PROJECT PROGRESS REPORT

PREPARED FOR THE ALASKA ENERGY AUTHORITY
BY THE ALASKA CENTER FOR ENERGY AND POWER

PROJECT TITLE:	Emerging Energy Technology Fund – Data Collection
COVERING PERIOD:	4th Quarter 2013 – 1st Quarter 2014
DATE OF REPORT:	April 28, 2014
GRANT RECIPIENT:	Alaska Center for Energy and Power University of Alaska Fairbanks 451 Duckering Building Fairbanks AK 99775-5880

Project #001 – Alaska Applied Sciences, Ammonia Synthesis

No work has been completed for this project during this quarter. AEA has notified ACEP that due to delays in pre-grant project activities, this grant will not be awarded. ACEP has archived project management documents and will not include project reporting in future quarterly reports.

Project #003 – Alaska Division of Forestry, Biomass Reforestation

Activity this quarter has been minimal as the off-season continues. ACEP is working with AEA to understand the revised project scope of work and is beginning planning for field season activities. Anticipated activities include checking on field temperature data loggers, retrieving seasonal data and ensuring functionality, and collecting field notes from the project.

Project #006 – Arctic Sun, Arctic Thermal Shutters and Doors

Activities this quarter have focused on the continued collection of automated data from the project. ACEP has periodically checked the data for consistency, and have not discovered any areas of concerned to date.The following is the data log from the collected data to date:

DATE	TIME	ACTIONS	OBSERVATIONS	
12/9/2013	1:00 PM	Cleared snow from wind sensors		
	2:00 PM	Sealed test box hatch		
	2:45 PM	Started Dataloggers	No condensation on windows, no shutter present	
12/10/2013	2:45 PM	N/A	Light condensation, bottom 1 inch inside glass	
12/12/2013	2:30 PM	N/A	Light condensation, bottom 2 inches inside glass	
12/13/2013	2:50 PM	N/A	Light condensation, bottom 2-2.5 inches inside glass	
12/16/2013	12:00 PM	N/A	Condensation, bottom 3 inches inside glass	
12/17/2013	4:40 PM	Replaced plastic cover on east 1/3 roof	Condensation, bottom 2 inches inside glass	
12/18/2013	2:20 PM	Weather Station Battery fully charged	Condensation, bottom 1.5 inches inside glass	
12/19/2013	2:15 PM	N/A	Condensation, bottom 1.5 inches inside glass	
12/20/2013	3:20 PM	N/A	Condensation, bottom 1 inch inside glass	
12/23/2013	1:55 PM	N/A	Condensation, bottom 1.5 inches inside glass	
12/24/2013	1:00 PM	Charged Battery on Weather Station	Condensation, bottom 2.5 inches inside glass	
12/31/2013	3:46 PM	Battery Charged	No Observation	
1/6/2014	2:20 PM	N/A	Condensation, bottom 3/4 inch inside glass	
1/7/2014	2:00 PM	N/A	Condensation, bottom 1 inch inside glass	
1/10/2014	12:30 PM	Download and send data	Condensation, bottom 1.5 inches inside glass	
	1:00 PM	Install Shutter (Opened and closed repeatedly until 4 pm)		
	4:00 PM	Shutter Closed		
1/13/2014	11:30 AM	Shutter Opened < 1 Minute for Observation	Condensation, bottom 1 inch inside glass	
1/14/2014	11:40 AM	Shutter Opened 3 Minutes to place temp sensors on shutter	No Condensation on glass	
1/21/2014	9:45 AM	Removed snow buildup from both wind sensors	Light frost buildup on back of track, next to wall	Weather station battery at 65%
	10:35 AM	Relaunched three four channel loggers		Memory had run out on Loggers 1-3 -- must download and relaunch in future
1/28/2014	10:45 AM	Download and send Data, checked cavity for frost	Light frost buildup on back of track, next to wall	No frost in cavity, Weather station battery 65%
2/6/2014	10:45 AM	Download data	U12s memory at 42% full	Weather station battery at 60%
2/11/2014	9:45 AM	Download Data		Weather Station Battery at 65%
2/14/2014	1:30 PM		Observed frost pattern outlining vaccuum panel, took photos	
2/18/2014	1:45 PM	Download Data		Weather station battery at 60%, small logger memories at 75% full
2/25/2014	10:35 AM	Download Data		Weather station battery at 85%
	10:39 AM	Relaunched Logger 1		
	10:41 AM	Relaunched Logger 2		
	10:42 AM	Relaunched Logger 3		
	12:00 PM	Removed VIP Shutter		
	12:30 PM	Installed R-MAX Shutter	No Frost on glass, or in cavity	
	12:35 PM	Power to heat shut off to wire shutter motor (no heat to box)		
	12:48 PM	Power Restored		
	12:50 PM	Shutter closed		
3/6/2014	8:50 AM	Download data		Weather station battery at 70%
3/18/2014	4:45 PM	Download Data		Weather Station Battery at 100%

Project #009 – Genesis, Ultra-Efficient Generators and Diesel-Electric Propulsion

Activities this quarter have focused on project technical support and feedback, and the shipment of instrumentation to site. In particular a flow meter and torque meter were sent to the project team in Kodiak. In addition, the data collection team has been closely coordinating with the project team on various tests, calibrations, and results, and providing feedback when necessary. Activities next quarter will include a site visit on 5/9/2014 to

review instrumentation and system programming and calibration, and to collect raw data generated from the project to date.

Project #026 – Cold Climate Housing Research Center, Ground-Source Heat Pump

Overview

In the fall of 2013 the Cold Climate Housing Research Center (CCHRC) installed a ground source heat pump. At the same time, a data collection system was installed by the staff at the CCHRC to gather data about the heat pumps operation and efficiency. The heat pump and data collection system are now functioning normally and transmitting updated data on a daily basis to a server at the Alaska Center for Energy and Power.

The exterior data collection system is made up of fifty-two sensors at various points around the ground loop to monitor the ground temperature in the area where the ground loops are buried. The thermistor strings are designed to monitor the long term ground temperature trends and measure the overall ability of the earth to sustainably provide heat to the heat pump. These temperatures are collected every ten minutes.

Interior temperatures, flow rates, and the power consumption of the heat pump and circulating pumps are also measured and recorded. Data from these sensors is logged every five seconds and then averaged into time intervals ranging from 15 minutes to one hour.
All data is collected via a Campbell Scientific CR1000 data logger and data points are converted within the data logger program to SI units such as liters/minute, watts, kilowatt hours, and degrees Celsius.

Purpose

There are two primary purposes of the data collection effort at the CCHRC for their ground sourced heat pump demonstration. The first is to calculate cost savings over a traditional fuel-oil fired boiler by measuring fuel oil displacement, and the increase in electricity consumption. An estimation of displaced CO2 will also be made. These metrics are enabled through data collected that measures the heat delivered to the building and the electricity that is used in the system to deliver this heat to the building. Heat delivered to the building is measured by monitoring the difference in temperature in the interior circulation loop as it leaves and returns to the heat pump as well as the flow rate of this loop.

The second purpose of the study it to analyze the long term viability of a ground sourced heat pump in a permafrost environment in an extreme northern climate. The primary question is whether the amount of heat removed from the ground can naturally be restored so that the heat pump can be sustainably used into the future. This is done by measuring the temperature and flow of the fluid in the ground loops that remove heat from the ground as well as the ground temperatures in the area at various depths.

The instrumentation of this project has been in line with the expectations expressed in the data collection plan that was agreed upon by AEA, CCHRC and ACEP. Initial installation of power monitoring equipment on the circulation pumps resulted in transducers that were incompatible with the logging equipment according to staff at the CCHRC. At the beginning of February, project PI, Robbin Garber-Slaght replaced the current transducers and they now

appear to be functioning properly and delivering reliable data. Currently, there are no other known monitoring problems.

Initial Results

An initial review of the data indicates a good complete data set with numbers consistent with expectations. Temperature sensors near the ground surface are more affected by ambient temperatures, and deeper sensors have more consistent temperatures that slowly decline as the winter proceeds. During the period from December 6th through January 16th, the calculated mean COP was 3.36 with a standard deviation of .88. After this period, work was done to fix the non-functioning current transducers discussed above. Between January 30th, and February 5th, the mean COP was 3.54 with a standard deviation of .39 (see table 1). The most recent data set also has consistent power consumption data for all circulation pumps.

Table 1. Coefficient of Performance

Date	Average COP (Heat Energy delivered to hydronic loads/ Electric energy sent to heat pumps)	Standard Deviation
12/6/13-1/16/14	3.36	.88
1/30/14-2/5/14	3.54	.39

Weather data is also a crucial component in this study which can be used to compare heat pump performance and ground temperatures to a constant such as heating degree days. It is not collected as part of this project, but is being collected by CCHRC as part of another data collection project and is available on request. It will be included in future detailed reporting. Overall project data collection appears to be going well. It is still early in this process however and careful data review will continue. In particular, attention will paid to the COP, electricity consumption of the heat pump and circulation pumps as well as ground temperatures. The data will be graphed and reviewed to reveal any possible abnormalities and data quality issues.

A detailed list of data points is listed in an update data management plan, submitted to ACEP by CCHRC on 1/13/2014. This document was created by the CCHRC and serves as a roadmap to the data collection system. One can see that it includes a variety of information including the programing language that drives the CR1000 data logger, one line diagrams, and system data collection objectives and what measurements are required to meet these objectives.

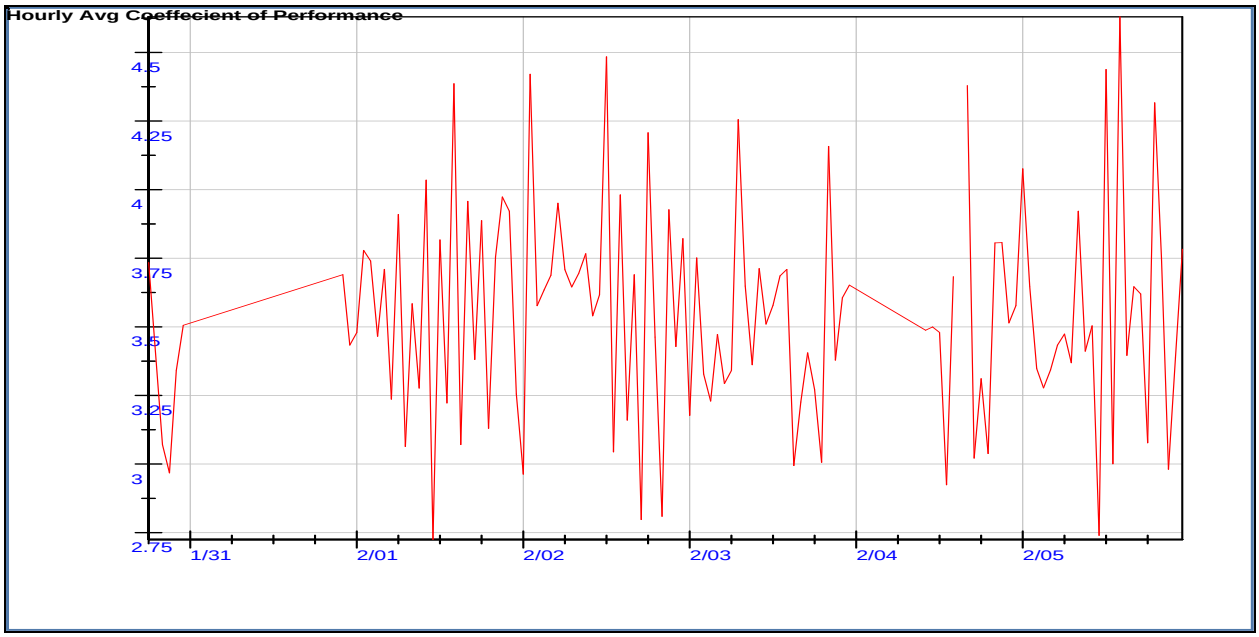

Figure 1: The graph above shows the calculated COP over a week long period in early February. The mean COP for this period was 3.54.

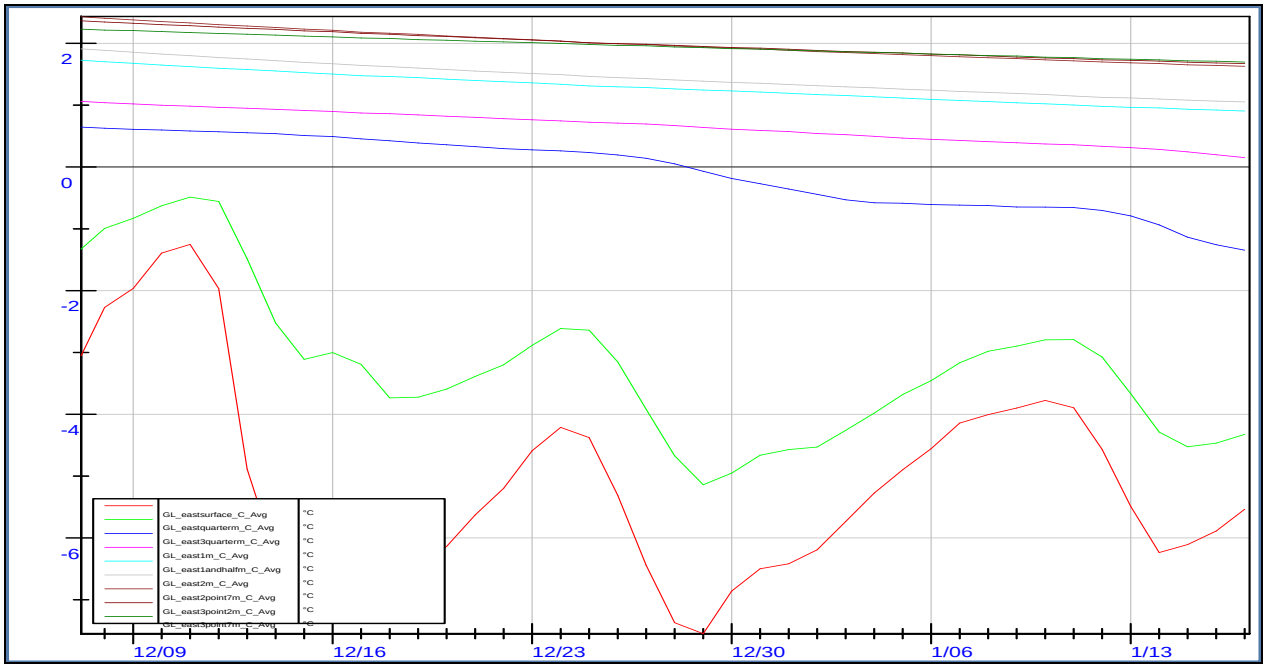

Figure 2: The graph shows the recorded temperatures of the area around the eastern ground loop for a month long period in late December. The temperatures (in degrees Celsius) are shown on the Y axis. The curves representing the coldest temperatures are measured closest to the ground surface and the warmer stable temperatures are measured at greater depths.

<u>Project #028 – University of Alaska Fairbanks, Organic Rankine Cycle</u>

ACEP continues to monitor progress on the ORC project. On 1/17/2014, ACEP research engineers conducted a site visit. The test apparatus, shown below, is complete and baseline data are being collected.

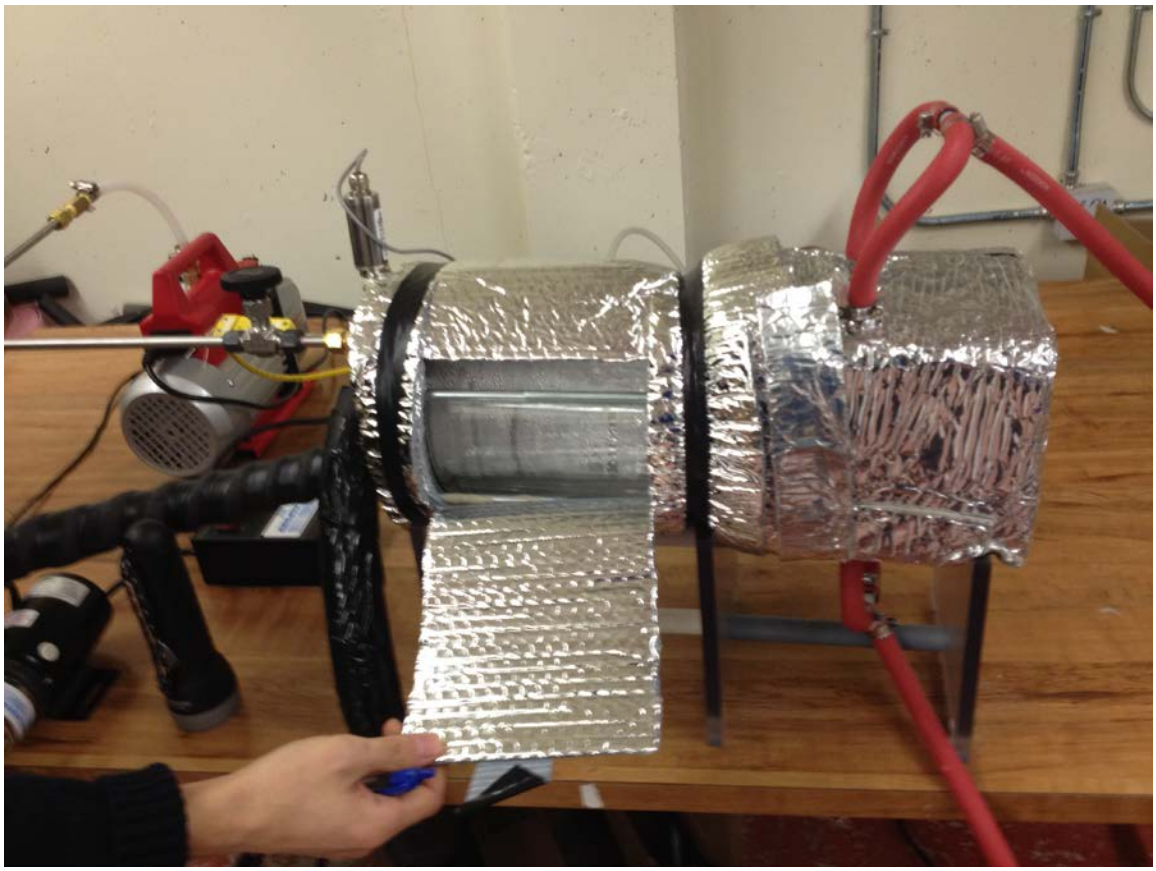

Figure 3: Testing chamber under baseline operation

Shakedown testing is being conducted with steam rather than with organic fluids and the PI indicated that although they are about a month behind schedule, there have been no surprises. Currently, data are collected both automatically and manually resulting in several data files for each experiment. Additionally, the electric power supplied to the boiler is not measured. Rather, a Variac is manually adjusted and the dial setting is logged.

A follow up visit was scheduled. During this visit, ACEP assisted with the installation of a power meter as well provide LabVIEW assistance. The goal of this assistance was to modify the data collection program such that a single output file was produced that contains both quantitative data and experimental notes and observations.

Project #029 – University of Alaska Fairbanks, Exhaust Thimble

Project #035 – Altaeros, Airborne Wind Turbine

Activities this quarter have focused on monitoring project progress and grant milestone completion. ACEP has communicated with the project by email to understand progress on turbine prototype development and testing, and to anticipate collaboration on instrumentation specification and review and data collection procedure development.

From the project team, it has been determined that initial prototype development and testing has gone well, and that the project team has progressed to developing and testing the Alaska prototype. In addition, site selection for eventual testing has been narrowed down to two sites, Delta Junction and Eva Creek, with testing to likely occur at Eva Creek pending FAA approval as support from GVEA has been secured. Once the team has finalized the Alaska prototype design (anticipated to be next quarter), ACEP will be back in touch to discuss the strategy for data collection with respect to the original data collection plan.

Project #037 – Oceana, Hydrokinetics

Project planning activities have commenced, in particular planning and coordination efforts between Oceana, the Alaska Hydrokinetic Energy Research Center (AHERC) at UAF, UAA, and the ACEP Nenana test bed team. The ACEP EETF data collection team has been monitoring these discussions, in particular data collection planning efforts. To date, environmental data collection efforts outlined in the data collection plan will be led by Dr. Tom Ravens at UAA while device data collection efforts will be led by Oceana. Some instrumentation and personnel from AHERC will be used for environmental data collection efforts. Next quarter, the Oceana team and all partners will be meeting in Fairbanks to review project planning and deployment, as well as instrumentation. The data collection team will be a part of these meetings. In addition, it is anticipated that project testing at Carterock, the naval testing facility in Maryland, will commence the final week of June. The data collection team will monitor testing plans with the project and is planning on attending this testing.

Project #043 – ORPC Alaska, Hydrokinetics

Activities this quarter have focused on monitoring project progress and grant milestone completion. ACEP has had some discussions with the project team concerning the work at Nikiski and TGU testing in Maine. A significant change from the original scope of work is the removal of testing at the ACEP Power Systems Integration Laboratory due to budgetary, timeline, and technology constraints. ORPC is coordinating closely with Marsh Creek and has developed a system utilizing commercially-available components which they believe do not require significant testing and demonstration before field deployment.

ACEP is monitoring project activities. In particular, ORPC will be conducting their Nikiski pre-testing at Nenana next quarter. ACEP plans on being in attendance during this testing to qualitatively monitor activities.

Project #045 – Hatch, Flywheel

The ACEP data collection team is monitoring discussions between the Hatch project and the ACEP Power Systems Integration laboratory with regards to testing plans, schedule, and protocols. A draft agreement has been developed between the two entities. It is anticipated that this agreement will be finalized next quarter, and pre-testing activities will commence in earnest In particular, the ACEP data collection team will collaboration with the PSI lab team to review data collection plans against the original data collection agreement, and to provide technical support when necessary.

Project #049 – Intelligent Energy Systems, Self-Regulated Grid, Project #051 – Intelligent Energy Systems, Wind-Diesel-Battery Hybrid System

ACEP conducted a site visit to Tuntutuliak on 1/21/2014. The following is a summary ACEP trip report:

No personnel from IES were in the village so Carl Andrew, the utility manager showed ACEP around. He was very helpful and answered all questions to the best of his ability. Tuntutuliak, Alaska is located in the Yukon-Kuskokwim delta about 45 miles southwest of Bethel. Population is about 450 people.

The village has a winter base load of about 180 to 190 kW. The power house has 4 generators:

1. 120 kW – functioning, usually used to power the power house
2. 180 kW – broken
3. 275 kW – functioning
4. 275 kW – broken

Only one generator that is capable of powering the village is currently operating and this was very worrisome to Mr. Andrew. They are supposed to plan to get the gen set repaired soon, and also get another generator.

The village also has 5 95 kW wind turbines which were installed a couple of years ago. Recently one turbine 'burned up' (villagers reported seeing fire shooting 20 feet out of the back of the turbine during a high wind even, and the cowling was melted). This is supposed to be repaired later in the spring.

In Jan 2012, 27 Steffes units were installed. Excess wind is shared between each stove. Stoves operate well when wind is over 20 mph. At least three turbines are needed to make the stoves function, currently only 4 are operational. Each stove is "charged" by sending heat into an insulated compartment filled with thermal mass (ceramic bricks). A fully charged stove can provide heat for about 8 hours. You can turn the boiler off during this period, or do what many people do, set the thermostat on the boiler lower than the stove. Software at the powerhouse shows how charged each stove is and shows which stoves are functioning. As part of the project, a big load regulator was installed. The load regulator sells power either to the main electric grid, or to the stoves depending on the amount of power that the turbines are generating. Consumers pay 10 cents per kWh for the energy. This equates to just over $4/gal of diesel (it should also be noted that electric heat is considered 100% efficient while a boiler is not, so actual cost savings would be higher than the price per gallon of oil suggests).

One Steffes unit has been taken out of a house because the home owners didn't like it. A while back it was estimated the average person in Tunt spent about $1500/month on heat. Carl gets monthly reports that spell out power quality, how much wind is going to electric grid, stoves, etc. Patrick Boostra with IES indicates that the money collected from the power going to the stoves is used for with turbine maintenance.

Currently the load regulator supplied the stoves with the same amount of energy, and is charged the same. The customers are the ones to set the thermostat and decide at what level the stoves function. On the electric bills, there is a separate line item for going to the stoves. Various people around the village that ACEP spoke to were happy with the electric heaters and believed that they were saving people money. However, not all stoves are on and many

people don't have a very good idea about how they work. You can imagine that some people expect heat right away (similar to a boiler, or Toyo). They don't understand that this stove heats bricks to then slowly release that heat, and if there are light winds, the stoves may not work.

IES is contracted by Chininik wind group to manage the wind diesel systems. A new distribution system is planned for the next winter. The poles are leaning a lot right now and the system is pretty old. They are planning on attaching new poles to pilings.

The day before ACEP's visit, a problem with the communication between the Steffes stoves occurred. Currently Steffes headquarters can only see the load regulator, and not each of the individual stoves. When ACEP was in the village, Carl and the other workers were checking the connections with a number of antennas.

Data related to the Steffes units is collected by Steffes. Data on the SCADA system includes:

- Village load
- Turbine operation
- Wind speed
- Temperature
- Generator KVar and kW
- Stoves state of charge
- Daily, monthly and annual energy summaries
- Energy to electric loads
- Energy to load regulators
- Energy from load regulators to heaters
- % of diesel displaced

ACEP wasn't able to see any detailed Steffes data collection and reporting. Carl wasn't able to speak to the future advanced controllers that are to be put on the individual heaters, or the data collection that has taken place.

ACEP notes a concern about the ability to conduct a careful survey of system effectiveness when heaters are in homes, as every home has a different living situation. In other words, consistency to enable careful data collection will need to be reviewed and monitored.

The following are photos from this site visit, highlighting the wind farm, power system controls, and Steffes units:

ACEP also conducted a review of the project milestone report, *Review and Testing of Steffes Electric Thermal Storage Unit with Grid-Interactive Frequency Regulation*. The following is an ACEP summary report of a debriefing with report author Prof. Richard Wies on 4/1/2014.

ACEP met with Prof. Wies and his graduate student assistant Nick Janssen in his lab where testing of the Steffes unit is taking place. In addition to the study of the unit commissioned for AEA, his graduate student is using the unit to complete his PhD thesis. As part of this, he is modeling the unit characteristics, electrically and thermally. The unit that is currently being tested is smaller than the one that is installed in the villages. It is also specially fitted with a grid-interactive electric-thermal storage (GETS) controller. This controller is described in depth in the paper that resulted from the study. Its purpose is to turn the coils in the unit on and off when the frequency of the grid is above 60 Hz in an attempt to regulate grid frequency and act as a dump load for excess wind generation in high penetration wind diesel systems.

The GETS controllers can be set (by those with access which Prof. Wies did not have) via an Ethernet cable to adjust the unit's reaction time to frequency modulations. He stressed both verbally and in his report that this was the reason for the longer reaction times of the units to frequency modulations. In order to use the units for frequency control in a small grid situation with many units, each unit would need to be adjusted to have a slightly different reaction time; otherwise all units could respond to a high grid frequency at once and "crash" the grid. He wasn't able to give me a clear answer about what happens when a system loses power (in regards to whether the GETS resets to

default settings) except to say that when their unit had a shut down due to low frequency (56 hz) they left it unplugged overnight and it worked again in the morning.

Prof. Wies sees a role for these units in a high penetration wind diesel system as an assist, however he does not believe that the units alone can regulate grid frequency in a diesel off scenario. To fully understand the role of the Steffes Units in a grid format, many units would need to be tested in a small village setting. Optimal instrumentation of the units in a village wide test would involve instrumenting three units per phase at different distanced from the main bus. This would take line voltage losses into account. So for each phase one unit would be instrumented close to the powerhouse, one at the end of the line, and one somewhere in between. This equates to 9 instrumented units. In addition, very high resolution data is necessary- on the order of ½ Hz to properly measure response times of the different units to frequency changes.

ACEP conducted a site visit to Kwigillingok on 1/20/14. The following is a summary ACEP trip report:

Kwigillingok, Alaska is located in the Yukon-Kuskokwim Delta about 75 miles southwest of Bethel. The village has a population of about 320. ACEP met with Patrick Boonstra, the project manager with IES. He has been involved in the project and working for IES since August. He showed us the village power house and attempted to show us the IES designed SCADA system however it was not working correctly and he was not able to show us details. For more information about the SCADA system, see the Tuntutuliak report (above) that describes the system in more detail.

According to Patrick, Kwig has a winter base load of about 230 kw. Kwig has 4 generators (180 kW, 190 kW, 275 kW, 90 kW). During our visit one generator was running producing 136 kW according to the SCADA system and two wind turbines were producing 53 kW. Patrick indicated that another generator had recently broken down. They planned on trying to fix it in the next couple of days. A new school is under construction and Patrick believes the base load will likely go up to about 300kW when it's done. They are doing their own water and sewer treatment there which is energy intensive.

The village has 5 windmatics 17s, 95 kw turbines. Currently 2 turbines are currently operational. The power plant operators have been to wind class and do the maintenance on the turbines. They have lattice towers and can only be worked on in good weather.

There are also 30 Steffes units in the town. They don't get PCE for the electricity those units consume. They charge 10 cents/ kwh for this electricity. The money that this generates goes into a fund which is used for turbine maintenance. They are considering eliminating this charge however. The load regulator determines the power that is sent to the stove. Turbines need to produce at least 20 kW before they start sending power to the stoves.

All homes in the village also have smart meters.

According to Patrick, the lithium ion batteries are the same models that are used in the Chevy Volt. It's a 50 volt battery system, 42 batteries. He doesn't know what the total battery size is. Cost was approx. $500,000. The decision was made to go with that battery to keep it

mobile so it can be moved if necessary. The entire battery structure which includes the batteries, a grid forming invertor, transformer, and HVAC system is the size small conex. Just last week, the ground finally froze hard enough to move the structure from the barge landing to the open area near the airfield where it now sits on large rig mats. They were building a deck like structure onto it when ACEP was there.

A multi-unit controller collects grid data and they have SEL meters which keep power house logs. IES is contracted to manage the wind diesel systems for Chininak wind group (kwig, Kong, Tunt, and Kipnuk).

The battery that is currently being installed is part of a larger system which includes smart meters, Steffes units, wind turbines, generators, etc. Frontier power systems with Carl Brothers out of Canada has been very helpful as this project has progressed and they use a lot of their stuff. Currently battery commissioning is at least a month away, although Patrick doesn't have exact dates from ABB. He would like ACEP's involvement in the process so we can have data collection equipment installed correctly the first time.

The following are photos from this site visit, highlighting the battery module:

Project #058 – BRI, Hydrokinetics

ACEP is monitoring project pre-grant activities and communicating with AEA as to the status of the project. In particular, ACEP has been communicating with the project regarding instrumentation of the system. Per these verbal discussions the project is meeting the expectations for instrumentation outlined in the data collection plan. ACEP will continue to monitor project progress with AEA.

Project #061 – Marsh Creek, Various Speed Diesel-Electric Generation

ACEP conducted a site visit to Marsh Creek on 3/14/2014 to review the instrumentation and data collection protocols for Marsh Creek testing. During the site visit, Marsh Creek showed ACEP the testing unit which was finalizing baseline testing (the flux drive was not integrated). In addition, the project team reviewed the system instrumentation, controls, and data collection, conducted a live demonstration of system operation and data collection, which was finalizing baseline testing (the flux drive was not integrated). In addition, the project team reviewed the system instrumentation, controls, and data collection, conducted a live demonstration of system operation and data collection, and reviewed the online interface. ACEP has confirmed initial instrumentation, and has access to the online interface, as shown with the following screen capture:

The following are photos from the site visit, and include images of the fuel flow meters, the testing unit, and the system controls and data instrumentation.

ACEP is currently reviewing the data from completed baseline testing. Marsh Creek is currently receiving and installing the flux drive system; ACEP will monitor the testing of the unit, set to commence next quarter.