Closeout Report for U.S. Department of Energy, Office of Indian Energy
Award DE-IE0000084 - Bethel (Alaska) Wind Construction
Submitted by Alaska Village Electric Cooperative, Inc. (AVEC)
March 30, 2020

This grant award DE-IE0000084 is being closed because the project it funded is complete and is in full operation, and the grant expired December 31, 2019; this report represents the project status as of that date. The grant funds were fully expended. The grantee is Alaska Village Electric Cooperative, Inc. (AVEC).

Background – AVEC is a member-owned rural electric cooperative serving 58 member communities; all but one is located off the road system in rural Alaska. Its prime power plant located in Bethel, Alaska (pop. 6,244) provides power to that community and to nearby communities of Oscarville and Napakiak, Alaska. Bethel is AVEC's largest member community, and also one of the communities to most recently join AVEC (2014). It's located in SW Alaska, in the Yukon Delta National Wildlife Refuge about 400 air miles west of Anchorage, and situated on the west bank of the Kuskokwim River about 40 miles upriver of its terminus in Kuskokwim Bay on the Bering Sea coast.

Bethel is the regional transportation hub for the Yukon-Kuskokwim Delta and the main port on the Kuskokwim River. The Kuskokwim River is typically ice-free and open to barge traffic from June through October. Bethel has 38 miles of public roads and is connected by road to several nearby villages during the summer. A 28-mile ice road along the Kuskokwim River connects the community with neighboring villages in the winter. The Bethel Airport is the third busiest in the state, with daily jet-aircraft service to and from Anchorage, and scheduled and chartered small-plane service to 56 surrounding villages. Bethel maintains a medium-draft port for ocean-going vessels, as well as the Bethel cargo dock, a petro port, a small boat harbor, a float plane beach and a seawall. Transportation within the community is served by taxi and a public transit system. A series of traditional trails provide access within the city and to nearby communities.

Bethel falls within the western transitional climate zone, characterized by tundra interspersed with boreal forests, and weather patterns of long, cold winters and shorter, warm summers. Energy prices - for electric power, gasoline and diesel/heating fuel - are among the highest in the nation. Bethel incorporated in 1957 under state law as a second class city. Traditional Yup'ik practices and language remain predominant in the area. Subsistence activities and commercial fishing are major contributors to residents' livelihoods.

Activities – Project scope included planning, permitting, design, construction and commissioning of 1 new 900 kW-capacity wind turbine at a site in Bethel about 3.3 miles NE of the diesel-fired prime power plant. (Note: only certain (though most) construction-phase costs were eligible to be reported on this DOE OIE award, including for cost share; and only the construction-phase costs of the construction contract were eligible for actual reimbursement.) The main objective of this project is to generate electric power from a renewable resource in an effort to reduce the local dependency on fuel oil as the sole source of electric power generation. The wind generator's output will augment the prime source generation provided by the diesel-powered generators. By the time the subject federal grant was put into place, feasibility studies were complete, and design and permit-ting were nearly complete.

AVEC selected Bethel as the place to locate its first MW-range wind turbine due simply to the size of the grid. 2019 generation in Bethel totaled 41,406 MWh, with a 7.27 MW peak load and 4.96 MW average load. With these grid characteristics, AVEC could expect a wind turbine (or wind farm) in the 1MW range to run at peak capacity without

curtailment almost continuously, except in rare instances of threatened damage to the turbine(s) from excessively high and/or turbulent winds. In the quarter ended 12/31/2018, AVEC's new Bethel wind turbine generated a total gross 562 MWh; this represents 4.9% of the 11,395 total gross MWh AVEC generated during that period from all energy sources there; in the full calendar year 2019, it generated a total gross 2,000 MWh, and this represents 4.6% of the 43,405 total gross MWh AVEC generated in 2019 from all energy sources there.

AVEC's wind turbine selection policy, in part, prefers turbine models which are direct-drive, have multiple I/O controls, and are built to withstand the severe operating environments found in the arctic. During the selection process for this project, AVEC partly expanded this policy to also consider simplified induction turbine models with limited I/O controls. Another major factor in turbine selection and overall wind-diesel system design in this particular case is the large size of Bethel's power grid (described above) in comparison to all earlier-built AVEC wind farms. Ultimately the wind turbine selected and procured for this application was an Emergya Wind Technologies (EWT) 900-kW generator placed atop a 50-meter tubular steel tower, with blades that sweep a circular area 52 meters in diameter. AVEC constructed a nearly-identical turbine in St. Mary's, Alaska, less than a year after the subject project; together these two wind turbines are AVEC's largest; the remainder of AVEC's 30 wind turbines are Northwind 100kW models.

AVEC entered into a Ground Lease and Agreement with Bethel Native Corporation on April 3, 2018, which secures site control for the subject wind turbine and all related facilities through October 31, 2037.

To gain access to the undeveloped wind turbine site, a 26-foot-wide, 300-foot-long gravel access road was built off Sidney Street/Old BIA Road, and a 150' x 165' gravel pad was then built at the end of this access spur. Both the access road and site pad were underlain with geotextile. The turbine's tower is attached to a combination driven-pile and steel-rebar-reinforced concrete foundation. The essential components are:

- 12 steel piles, 55' long and 20" diameter, driven their entire length into the native soils, arranged in the pattern of a circle 24' in diameter, and each pile is capped at grade with a steel cap;
- a steel rebar structure consisting of several layers spanning across the circle circumscribed by the driven piles and laid at specified angles across each succeeding layer, and three-dimensional rebar cages welded (in part) to the piles' steel caps, all tied together prior to concrete pouring;
- upper levels of steel rebar, one of which extends through holes in the 12'-diameter steel foundation tower anchor ring, which sits into the rebar structure described above, is cast into the concrete, and serves as the first (lowest) section of the tubular steel tower and to which the tower is attached;
- specified concrete, mixed on site and poured into the rebar system, and both around and inside the steel foundation tower anchor ring;
- insulation underlying and extending beyond the entire reinforced concrete structure, consisting of 8"-thick rigid foam;
- 16 thermosyphons installed on perimeter of foundation to keep the foundation and the subsurface soils cool, in order to prevent warming and consequent degradation of local permafrost, and

- 16 thermoprobes (thermistors) installed adjacent to the thermosyphons to enable long term monitoring of subsurface temperatures to assure the thermosyphons are performing adequately.

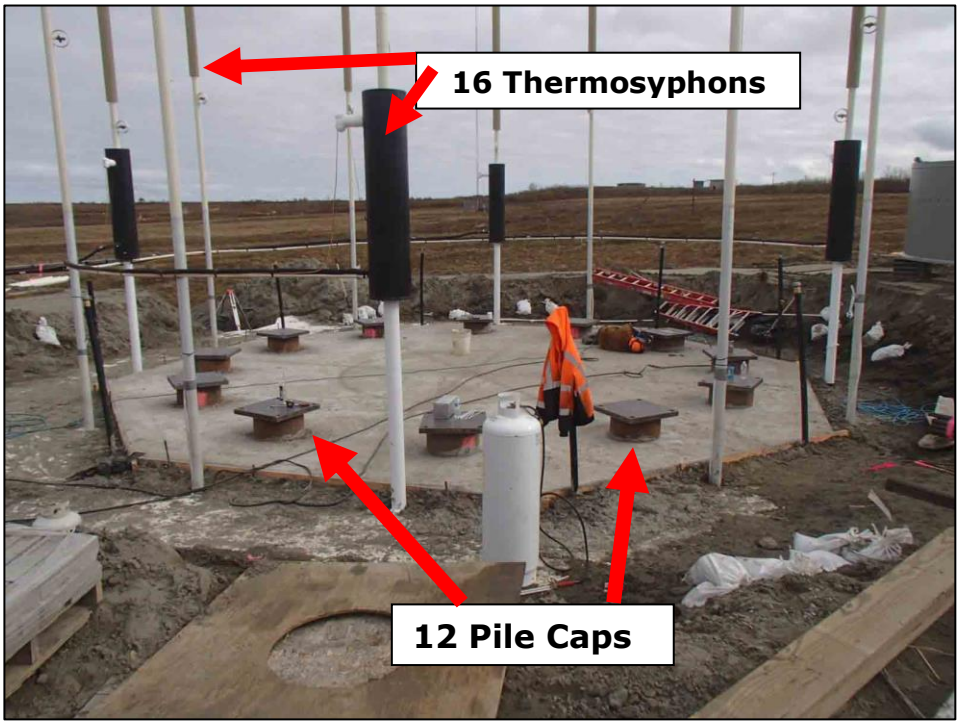
Other key components of the overall project include the following. A new three-phase primary distribution line segment was installed along the access road to connect the new wind turbine to the three-phase distribution line running along Sidney Street, and therefore to the Bethel grid and power plant. A 1,000 kVA transformer sits on a cast concrete pad just outside the tower foundation. A standard landline data link provides communication between the new wind turbine and the control switchgear in the Bethel prime power plant; this allows the wind turbine to be either manually or automatically controlled both at the power plant and from AVEC headquarters in Anchorage, maximizing operating stability and allowing remote trouble shooting in the event of alarms or warnings. Finally, major upgrades were made to the governors inside the diesel-fired power plant to enable it and the local grid to absorb and integrate the new wind energy in an optimal manner.

Feasibility phase: feasibility and pre-design investigations were accomplished prior to the effective date of, and with funding other than, the subject DOE OIE award; no feasibility phase costs were eligible for reimbursement or eligible for reporting as cost share on that award. Several sites in Bethel were evaluated.

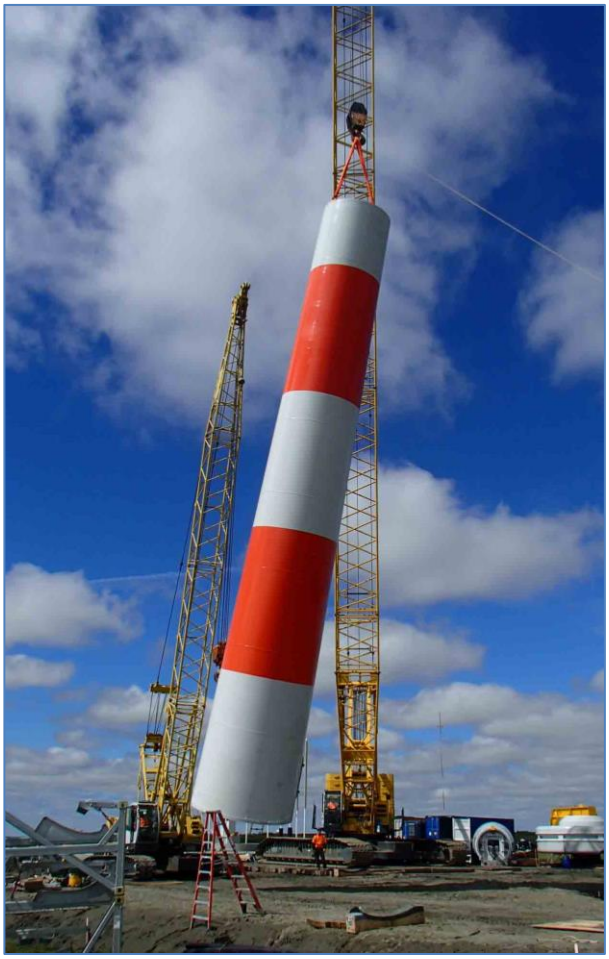
Wind data was gathered at two sites not proximate to each other, referred to as Site 1 (City site) and Site 2 (KYUK site). At each site, starting in December 2015, instruments mounted on two 60-meter ("met") towers gathered meteorological data which was ultimately used to inform the feasibility study. Data gathered from the Site 1 met tower, after modeling and analysis, indicated a class 4 wind regime. Data gathered from the Site 2 met tower, after modeling and analysis, indicated a class 6 wind regime. Geotechnical conditions at the two sites were studied in the field in summer 2016 and evaluated later that year.

The new Bethel wind turbine was eventually constructed at a third site (BNC site), a location proximate enough to Site 2 for the wind data collected at Site 2 to also be applicable to the BNC site, so no wind data was gathered specific to the BNC site. However, a fresh geotechnical field study was performed on the BNC site and an evaluation report issued in August 2017; this effort informed the eventual design of the wind turbine's foundation for this specific site.

Design and permitting phase: major engineering and design for the entire scope was accomplished by CRW Engineering Group, LLC; additional engineering was provided by AVEC Engineering Department staff. Wind energy studies were conducted by V3 Energy, LLC; geotechnical services were provided by Golder Associates, Inc.; permitting was coordinated by Solstice Alaska Consulting, Inc.; wetlands were delineated by HDR; and avian migration and nesting studies were conducted by ABR, Inc. No costs of engineering, design, permitting and construction assistance provided by consultants throughout the project, and no in-house AVEC labor incurred prior to the effective date of the DOE OIE award, were eligible for reimbursement or eligible for reporting as cost share on that award.


16 Thermosyphons
12 Pile Caps


Tower Anchor Ring
Pile Cap



Construction phase: AVEC utilized a Statement of Qualifications (SOQ) procurement process to award the wind turbine prime construction contract, ultimately to Anchorage-based STG, Inc., which accomplished all construction scope through its Bethel satellite location, with its in-house resources combined with locally-available labor and other resources. Inside the power plant, Electric Power Systems, Inc., designed and installed the significant upgrades to the governors and voltage regulators; this was a key part of the overall project, however the associated costs were not eligible to be reported as cost share to the subject DOE OIE award.

Design, permitting and construction milestones summary (continued on next page):

2014Q4	Awarded grant from Alaska Energy Authority for design, permitting, and partial construction (grant transferred from prior grantee City of Bethel to AVEC)
	Secured site control and received DNHAN from FAA for met tower site west of city on radio station KYUK property - Site 2
	Contracted with TDX Power to study feasibility of low-medium-high penetration scenarios
2015Q3	Secured site control for met tower on City of Bethel property near landfill - Site 1
	Budgetary cost proposal received from Emergya Wind Technologies (EWT)
2015Q4	Met towers installed at Site 1 (City site) and Site 2 (KYUK site)
	High-speed recorder installed at power plant to collect engine response data for use in modeling for turbine selection
	Design engineer CRW Engineering Group LLC began preliminary evaluation of both met sites
2016Q1	Commenced planning and procurement for governors upgrade in power plant (upgrade necessary for wind power integration)
	Selected EWT 900kW model; started supply agreement and warranty negotiations
	Established avian monitoring plan with USFWS re: spring and fall bird migrations
2016Q2	Geotech field study completed
	City site (Site 1) selected as preferred site for new wind turbine
	Summer local bird nesting study completed at Site 1
	Governors testing completed at power plant
2016Q3	Investigated possible new site at location of abandoned White Alice site with USFWS; this site determined unsuitable due to environmental concerns
2016Q4	Draft bird movement study accepted; City site revealed to have significant bird activity
	Approached Bethel Native Corporation (BNC) to investigate new site on its property, located near Site 2 and established met tower
	STG, Inc., selected as prime construction contractor
	Signed Turbine Purchase Agreement with EWT
2017Q1	Replaced SPMD, voltage regulators and digital power and tachometer in power plant
	AVEC/BNC joint venture applied for USDOE OIE grant
2017Q2	EWT started manufacturing wind turbine
2017Q3	Geotech field study completed at BNC site (site of eventual construction)
	USDOE OIE grant awarded and grant issued
	FAA approved 50 meter hub height at BNC site (site of construction)
	Prime contractor STG mobilized heavy equipment and foundation materials

2017Q4	Ordered 50 meter tower to substitute for 75 meter tower already on order
	Ordered land appraisal for BNC site (site of construction)
	Access road and pad completed
2018Q1	Turbine (incl nacelle and blades) & tower (incl foundation tube anchor) inspected by AVEC, STG and EWT at Port of SEA
	All 12 foundation piles driven, 12 of 16 thermosyphons installed (drilled and slurry-backfilled), and all 16 thermo-probes (thermistors) installed adjacent to thermosyphons
	Tall Tower permit issued by City of Bethel
2018Q2	Wind turbine and tower received on site in Bethel
	Temporary active cooling installed to cool foundation faster and keep project on schedule
	Foundation rebar set and tied, concrete foundation poured
2018Q3	Tower erected, and turbine and blades installed
	Pad-mount step-up transformer installed next to tower
	Communication system installed (line-of-sight radio link)
	Turbine commissioned in late Septermber
2018Q4	Remaining 4 thermosyphons installed
	Active cooling system removed

Funding and costs on this project are depicted in the table below:

AVEC - Bethel , Alaska EWT 900kW Wind Turbine Project			Funding	Expenditures	Additional AVEC Contribution
Source	**Award #**	**Phase**			
State of Alaska - Alaska Energy Authority (AEA)	2195432	Design and Construction	$ 2,598,320	$ 2,598,320	
Denali Commission (Alaska)	See Note 1	Design	$ 399,777	$ 399,777	
Alaska Village Electric Cooperative, Inc. (AVEC)	match to AEA 2195432	Design and Construction	$ 199,889	$ 1,043,789	$ 843,900
U.S. Department of Energy, Office of Indian Energy (DOE)	DE-IE0000084	Construction (See Note 2)	$ 1,000,000	$ 1,000,000	
Award and Project Totals			$ 4,197,986	$ 5,041,886	$ 843,900

Note 1: Denali Commission contribution was supplemental to (and administered by AEA through) AEA award 2195432.

Note 2: Of the $4,041,886 of total project costs provided by sources other than DOE OIE, a subtotal of $2,724,606 of construction costs only was reported as cost share to award DE-IE0000084.

Problems Encountered and Lessons Learned

Under the Turbine Purchase Agreement (TPA) with manufacturer EWT, in order to maximize wind power generation AVEC specified a 75-meter tower for this project over the optionally available 50-meter tower. After signing the TPA, the State of Alaska Department of Transportation and Public Facilities (DOTP&F) filed a new Airport Landing Plan (ALP) with the Federal Aviation Administration (FAA). When DOTP&F implemented this new ALP, it extended the crosswind runway by about 2,000 feet. This in turn expanded the Bethel-area controlled airspace by up to 4 miles, encompassing all potential tall tower sites located within the local electric grid or reasonably close to it. When combined with height standards within the controlled airspace, this change caused FAA to limit its permitting on the subject project to the 50-meter-high tower. As it was too late to change the initial TPA, AVEC had to order a new 50-meter replacement tower for this project. The still-valuable 75-meter tower was placed into storage outside of Alaska, and AVEC anticipates employing it fruitfully on its next planned EWT wind turbine installation in another of its member communities.

The prime construction contractor sub-contracted the construction of the access road and foundation pad. The contractor did not adequately control the work of this subcontractor, which built the foundation pad to full final design height, versus the specifications of the first phase civil plan which called for the pad to be built to the bottom of turbine foundation. When the prime contractor started driving pile they believed the foundation pad was built to bottom of foundation elevation, hence they left the pile five feet higher (five feet less driven) than final design elevation. Upon inspection by AVEC's design engineer the error was discovered and the prime contractor had to reset and drive the pile down the final five feet to design elevation. This correction was a significant undertaking as the pile were driven in frozen ground. This problem extended to the passive cooled thermosyphons as they also were left five feet higher then design depth and could not be adjusted as they were drilled and slurry backfilled. After consultation with the design engineer, it was decided installation and operation of an active cooling system was required through the summer to ensure competent pile adhesion. To ensure no further issues arose AVEC increased its inspection and oversight of the project to fulltime onsite presence during the remainder of the project.

Project Outcomes – In its first 15 months of operation - October 2018 through December 2019 - the new Bethel EWT wind turbine produced 4.7% of all the power generated and consumed on the Bethel grid, well within the range of design expectations.

Bibliography (all prepared for Alaska Village Electric Cooperative, Inc.):

Golder Associates, Inc: *AVEC Bethel EWT Tower Summary Geotechnical Field Report (August 21, 2017).*

HDR Alaska: *Bethel Wind Project, Wetland and Waterbody Delineation (July 2017).*

TDX Power: *1) Bethel Wind Power Project Phase 1 Feasibility Study (July 5, 2016);* and *2) Bethel Wind Power Project Phase 2 Simulation and System Upgrade Report (September 7, 2017)*

CRW Engineering Group LLC: *Combined Plan Set for Bethel, Alaska, Wind Energy Project (February 2018).*