ACEP Technical Report

Chevak REF Round 5 and Round 7

Report – September, 2019

A report for the Alaska Energy Authority as part of the Renewable Energy Fund Data Collection and Analysis Effort

Alaska Center for Energy and Power

Table of Contents

Introduction

The Renewable Energy Fund (REF) grant program was developed to reduce and stabilize the cost of energy for Alaskans through the implementation of renewable energy projects. To date, the REF has distributed more than $250 million to qualified projects around the state, and this funding has been matched with hundreds of millions of dollars in funding from local sources.[1] This report evaluates the performance and impacts of two REF projects in the community of Chevak, AK. Chevak is located in western Alaska and has a population of a little over 1,000. Chevak is a member of the Alaska Village Electric Cooperative (AVEC) and has water infrastructure provided by the Alaska Native Tribal Health Consortium (ANTHC).

Chevak was awarded two REF projects to reduce consumption of diesel energy. Diesel fuel is used in diesel generators to produce electricity, and is used as heating fuel in boilers to produce space heating. In 2011, AVEC was awarded REF Round 5 funding to install an electric boiler and control system to use excess wind generation to provide process heat in the water treatment plant (WTP). In 2013, the City of Chevak was awarded REF Round 7 funding to recover waste heat from diesel generators for use in the water and vacuum plant. In both of these projects, otherwise unused energy is captured and used to provide heat that would otherwise be produced by burning heating fuel.

In Chevak, the electric utility AVEC operates diesel generators and a wind farm containing four Northern Power Systems 100 B model wind turbines, each rated at 100kW. During the winter months, the Chevak grid load varies from approximately 200 to 450 kW. In times of moderate to high wind speeds and low village grid load, the wind turbines are curtailed because there is insufficient load. There is significant opportunity to utilize existing wind turbine capacity to meet thermal loads and reduce the use of heating fuel.

The REF Round 5 project in 2011 involved the installation of an electric boiler in the water treatment plant (WTP) and implemented a control system to operate the electric boiler in times of excess wind generation capacity. Initial analysis predicted that this implementation would eliminate 8,603 out of 14,480 gallons of heating fuel usage annually at the WTP, or roughly 60% savings.

Prior to the Round 7 project, the existing diesel generators dissipated all excess heat from the cooling jackets to the atmosphere via radiators. The REF Round 7 project installed heat exchangers in the generator coolant loop to use heat from the engines to warm a secondary glycol loop. This secondary loop was plumbed in insulated above-ground piping to a second heat exchanger in the water and vacuum plant boiler room to pre-heat heating glycol returning to the boiler. This project was estimated to displace 12,500 gallons of the 16,800 gallons of heating fuel used annually at sanitation facilities, a roughly 75% reduction.

Summary

Analysis of the limited available data led to the following assessments of the REF Round 5 and Round 7 projects in Chevak. The available data included various electrical power and wind speed measurements and were collected during periods of September 1 2015 through February 29 2016 and from October 1

[1] http://www.akenergyauthority.org/Portals/0/DNNGalleryPro/uploads/2017/1/27/REF%20Round%20X%20Status%20Report.pdf

through December 31 2017. These figures are valid for the periods during which data was collected and may or may not be representative of opportunities on an ongoing or annual basis.

- Average wind farm capacity factor was 28%
- Average wind penetration on the electrical grid was 34%
- Average wind resource utilization was 54%. 50% of the resource was used for electric grid loads, and 4% for wind-to-thermal loads.
- On average, 16% of potential wind energy was curtailed. 30% was lost to turbine downtime.
- In an average month, 6,400 kWh of wind was directed to thermal loads, equivalent to 203 gallons of heating fuel usage using an 80% efficient boiler.
- Based on heating fuel deliveries to the WTP, the REF Round 5 project resulted in annual reduction of 2,440 gallons, and the Round 7 project resulted in additional annual reduction of 4,730 gallons.
- If wind farm losses could be reduced to 18%, an additional 36,500 kWh per month of wind energy could be used for electric grid or thermal loads. If used entirely for thermal loads, this could result in an additional offset of up to 1,150 gallons of heating fuel per month. If used entirely for electrical grid load, this could displace up to 2,960 gallons of diesel per month.

Methodology

The analysis and findings of this report were based on data collected during the periods of September 1 2015 through February 29 2016 and from October 1 through December 31 2017. The dataset included measurements of power output from each diesel generator and each wind turbine. Wind speed as measured by each wind turbine's anemometer was provided. Also measured was the total village grid load and the electrical usage of the Secondary Load (SLC) and Interruptible Load (ILC) used to convert excess electricity to heat.

Periods of incomplete, erroneous, or duplicative data were omitted from the analysis. Additionally, any data timestamp that included a wind turbine output and wind speed measurement that indicated turbine output exceeding 120% of rated output were excluded from analysis as either the wind speed or turbine output data are in error. In total, approximately 30% of recorded data were excluded from analysis. Hourly, daily, and monthly averaging were performed on the remaining data, with the gaps in data given no weighting in the averages. This procedure assumed that the non-excluded data are representative of the entire averaging period. For example, if a week was missing in a month, that monthly average was the average of the three weeks of data that were present and assumed to be representative.

This analysis quantified only what is recorded in the data. Any errors or omissions in the data set affected the validity and applicability of this analysis. A heating value (LHV) of 135,000 BTU/gal for #1 heating fuel and a boiler efficiency of 80% were assumed for calculating fuel savings of wind-to-heat and recovered heat.

The manufacturer's wind speed curve at standard conditions, with air density of 1.225 kg/m^3, was used to predict wind turbine maximum output at measured wind speeds. The power curve is shown in Figure 1.

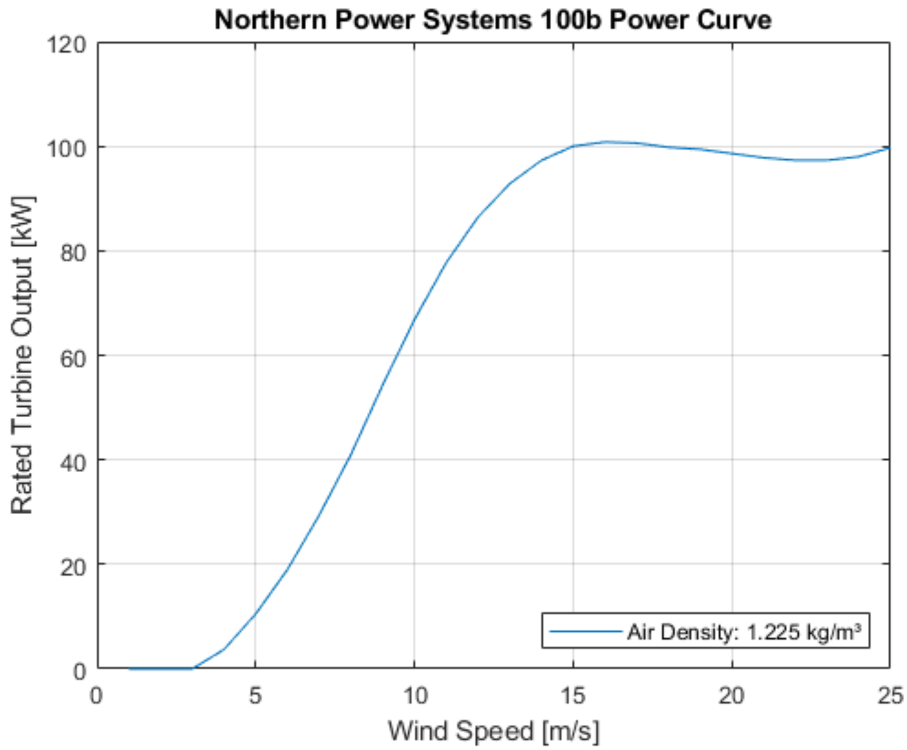

Figure 1. NPS 100b wind turbine power curve

The functioning of the wind-diesel system and wind-to-heat system was dependent on control parameters and settings. This analysis did not evaluate control settings but sought to evaluate the overall performance of the system and address the areas of inquiry identified by the project stakeholders.

Terminology:

From the available data, several additional parameters were calculated to quantify the performance of the wind turbines and wind to heat system on the Chevak grid:

- *Wind to Grid* - Energy generated by wind turbines and consumed in Chevak grid electrical load. Direct offset to diesel generators.
- *Wind to Thermal* - Energy generated by wind turbines and consumed in SLC and ILC thermal loads. Direct offset to heating fuel boilers.
- *Total Wind Output* - Sum of Wind to Grid and Wind to Thermal.
- *Total Available Wind* - Calculated by finding the rated turbine output corresponding to the average of the wind turbine wind velocity measurements on the factory wind turbine power curve (Figure 1) and multiplying by the quantity of wind turbines in the wind farm (4). This is the power that could have been generated if all wind turbines were online and not curtailed.
- *Total Online Wind* - Calculated by multiplying the Total Available Wind by the fraction of wind turbines reported to be online. This is the power that could have been generated at standard conditions if all available wind turbines were not curtailed.

- *Wind to Curtailment* - Difference between the Total Online Wind and the Total Wind Output. This is wind energy that could have been generated from online wind turbines, but was not being used in grid or thermal loads.
- *Wind Penetration* - Total Wind to Grid divided by the village load
- *Wind Utilization* - Total Wind Output divided by the Total Available Wind.
- *Capacity Factor* - Average wind turbine output divided by the rated maximum output. It is a factor of wind conditions and turbine uptime.

Areas of Inquiry

This report investigated four areas of inquiry identified by the project stakeholders.

- Performance assessment of wind turbines and evaluate curtailment relative to rated capacity.
- Quantification of excess wind diverted to the community's water plant system and associated fuel savings.
- Evaluation of delivery system losses for recovered heat and associated fuel savings from recovered heat system.
- Assessment of additional wind power available for diversion into demand managed thermal loads.

Performance of Wind Turbines

An average grid penetration and capacity factor was calculated on a monthly basis for the Chevak wind farm (4 NPS 100b turbines). To illustrate a typical week of loads and generation, Figure 2 shows hourly grid load, diesel power, and wind power for the first six days of December 2015. The progression from low winds and near 100% diesel fuel utilization to higher winds and over 80% wind penetration on an hourly basis are visible. Wind to thermal power is visible on December 6.

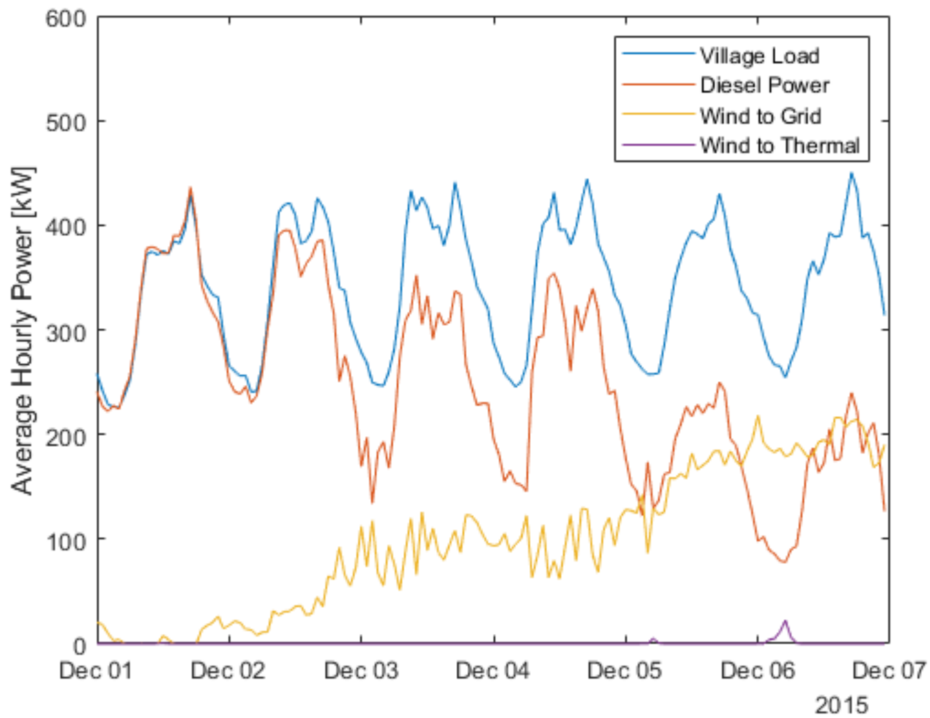

Figure 2. Hourly average power data for one week

The maximum daily penetration of wind power in the grid (excluding wind to thermal loads) observed in the data was 72% on October 28, 2015. The power data from October 28, 2015 are plotted in Figure 3. At approximately 9 a.m., a decrease in wind power was matched by elimination of thermal loads and an increase in diesel power.

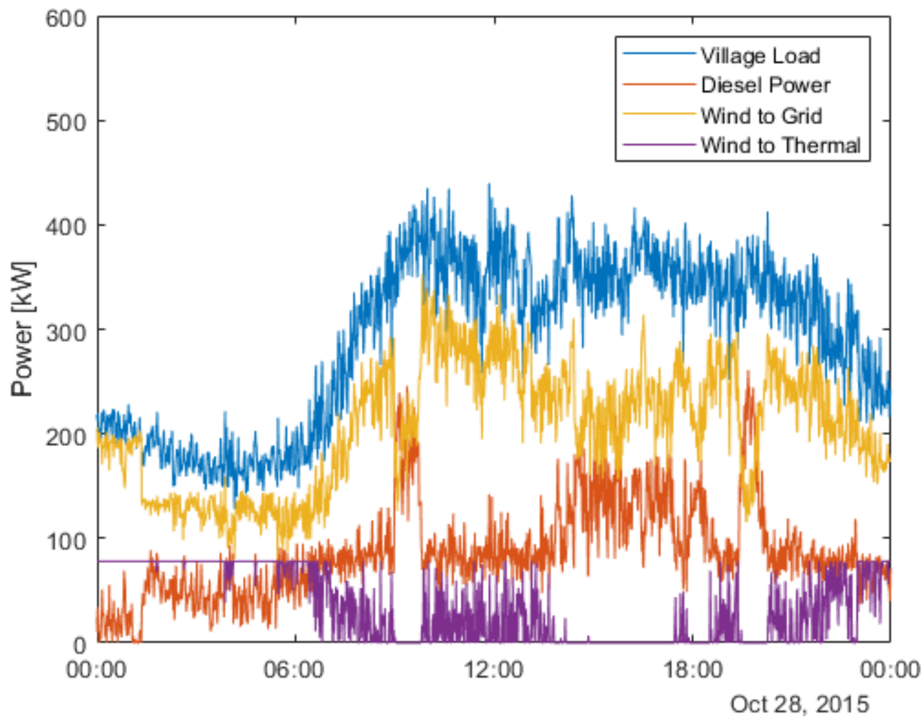

Figure 3. Raw power data from day of highest wind penetration.

During the periods data was collected, the wind farm averaged a capacity factor of 28%, and the wind penetration on the diesel microgrid averaged 34%. Table 1 presents the monthly and total average capacity factors and penetration (excluding thermal loads).

Table 1. Monthly wind penetration and capacity factor

	Sep 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Nov 2017	Dec 2017	Total
Average Wind Grid Penetration	39%	43%	32%	29%	26%	27%	43%	32%	34%
Average Wind Farm Capacity Factor	30%	33%	27%	26%	24%	22%	33%	27%	28%

The REF Round 5 project installed an electric boiler in the water treatment plant (WTP) to provide additional load during periods of high wind and allow for the offset of heating fuel usage with excess wind. Figure 4 plots the monthly total energy from the diesel generators, wind to grid load, and wind to thermal load. Using a 2013 metric for Chevak generator efficiency of 12.34 kWh per gallon[2], the diesel offset of the energy supplied by the wind farm to the grid for the periods averaged 6,000 gallons per month.

[2] https://akenergygateway.alaska.edu/

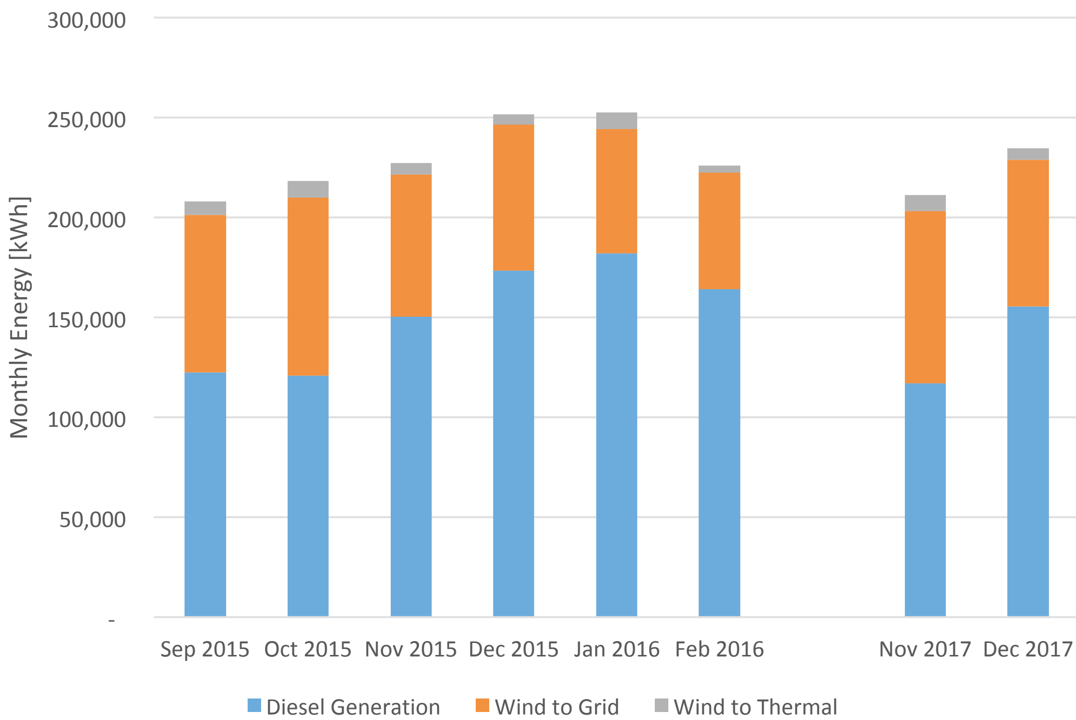

Figure 4. Chevak electricity generation

Anemometer and wind turbine power data were used to determine the potential wind farm energy production and actual wind turbine energy produced. To determine total available wind energy, the anemometer data were used to determine the theoretical power output of the wind farm based on the wind turbine manufacturer's power curve. This total is referred to in this report as the *Total Available Wind Capacity*. To account for the impact of wind turbine downtime, the *Total Online Wind Capacity* is determined by multiplying the *Total Available Wind Capacity* by the fraction of wind turbines that are online. The difference between the *Total Available Wind Capacity* and the *Total Online Wind Capacity* is the amount of energy unavailable due to turbine downtime, *Wind to Downtime*. Subtracting the *Wind to Grid*, *Wind to Thermal*, and *Wind to Downtime* from the *Total Available Wind Capacity* gives the *Wind to Curtailment*. These categories are plotted on a monthly basis in Figure 5. For the periods covered by the dataset used for this analysis, 50% of the Total Available Wind Energy was used in the Chevak grid, 30% was lost to wind turbine downtime, 16% was curtailed, and 4% was used by the new controlled thermal loads. This breakdown is shown in Figure 6.

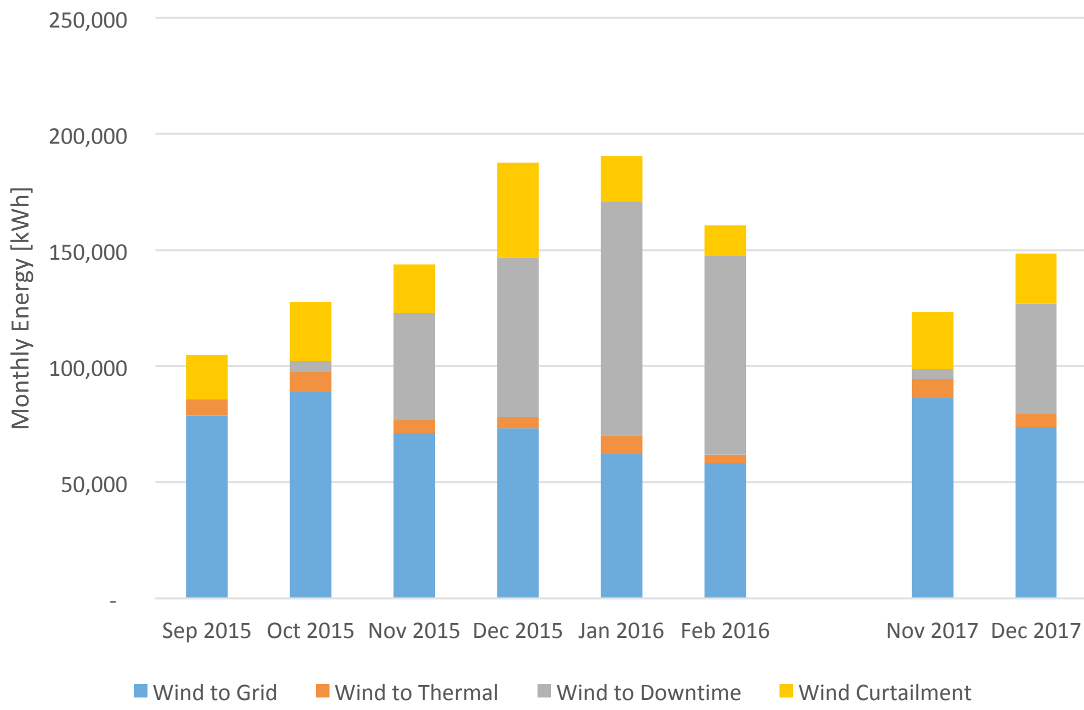

Figure 5. Chevak monthly wind energy utilization

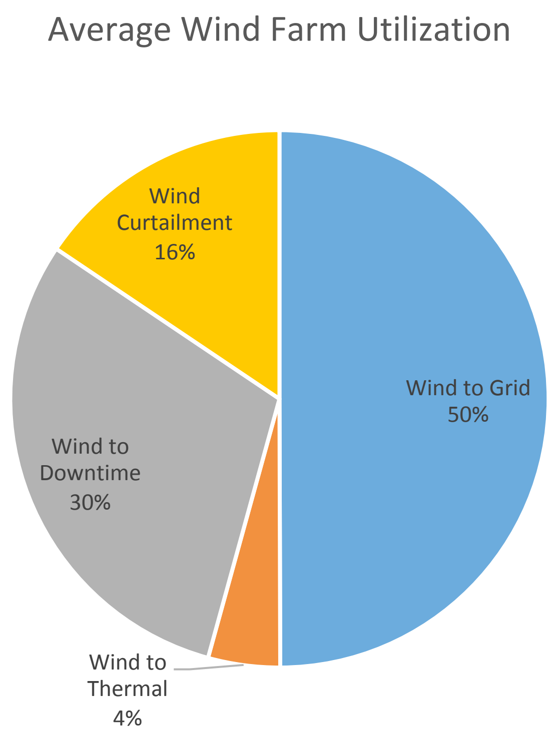

Figure 6. Chevak total wind utilization across dataset.

A widely used number for expected losses in a rural Alaska wind farm is 18%[3], to account for typical turbine down time, wake effects, grid outages, icing, and curtailment. The Chevak wind farm, for the period of data evaluated, had an average loss of 46%. The majority of the losses are attributed to downtime rather than curtailment; this energy was not recoverable due to the turbine not being listed as "online" in the dataset.

When each turbine was examined individually, the impact of several-month long outages for individual turbines was seen. The monthly wind turbine utilization rate is plotted in Figure 7. On a monthly basis, individual wind turbines produced as much as 86% of the expected output based on measured wind speeds and manufacturer's power curve. The wind turbine performance was improved by cold air with higher density than the standard test conditions.

[3] Personal communication: Rich Stromberg

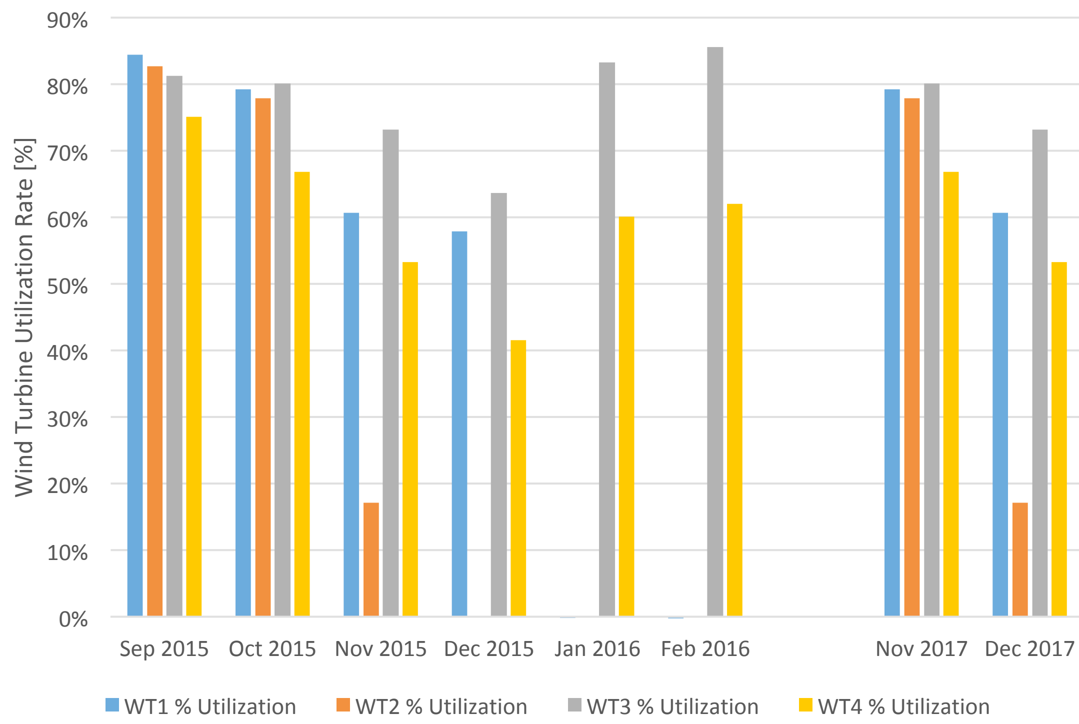

Figure 7. Monthly wind turbine utilization

Quantification of excess wind diverted to Water Treatment Plant (WTP)

The WTP system uses thermal energy to maintain system temperatures. The water system must supply heat to raise the temperature of incoming water and to replace heat lost through the storage tank and distribution system. The WTP heat load is a function of water usage and outside air temperature.

Power data for the secondary load controller (SLC) and interruptible load controller (ILC) at the water treatment and vacuum plants were used to quantify the electric energy input to these thermal loads. These loads harnessed otherwise curtailed wind energy to offset diesel usage in water heating. The electrical data available for analysis did not cover full calendar years and could not be used to correlate with real world fuel deliveries.

Assuming a heating value (LHV) of 135,000 BTU/gal for #1 heating fuel and a boiler efficiency of 80%, the kWh thermal load was converted to the total gallon offsets for the months in the dataset. Also computed was the percentage of excess wind capacity that is converted to thermal loads. These figures are shown in Table 2. On a monthly basis, the SLC and ILC thermal loads were able to capture between 11% and 29% of the available excess wind. In the best month, the energy equivalent of 269 gallons of heating fuel was captured from excess wind capacity.

Table 2. Monthly wind to thermal fuel offset

	Units	Sep 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Nov 2017	Dec 2017	Total
Wind to Thermal	kWh	6,690	8,521	5,511	5,022	8,060	3,579	8,246	5,694	51,323

% Excess Wind to Heat Load	%	26%	25%	21%	11%	29%	21%	25%	21%	22%
Heating Fuel Offset	gal	211	269	174	159	255	113	261	180	1,621

The day with the highest total wind to thermal energy was November 1, 2015 when approximately 1,160 kWh of wind was utilized by thermal loads, offsetting approximately 37 gallons of heating fuel. The power data for the village load, diesel generators, wind to grid, and wind to heat are shown in Figure 8. At approximately 2 a.m., the instantaneous penetration of wind appeared to be near 100%. From midnight to approximately 7 a.m., the wind to thermal load was consistently at 78 kW. Later in the day, the thermal load modulated. Figure 9 shows the total wind diverted to thermal load, across the entire dataset, binned by the hour of the day. More wind was diverted to thermal loads during the overnight hours when village load is at its minimum.

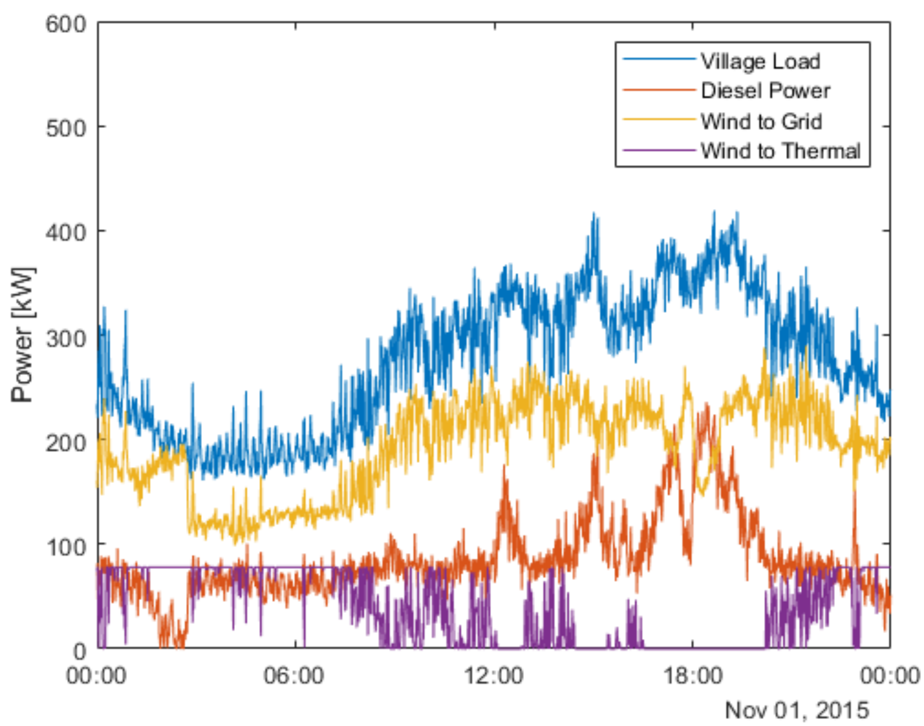

Figure 8. Power data on day of highest wind to heat output.

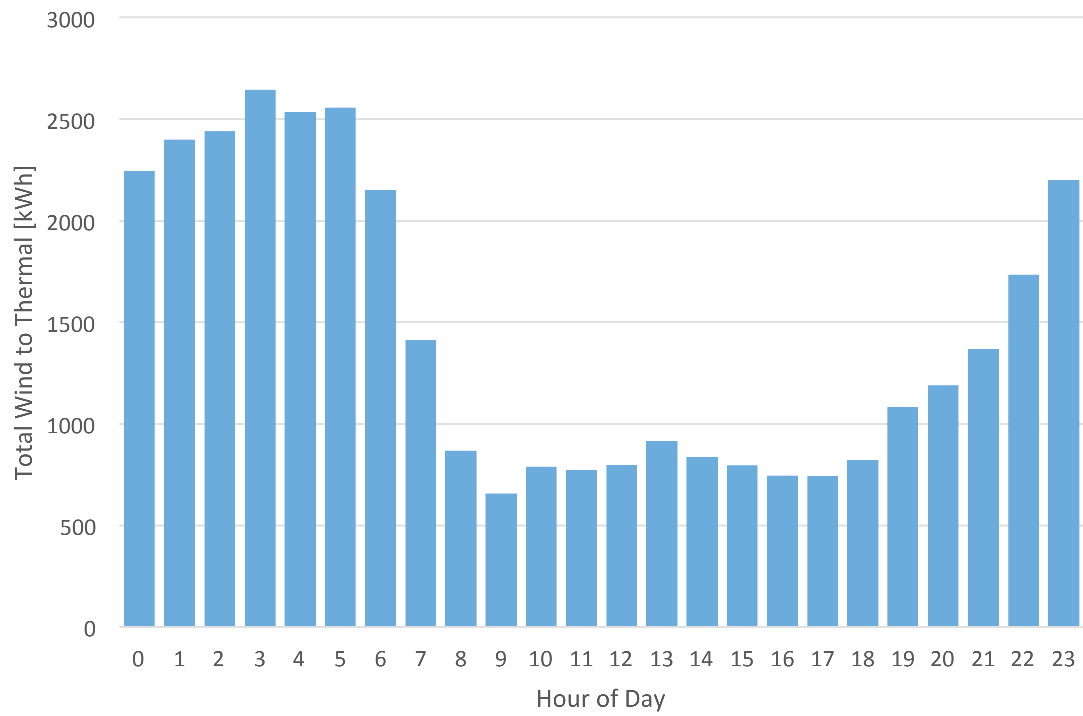

Figure 9. Wind to thermal load by hour of day. Entire dataset.

Recovered Heat and Associated Fuel Savings

Recovered heat from the diesel generators was not quantified in the available data sets. Glycol loop temperatures from the ANTHC BMON site were used to look for correlations between temperature changes in various glycol loops and Chevak weather station temperatures and wind speeds. However, the variability of the data prevented any trends from emerging. Without glycol loop flowrate measurements, no energy calculations were possible.

ANTHC provided annual fuel delivery data for the WTP, as shown in Table 3. The average WTP fuel deliveries for 2011-2014, prior to the REF projects, were 15,623 gallons per year. For 2016 and 2017, the WTP fuel deliveries averaged 8,450, a reduction of 7,170 gallons, or 46%.

Table 3. Chevak WTP annual fuel deliveries

	Units	2011	2012	2013	2014	2015	2016	2017
Annual WTP Fuel Deliveries	gal	17,221	18,025	12,625	14,622	15,455	8,973	7,928

The electrical data for the Round 5 project indicated wind-to-heat thermal loads offset heating fuel at an average rate of 2,436 gallons per year. If this is subtracted from the total WTP reduction of 7,170 gallons, it can be inferred that 4,734 gallons of the reduction was due to diesel generator waste heat recovery from the Round 7 project.

Assessment of additional wind power available for diversion into demand managed loads

This analysis indicated that there was significant unused wind energy that could be harnessed with existing wind turbines. During the data periods evaluated, curtailment of online wind turbines averaged 23,100 kWh per month, enough to power thermal loads to offset 730 gallons of heating fuel usage per month.

A standard wind turbine loss figure given for Alaska wind farms is 18%. If Chevak's wind turbine downtime and curtailment could be reduced to realize a 82% wind energy utilization, then the existing wind turbines could supply an average of 36,570 additional kWh per month. This excess electricity could potentially offset 2,960 gallons of diesel electricity generation or 1,160 gallons of heating fuel for heat per month.

Table 4. Monthly non-utilized wind fuel equivalent

	Units	Sep 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Nov 2017	Dec 2017	Total
Wind to Thermal	kWh	6,690	8,521	5,511	5,022	8,060	3,579	8,246	5,694	51,323
% Excess Wind to Heat Load	%	26%	25%	21%	11%	29%	21%	25%	21%	22%
Wind Utilization Rate	%	81%	77%	53%	42%	37%	39%	77%	53%	54%
Non-Utilized Wind	kWh	19,536	29,891	66,967	109,304	120,273	98,709	28,927	69,199	542,808