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Executive Summary

Expanding wind power capacity with inclusion of battery energy storage in larger Alaska Village Electric Cooperative villages that have existing wind turbines presents an opportunity to not only save diesel fuel for electrical energy generation, but also save heating fuel for community thermal energy (water and space heating) needs. Hooper Bay presents an excellent opportunity to achieve this objective with the installation of 1,000 kW capacity EWT wind turbines at the wind farm. Modeling demonstrates favorable discounted benefit/cost ratios and short simple payback periods for several options including one or two EWT wind turbines and between one and six remote electric wind-to-heat boilers at facilities in Hooper Bay.

The community could additionally benefit from selling power to the Alaska Village Electric Cooperative (AVEC) through a Power Purchase Agreement (PPA), which would pay for the additional jobs necessary to operate a wind system. To insulate Hooper Bay from fuel price volatility and create a more sustainable local economy, it is the recommendation of the authors that they consider the benefits of producing power through wind/battery systems.

Introduction

Alaska Native Tribal Health Consortium (ANTHC) contracted V3 Energy, LLC to prepare this analysis; its purpose is to demonstrate the technical and economic feasibility of substantially increasing the wind power penetration of the Hooper Bay power system by installing one or more 1,000 kW capacity EWT wind turbines.[1] It is hoped that increased wind power capacity in Hooper Bay will encourage further development of renewable energy in the community, including the widespread electrification of its thermal energy needs.

Hooper Bay is an Alaska Native village in western Alaska, on the Bering Sea coast south of the Yukon River, with a population of 1,239 people. It is approximately 17 miles due west of Chevak, but the two communities are not electrically intertied (connected via power transmission lines). Hooper Bay is a member of Alaska Village Electric Cooperative (AVEC), a rural utility cooperative serving over 50 villages in rural Alaska.

Figure 1: Hooper Bay; Google Earth image

The Hooper Bay power system is comprised of approximately 2.6 MW diesel generation capacity augmented by 300 kW of wind power capacity. The Hooper Bay diesel powerplant includes a district (or recovered) heat system that routes engine jacket water waste heat to the nearby ANTHC water treatment plant for co-generation capability.

For the most recently posted Power Cost Equalization[2] (PCE) period of July 1, 2020, to June 30, 2021, AVEC reported 3.21 GWh of diesel generation and 0.39 GWh of wind generation, for a total of 3.60 GWh. This represents 10.8% average annual wind power penetration, as a percentage of total load demand.

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[1] EWT: Emergya Wind Technologies B.V., a Netherlands-based company; Home - EWT - Creating distributed energy champions (ewtdirectwind.com)

[2] Alaska Energy Authority > What We Do > Power Cost Equalization (akenergyauthority.org)

Wind Resource

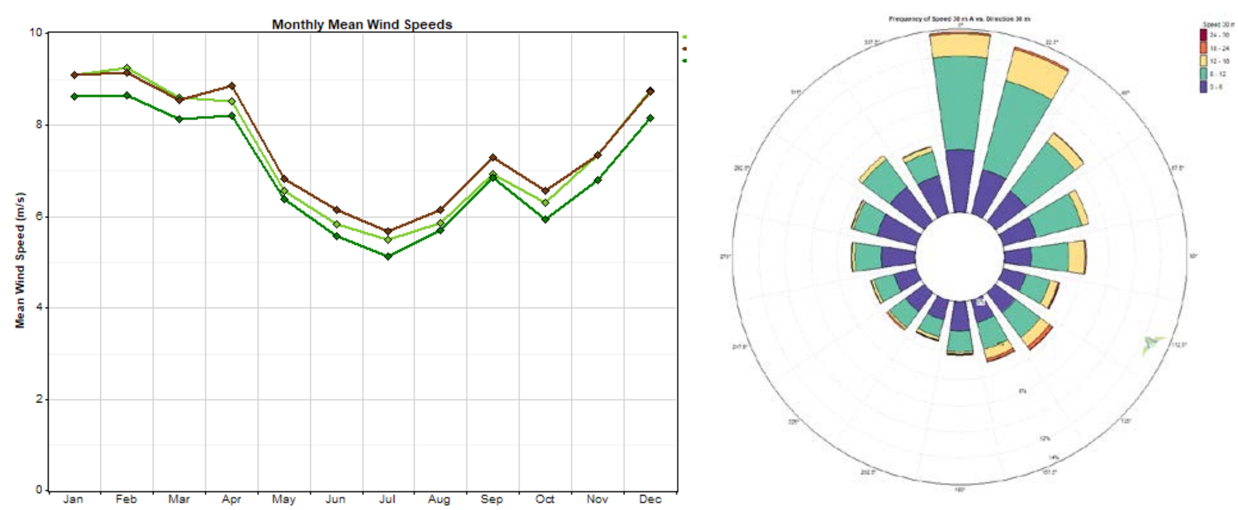
For this report, the Hooper Bay wind resource was assessed from two sources: an Alaska Energy Authority report titled *Wind Resource Assessment for Hooper Bay, Alaska Site* dated February 21, 2006, based on a review of airport weather station data, and met tower data from the village of Chevak, 16 miles east of Hooper Bay (refer to Table 1 for summary data). The AEA Hooper Bay Airport analysis estimated a mean wind speed of 7.4 m/s at the 30-meter level, which equals the mean wind speed measured in Chevak, hence the Chevak wind resource will be used to represent Hooper Bay.

Table 1: Chevak met tower data set summary (representing Hooper Bay)

Variable	Value
Latitude	N 61° 31.492'
Longitude	W 165° 36.389'
Elevation	22 m
Mean wind speed at 30 m	7.4 m/s
Mean temperature	-1.4 °C (29 °F)
Mean air density	1.270 kg/m^3
Power density at 30 m	509 W/m^2
Wind power class	6 (outstanding)
Power law (shear) exponent	0.15
IEC 61400-1 classification	Class IIC

Chevak met tower data (as a stand-in for Hooper Bay) shows a typical Yukon-Kuskokwim coastal wind profile of high winter winds and lighter summer winds. The measured wind rose indicates variable winds with a predominance of northerly winds (see Figure 2).

Figure 2: Hooper Bay monthly mean wind speed and wind rose, 30-meter level (Chevak met tower data)



Hooper Bay Electric and Thermal Load Demand

Energy demand in a community is comprised of three primary elements: electrical, thermal (or heat), and transportation. This analysis focuses on electrical and thermal energy demand, though transportation demand can also be accommodated with renewable energy resources through adoption of electric vehicles.

Electric Load

Hooper Bay electric power demand averages 410 kW with a peak electric demand of 920 kW and an approximate minimum demand of 250 kW. It exhibits typical northern-climate seasonal demand variation (see Figure 3) with a diurnal profile that peaks in early evening (see Figure 4).

Figure 3: Hooper Bay electric load seasonal profile

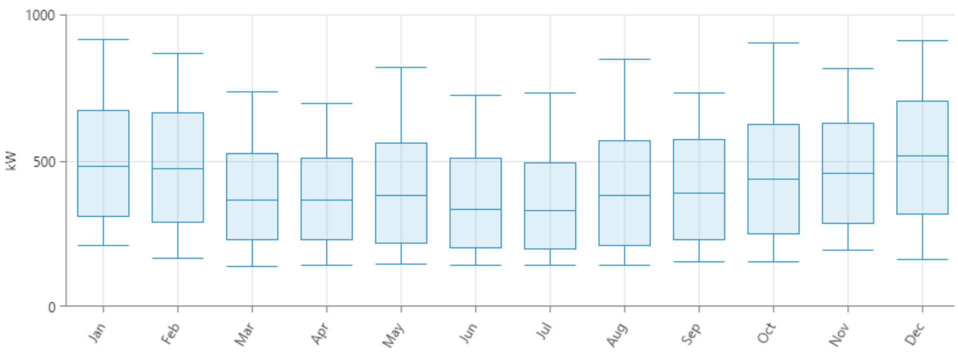
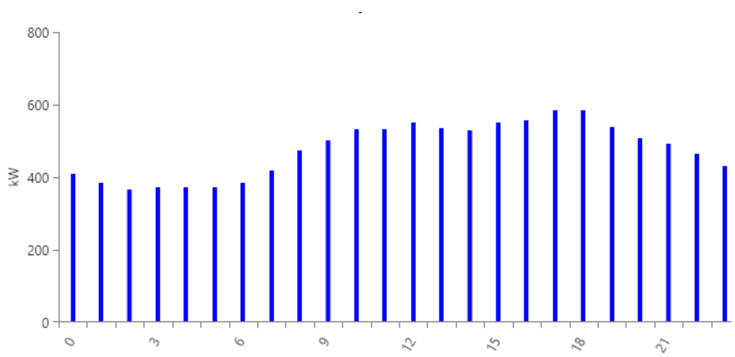


Figure 4: Hooper Bay electric load diurnal profile



Thermal Load, Recovered Heat Loop

Hooper Bay's total thermal load demand is difficult to comprehensively measure as it is comprised of three primary types: large facilities connected to recovered heat from the diesel generators, structures that employ hydronic (circulating hot water) heating, and generally smaller structures such as homes that are equipped with fuel oil-powered, air-driven stoves (e.g., Toyo) for heat. The larger structures are more readily characterized as they have often been audited for energy efficiency and usage, while the smaller structures with Toyo stoves are rarely audited and individual and aggregate energy usage are often uncertain.

The Hooper Bay water treatment plant and washeteria (WTP) is the only structure connected to the powerplant recovered heat system and as such benefits from the co-generation capabilities of the diesel generators. As documented in an AkWarm[3] file dated 18 September 2017 that documents an energy

[3] AkWarm is a specialty software designed to assess the efficiency and energy usage of infrastructure in rural Alaska.

audit, the WTP is augmented by three fuel oil boilers to meet the thermal load demand. To create a thermal load profile for Homer software (see Figure 5 and Figure 6), recovered heat and fuel oil usage as documented in the AkWarm file were converted from million British Thermal Units (BTU) and gallons to kilowatt-hours (kWh).

Figure 5: Hooper Bay Water Treatment Plant thermal load seasonal profile

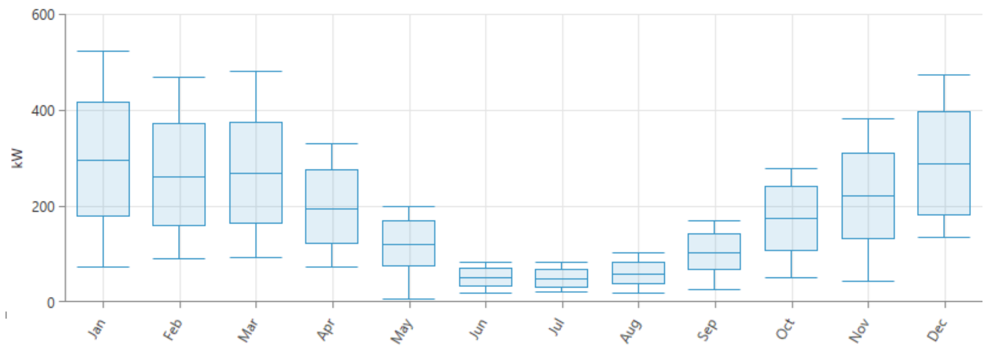
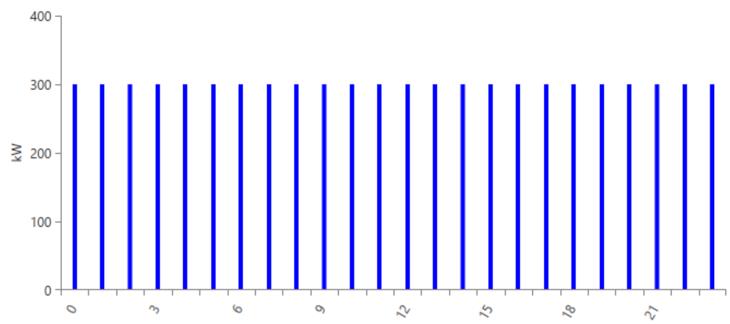


Figure 6: Hooper Bay Water Treatment Plan thermal load diurnal profile (assumed)



Hooper Bay Power System

Hooper Bay's power generation system is comprised of four diesel-electric generators and three wind turbines. Diesel generator information is detailed in Table 2. The three wind turbines are 20-meter rotor diameter, 100 kW capacity Northern Power Systems (NPS) Northwind 100 A models on 32-meter towers for 300 kW total capacity. The turbines are at a wind farm about two-thirds mile northeast of the community center (see Figure 7).

Table 2: Hooper Bay diesel generators

	Engine Data		Generator Data			Commissioning
Bay	Make	Model	Rating (kW)	Make	Model	Date
3	Caterpillar	3456	505	Caterpillar	HC 54F	8/25/2021
4	Caterpillar	3456	505	Newage	HC I544F1	7/26/2013
5	Cummins	QST30	750	Newage	HC I634J1	3/1/2017
6	Cummins	K38G2	824	Newage	HC I604J1	8/1/1991

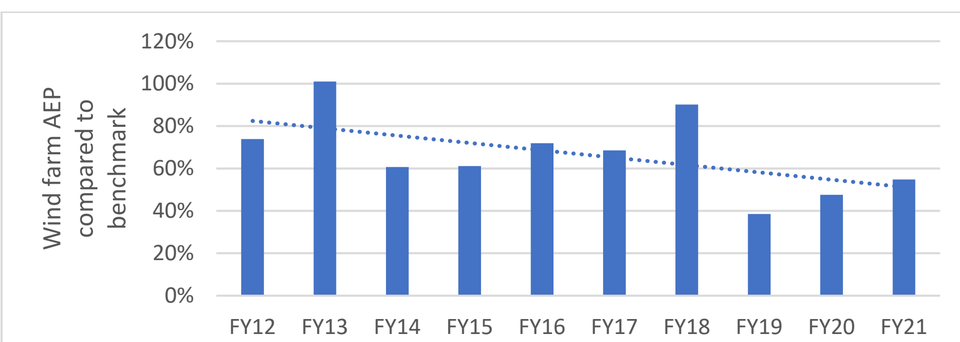
For the 2021 PCE report, AVEC reported a combined diesel generation efficiency of 13.4 kWh/gal (diesel generation only, exclusive of wind power input), which is very good for a village power system and indicates usage of appropriately sized generators, electronic governor control, and proper maintenance.

Figure 7: Hooper Bay wind farm location

Excess wind energy production is presently controlled via a secondary (or thermal) load controller (SLC) and electric boiler in the recovered heat system that supplies jacket water waste heat to the water treatment plant. To help the diesel generators maintain power system frequency, the SLC absorbs excess wind energy regardless of thermal load need. Recovered heat system energy not absorbed by the WTP, whether from the diesel generators or the wind turbines, returns to the powerplant to be ejected into the atmosphere via radiators.

As noted in Figure 8, over a ten-year period the three wind turbines in Hooper Bay operated at about 65 percent of the benchmark performance established by AVEC several years ago.[4] Several factors influence this underperformance, including the financial difficulties and eventual bankruptcy of the turbine manufacturer, curtailment, age of the turbines, and the technical challenge of operating stall-controlled wind turbines at high instantaneous penetration in a wind-diesel power system without a battery energy storage system as a buffer.

Figure 8: Hooper Bay wind farm annual energy production as ratio of benchmark performance



[4] From AVEC fleetwide wind turbine baseline performance study; internal review; 2014

Power Distribution

Hooper Bay's electrical three-phase distribution system, to which the wind farm connects to the powerplant, operates at 7,200 volts phase-to-neutral and 12,470 volts phase-to-phase. The conductors are no. 2 ACSR (aluminum conductor, steel reinforced) with a capacity of 175 amps, equating to approximately 3,800 kW of power transfer capability.

Proposed Project

The proposed project will use additional wind power to supply a significantly higher percentage of electrical load demand than the present 10.7 percent average wind penetration and concomitantly to supply as much thermal load demand as reasonably achievable. It is widely understood that at present solar and wind power are the only realistic renewable energy options for Hooper Bay. Wind power is the primary focus of this study as its seasonal resource availability matches the seasonal energy demand of the community (i.e., high winter winds match high winter load demand), whereas solar power is the opposite. Solar power though has seen important gains in recent years as a significant renewable energy supply option in rural Alaska and may have excellent potential applicability in Hooper Bay despite the often-cloudy summer weather.

The proposed wind turbine of choice for Hooper Bay is the 1,000-kW capacity Emergya Wind Technologies (EWT) Direct Wind (DW) series models.[5] This turbine is in wide use in rural Alaska with operational installations in Kotzebue, Nome, Delta Junction, Bethel, and St. Mary's, with many more planned. The EWT DW series occupies a market niche between home and farm-scale turbines in the 5 to 100 kW capacity range and the much larger utility-scale turbines in the 2 to 6 (and even higher for offshore installations) MW range.

Although the existing Northwind 100 wind turbines are nearing the end of their 20-year operational life, AVEC prefers to leave the Northwinds in service in lieu of decommissioning them during installation of the larger EWT turbine(s). With that in mind, the proposed project was assessed with both turbine models operational.

Site Location

The existing wind farm (refer to Figure 7) is the preferred location to install one or more EWT wind turbines due to landownership, existing electrical distribution connection to the site, known geotechnical conditions, and relatively far distance from Hooper Bay Airport. The existing wind farm site and surrounding land, where an EWT turbine site appears to be most suitable, belong to Sea Lion Corporation (see Figure 9). Sea Lion Corp. provided AVEC with a contractual land use permit for installation of the Northwind 100 turbines and it is assumed they would support installation of EWT wind turbine(s) near the Northwind turbines.

[5] Emergya Wind Technologies B.V. is based in Amersfoort, The Netherlands. Website: [Home - EWT - Creating distributed energy champions (ewtdirectwind.com)](ewtdirectwind.com)

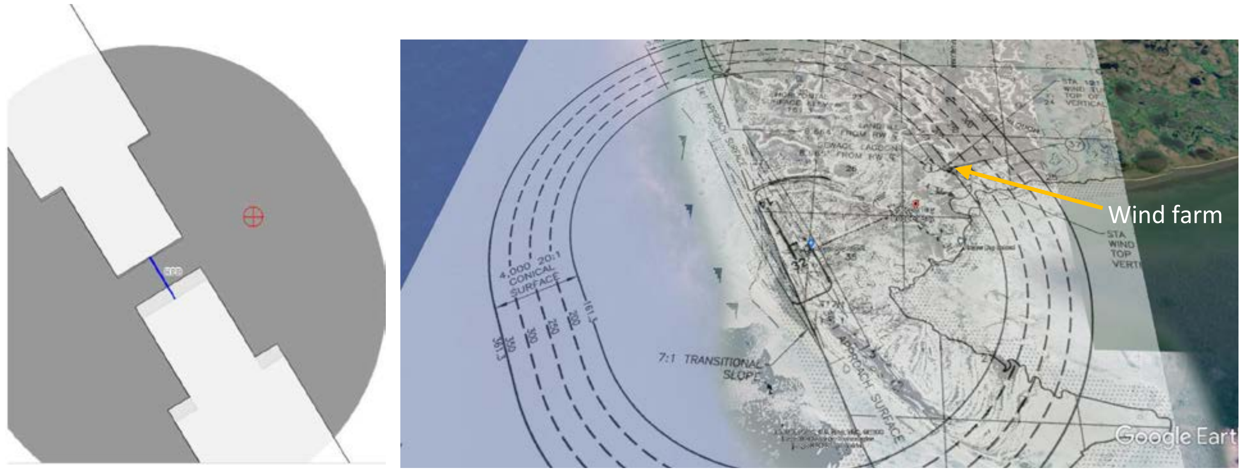
Figure 9: Hooper Bay wind site land ownership, DCRA[6] community profile map; red circle, wind farm site

The new version EWT turbines are available with 46- and 69-meter height towers, with the lower tower acceptable considering Hooper Bay's strong wind resource (note that 46 meters is significantly higher than the existing Northwind turbine hub heights).

As with nearly all rural Alaska wind power projects, installation of turbines near an airport poses potential air safety concerns for Federal Aviation Administration (FAA). Use of FAA's notice criteria tool on its obstruction evaluation website indicates that an EWT DW58-1000 at a 46-meter hub height (a tip height of 75 meters or 246 ft.), located immediately west of the existing Northwind turbines, exceeds notice criteria for CFR Title 14 Part 77, subpart B, Notice Requirements, for construction exceeding an imaginary sloped surface from Hooper Bay Airport, specifically Part 77.9(b) (see Figure 10). Exceeding Part 77.9 criteria is not uncommon for proposed wind power projects in rural Alaska and does not necessarily indicate FAA objection to the proposed project. Further review is required by formal submission of the project to FAA for evaluation.

[6] Division of Community and Regional Affairs, Alaska Department of Commerce, Community, and Economic Development

Figure 10: FAA obstruction evaluation result and Hooper Bay Airport Layout Plan overlay on Google Earth imagery



Electrical Upgrade

In a preliminary review, AVEC's engineering department noted the following requirements to add one or two EWT wind turbines to the Hooper Bay wind farm:

"A #2 ACSR three-phase overhead distribution line feeds out of the AVEC powerplant from a 480 volt, 600 amp feeder breaker to a step-up transformer bank consisting of three 100 kVA transformers connected Y-grounded to Y-grounded. The #2 ACSR overhead distribution line that extends to the wind farm also serves a UIC store, homes, water treatment plant, community hall, jail, several pumphouses, and the gas station. At the northern point of Hooper Bay, the existing three 100 kW Northwind turbines connect to the overhead #2 ACSR line via a 4/0 AL overhead distribution line.

To accommodate one new 1,000 kW EWT in Hooper Bay adjacent to the existing Northwind turbines, the existing 480 volt, 600 amp feeder breaker and the existing three 100 kVA step-up transformers would require upgrading at the powerplant. The breaker would be upsized to 1,600 amp to interconnect up to 1,300 kW (1000 + 300 kW) of wind power and the pad-mount 100 kVA transformers would require upgrading to three 500 kVA pad-mount transformers with a spare unit. The associated 480 volt conductors would be replaced to meet the capacity requirements of 1,300 kW on the 480 volt feeder breaker out of the powerplant.

The addition of two 1,000 kW EWT turbines at the existing wind farm would require substantial switchgear replacement and infrastructure improvements that would warrant further investigation."

AVEC estimated $175,000 of upgrades to support one EWT turbine and $750,000 of upgrades to support two EWT turbines.

Evaluation Method

The proposed project was evaluated using UL's Hybrid Optimization of Multiple Energy Resources (HOMER) Pro software. From UL's Homer Energy website: *HOMER Pro® microgrid software by HOMER Energy is the global standard for optimizing microgrid design in all sectors, from village power and island utilities to grid-connected campuses and military bases. Originally developed at the National Renewable Energy Laboratory, and enhanced and distributed by HOMER Energy, HOMER (Hybrid Optimization*

Model for Multiple Energy Resources) nests three powerful tools in one software product, so that engineering and economics work side by side.

The HOMER project evaluation model was constructed using the existing diesel generators, existing Northwind 100 wind turbines, recent electric load demand, water treatment plant thermal load demand, wind resource data from a met tower in Chevak, one and two EWT DW58-1000 wind turbines at 46-meter hub height, and a battery energy storage system (BESS) equivalent to AVEC's planned battery installation in St. Mary's. Given EWT's large capacity compared to the load, a BESS comprised of Li-ion batteries and a grid-forming inverter is necessary to control system frequency and to enable diesel-off operations.

Cost Estimates

HOMER software is an economic optimization tool and as such requires cost data for capital expenses, fuel, and operations and maintenance (O&M). Installing a wind turbine in rural Alaska is a complex task with barge access challenges, road and distribution connection needs, and foundation design as primary variables. Default capital and O&M cost assumptions from AEA's Renewable Energy Fund (REF) Round 14 (Nov. 2021) were used in Table 3, and actual costs reported by AVEC. Project capital costs were further evaluated at -20% and +25% of those noted in Table 3 for use in a sensitivity analysis.

Table 3: AEA REF14 cost assumptions

		REF14 assumptions		Other assumptions		
Type	Capacity	Capital ($/kW)	O&M ($/hr)	O&M ($k/yr)	Overhaul ($K/90K hours)	Add'l Capital ($K)
Wind	1,000 kW	8,379		58		
	2,000 kW	6,498		116		
Diesel	361-600 kW		9.95		150	
	601-1,300 kW		15.16		250	
Distribution	for 1 EWT					175
	for 2 EWT					750
BESS	935 kWh			9.3		1,020
Inverter	900 kW					
Note: Turbine O&M data from EWT, + 30% per ANTHC; add'l capital from AVEC						

Project Results and Optimization

Homer software evaluates cost optimization for each scenario requested. There can be many scenarios depending on sensitivity cases. For instance, two fuel costs entail two cost scenarios with all other variables held constant. Should two wind turbine costs be considered, that yields four cost scenarios, all other variables constant, and so on. Results for each cost scenario are ranked by net present cost (NPC), which generally tracks levelized cost of energy (LCOE), which is also calculated.

For this analysis, Table 4 details the chosen cost assumptions. Renewable energy capital expense assumptions are as noted in Table 3. Fuel costs were chosen to reflect the average price of fuel listed in the 2021 PCE Statistical Report ($2.76/gal), this year's anticipated market rate fuel cost recently communicated to AVEC from their fuel provider ($5.37/gal), and a possible near-term higher fuel cost should energy markets remain unstable ($6.50/gal).

Table 4: Homer software modeling assumptions

Real discount rate	3%
Fuel escalation rate	1.5%
Project life	25 years EWT turbines; BESS replaced at 20 years
Fuel price	$2.76, $5.37 and $6.50/gal ($0.73, $1.42 and $1.72/Liter)
Fixed system O&M cost (excludes component-specific O&M in the model)	$667.2K (2021 PCE report)

Modeling results with assumptions as noted above are presented in simplified form in Table 5. These indicate that the proposed project – constructing one or two EWT DW58 wind turbines with a BESS to maximize the offset of diesel fuel for electrical energy production – has lower NPC and LCOE than the existing energy generation system of diesel generators and four NPS100 wind turbines. Hence, installing EWT wind turbine(s) at the wind farm site is an economically advantageous project to develop. Note that the benefit cost ratios of 1.23 for 1 EWT turbine and 1.17 for 2 EWT turbines both reference the existing power system as the base case.

Table 5: Homer modeling results, $5.37/gal fuel

Scenario	Capital Cost ($M)	Wind Penet. (electric) (%)	Benefit/ Cost Ratio	LCOE ($/kWh)	Net Present Value ($M)	Fuel Saved (diesels) (gal/y)	Excess Energy (MWh/y)	Diesels Off Time (hr/y)
3 Northwind (base case)	0.00	14.7	1.00	0.564	40.3	-	3	-
1 EWT, 3 Northwind, BESS	9.57	109.0	1.23	0.460	33.8	152,902	1,204	5,599
2 EWT, 3 Northwind, BESS	14.80	203.0	1.17	0.483	35.3	188,494	4,141	7,094

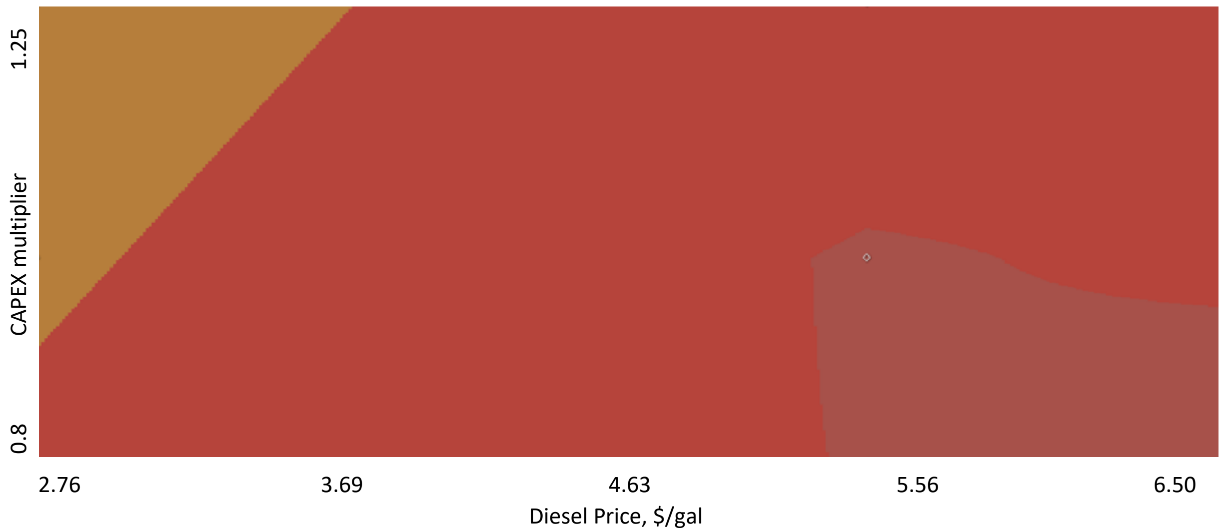
Several assumptions are contained within Table 5, including:

- All scenarios include diesel generation.
- The ABB-PSC battery energy storage system, included with the EWT DW58-1000 options, enables diesel-off capability. This results in lower diesel generator O&M costs and longer diesel overhaul cycles.
- To reflect that the Northwind turbines have been operational for over 10 years, they are modeled with 15 years of remaining life. The EWT DW61 is modeled with a 25-year life.
- The scenario with a 1.0 benefit/cost ratio is the base case, or existing power system.
- Minimum 10% diesel generator loading with BESS; 25% without BESS
- Assumed turbine losses (all causes): 10% for EWT, 45% for Northwind

Sensitivity Analysis

A sensitivity analysis provides insight into conditions where the proposed project may no longer have the lowest projected NPC/LCOE/benefit-to-cost ratio. Figure 11 demonstrates the sensitivity of fuel cost (x-axis) versus capital cost (y-axis) with the proposed project in red and the existing system configuration in gold. Notably, the proposed project returns a 1.0 benefit-to-cost ratio with fuel price well below $2.76/gal and a capital cost 80% of nominal (see cost assumptions in Table 3). The minimum fuel price rises to approximately $3.70gal with a capital cost 125% of nominal to achieve a 1.0 benefit-to-cost ratio.

Figure 11: Sensitivity analysis of optimal system type; gold color is existing base case; brick color indicates 1 or 2 EWT wind turbines with battery energy storage system



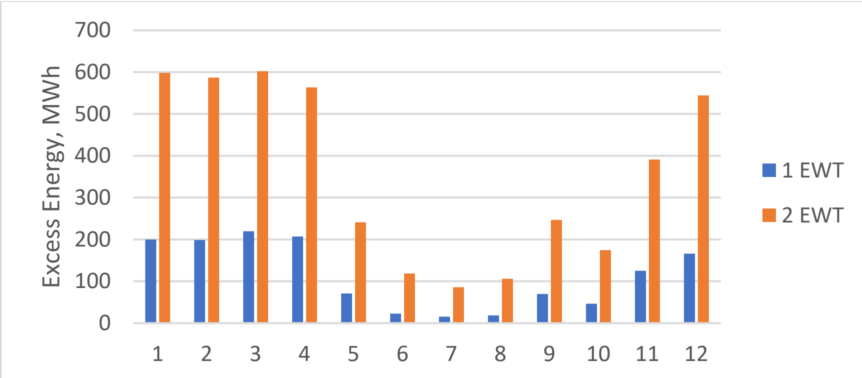
Wind-to-Heat

The economic benefit presented in Table 5 represents the perspective of AVEC as the electric utility of the community or perhaps that of an independent power producer with AVEC as the primary customer. Another benefit however of installing high-capacity EWT wind turbine(s) in Hooper Bay is the option to make use of excess energy via wind-to-heat.

Excess energy occurs when wind turbines produce more energy than the electric load, battery capacity to accept a charge, and/or water treatment plant thermal load (served by a thermal load controller) collectively demand. Because electricity generation must equal electrical load demand to maintain stable power system frequency, excess wind power must be curtailed, disposed of, or directed to beneficial use. The latter option has economic value beyond that demonstrated in Table 5 (see Figure 12) and can be accomplished, depending on the heating system design of the building, with an electric boiler connected to a hydronic (hot water) heat system or via an electric-thermal storage heater such as manufactured by Steffes.[7]

[7] Electric Thermal Storage - Steffes

Figure 12: Monthly distribution of excess energy for 1 or 2 EWT wind turbines in Hooper Bay, Homer modeling result



There are several large structures in Hooper Bay that are potentially suitable for remote node wind-to-heat. A review of ANTHC audit reports and an April 2020 report by CRW Engineering Group of heat recovery options for Toksook Bay[8], used in this report as a stand-in for Hooper Bay School, revealed a partial list of thermal loads (see Table 6 and Table 7).

Table 6: Hooper Bay thermal loads, partial listing, monthly heating fuel usage (gallons)

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Hooper Bay School	739	512	557	471	331	171	153	199	258	412	591	795
Sea Lion Corp. Bldg	360	225	200	180	90	50	50	85	177	200	222	360
Tribal Council Office	101	65	85	40	73	10	10	40	73	65	85	101
Satellite Facility	1,800	1,500	1,500	900	300	100	100	100	150	600	1,250	1,700
Community Bldg	116	64	90	40	78	10	10	10	78	78	78	78
ACC Store	369	256	278	235	165	86	77	99	129	206	295	397

Table 7: Hooper Bay thermal load data source

Hooper Bay School	CRW Heat Recovery Report, assume same as Toksook Bay school
Sea Lion Corp. Bldg	AkWarm file, 10/6/2017
Tribal Council Office	AkWarm file, 5/3/2011
Satellite Facility	AkWarm file, 9/18/2017
Community Bldg	AkWarm file, 5/3/2011
ACC Store	Assume same as Alakanuk store

Cost Estimate

A December 2021 analysis by ANTHC for the expansion of wind-to-heat in Kotzebue estimated a capital cost of $700K to engineer, permit, and install a 300-kW boiler in a hydronic heating system to use excess wind energy to offset heating fuel for the system boilers, or $657K for a 200-kW boiler. ANTHC has indicated though that those cost estimates included elements not normally required for a typical wind-to-heat installation, hence for this analysis $500K is assumed for one 300 kW boiler in Hooper Bay with additional 300 kW boilers costing $450K each – 90% of the first boiler cost – as economies of scale are presumed. Later detailed analyses may reveal that smaller or larger boilers are required for individual facilities, with attendant lower or higher costs. This analysis is intended to demonstrate the economic potential of excess energy for wind-to-heat in Hooper Bay.

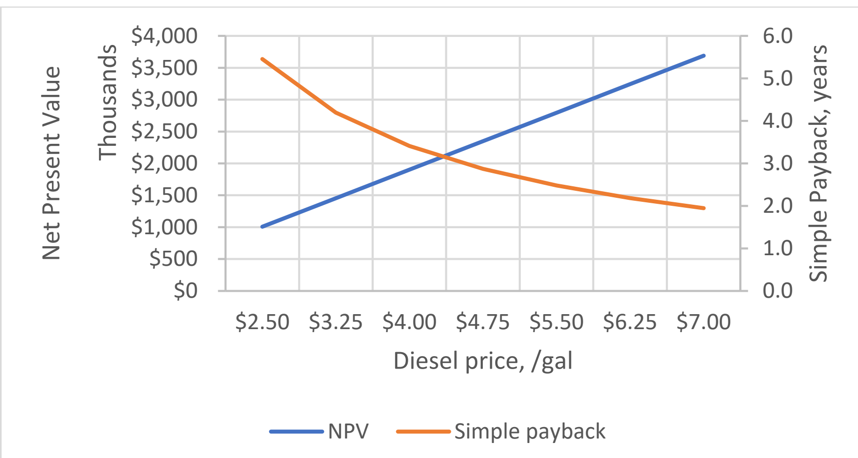
[8] *Heat Recovery Feasibility Study Toksook Bay, Alaska*, CRW Engineering Group, LLC, April 17, 2020

Economic Evaluation

The prospective economic valuation of wind-to-heat is evaluated with the assumption that all excess wind energy can be used by remote node electric boilers or Steffes-type heaters to displace no. 1 diesel for fuel oil boilers. This may be idealized but provides a reference point for subsequent analysis to match excess heat availability with thermal load demand. A project life of 25 years, like the EWT wind turbine, is assumed, with a 3% real discount rate applied for a net present value (NPV) evaluation. Boiler capital costs are applied to year 0 and fuel savings are tabulated over the following 25 years beginning with an initial fuel cost and adding a 1.5% per year fuel price escalation. It is assumed that AVEC will charge 30% of avoided fuel cost for wind-to-heat electric energy and that the efficiency of the companion fuel oil boiler is 80%.[9] Besides NPV, simple payback period (where NPV is not considered) is also calculated.

The initial wind-to-heat evaluation is one EWT wind turbine (plus the existing four Northwind wind turbines), a BESS, and two remote-node wind-to-heat boilers in facilities in Hooper Bay. As demonstrated in Table 5, 1,204 MWh/year of excess wind energy is projected. With that, positive NPV and short simple payback periods are anticipated for all fuel prices modeled (see Figure 13).

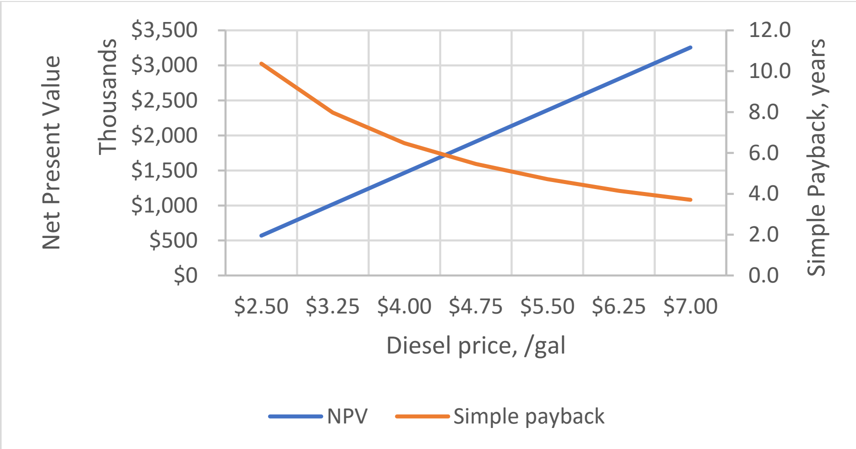
Figure 13: One EWT turbine, one wind-to-heat boiler, NPV and payback period (25 yr. project, 3% real discount rate)



One EWT wind turbine and two remote node electric boilers would provide more flexibility with facilities in which to install remote node electric boilers and yet still demonstrate desirable economic benefit (see Figure 14).

[9] ANTHC assumption

Figure 14: One EWT turbine, four wind-to-heat boilers, NPV and payback period (25 yr., 3% real discount rate)



Two new EWT wind turbines provide considerably more flexibility with wind-to-heat. Table 5 demonstrated that two EWT's generate over three times more excess wind energy compared to one EWT. This enables heating fuel displacement in many facilities with sufficient heat loads to absorb the cost of multiple wind-to-heat boilers. Figure 15 demonstrates the economic valuation with four boilers, which is excellent even at low fuel prices.

Figure 15: Two EWT turbines, four wind-to-heat boilers, NPV and payback period (25 yr., 3% real discount rate)

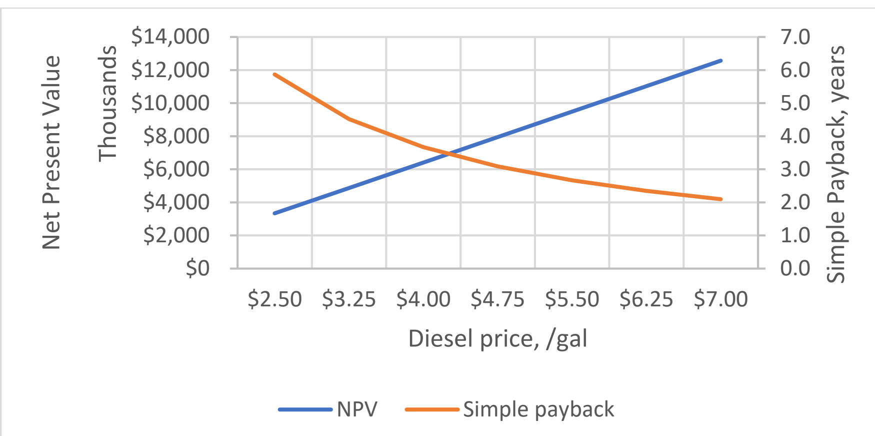
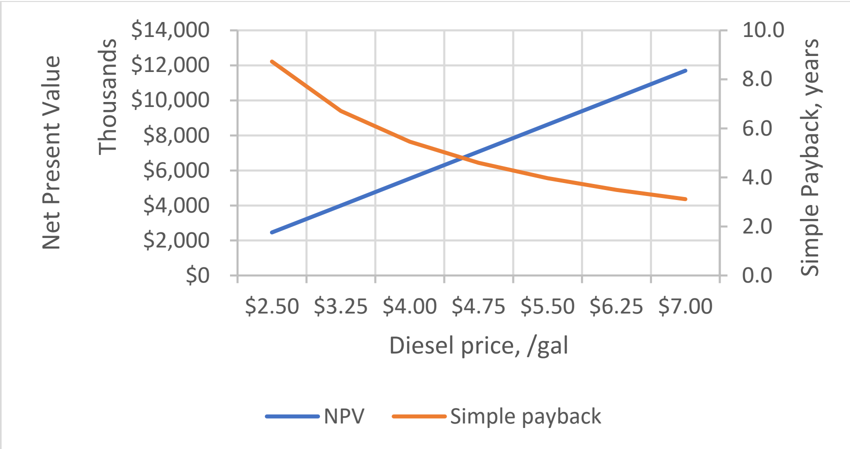


Figure 16 demonstrates that even six wind-to-heat boilers absorbing all excess energy of two EWT wind turbines also demonstrates excellent economic potential, including at very low fuel prices.

Figure 16: Two EWT turbines, six wind-to-heat boilers, NPV and payback period (25 yr., 3% real discount rate)



Discussion

This report separates the economic analysis of new EWT wind turbines in Hooper Bay into two parts: the first a utility perspective of displacing diesel fuel for electricity generation and the second a community or facility owner perspective of displacing heating oil for thermal needs via wind-to-heat. Table 5 demonstrates that installation of one or two EWT turbines are economically advantageous with discounted benefit-to-cost ratios of 1.23 and 1.17 respectively.

The benefit/cost evaluation however is before consideration of wind-to-heat potential. Including wind-to-heat improves the economic valuation for all scenarios. Of the four turbine and wind-to-heat boilers scenarios presented, at $5.50 per gallon fuel cost, one EWT wind turbine and two wind-to-heat boilers demonstrates the lowest simple payback period in the isolated context of wind-to-heat only (see Table 8), assuming the thermal loads are sufficient to absorb all excess wind energy generated. When aggregating wind-to-heat with installation of the wind turbines to provide a more holistic perspective, the resulting combined simple payback periods improve but are dominated by the higher expense of turbine development, as one would expect.

Table 8: Summary of wind-to-heat simple payback period with $5.50/gal diesel fuel cost

	Turbine/BESS Only			Wind-to-Heat Only*			Combined
Scenario	No. EWT turbines	Capital Expense ($M)	Simple Payback (yr.)	Wind-to-Heat Boilers	Capital Expense ($M)	Simple Payback (yr.)	Simple Payback** (yr.)
1 EWT, BESS, 1 WTH	1	9.57	11.1	1	0.50	2.5	10.7
1 EWT, BESS, 2 WTH	1	9.57	11.1	2	0.95	4.7	10.5
2 EWT, BESS, 4 WTH	2	14.8	13.3	4	1.85	2.7	12.1
2 EWT, BESS, 6 WTH	2	14.8	13.3	6	2.75	4.0	11.8

*Presumes new turbines (considered independently of turbine)
**Calculated as a weighted average of capital expense and associated payback periods

The objective with wind-to-heat is to match appropriate thermal loads with available excess electrical energy to maximize both the investment of wind-to-heat boilers and use of the projected availability of excess wind energy. Hooper Bay thermal load fuel usage documented in Table 6 was converted to kWh and the excess energy presented in Figure 12 are listed in Table 9. As one can see, there are several options to use the excess energy from installation of one EWT wind turbine but using all excess energy from two EWT wind turbines may not be economically viable, except perhaps via widespread adoption of Steffes heaters in individual homes, provided the capital costs are near comparable to wind-to-heat boilers for large structures. Even if full utilization of excess energy is not possible for either scenario, installing one or two EWT wind turbines in Hooper Bay is nevertheless economically advantageous from the perspectives of fuel savings for electrical energy generation and reduced generator maintenance with frequent diesel-off operations.

Table 9: Hooper Bay thermal loads compared to modeled excess wind energy, monthly kWh

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Hooper Bay School	22,638	15,684	17,063	14,428	10,140	5,238	4,687	6,096	7,903	12,621	18,104	24,353
Sea Lion Corp. Bldg	11,028	6,892	6,127	5,514	2,757	1,532	1,532	2,604	5,422	6,127	6,801	11,028
Tribal Council Office	3,094	1,991	2,604	1,225	2,236	306	306	1,225	2,236	1,991	2,604	3,094
Satellite Facility	55,140	45,950	45,950	27,570	9,190	3,063	3,063	3,063	4,595	18,380	38,291	52,076
Community Bldg	3,553	1,961	2,757	1,225	2,389	306	306	306	2,389	2,389	2,389	2,389
ACC Store	11,304	7,842	8,516	7,199	5,054	2,634	2,359	3,033	3,952	6,310	9,037	12,161
Total	106,756	80,320	83,016	57,161	31,766	13,080	12,253	16,327	26,498	47,818	77,226	105,102
Excess energy, 1 EWT	199,729	198,396	219,730	207,014	70,733	22,568	15,510	18,487	69,760	46,230	125,220	166,224
Excess energy, 2 EWT	598,227	586,869	601,968	563,420	240,965	118,779	85,773	105,837	246,842	174,334	390,820	544,534

Independent Power Producer Option to Lower Water and Sewer Rates

The community of Hooper Bay could capitalize on the revenue generating opportunity of owning the proposed wind turbines and selling the electricity to AVEC through a Power Purchase Agreement (PPA) to create a revenue generating asset and local jobs. This model has been implemented in Shungnak for their community sized solar system, which has allowed for diesel off operation during the spring and summer season and has generated $100,000 in nearly passive revenue for the Tribe in 12 months. If a local or regional entity acted as an Independent Power Producer (IPP) to own and operate the renewable assets, AVEC would buy the power through a PPA at a fuel-avoided rate equal to roughly 80% of an equivalent cost of a gallon of diesel bought locally. Given that AVEC prefers to charge a fluctuating annual rate related to diesel price for renewable energy purchased from an IPP, this means that annual profits are variable. If the fuel price is high, profits from the wind systems are high, and will proportionally change annually with a new fuel price. AVEC's avoided fuel rate method ensures that total electricity costs borne of renewable assets stay below the base case of diesel, lowering electrical costs pre-PCE no matter what the bulk fuel cost or global fuel price instability. While this makes financial planning slightly harder for an IPP, it ensures the lowest possible electricity costs for the community if the Power Cost Equalization endowment were to disappear.

To give an example for Hooper Bay, which illustrates the revenue generating ability had the system been online for 2022, the current fuel price was multiplied by AVEC's fuel avoided rate and again multiplied by the annual amount of power generated by the system. Operations and Maintenance costs were subtracted along with the cost of two part time jobs that would be created locally. Wind to Heat systems are not included in this scenario and only identify revenue from wind production at the turbines. Thirty dollars an hour was estimated for two part-time operators working an average of 10 hours per week year round, alternating two week shifts.

If this annual revenue of over half a million dollars was set aside to reduce the billed rates for water and sewer, this would mean a $3,824.00 reduction in each of the 146 households annual bills. Given the high percentage of families living below the poverty line, this revenue would ensure clean water was not shut off for non-payment and the critical sanitation infrastructure would continue to be financially sustainable.

Table 10: 2022 IPP Earnings from 1 EWT Energy Sales to AVEC

Fuel Price 2022/gallon	Annual Gallons Diesel Avoided	80% of Avoided Gallon = AVEC Purchase Price	Two Part Time Operators	Annual O + M Costs for 1 EWT & BESS	Net 2022 Revenue	Annual Household Savings if Applied to Water and Sewer Bills
$5.37	152,902	$4.296	-$31,200	-$67,300	$558,366	$3,824