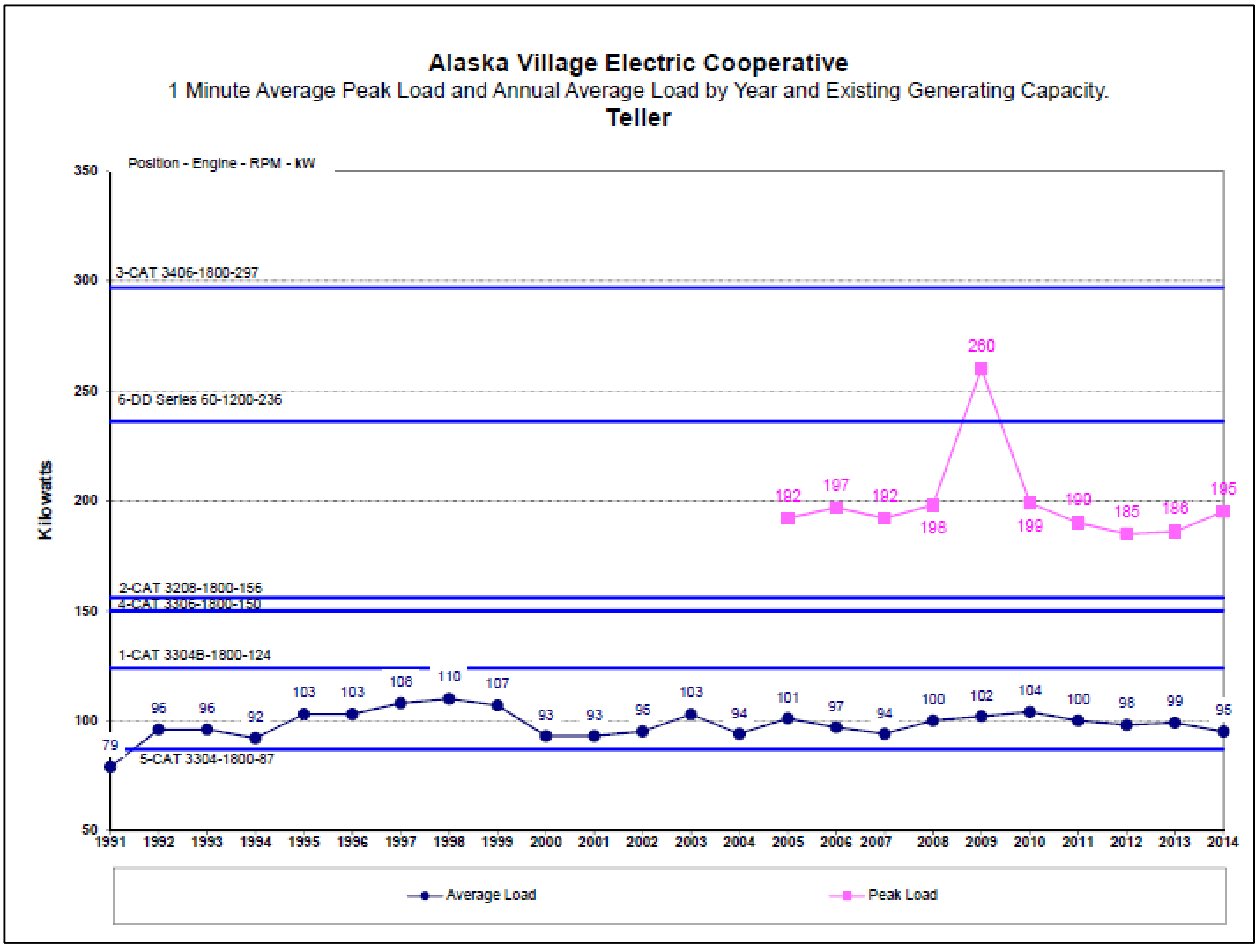


Figure A1: The power load for Teller from 1991-2014

Given the data, the average load for Teller was estimated at 200 kW during the winter season and 100 kW otherwise. Analyzing Brevig Mission's statistics, the average loads were comparable. The current in place systems in these two location are three-phase with a distribution voltage of 12.47 kV. The transformers at the power plant is 480 V to 12.47 kV. These systems were once interconnected, however, a flood destroyed the connection leading to Teller. This lead to providing power for Teller being the primary objective of this feasibility study.

The average load for Teller is approximately 100 kW with peaks occurring in winter at around 200 kW. Brevig Mission, due to its population size, can be assumed to have the same load patterns. Their systems operate on a three phase system with a distribution voltage of 12.47 kV [4]. The transformers at the power plants are 480 V to 12.47 kV and are sized to match the load of 300 kVA with a 3% impedance [4].

The next step in the study was to determine the currently available generation. In order to find this generation, the data regarding flow rates, temperatures and freezing periods for the Tuksuk Channel were required. In order to gather this data we spoke with Christian Zimmerman of the USGS.

Figure A2: Tuksuk Channel. Courtesy of Christian Zimmerman [2]

During the group meeting with Christian Zimmermann, several concerns were raised regarding the lack of information for the channel; including icing, tidal surges and flow rates. The National Weather Service Anchorage and Fairbank offices were contacted, but were unable to provide us information regarding the Tuksuk Channel. The National Ocean and Atmospheric Administration was then contacted to no avail. Finally, the Norton Sound Economic Development Corporation was contacted, but they also did not have any data for the channel. Since viable data could not be produced, only estimations could be derived for the amount of generation that would be possible from placing the hydroelectric generators in the channel.

If the hydroelectric generation system were to be implemented it would require a transmission system in order to deliver the power. The distance between the source (the mouth of the Tuksuk Channel) and the load (located at Teller) is more than five miles and due to the long distance between these sites, a medium-voltage transmission system would need to be constructed. The minimum linear distance between Teller and the generation site is 9.6 miles. Figure A3 shows three potential routes for a transmission system:

Figure A3: Teller Transmission Routes

Three potential routes were analyzed. The red route would follow the coast, but would be vulnerable to flooding. The black route would proceed inland and take advantage of the higher terrain, however strong winds could potentially damage the transmission lines [6]. These distances, which include variances in elevations, for the red and black routes would be approximately 10.91 miles and 12.37 miles, respectively [5]. After consulting with Tom Brown, former owner of TAB Electric, a recommendation was produced. This recommendation included running the transmission lines at 12.47 kV. According to Tom, the ideal transmission line route would be as short as possible while avoiding high wind and flooding areas. The system should also cross the road so that the lines will have protection from the river, in case of a flood. Lastly, the blue route avoids both flooding and wind hazards with an estimated total distance of 14.74 miles.

Given the lack of flow data, the amount of power produced from the generators could not be accurately estimated and this is compounded by the required long and costly transmission line system that would accompany the generators. Due to these findings, using a small-scale hydroelectric generation system would be unfeasible.

The next step in this study was to analyze potential alternatives. The alternative the group decided to pursue was using wind generation to offset Teller's energy costs. In order to successfully implement wind generation in Teller, we first needed to obtain wind data for Teller. To obtain this data, we first contacted NOAA.   While they could not provide the group with the information we needed, they guided us to the local weather station in Teller, named PATE. The weather station was able to provide the group with valuable wind data for Teller. The data, which includes wind speed, gusts, direction, temperature and pressure were further analyzed [3].

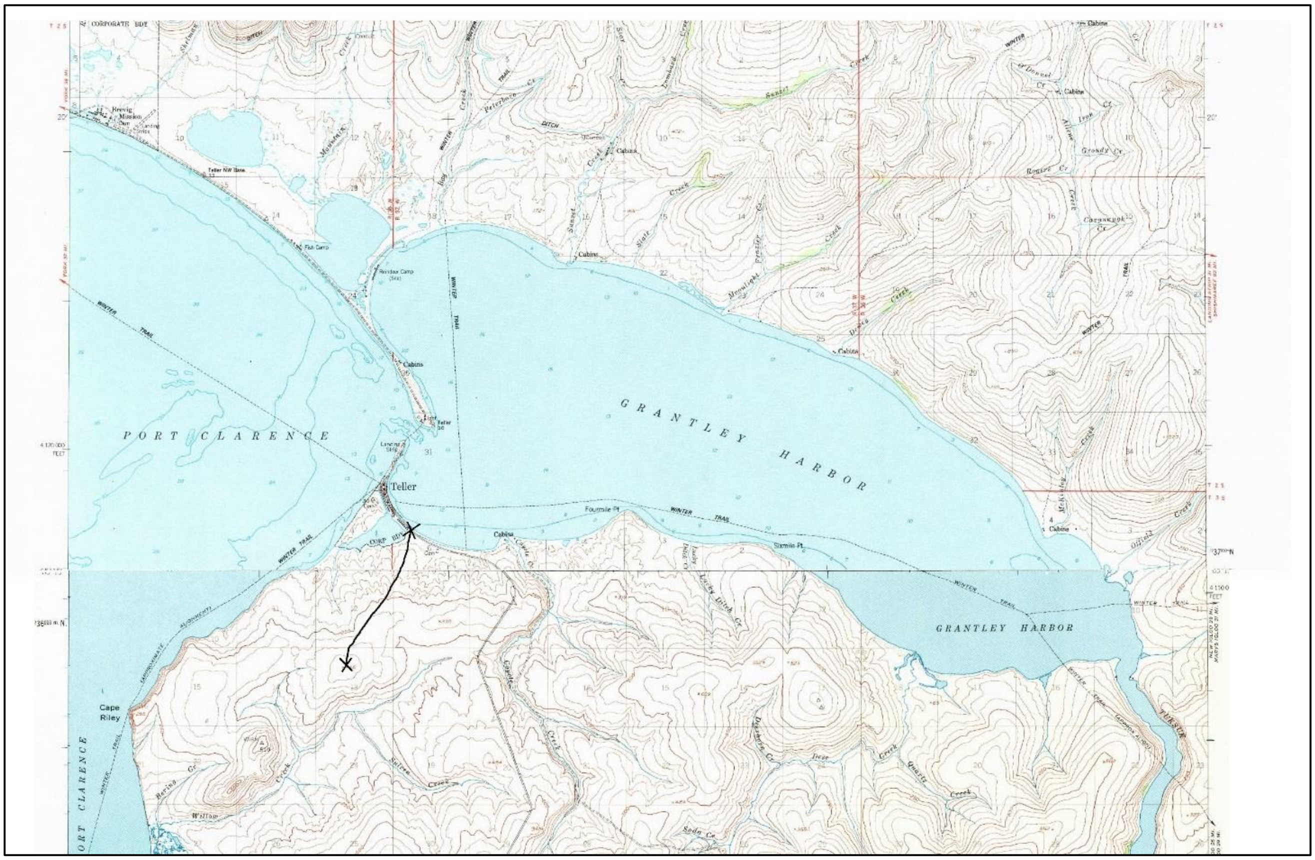


Figure A4 Potential wind route

Multiple options for the proposed wind turbines were analyzed. These options included the use of either 100 kW or 200 kW wind turbines. The first option would be four 100 kW turbines working in tandem and the second option would be solely two 200 kW turbine. The location that the group selected for the turbines would be an estimated 1.83 miles from Teller. This location was selected due to its relatively short distance from the town, a modest elevation of 445 feet and it is free from obstructions [5].

Analysis

Hydroelectric Transmission System Costs

In Alaska most construction takes place during the summer months. If this transmission line system were to be implemented, prices will need to be estimated. This price estimation will include labor, materials, equipment and engineering costs. Given inaccurate data on permitting costs we did not consider permitting costs in these estimates.

Given Teller's remote location, long working shifts will be performed by construction workers. These estimations were based off a typical construction work week of 70 hours with a two week on and one week off schedule. The workweek will consist of 40 hours of regular time, 8 hours of overtime and 22 hours of double time. This project will be implemented using two crews each consisting of four laborers. The base pay for a lineman is $54, based on the IBEW. The adjusted rate per hour was estimated to be $74.05 [6].

The engineering were estimated to be 800 hours until completion of the project. There will be two crews consisting of eight men. Optimally, these crews will require a minimum of 100 hours, or 10 days, to complete a mile of transmission line. The required construction material cannot be sourced from Alaska. The material will be sourced from Seattle, Washington and shipped to Nome, Alaska. After the material is received in Nome, it will be transported to the appropriate site in Teller. The shipping cost is estimated at $0.80 per pound. In Table A2, the cost breakdown for the material and shipping are analyzed per mile. This is estimated to total $41,200 per mile. An engineer will be on site to supervise the construction [6]. See Table A3 for more complete engineering cost estimates.

The cost per mile was calculated for a 12.47 kV line and it included material, transportation, shipping and labor costs. The industry standard is to use a transmission pole every 300 feet for a total of 18 poles per mile. Based on professional recommendations, we decided to use pilings to compensate for permafrost issues. These calculations can be seen in Table A1 of the appendix.

The fringe benefits at union rates and additional construction factors totaled $947,332 per mile of transmission line. The estimated rate includes contractor salary costs and when analyzing current industry trends, may be doubled by projects completion. Due to the trend of increases in costs due to unforeseen events and contractor profitability, an additional 100% was aggregated to the salary costs. See Table A4 for a complete cost breakdown.

Direct Job expenses per mile		Non-Productive Labor per mile	
Tool and Equipment		Total direct labor	$800.00
Fringe Benefits	$25,512.00	Martial handling 20%	$160.00
31% labor burden	$24,289.00	Travel Time	$63.00
Telephone	$200.00	Lost Time	$40.00
Storage	$1,200.00	Total labor Hours	$1,063.00
Freight	$41,200.00	Avg Labor Rate adjusted for Overtime	$74.00
Engineering	$29,970.00		
Martial	$120,780.00	Total labor per hour	$78,715.00
Road concoction	$151,800.00	Salary costs	$473,666
Total costs per mile:			**$947,332.00**

Table A4: Labor and Material Cost per mile.

Hydro-electric Generator

The transmission line system for the hydroelectric generator was analyzed for three potential routes. The affordability is directly related to the total distance of the transmission lines. The first route (Red Route) was the most affordable as it followed the banks of the Tuksuk Channel and totaled 10.91 miles, however, it was vulnerable to flooding. The second route (Black Route) traversed more inland, following the local road, and totaled 12.37 miles. The third route (Blue Route) had a total length of 14.47 miles and cuts inland while avoiding high elevation which can cause wind damage [5]. The initial surveying, engineering, generation and transformer equipment costs are assumed to be equal for all three routes. See Table B4 for the total initial cost for the three options. Note, these estimations do not take land purchases or permitting costs into consideration as there was a lack of respectable information. For more information, see Tables B1, B2 and B3 for additional breakdowns.

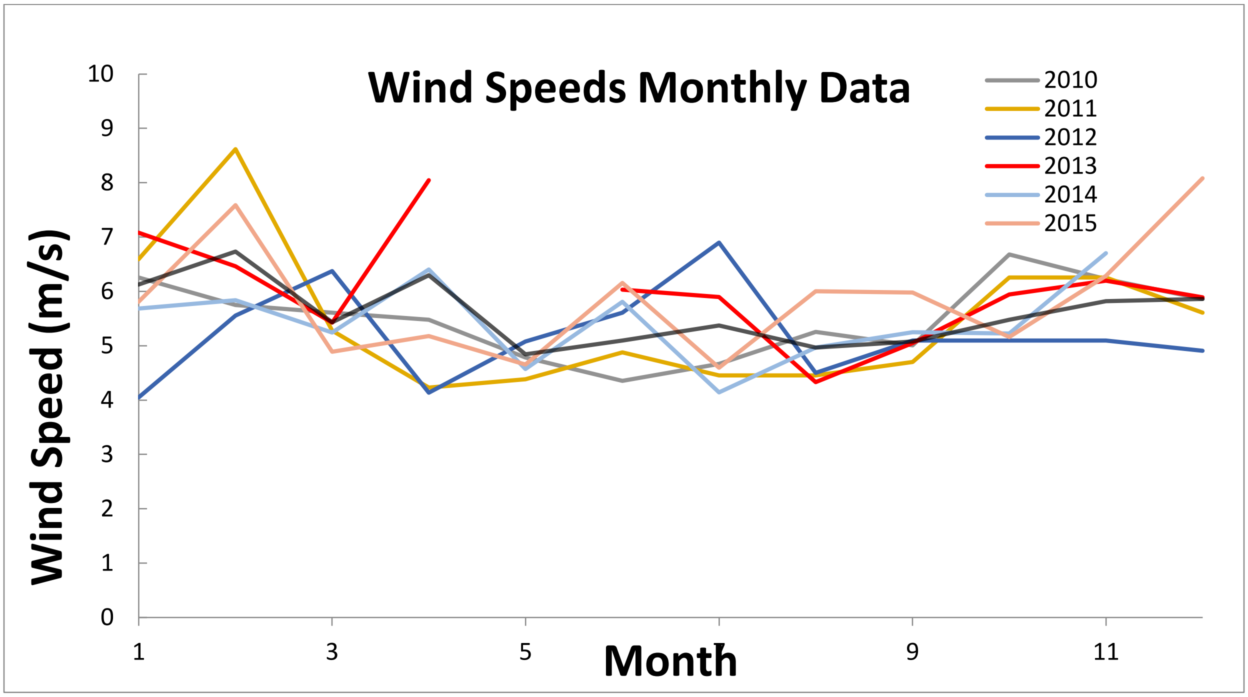
	Distance (Miles)	Material Cost per Mile	Design costs total	Surveying costs total	Transformers & Generation	Total
Red route	10.91	$947,332.00	$601,920.00	$218,000.00	$1,530,000.00	$12,685,312.00
Black route	12.37	$947,332.00	$601,920.00	$218,000.00	$1,530,000.00	$14,068,417.00
Blue route	14.47	$947,332.00	$601,920.00	$218,000.00	$1,530,000.00	$16,057,814.00

Table B4 Initial cost per mile for all three options.

Wind Farms

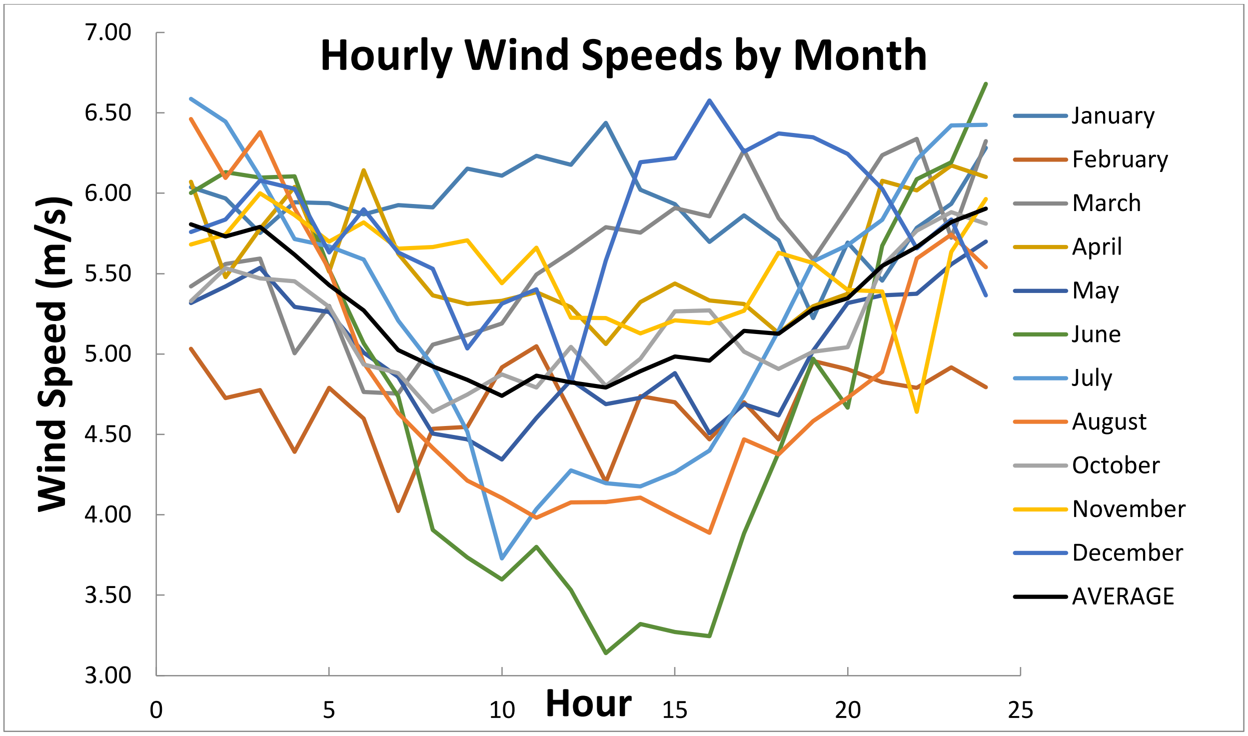
After the hydroelectric generator option was analyzed and found unfeasible, the wind turbines were further analyzed. The location of these turbines will be 1.83 miles from Teller and situated on the apex of 445 foot hill. This additional boost in height allows the turbines to use higher speed winds and thus potentially increasing the amount of generated power.

Having the information on the winds in Teller was quintessential for the proper evaluation of the feasibility of using wind turbines. The wind data was obtained from PATE, the local weather station in Teller's airport. There was more than 30 years of obtainable data, however, the group decided to use information from the last six years, 2010 – 2015. After carefully analyzing the information, the average wind speeds for this six year period in Teller was found to be 11.78 miles per hour, or 5.18 meters per second [3]. The monthly wind speeds were calculated and the average for the period ranged between 4 and 9 meters per second. A noticeable trend found in the data is that May has the lowest wind speeds compared to February which has the highest. See Graph C1 for the average monthly speeds plot.

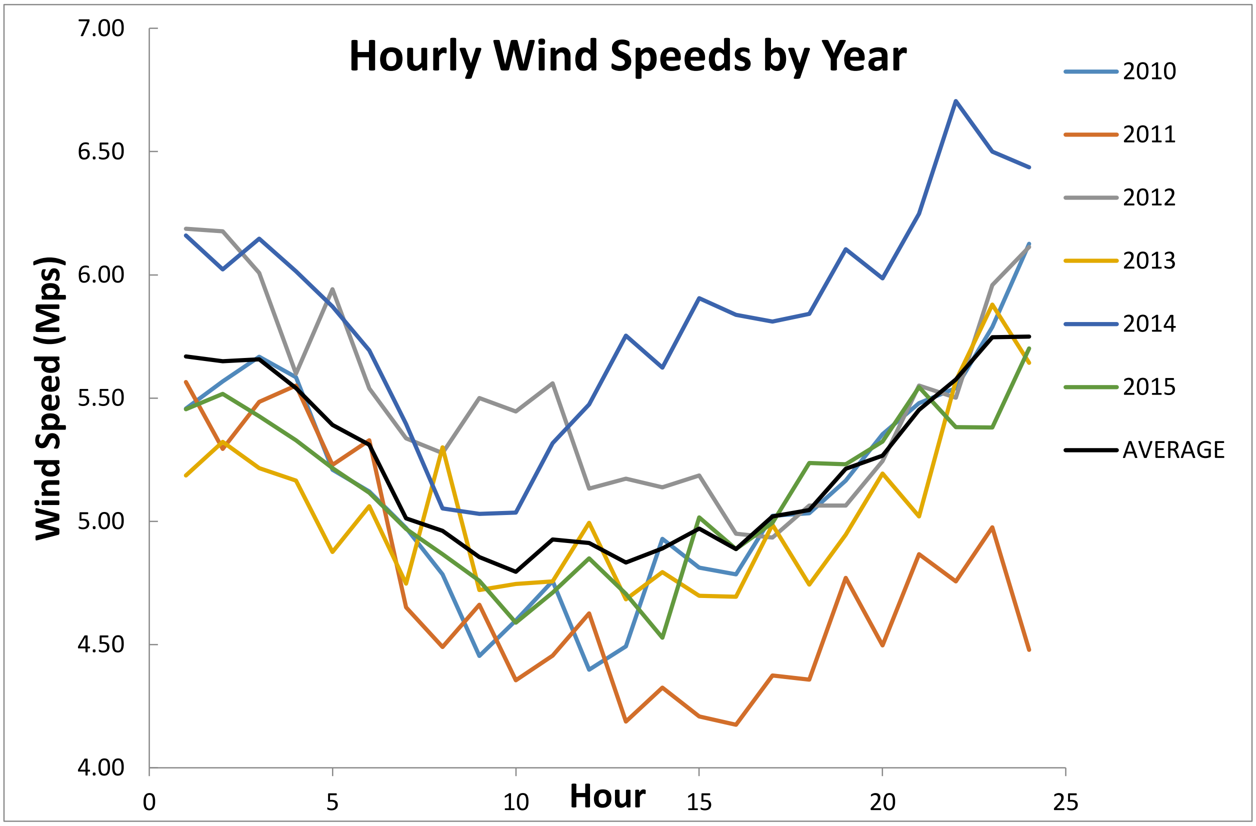


Graph C1: monthly wind speeds

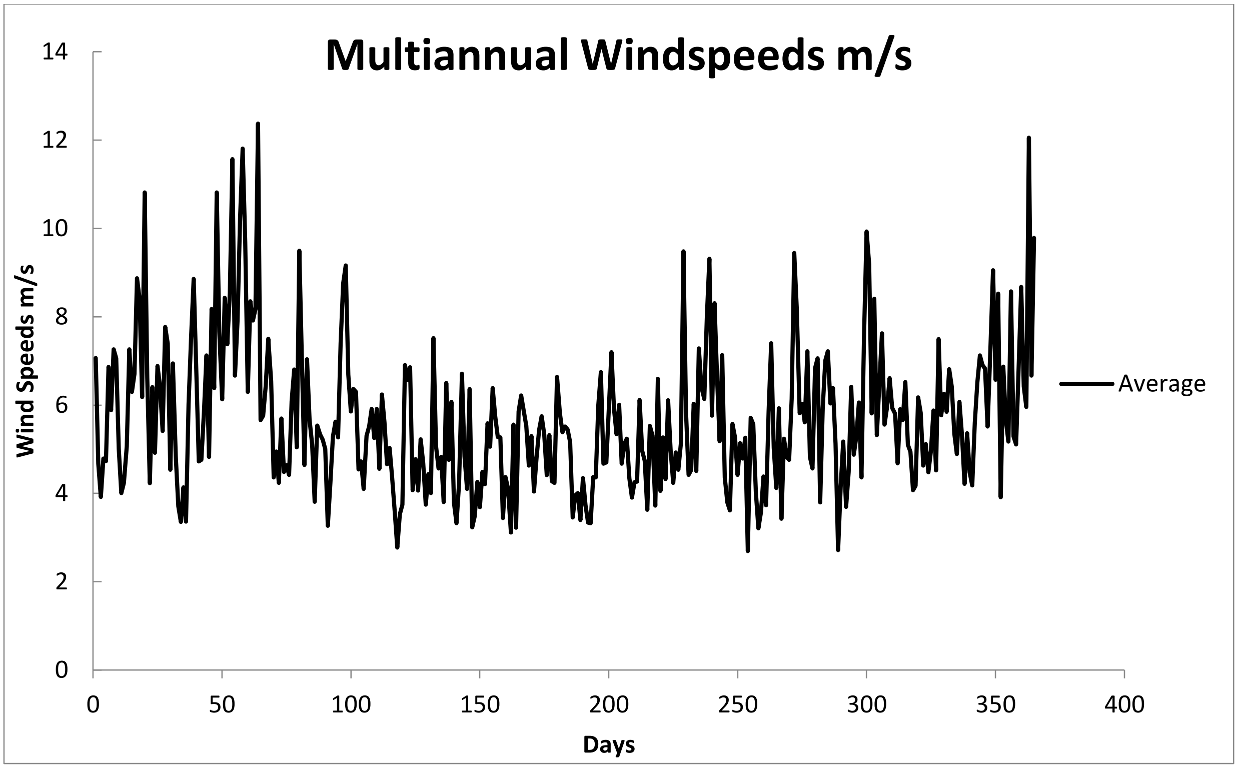
The next set of data that was derived was the hourly trends, for every hour, for six years. These results were organized, analyzed and graphed. The continuous trends includes high wind speeds in the morning, before 5:00 AM and again in the evening after 8:00 PM. The period between 5:00 AM and 8:00 PM is the time period where the wind is at its slowest velocity. Coincidentally, the power demands for most homes also follow this trend where more power is required in the morning and night. A trend found is that the yearly wind speeds mimic the hourly wind speeds by month. The average daily wind speeds for all five years are seen Graph C4.



Graph C2: Hourly Wind Speeds by Month



Graph C3: Hourly wind speeds for the year



Graph C4: Multiannual wind speeds

Weibull Distribution

In statistics, the Weibull distribution is a continuous probability distribution. This distribution is useful with respect to wind turbines because it estimates the wind power potential of a region through its distribution of windspeed. The following equaiton is an expression of the Weibull distribution:

$$f_{WB} = k\frac{v^{k-1}}{c^k}exp\left(-\left(\frac{v}{c}\right)^k\right)$$

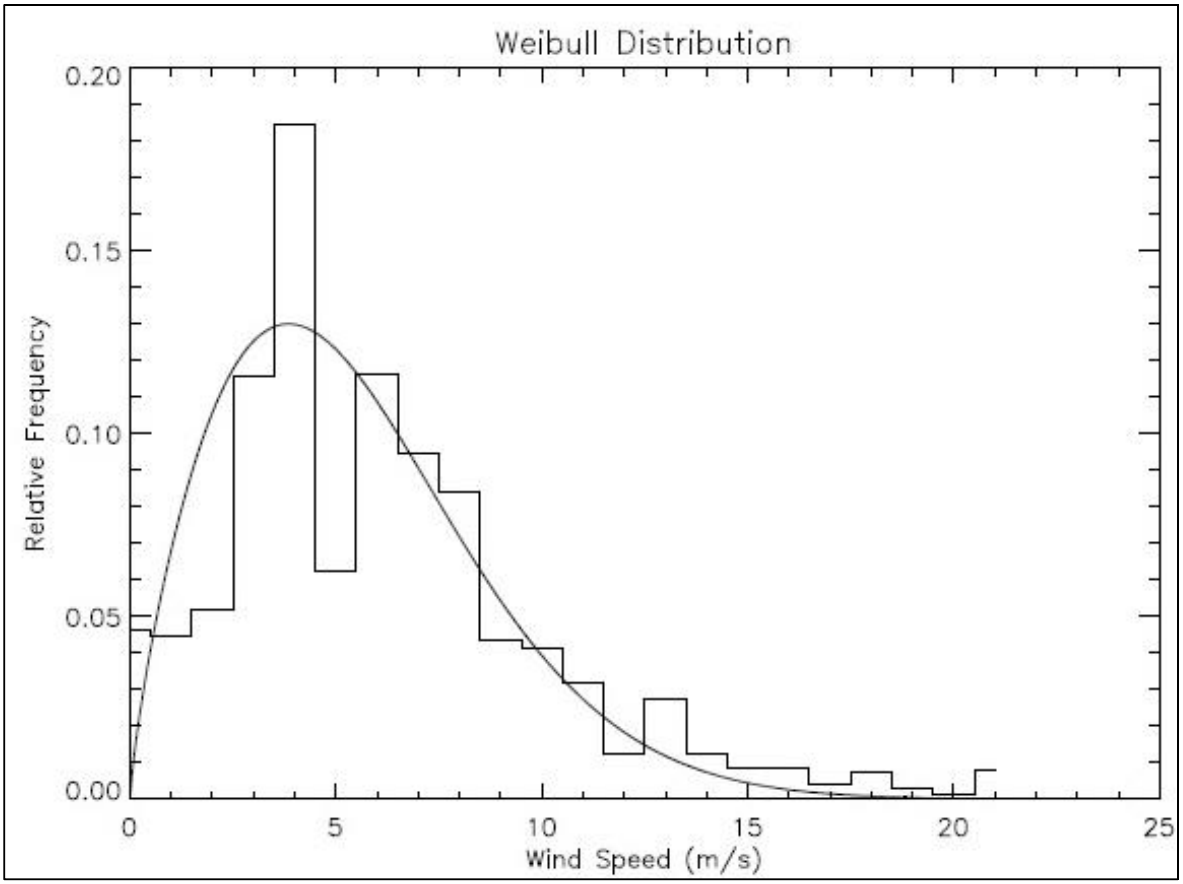
The 'k' is the shape praramer (1.774) and is an expression of distrubution. A value of k < 1 represents that the failure rate decreases over time. A value of k = 1 represents that the failure rate is constant over time and a value of k > 1 indicates that the failure rate increases over time. The next parameter, c, is the scale peramter (6.147 m/s). The scale parameter is a function of the average windspeeds.

The Weibull Diagram is used to find the Energy Patteren Factor (EPF):

$$e(k) = \frac{\Gamma\left(1+\frac{3}{k}\right)}{\Gamma^3\left(1+\frac{1}{k}\right)}$$

The EPF is then used to find the average power per area (218.3 W/m^2):

$$\frac{P_{w,mean}}{A} = 0.5 \cdot \rho \cdot e(k) \cdot \langle v \rangle^3$$



Graph C5: Weibull Distribution for Teller, Alaska

Wind energy is proportional to the change in wind speed and the mass flow rate $E = \frac{1}{2}\dot{m} * v^2$. The mass flow rate is dependent on velocity, the density, and area of the wind turbine; as seen in the following equation: $E = \frac{1}{2}Apv^3$. The generators used in the wind turbines do not operate at 100% efficiency. When these turbines generate power, mechanical and electrical losses form and to account for these losses, a correction factor must be applied in the form of: $E = \frac{1}{2}Cf * A * p * v^3$. Regardless of the implementation, there will be losses when turning wind energy into mechanical energy. The maximum amount of mechanical wind energy that can be extracted from this type of system is calculated to be approximately 59.3% [6].

Wind Farm: Four 100 kW Turbines

Due to the scalability and compatibility of turbines, various implementations were considered when designing and analyzing the proposed farm. The first consideration was to use four Northwind 100C-24 Class III Turbines. This turbine has a manufacturer estimated 20 year lifespan along with a combined rotor and tower weight of 45,700 lbs. This turbine also has a cut-in speed of 3 m/s, a rated wind speed of 12 m/s and a cut-out speed of 25 m/s. The cut-in speed is the required speed the wind must be travelling at in order for the turbine to ignite generation. The rated speed is the maximum wind speed the turbine can optimally generate power. The cut-out speed is the speed where the turbine shuts down in order to avoid damage. Another attribute this apparatus possesses is that the blades are black in color and coated in a compound that limits ice buildup. This additional feature is an important factor considering the low temperatures of Teller.

For wind turbines, manufacturers typically provided a power curve, as seen in Figure C1. What this plot shows is the function of generated power compared to wind speeds at various speeds. In a best case scenario, the turbine will be operating in the 10 – 13 m/s range as most of the rated power is generated there, however, the speeds in Teller hover around 5 m/s.

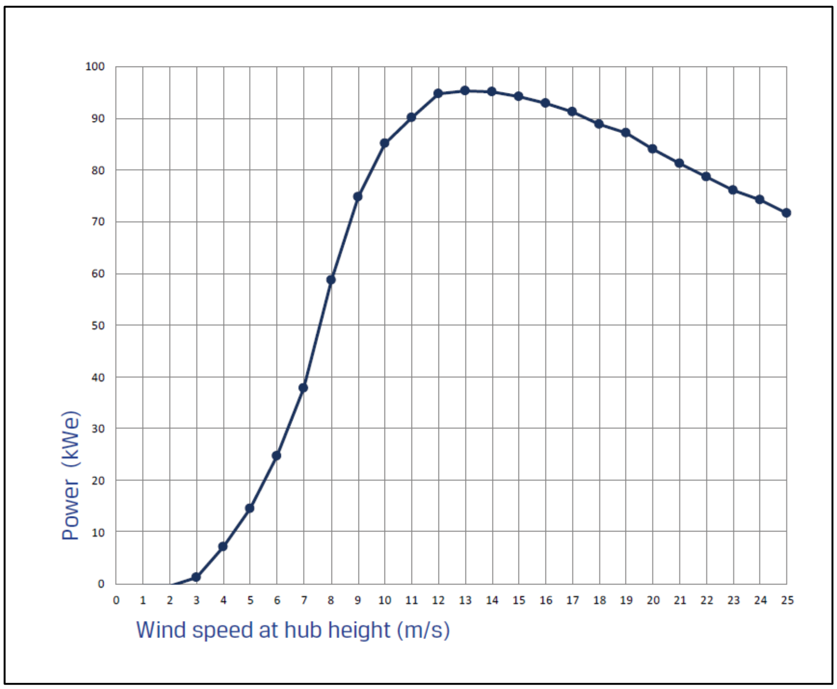


Figure C1: Generation curve for a 100 kW wind turbine [9]

The weighted average for wind speeds can be used to approximate the wind farms' effectiveness in generating energy. This was accomplished by determining how often the wind farm is running at a specified speed. Table C1 below defines each state for the wind farm using data from 2010 – 2016.

Energy State	Lower m/s	Upper m/s	Power Lower kW	Power Upper kW	Power kW
1	0	2.99	0	0	0
2	3	5.01	1.2	14.5	7.85
3	5.01	7.01	14.5	37.5	26
4	7.01	9.01	37.5	74.8	56.15
5	9.01	11.01	74.8	90.2	82.5
6	11.01	13.01	90.2	95.3	92.75
7	13.01	15.01	95.3	94.2	94.75
8	15.01	17.01	94.2	91.2	92.7
9	17.01	19.01	91.2	87.1	89.15
10	19.01	21.01	87.1	81.3	84.2
11	21.01	23.01	81.3	76.1	78.7
12	23.01	25.01	76.1	71.7	73.9

Table C1: States for the 100 kW Wind Turbine [9]

Using the information from Table C1, the amount of time the wind farm is producing energy can be determined. To find the weighted average, the produced power was multiplied by the time the power has taken to be produced. The runtime percentage compared to the weighted output is visualized in Table C2.

The 100 kW turbines were estimated to produce a weighted average of 30.9 kW of power while operating approximately 80% of the time. If each of the two turbines are running, the average load is either met or exceeded, 49% of the time.

Energy State	Generated Power (kW)	Total Power	Run time (%)	Power*Runtime (kW)
1	0	0	19.9%	0
2	7.85	31.4	30.6%	9.62
3	26	104	16.4%	17.08
4	56.15	224.6	14.7%	33.04
5	82.5	330	8.6%	28.32
6	92.75	371	4.7%	17.29
7	94.75	379	2.4%	9.05
8	92.7	370.8	1.3%	4.81
9	89.15	356.6	0.5%	1.95
10	84.2	337	0.5%	1.79
11	78.7	314.8	0.1%	0.47

Table C2: Wind farms Runtimes and States for 100 kW Wind Turbines

Wind Farm: Two 200 kW Turbines

The second design option considered was the use two Siva 200 kW turbines. This turbine has a manufacturer specified 20 year life span with a combined rotor and tower weight of 60,000 lbs. This apparatus has a rated cut-in speed of 3.5 m/s, a rated wind speed of 13 m/s and a cut-out speed of 50 m/s. The power curve for this turbine is shown in Figure C2.

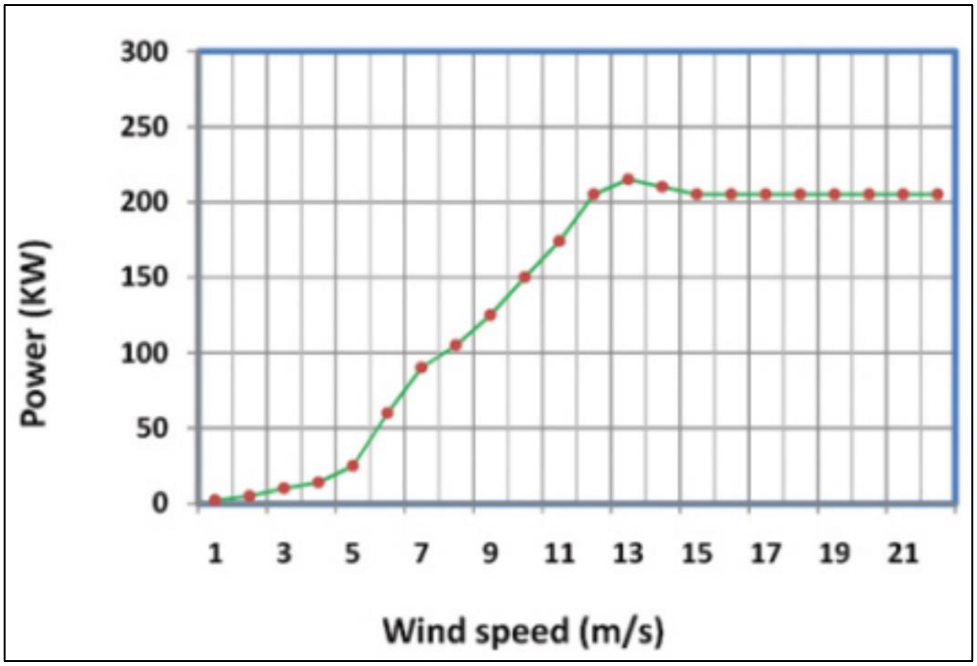


Figure C2: Generation curve for a 200 kW wind turbine [10]

Using the same process used on the Northwind 100C, the determined energy states for the Siva turbines are shown in Table C3.

Energy state	Lower m/s	Upper m/s	Lower kW	Upper kW	kW
1	0	4	0	0	0
2	4	6	7.5	28.9	18.2
3	6	8	28.9	91.1	60
4	8	10	91.1	151.8	121.45
5	10	12	151.8	186.9	169.35
6	12	14	186.9	212.8	199.85
7	14	16	212.8	200.1	206.45
8	16	18	200.1	200.9	200.5
9	18	20	200.9	201.3	201.1
10	20	22	201.3	200.1	200.7
11	22	24	200.1	200.2	200.15
12	24	25	200.2	200.5	200.35

Table C3: States for 200 kW Wind Turbines [10]

For every energy state, the runtimes and mechanical power produced are shown below for the Siva 200 kW turbines:

Energy state	Generated power (kW)	Total power	Runtime (%)	Power*Runtime (kW)
1	0	0	31.8%	0
2	18.2	0	24.7%	9
3	60	0	18.7%	22.5
4	121.5	0	11.2%	273
5	169.35	0	6.4%	21.8
6	199.9	399.7	3.3%	13.2
7	206.5	412.9	1.4%	5.9
8	200.5	401	1.3%	5.1
9	201.1	402.2	0.4%	1.8
10	201	401	0.4%	1.5
11	200.2	400.3	0.1%	0.5
12	200.4	400.7	0.0%	0.2

Table C4: Turbine runtimes and states for two 200 kW Wind Turbines

For the Siva branded turbines, they have been determined to be operating 68% of the time and meeting, or exceeding, the load requirements 43% of the time. The weighted average power for a single turbine is estimated at 27.12 kW.

Sizing and Costing

Similar to the hydroelectric generators, a transmission line system is still required to deliver the generated power to Teller. The cost for the transmission line has not been altered and can still be assumed to run $947,000 per mile. The engineering and surveying cost are assumed be unchanged, at $601,920 and $218,000, respectively. The proposed site for the wind farm, albeit the Northwind 100C or the Siva 200 kW, will be 1.83 miles to Teller. This transmission system will be estimated to cost $860,000, as seen in Table A4. The cost for the materials and shipping will vary due to requiring different materials. The material and shipping cost for the four Northwind 100C (100 kW) and two Siva (200 kW) wind turbines are in Table C5 and Table C6, respectively. Lastly, the cost summery table is shown below in Table C7. The 4 Northwind 100C wind farm option is estimated to cost $150,000 more than the two Siva 200 kW wind turbines.

	Transmission	Design	Surveying	Materials and Equipment	Total
100 kW	$1,733,599	$601,920	$218,000	$1,540,357	$4,093,876
200 kW	$1,733,599	$601,920	$218,000	$1,390,117	$3,943,636

Table C7: Cost summery table for the two Wind farms options

Results and Discussion

Teller currently uses diesel fuel generators to provide their energy needs. In 2010, the base rate of diesel power in Teller was $0.56 per kWh, unsubsidized. The subsidized rate was $0.22 per kWh [11]. When adjusting these rates to take inflation into consideration, the cost of diesel would be $0.63 per kWh (unsubsidized) and $0.25 per kWh (subsidized) [12]. The generation output for Teller was found to be 912,225 kWh. Due to the static population growth trend for this location there are no further plans for increasing power development. Currently, Teller pays $574,000 (unsubsidized) or $231,000 (subsidized) every year in fuel costs [11].

A wind turbines generator efficiency is an important factor to consider and is a function of rotor speed, however, for the scope of this feasibility study, the efficiency will be assumed to be 35% [13]. The transformers losses have been calculated to be at 90% where the resistance for 1.83 miles of 1/0 ASCR cable is 0.00058 Ω [14]. For the 100 kW load, the current through the 12.47 kV delta configured line is 4.629 A. Due to the properties of the designed system, the inductance and capacity of the line are considered negligible. When power is run through transmission lines, losses occur in the form of voltage drops. The calculated losses were found to be 0.012 W and 0.0027 V. Due to these small variances, the loss will not be considered for the remainder of this report. The implemented system will need to be aggregated into the current power grid. The net power feed into the grid is expressed in the equation:

$$P_{grid} = P_{windfarm} * \eta_{Generator} * \eta_{Transformer} * \eta_{Transformer}$$

Plugging in the found values gives the following efficiency:

$$P_{grid} = P_{windfarm} * 0.35 * 0.9 * 0.9$$

Using the results of the P_{grid} equation, the wind power reaching the grid is approximately 28% of the power curves.

River Turbines

Due to the lack of flow and tidal data, accurately determining the amount of diesel offset by the hydroelectric generators is impossible. Since an accurate representation of the potential cost savings cannot be analyzed, it is in the best interest of the feasibility study to discontinue additional research in this topic.

100 kW Turbines

Diesel Offset

Energy state	Generated power	Total power	Runtime (%)	Power*Runtime (kW)
1	0.00	0.00	19.9%	0.00
2	7.85	8.79	30.6%	2.69
3	26.00	29.10	16.4%	4.78
4	56.15	62.89	14.7%	9.25
5	82.50	92.40	8.6%	7.93
6	92.75	103.90	4.7%	4.84
7	94.80	106.00	2.4%	2.53
8	92.70	103.80	1.3%	1.35
9	89.15	99.85	0.5%	0.55
10	84.20	94.30	0.5%	0.50
11	78.70	88.14	0.1%	0.13
12	73.90	82.77	0.0%	0.11

Table D1: 100 kW diesel offset table

The power weighted average of the four 100 kW turbines has been estimated to be 34.6 kW. This power weighted average will offset 34% of Teller's load requirements.

Cost Analysis

The price of crude oil varies as it can be considered a product based in volatile market. The price of oil can be affected by disruptions in geopolitical and weather related incidents [15]. The United States Energy Service only projects fuel prices for the next calendar year. Due to the limited reliable sources on forecasted crude oil prices, an estimation on the fuel prices in rural Alaska was conducted. The estimation was conducted by taking the average diesel fuel cost for the last 20 years in the United States and scaling it upwards to better reflect the cost of fuel in rural Alaska [16]. The projected fuel cost was not based on the traditional nominal price, but instead on the real market cost. The nominal price can be considered the pure rate, which does not account for changes in cost due to season changes or other factors. See Table E1 for the projected fuel cost for a 10 year period.

Assuming the turbines will offset 34% of the diesel requirements per year the average money saved has been calculated to be $142,000 per year with an estimated payback period of 7 years. See Figure E1 for a cost breakdown for a 10 year period. The payback period is based on the condition that the price of fuel follows the trend outlined in Table E1. If the price of fuel were to rise, then the yearly savings can potentially rise and lower the payback period. On the other hand, if the price of fuel drops, then the payback period can increase. Due to relativity, the best case scenario was chosen where the price of fuel follows the yearly trends. The average forecasted price of diesel has been calculated to be $3.88. Considering the 20 year lifespan for the turbines, the total amount of fuel saved is estimated to be 730,656 gallons of diesel which will lead to an estimated total savings of $2,840,000.

Projected Fuel Costs Based on 10 Year Period			
Year	**Projected Cost of Fuel**	**Gallons Saved Annually**	**Savings**
2016	$3.74	36532.8	$136,523.07
2017	$3.76	36532.8	$137,261.04
2018	$3.80	36532.8	$138,736.96
2019	$3.81	36532.8	$139,105.94
2020	$3.88	36532.8	$141,688.81
2021	$3.90	36532.8	$142,426.77
2022	$3.94	36532.8	$143,902.70
2023	$3.93	36532.8	$143,533.72
2024	$3.96	36532.8	$144,640.66
2025	$4.03	36532.8	$147,223.53
2026	$4.04	36532.8	$147,592.51
	Average Cost per Gallon:		**$3.89**
	Average Savings per Year:		**$142,057.79**

Table E1: Estimated Fuel Savings

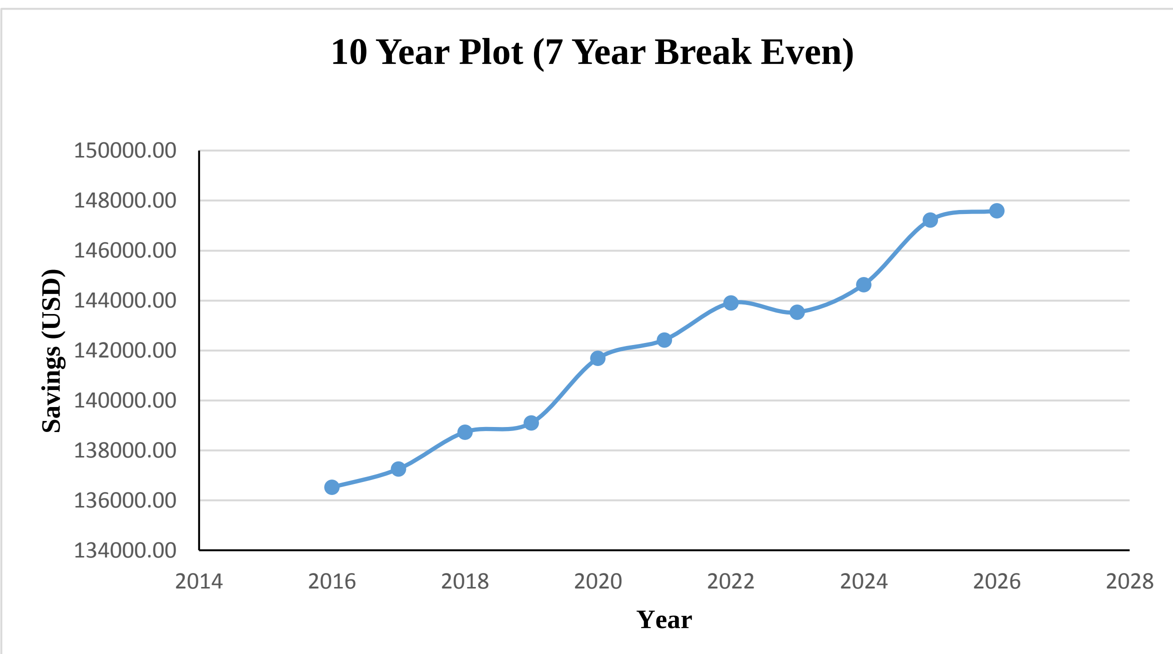


Figure E1: Ten Year Cost Breakdown

200 kW

Diesel Offset

Energy state	Produced power	Total power	Runtime (%)	(Power produced) *(Runtime)
1	0.00	0.00	31.8%	0.00
2	18.20	10.19	24.7%	2.50
3	60.00	33.60	18.7%	6.30
4	121.50	68.01	11.2%	7.60
5	169.40	94.84	6.4%	6.10
6	199.90	111.90	3.3%	3.70
7	206.00	116.00	1.4%	1.70
8	200.50	112.30	1.3%	1.40
9	201.10	112.60	0.4%	0.50
10	201.00	112.00	0.4%	0.40
11	200.20	112.10	0.1%	0.10
12	200.40	112.20	0.0%	0.10

Table D2: 100 kW diesel offset table

The power weighted average of the two 200 kW wind turbines has been estimated to be 30.0 kW. Analyzing this turbine, we have determined that it can potentially offset 30% of the diesel requirements per year. This leads to a yearly cost savings of $123,000. Due to selecting the Northwind 100C turbines due to their efficiency and higher power output, a complete cost savings for the Siva 200 kW turbine was not completed.

Conclusions

The grand scope of this project was to offset the costly diesel generators that provide the energy needs for Teller and Brevig Mission with a renewable source for our client, Dr. Metzger. The original plan was to install a hydroelectric generator at the mouth of the Tuksuk Channel on the Seward Peninsula. This plan, however, fell through due to issues with finding accurate flow and tidal data. The plan of utilizing hydroelectric generators was then discarded and an alternative was considered.

The renewable alternative that was selected was the use of wind turbines. The wind turbines provided the best alternative as they favorably compared to the hydroelectric generators for various reasons such as the ability to continuously operate the entire year, shorter transmission line systems connecting the generation and load sites, and a faster payback period. The wind data that was collected and analyzed showed an average wind speed of 5.3 m/s.

The two considerations for the wind turbines were four Northwind 100C and two SIVA 200 kW turbines. When analyzing the potential of using the Northwind 100C turbines we determined they will be generating power approximately 80% of the time. If each of the two turbines are in operation, the average load is either met or exceeded 49% of the time. Each of the Northwind

100C turbines were estimated to produce a weighted average of 30.9 kW. When analyzing the potential of the Siva 200 kW turbines it was determined to be operating 68% of the time and meeting, or exceeding, the load requirements 43% of the time. The weighted average power for a single turbine is estimated at 27.12 kW. The differences for operation time (+12%), (load meeting (+6%), and total power weighted average (+3.8 kW) were favorable towards the Northwind 100C. The Northwind option would have a total cost of $4,093,876 and the Siva option would cost $3,943,636. Although the Northwind implementation would cost $150,240 more than the Siva, when considering these differences, the Northwind 100C turbine was selected as the better apparatus.

The Northwind turbines will offset an estimated 35% of the load in Teller. This offset will save 32,473 gallons of diesel and considering the average price of diesel in rural Alaska at $3.70 per gallon, there will be an estimated amount of savings of $126,000 per year. The turbines have a manufacturer specified lifespan of 20 years and in a best case scenario where the price of diesel stays constant (and accounting for year inflation of 0.90%), the payback period is estimated to be seven years with a total lifetime savings of $2,840,000.

There are other forms of renewable energies, such as photovoltaic cells. However, this option was not considered or analyzed in depth due to time constraints. We believe research into this option could potentially yield additional offset capabilities. If the villages were to consider using wind turbines they could potentially save a substantial amount of money.

Appendices

Appendix A: Transmission Costs

Material Cost Projections per mile

		Material			**Labor to Install**	
	Quantity	Unit cost	Amount		Unit	Amount
Pile 20 foot	18	$5,000	$90,000		4	72
Class 1 40 feet	4	$1,000	$4,000		8	32
Class 3 40 feet	6	$750	$4,500		8	48
Class 4 40 feet	8	$650	$5,200		8	64
DDE 10'	4	$1,200	$4,800		16	64
Double Angle 10'	4	$250	$1,000		10	40
Taw Out 10'	8	$150	$1,200		14	112
Down Guy 12.5 M	20	$100	$2,000		10	200
1/0 ACSR ft.	24000	$0.27	$6,480			
Anchor	20	$80	$1,600		8	160
	Total:		**$120,780**		**Total:**	**792**

Table A1: Materials cost projection per mile

One mile Material shipping costs

		Material		
	Quantity	Weight (lbs)	Unit cost	Per
Pile 20 feet	20	840	$0.80	$13,440
Class 1 40 feet	4	1400	$0.80	$4,480
Class 3 40 feet	6	1800	$0.80	$8,640
Class 4 40 feet	8	1000	$0.80	$6,400
DDE 10'	4	1400	$0.80	$4,480
Double Angle 10'	4	200	$0.80	$640
Taw Out 10'	8	100	$0.80	$640
Down Guy 12.5 M	20	15	$0.80	$240
1/0 ACSR ft.	4	600	$0.80	$1,920
Anchor	20	20	$0.80	$320
	Total:			**$41,200**

Table A2: One Mile Shipping Cost

Engineering Team per Mile Cost			
	quantity	Material unit price	Amount
Man hours	100	$250	$25,000
Air travel	1	$700	$700
Logging day	14	$130	$1,820
Vehicle Rental day	14	$115	$1,610
Meals	42	$20	$840
Total:			**$29,970**

Table A3 Engineering Team cost estimates

Appendix B river turbine costs

Total Cost of Surveying Team			
	Quantity	Unit cost	Amount
Man Hours	1680	$125	$210,000
Air travel	3	$700	$2,100
Logging	28	$110	$3,080
Vehicle Rental	14	$115	$1,610
Equipment rental	1	$500	$500
Meals	42	$20	$840
Total:			**$218,130**

Table B1: Total Cost of Initial Surveying

Engineering intel cost			
	Quantity	Material Unit cost	Amount
Air travel	3	$700.00	$2,100.00
Electrical Engineering	1000	$167.04	$167,040.00
Civil Engineering	1000	$158.73	$158,730.00
Mechanical Engineering	500	$188.10	$94,050.00
Non-engineering staff	3000	$60.00	$180,000.00
Total:			**$601,920**

Table B2 Total Cost of initial Engineering

One time Shipping Cost for the River Turbine							
	Material shipping				**Material cost**		
	Quantity	Weight lb.	Unit cost	per	Amount	Unit cost	amount
Boom truck	1	30000	$0.80	$24,000	1	$40,000	$40,000
Line Truck	2	15000	$0.80	$24,000	2	$20,000	$40,000
Excavator	2	20000	$0.80	$32,000	2	$100,000	$200,000
Westinghouse T1004	2	2323	$0.80	$3,717	2	$10,000	$20,000
12 kW water turbine including generator	17	500	$0.80	$6,800	17	$60,000	$1,020,000
Switch Gear/grid upgrades	1	500	$0.80	$400	1	$10,000	$10,000
Control upgrades and equipment	1	0	$0.80	$ -	1	$200,000	$200,000
Capacitor bank	1	1000	$0.80	$800	1	$8,000	$8,000
	Total:			**$90,917**		**Total:**	**$1,530,000**

Table B3: One time shipping and material cost for the River turbine

Appendix C: Wind farms Costing

One time Shipping Cost for 100kW Wind Turbine							
		Material shipping				**Material cost**	
	Quantity	Weight lb.	Unit cost	per	Amount	Unit cost	amount
Boom truck	1	30000	$0.80	$24,000	1	$40,000	$40,000
Line Truck	2	15000	$0.80	$24,000	2	$20,000	$40,000
Excavator	2	20000	$0.80	$32,000	2	$100,000	$200,000
Westinghouse T1004	2	2323	$0.80	$3,717	2	$10,000	$20,000
100kW Wind Turbine	2	91400	$0.80	$6,800	4	$200,000	$800,000
Switch Gear/grid upgrades	1	500	$0.80	$400	1	$10,000	$10,000
Control upgrades and equipment	1	0	$0.80	$ -	1	$200,000	$200,000
Capacitor bank	1	1000	$0.80	$800	1	$8,000	$8,000
	Total:			**$230,357**		**Total:**	**$1,310,000**

Table C5: One time shipping cost for 100 kW Wind turbines

One time Shipping Cost for the River Turbine							
		Material shipping				**Material cost**	
	Quantity	Weight lb.	Unit cost	per	Amount	Unit cost	amount
Boom truck	1	30000	$0.80	$24,000	1	$40,000	$40,000
Line Truck	2	15000	$0.80	$24,000	2	$20,000	$40,000
Excavator	2	20000	$0.80	$32,000	2	$100,000	$200,000
Westinghouse T1004	2	2323	$0.80	$3,717	2	$10,000	$20,000
200kW Wind Turbine	17	500	$0.80	$6,800	17	$60,000	$1,020,000
Switch Gear/grid upgrades	1	500	$0.80	$400	1	$10,000	$10,000
Control upgrades and equipment	1	0	$0.80	$ -	1	$200,000	$200,000
Capacitor bank	1	1000	$0.80	$800	1	$8,000	$8,000
	Total:			**$180,117**		**Total:**	**$1,530,000**

Table C6: One time shipping cost for the 200 kW Wind Turbines

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