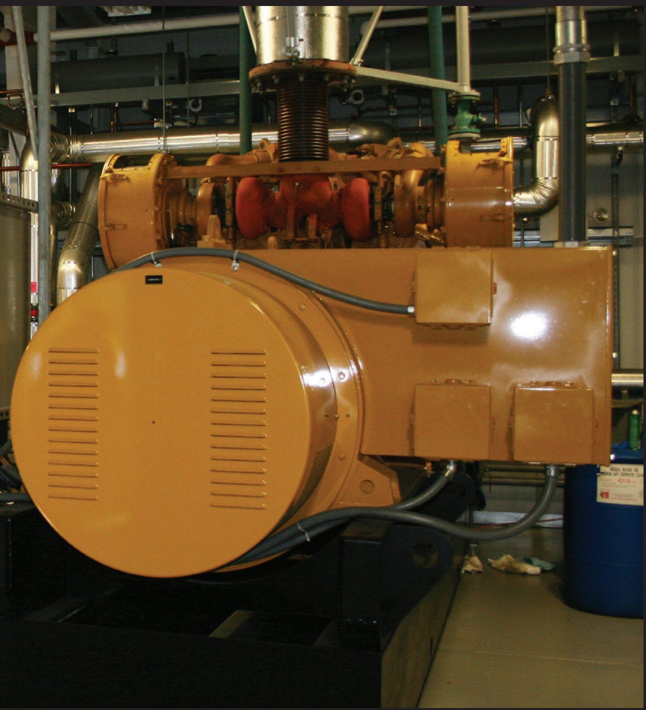

EPSCoR Final Report

PHASE I PROJECT (1 July 2010 – 30 June 2013)
Making Wind Work for Alaska: Supporting the Development of Sustainable, Resilient, Cost-Effective Wind-Diesel Systems for Isolated Communities

PHASE II PROJECT (1 July 2013 – 30 June 2014)
Sustainable Village Energy: Integration of Renewable and Diesel Systems to Improve Energy Self-Reliance for Remote Rural Alaska Communities

December 20, 2016

Prepared for the U.S. Department of Energy by the Alaska Center for Energy and Power with support from DE-SC0004903

Alaska EPSCoR

ACEP
Alaska Center for Energy and Power

UAF
UNIVERSITY OF ALASKA FAIRBANKS

FINAL REPORT

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PHASE II PROJECT:	Sustainable Village Energy: Integration of Renewable and Diesel Systems to Improve Energy Self-Reliance for Remote Rural Alaska Communities, 1 July 2013 – 14 July 2014
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LIST OF ACRONYMS

ACEP – Alaska Center for Energy and Power

AEA – Alaska Energy Authority

AEDG – Alaska Energy Data Gateway

ARPA-E – DOE Advanced Research Projects Agency (Energy)

ARSC – Alaska Regions Supercomputing Center

CPS – Community Partnership for Self-Reliance

DOE – U.S. Department of Energy

EDA – U.S. Economic Development Administration

EPSCoR – Experimental Program to Stimulate Competitive Research

ETF – Energy Technology Facility

ETS – Electric thermal storage

FESS – Flywheel energy storage system

ISER – Institute for Social and Economic Research

NREL – National Renewable Energy Laboratory

UA – University of Alaska

UAA – University of Alaska Anchorage

UAF – University of Alaska Fairbanks

PSI – Power Systems Integration Laboratory (located at UAF ACEP)

RCRE – Remote Community Renewable Energy Partnership (led by NREL)

SNL – Sandia National Laboratory

Executive Summary

This project originated as a means to expand existing capacity at the University of Alaska in the niche market technology of hybrid wind-diesel systems. The central project theme is to deliver low-cost, reliable, and sustainable energy, and it started focused on a wind-diesel platform, later broadening to include other technology foci as they matured and appeared to be technically and economically viable in rural Alaska. Many parts of the state have excellent energy resources; however, most rural Alaskan communities are more similar to less-developed countries than to places in the continental U.S. Small populations, isolated off-grid systems, difficult environmental conditions, dependence on imported fuels, lack of roads and infrastructure, and slim, mixed cash-subsistence economies all combine to produce the highest energy costs in the country, with electric power approaching $1 per kWhr, and gasoline prices as high as $10 per gallon.

Alaska is considered a world leader in renewable energy and microgrid technologies. Our workplan started as an analysis of existing wind-diesel systems, many of which were not performing as designed. We aimed to analyze and understand the performance of existing wind-diesel systems, to establish a knowledge baseline from which to work towards improvement and maximizing renewable energy utilization. To accomplish this, we worked with the Alaska Energy Authority to develop a comprehensive database of wind system experience, including underlying climatic and socioeconomic characteristics, actual operating data, projected vs. actual capital and O&M costs, and a catalogue of catastrophic anomalies. This database formed the foundation for the rest of the research program, with the overarching goal of delivering low-cost, reliable, and sustainable energy to diesel microgrids.

Phase I ran from July 2010 – June 2013, and specifically focused on wind-diesel analysis, which was the most promising and mature arctic renewable energy technology at the time. We maximized Alaska-specific expertise to focus on the following issues:

1) High Penetration: Technical issues related to higher penetration of wind, such as power stability, long term energy storage, and advanced control technologies including the use of excess wind power to supplement residential and commercial space heating and transportation.
2) Cold Climate: Issues related to operation of turbines and ancillary equipment in cold climates and remote locations, such as production loss due to rime ice buildup, remote monitoring, and foundation design in areas with geo-technical problems.
3) Socioeconomics: Social, economic, and political barriers to the development of wind, including local capacity to develop and support sustainable systems.

The Wind Diesel Applications Center (WiDAC), based at the University of Alaska, was formed in 2008 as a consortium of university, national laboratory, and over 50 industry partners with the goal of supporting deployment of cost-effective wind-diesel technologies. Since that time, The Alaska Center for Energy and Power has broadened its focus to include research in other energy technologies, such as solar photovoltaic and heat recovery, and the WiDAC name was phased out in favor of Power Systems Integration Laboratory (PSIL). Our EPSCoR program was developed through a series of discussions with our WiDAC partners, and has significantly increased the University of Alaska's ability to carry out the Center's mission through key new faculty hires, graduate student fellowships, faculty and staff training opportunities at national labs, and acquisition of needed equipment. Because WiDAC was and PSIL is a strong partnership among manufacturers, the research community, and the technology end-users, it not only serves as a practical and effective mechanism to ensure the project goals continue to be successfully met, but that the overall program is sustainable beyond the timeframe of this project.

Phase II ran from July 2013 – July 2014, and broadened the scope of analysis and examination from wind-diesel systems only, to multifaceted microgrids that incorporate various renewable generation technologies (e.g. solar, wind, hydrokinetic), with energy storage devices (e.g., batteries, flywheels) and demand response. As part of the redefined scope on microgrid technologies, the specific research emphases on socio-economic challenges and turbine performance in harsh climate conditions were both dropped. These shifts in emphasis reflected course adjustments based on reviewer comments, budget limitations, and what we learned in Phase I about the nature of technical constraints to reducing community dependence on expensive refined fuel products.

For our renewal program, we selected the title ‘Sustainable Village Energy’ purposefully. The term ‘village’ generally is used to describe ‘a group of houses and associated buildings, larger than a hamlet and smaller than a town, situated in a rural area’. However, a secondary definition is ‘a self-contained district or community within a larger town or city’. When considering this broader definition, we believe sustainable village energy encompasses not only the Alaska context but also analogous systems in the developing world, military forward operating bases, and microgrids located in the continental US and throughout the world.

The main objective of phase II was to address power stability challenges posed by integrating distributed and intermittent renewable energy resources into isolated diesel microgrids, with an emphasis on developing effective use of advanced controls, energy conversion equipment, energy storage, and smart-dispatch strategies. In addition, the accomplishments of Phase 1 were solidified and expanded. The integrated energy database created in Phase 1 was expanded to facilitate support of research, state agency project tracking, and our industry, academic and national laboratory partners. Furthermore, the capabilities of UA’s Power Systems Integration Laboratory were expanded for pre-deployment development and testing of innovative equipment and control/dispatch strategies for integration of multiple renewable resources into diesel-based microgrids. Finally, community partners were engaged to develop a structured community-driven renewable energy integration process for desirable and achievable future energy systems.

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1 Program Background

The State of Alaska is home to over 250 small, islanded diesel-powered microgrids ranging from 100kW to 5MW. These microgrids, many in operation for over 50 years, provide electric power service to rural populations and are not connected to each other, or any centralized grid service. In the past decade, Alaska has invested in developing and integrating renewable energy with established diesel-powered microgrids in order to reduce fuel costs. As a result, Alaska is now home to an estimated 12% of the world's established diesel-renewable hybrid microgrids, and has more than 2 million hours of continual operating experience for these types of systems. Our program addresses specific technical challenges related to sustainable village energy systems by leveraging existing Alaskan capacity within the University, industry, and rural communities, and expanding collaboration with national labs, DOE, and relevant international organizations.

Our overarching goal is to increase energy self-reliance in Alaska's remote rural communities and reduce dependence on imported diesel fuel by working with industry to develop and demonstrate promising technologies and control strategies that can be replicated in microgrids in Alaska and the developing world. Many rural Alaskan communities have excellent renewable resources, but are hampered in their efforts to capture these potential benefits because of small populations, isolated off-grid systems, harsh environmental conditions, lack of roads and infrastructure, limited technical capacity, and little cash income. These factors combine to produce the highest energy costs in the U.S., with electric power rates approaching $1.00 per kWh, and diesel and gasoline prices as high as $10 per gallon. Much of the limited cash income that is generated leaves these communities for imported fuels for heat, electricity and transportation. Reducing diesel dependence would provide more potential for economic development because the cash would remain in the local economy; and there is the added benefit of reducing carbon emissions in remote communities globally.

Phase I focused on obtaining data of how electricity is generated, transmitted, utilized, and lost due to system inefficiencies or deploying inappropriate technology. It involved collecting current baseline data, and establishing protocols for future data collection to ensure that it is robust and usable.

Phase II broadened the scope to examine the ramifications of different renewable energy deployment strategies on an islanded village microgrid. Technical engineering challenges as well as data management were addressed.

In parallel with both Phase I and Phase II, plans were established with the goal of ensuring long-term project sustainability. These included strengthening partnerships with industry, national labs, and local communities and increasing the amount of peer-reviewed publications.

2 Description of Activities and Accomplishments

The University of Alaska DOE EPSCoR program was initiated with a kick-off meeting held in September 2010 in Fairbanks with DOE program managers, a Peer Review Committee organized by DOE, University of Alaska researchers, and key external participants from the State of Alaska, federal agencies, and national laboratories. This meeting, along with a preparatory meeting with our WiDAC Industry Advisory Committee, allowed us to refine and refocus the scope and vision of the program in the first year based on reviewer feedback.

Phase I sought to collect—and enable future collection of—high-resolution engineering data and socio-economic information. Lack of knowledge surrounding current energy production and usage has been a major impediment to researching improvements in technology and to understanding how the communities utilize energy, i.e., how much of their energy bill goes toward electricity, heat, and transportation. In order to reduce electricity costs in a village, we needed to start from the perspective of how electricity is generated, transmitted, utilized, and lost due to system inefficiencies or deploying inappropriate technology.

Phase II focused on specific technical challenges relating to renewable energy integration into isolated microgrids. The database developed in Phase I, the Alaska Energy Data Gateway, was also improved and expanded. Based on feedback from the Phase I program review, the focus was technical only (social and economic issues were not addressed), and broadened beyond wind to examine other renewable energy generation and management technologies that could be viable for islanded microgrids.

Integrating intermittent renewables into a diesel microgrid requires maintenance of power stability, potential use of energy storage, and advanced control strategies. With a new Power Systems Integration (PSI) Laboratory at UA capable of recreating an entire village energy grid, we have been able to begin to address these challenges not only in isolation or through modeling, but also through full-power and real-world testing and analysis. The PSI Laboratory has been used successfully to test products and strategies for reducing community reliance on diesel fuel, and has gained the attention of several large companies looking for a place to demonstrate and further develop their technology at full-power.

Six broad work objectives provided a framework for our research. These are listed below, along with a discussion of how these objectives were approached and met.

1) *Expand the content and facilitate use of the integrated energy database created in Phase 1 to support research, state agency project tracking, and our industry, academic and national laboratory partners.*

   The Alaska Energy Data Gateway is fully operational, and has quickly become the go-to resource for reliable data about Alaska energy projects. The Alaska Energy Authority has entered into an MOU with the University of Alaska for long-term management and maintenance of the site beyond the end of the EPSCoR project. In addition, our national laboratory partners have used the AEDG to support projects such as the NREL-led Remote Community Renewable Energy Partnership (RCRE).

2) *Improve techniques for high-quality and high-resolution data collection from remote locations.*

   We have made substantial progress in developing a structure and methodology for managing high-quality, high-resolution data sets and making them accessible via the AEDG, but this feature is not fully enabled at this time. Several multi-year data sets provided by utility partners facilitate our research. We have also organized a utility industry advisory group to ensure we are addressing their interests by developing an automated reporting process to support utility and regulatory reporting. Finally, we have developed and are in the process of packaging a specialized data acquisition system, nicknamed the 'BlackBox' to collect data from remote sites without the capability to acquire or log high temporal resolution generation and demand data. Each of these activities is supported by additional funding from the Alaska Energy Authority, University of Alaska investment, or private sector contributions. The BlackBox has also resulted in two invention disclosures for UAF.

3) *Address power stability challenges posed by integrating distributed and intermittent renewable energy resources into isolated diesel microgrids, with an emphasis on developing effective use of advanced controls, energy conversion equipment, energy storage, and smart-dispatch strategies.*

   In support of our Phase I EPSCoR program, UAF invested in developing a state-of-the-art microgrid testing emulation laboratory that can recreate issues related to systems integration and power stability at full power levels (up to 500 kW). This laboratory became fully operational in 2013, and has since been used to develop and test a number of components and strategies for reducing the use of diesel fuel for isolated hybrid-diesel microgrids. Since then, the state has funded ACEP for an additional $745,000 to support research and industry collaboration, however the business model developed around operation of the lab is such that it should remain self-funded through industry and researcher driven projects. In 2015, a UAF (ACEP) and UAA (Business Enterprise Institute) were jointly awarded $499,064 through the U.S. Economic Development Administration i6 Challenge to develop a Microgrid Commercialization Facility Center to provide the technical and business assistance required to accelerate commercialization, and implementation, of the technologies needed to improve the affordability and reliability of microgrid energy systems. Finally, a number of public-private partnership funded projects have used the facility, recently a project by Hatch Engineering to test a high performance flywheel provided by Williams Hybrid Power, and later installed in a remote mine site in Northern Quebec.

Significant progress toward this objective has also been made by the engineering faculty involved in Task 2, including a tenure-track faculty member, Daisy Huang, who joined the Mechanical Engineering Department in 2014, PhD student Nick Janssen, and several MS students and visiting researchers working as part of the team. Significant progress has been made in assessing opportunities for integrating electro- thermal storage as a dispatchable load (demand response) and to displace diesel heating fuel.

Finally, we have completed a number of real-work assessments working with our community and utility industry partners, including Nome (wind-geothermal-diesel), Galena (high contribution PV integration), and Cordova (energy storage and demand response study). These reports, along with several others, are listed in Appendix A and are available for download at http://acep.uaf.edu/projects/sustainable-village-energy-integration-of-renewable-and-diesel-systems-to-improve-energy-self-reliance.aspx under the project status report link.

4) *Investigate common misconceptions concerning high-contribution wind hybrid-diesel operation such as low-load diesel efficiency or diesel-off mode, and the need for spinning mass and/or secondary load control to maintain stable operation.*

During our Phase I program, it became apparent that many widely held beliefs existed with regard to renewable-diesel hybrid systems that were not substantiated by available data, or for which no quantifiable data existed. We have worked to identify and systematically address these questions through technical reports or peer-review publications that are listed in Appendix A. Initial investigation into common misconceptions has provided theoretical baseline insights, improved, data-based information, and direction for research conducted in other engineering tasks (Task 2).

5) *Further enhance the capabilities of UA's Power Systems Integration Laboratory, and use it for pre-deployment development and testing of innovative equipment and control/dispatch strategies for integration of multiple renewable resources into diesel-based microgrids.*

ACEP has continued to invest in the Power Systems Integration Laboratory, based on the needs of specific funded projects utilizing the facility. In spring of 2015, we added a 313 kVA ABB PCS100 grid forming inverter to support diesel off testing, and more recently, we have added a 100 kW solar PV emulator and a fault emulator under the EDA i6 Challenge award. The laboratory's data acquisition capabilities have been significantly extended to now provide over 1000 channels of electrical and mechanical performance data at 5 Hz sampling rate, as well as power quality data at 60 kHz. Generic control architecture for scripted laboratory operation has also been developed. Additionally, capabilities we are working toward include a demand response simulator and emulator based on remote controllable under-frequency load shedding equipment provided by industry partner Saturn South.

6) *Collaborate with partner communities to develop a structured community-driven renewable energy integration process for desirable and achievable future energy systems.*

Our team has emphasized community engagement and spending time in our communities throughout the EPSCoR program, and have visited over 60 communities (approximately 25%) throughout this program. In addition to activity carrying over from Phase I, we have joined the Community Partnership for Self-Reliance, a novel community 'in-reach' program lead by UAF in partnership with the Alaska Native Science Commission (ANSC). Furthermore, we continue a broad, multi-faceted K-12 outreach effort and have engaged every school district in the state. These programs, including Wind for Schools, Kid Wind, and Energy Smart are no longer funded by EPSCoR at the recommendation of program reviewers, however we still see them as a valuable tool for community engagement that supports our research priorities.

A few notable activities, events, and accomplishments in chronological order for the program time span include:

- ***Annual International Wind-Diesel Workshops (annually since March 7th-11th, 2011)*:** The 5th International Wind-Diesel Workshop was organized by the Wind-Diesel Applications Center (WiDAC) and held in Girdwood, Alaska. We achieved our goal of having strong attendance from all EPSCoR participants, including faculty, students, and staff. This venue provided an excellent forum for researchers to share ideas with industry partners, and an EPSCoR team meeting was also held. We have continued to be involved in the annual workshop since then.

- ***WiDAC External Advisory Committee*:** We continue to coordinate closely with the WiDAC External Industry Advisory Committee, and appoint new members, including residents from rural communities, at the advice of the DOE Peer Reviewers and Program Managers. EPSCoR team advisor Per Lundsager, who is based in Denmark, spent three weeks in Alaska working with task leads and helping connect our researchers with the broader international network related to islanded grid systems. Per was awarded with a Lifetime Achievement Award during the 2011 International Wind-Diesel Workshop for his contributions to the field of isolated wind systems.
- ***Data Management Meeting (June 11th, 2011)*:** A lack of high quality, comprehensive data was identified early on as a major barrier to implementing our research plan, and has developed as a major focus of our research efforts. A data management meeting was held at UAA ISER in Anchorage to identify the types of data to be collected (economic and technical performance) and organize the teams for the collection and management of the data. A data manager was recruited and hired for Task 1. A remote data acquisition system was constructed at UAF Alaska Center for Energy and Power (ACEP), deployed in a few villages, and data collected. We continue to collect and manage data as part the program.
- ***Alaska Rural Energy Conferences (sesquiennially since September 27th-29th, 2011)***: The 7th Alaska Rural Energy Conference, originally organized in 2002 by Dennis Witmer as the director of the UAF Arctic Energy and Technology Development Lab (predecessor to the Alaska Center for Energy and Power) and the Alaska Energy Authority (AEA) was held in Juneau, Alaska. The meeting was attended by Alaska Native leaders, industry, university researchers, and many key constituents and stakeholders in the wind-diesel community. Several EPSCoR team members helped to organize, attended, and made presentations at the conference.
- ***EPSCoR Program Halfway Review (October 6th-7th, 2011)*:** An EPSCoR Program Halfway Review meeting (See Figures 1-2 in Appendix D) was held at UAA ISER in Anchorage, Alaska. The subtask leads and most of the graduate students working on the project presented their tasks and relevant progress on those tasks to key partners and constituents in Alaska. A follow up meeting of the EPSCoR team was held the following day. Notes from this meeting are included in Appendix A.
- ***Alaska Wind Working Group (semi-annual)*:** Meetings organized by the Renewable Energy Alaska Project (REAP) were held in Nome on November 11th-12th, 2010, Juneau on September 26 th, 2011, and Kotzebue on May 14th-15th, 2012. Several UA researchers participated in these meetings and provided updates on the EPSCoR program for the broader Alaska wind stakeholder community. The lack of good data, a poor remote communications infrastructure, and the lack of stability in high penetration wind systems in diesel-off mode were identified as major technical hurdles for wind systems in remote communities of Alaska. We continue to address these technical hurdles in Tasks 1, 2, and 4.
- ***Energy Technology Facility (ETF) and Wind-Diesel Hybrid Test Bed (WDHTB)*:** ETF opened at UAF in October 2011 and houses the WDHTB (see Figures 3-10 in Appendix D). Dave Light, with 22 years of experience in Alaska village diesel electric systems was hired in early 2011 to help design and manage the ETF after construction. WDHTB was temporarily constructed at Marsh Creek, LLC, in Anchorage, and was moved to the ETF in January 2012 currently in the final stages of reconstruction and commissioning. The ETF and WDHTB were funded through the state and external grants, but will be used under Task 2 for development, testing, and validation of novel hybrid energy technologies, control strategies, and energy storage applications in close collaboration with national labs such as ***NREL*** and ***Sandia*** which have similar testing labs.
- ***Graduate Students*:** Graduate student researchers were recruited for all tasks (see Appendix C). A graduate student intern was hired in Summer 2011 for technical data collection and management associated with Task 2. This student has since graduated with a PhD and is now a postdoctoral fellow in the EPSCoR program working directly under PI Holdmann on data management and the hybrid test bed. Three masters level graduate students hired under Task 1 and three masters level graduate students hired under Task 2 will be completing their

masters theses in 2012. Three PhD level graduate students hired under Task 2 and 4 will be completing their PhDs in 2014.

- ***Research Faculty and Post Docs***: Billy Muhando was hired by ACEP in January 2010 and has been leading Task 2.1 on high penetration wind-diesel systems, energy storage, and the Wind-Diesel Test Bed. A postdoctoral fellow was recently hired at UAF to work on the Hybrid Test Bed, data acquisition systems, and smart grid applications. A second postdoctoral position is currently open for smart grid applications under subtask 2.2. The state recently approved a new tenure track engineering faculty line at UAF that promises to provide a half-time joint appointment split evenly between the College of Engineering and Mines (CEM) with state funds and ACEP with EPSCoR funds.
- ***Peer Review Papers and Wind Diesel Best Practices Guide***: A number of papers, presentations, and technical reports have been generated in connection to the EPSCoR program as outlined in Appendix B. Most notable are a ***peer review journal paper on novel wind controls*** and a ***Wind-Diesel Best Practices Guide***. We have six *journal manuscripts in preparation* with *one paper in peer review* from Task 1 and five close to submission under Task 2. There are also a number of conference proceedings and presentations to date with at least three more scheduled in the next two months.
- ***Proposals***: We have been active in submitting a number of proposals to federal (USDOE, NSF) and state (Denali Commission, Alaska Energy Authority) funding agencies to support ongoing work (see Pending and Funded Proposals on pp. 23-25). The defining theme for these proposals has been the development of transformative and efficient energy technologies to address high penetration challenges in Alaska with a focus on intelligent control systems and advanced storage.
- ***Key Collaborative Affiliations***:
    - ***Alaska Energy Authority (AEA) and the Denali Commission***: The EPSCoR team continues to work closely with their emerging energy technologies programs as reviewers and third party evaluators. We also work closely with AEA on several fronts including data management.
    - ***Rural Utilities***: We continue to work with the ***Alaska Village Electric Cooperative (AVEC)*** in gathering information and garnering expertise from wind-diesel systems in remote villages in their service territory. We have also worked closely with the ***Kotzebue Electric (KEA)*** to develop high penetration wind-diesel systems and explore battery energy storage systems.
    - ***National Labs:*** We continue to partner and work closely with ***NREL*** and ***Sandia*** on research, testing, and validation of hybrid microgrids and energy storage technologies. Members of the EPSCoR team have visited both labs. We currently have a close collaborative relationship with Brian Hirsh at NREL's Alaska based office and the former manager of the DOE Arctic Energy Laboratory, Brent Sheets, was hired by ACEP as the Research Coordinator in July 2011.
    - ***Industry***: We have worked closely with ***Marsh Creek, LLC*** to collect data, model and validate the hybrid wind-diesel systems at Unalakleet and Kohkanok; ***Intelligent Energy Systems (IES)*** to collect data, model and validate the newly installed wind-diesel system at Kongiganak; and **Sustainable Automation** and **ABB/Powercorp** to develop the Wind-Diesel Hybrid Test Bed.
    - ***Cold Climate Housing and Research Center (CCHRC)***: We have an ongoing collaborative effort to research building energy systems such as solar PV, electrothermal heating, ground source heat pumps, residential smart grids, and most recently the UAF Sustainable Village.
- ***Key Education and Outreach:***
    - ***Alaska Native Community***: A meeting was organized by EPSCoR team members in November 2012 that brought together Alaska Native leaders, UAF Alaska Native faculty members, and UAF researchers like Terry Chapin from UAF Resilience and Adaptation Program (RAP) experienced in working with Alaska Native communities. We have developed partnerships with and continue to assist Alaska Native residents in realizing sustainability, while incorporating their input in our research program.

– ***Wind for Schools, Kid Wind, and Wind-Diesel Academy*:** The Wind for Schools, Kid Wind and Wind-Diesel Academy programs are critical dissemination activities that help us ensure we are teaching the future energy leaders and wind workforce. The programs are a huge success.

2.1 Phase I, Task 1.0: Wind-Diesel Knowledge Network

Steve Colt and Ginny Fay

Overview

Task 1 included the development of a comprehensive wind energy knowledge network that will provide a common empirical foundation for all other internal research tasks as well as serve as a compilation of wind-diesel information for external partners and researchers. This information is critical for evaluating the potential options for increasing penetration levels and adding more complex and costly optimization controls and configurations. Subtasks include identifying critical variables and information, on-going data collection efforts, data gaps, and solutions. In addition existing datasets will be linked and made more available to researchers, industry, and the public.

- <u>Task 1.1: Alaska Energy Data Gateway Development.</u> During Phase I, we developed the Alaska Energy Data Gateway (AEDG), a portal for comprehensive access to energy data for communities across the state, and a robust data collection system that can be deployed to remote communities to acquire data that heretofore was unavailable. In Phase II we continued to automate the data processing and make the data more readily accessible to researchers, agency partners, and stakeholders in both private and public sectors.
- <u>Task 1.2: Develop and Implement Protocols for Robust Data Acquisition.</u> In addition to data already available on energy projects statewide, there is a need for higher resolution engineering data to inform research and help design the systems of the future. To meet this need, we developed a robust data management system to feed high resolution data into the AEDG, as well as a specialized data acquisition system, nicknamed the 'Blackbox', to collect data from remote sites without the capability to acquire or log high temporal resolution generation and demand data needed to conduct research outlined in Task 2 below.

Tasks Accomplished:

- A data manager was hired and began work on Task 1 related activities in 2010.
- The Task 1 team met with the Alaska Energy Authority (AEA) in June 2011 to discuss their plans for remote monitoring and data collection on Renewable Energy Fund (REF) wind projects and identified a potential list of pilot projects for wind performance data.
- We set up a temporary server housed at ISER to host the database and web application during development. The server is a virtual machine running Ubuntu 10.04. We purchased the domain name alaskawind.org to point to this server.
- The data manager as well as graduate students and others working on the project attended the International Wind Diesel Conference in March 2011 in Girdwood, Alaska. At the conference we conducted one-on-one meetings with system developers and operators on potential configuration of performance data acquisition, hardware and software, and data agreements.
- We developed the relational database and data management web application using the Django framework. We have begun to build the database structure and populate it with data, including community names and codes, turbine models, utilities/IPPs, and installed turbines. We developed a framework for automated external data file import and used it to import basic community data. We developed a formal relationship with the Arctic Region Supercomputing Center (ARSC), which has agreed to host the data and web application that are currently housed on the temporary ISER server.
- We are working on database documentation and its presentation within the administration back-end, data download capabilities, additional table definitions and data import routines to populate them. We completed research in how best to store metadata. We worked toward creating ways of integrating data from ACEP's new

Remote Data Acquisition Units (RDAUs, or “black boxes”) into the web application. We met AEA and GINA (Geographic Information Network of Alaska) to understand the nature of the new statewide wind speed model dataset and possibilities for integrating that data.

- We are established data import routines and a user interface for querying and retrieving data, researched and developed algorithms for data query building, and researched software testing methodologies that may help improve the quality of the data portal and guard against regressions as the codebase evolves. We met with Geographic Information Network of Alaska (GINA) to learn about their work with wind resource data maps and spatial data capabilities, and looked into techniques and software libraries for data spatialization. We migrated the database from MySQL to PostgreSQL, a database system offering better support for spatialization and transactions (among other benefits). In particular, the improved transaction support allows us to keep the database in a consistent state as its structure develops by rolling back to the previous state in case of an error.
- We entered an agreement with AEA to create a system for managing data on Renewable Energy Fund projects for performance evaluation and reporting. This data comprises a portion of our database, and is populated directly from internal AEA databases as well as by manual data entry by AEA program managers.
- We have finalized the data conversion and quality assurance routines for our proof of concept project (Ugashik). Through the data analysis for the annual report for Ugashik we have significantly extended our code base of reusable subroutines for general data analysis and presentation. We now have a robust basic toolbox of custom MATLAB® routines to automate processing of larger datasets.
- Using data from Unalakleet we have laid the ground work to extend our custom MATLAB® data management and analysis toolbox with more sophisticated statistical and signal processing tools.
- The development of the data acquisition system for the Wind-Diesel Testbed began and continued under Task 2. We are using that system to develop expertise on custom data collection systems in remote locations.

Completed milestones, as proposed in work plan include:

Milestone	***Date of Completion***
Initial meeting with project personnel	9/2010
Recruit and hire data manager	2/2011
Develop definitions of economic and engineering components and variables and agreed upon methodology for data collection	4/2011
Determine network structure and content	4/2011
Establish development server and domain name	4/2011
Identify wind-diesel remote monitoring data collection system	5/2011
Deploy preliminary web application	8/2011
Establish data hosting agreement with ARSC	8/2011
Create plan with AEA for REF data management subsystem	4/2012

The Task 1 subtasks are listed below with estimated percentage of completion:

Subtask	*% Completed*
Task 1.1: Identify sources of data and information	100%
Task 1.2: Identify on-going data/information collection efforts	100%
Task 1.3: Establish processes for data collection	100%
Task 1.4: Develop database protocol	100%
Task 1.5: Complete background research on software technologies	100%
Task 1.6: Develop Web application	100%
Task 1.7: Determine variable definitions and organization	100%
Task 1.8: Establish working relationships with data source agencies/organizations	100%
Task 1.9: Populate database with data	ongoing

- A web hosting service is available at the Alaska Region Super Computing Center (ARSC).
- The data query algorithms and user interface continue to be developed.
- We continue ongoing assessment of data needs, building relationships and agreements with data partners.
- Remote data acquisition units continue to be deployed in pilot communities.
- We continue to focus on determining the data network structure and content.
- Information regarding team data needs are used to initiate specific data acquisition requests for currently operating systems.

2.2 Phase I, Task 2.0: Tackle Technical Issues Associated with High Penetration of Wind

Richard Wies, Marc Mueller-Stoffels, Rorik Peterson, and Gwen Holdmann

Overview

The research program associated with high penetration wind-diesel systems is designed to have a direct impact on the economic status of remote Alaska communities through efficient design of new systems and optimization strategies for existing systems. The broader and long-term impact of this work is to provide research and technical support for the efficient design and operation of wind-diesel systems throughout the world by modeling and analyzing the operation of wind-diesel systems installed in Alaska. Over half of the proposed capacity building occurred under this task, including two new research faculty hires, and two graduate student research fellowships. In addition, significant resources from our external partners were leveraged to complete this task.

The objectives of this tasks were originally divided into three subtasks as follows: 1) Develop control strategies and advanced storage technologies to support operation in a diesel-off mode, 2) Assess opportunities and test smart grid strategies for using wind power for space heating and transportation applications in hybrid wind-diesel grids, and 3) Undertake advanced modeling of wind-diesel systems for system optimization.

2.2.1 Phase I, Task 2.1: High Penetration Operation of Hybrid Power Systems: Diesel-off Mode Operation for Hybrid Power Systems

Billy Muhando and Frank Williams, now Marc Mueller-Stoffels and Rorik Peterson

Overview

The defining theme for this task was development of transformative and efficient energy technologies to address high penetration challenges in Alaska, with a focus on integration of intelligent control systems, power electronics, and advanced storage for overall power quality generation, with the added benefit of reduced diesel consumption. A test bed consisting of a wind-turbine simulator, power converter, battery bank, diesel gensets and load bank is the backbone of this Task; control of these integrated systems is via a supervisory control and data acquisition (SCADA) system that acquires real time data from all parts of the system. The SCADA with the associated controller manage the economic and reliable distribution of the generation sources to the loads and turns off (or on) the diesel generators using specified control algorithms. In this way a number of generation sources can be simulated to distribute power to electric loads and some of the loads can potentially inject electric power back into the grid, e.g., batteries. This this time, the test bed has been expanded to include other components, such as a solar PV emulator and a fault emulator.

Tasks Accomplished:

- A major technical hurdle identified was the so-called "holy grail" of high penetration wind-diesel systems: the diesel-off mode of operation. In order to properly research and develop methodologies for controlling high penetration wind-diesel systems, particularly in the diesel-off mode, a hybrid wind-diesel test bed was developed.
- A report on power electronics was completed. This comprehensive report features an initial review of inverter technology encompassing a broad range of power electronics for use in a high-penetration diesel-off wind-diesel system. The report can be downloaded at http://energy-alaska.wdfiles.com/local--files/high-penetration-hybrid-power-system/Phase%20I%20-%20Power%20Electronics%20Review.pdf.
- Wind-Diesel Hybrid Test Bed Delivery and Commissioning:
  - Key research questions were developed as well as the testing protocols based on final testbed equipment selection. Equipment models, developed in SimPowerSystems, were made available to the Task 2 Team in June 2011.
  - Graduate research assistant, Matt Van Atta, was hired in January 2011 under full EPSCoR support and worked on models for simulations, data collection strategies, and garnering background research information.
  - Sustainable Automation completed delivery of all the items on order for the wind-diesel test bed, including the wind turbine simulator, converter system, transformer and lead-acid battery bank. An ABB/Powercorp Distributed Control System and Secondary Load Controller were also purchased and installed.
  - The Hybrid Test Bed was constructed at a temporary location, Marsh Creek, LLC, in Anchorage and unveiled on October 6, 2011 at the EPSCoR Halfway Review. The Hybrid Test Bed was moved to the newly opened Energy Technology Facility at UAF in January 2012, set up during the Spring 2012 while awaiting the arrival of a diesel generator in early June 2012. Final testing and validation of the controls and power electronics by Sustainable Automation occurred during the third week of June and the Hybrid Test Bed was re-commissioned on June 20, 2012.
- Flow battery energy storage technologies have been evaluated as a means of storing energy and stabilizing the grid in an isolated high penetration wind-diesel system. NREL and Sandia are also very interested in collaborating on this work and have visited our testing facilities.
  - The Prudent Energy vanadium redox flow battery was delivered to UAF in September 2010 and commissioned at a facility managed by GVEA, our local electric utility. Extensive performance analysis

was completed in December 2011 and a report issued in March 2012.
  - Dr. Frank Williams who has a chemical engineering background was hired by UAF ACEP to aid in the research associated with flow battery technology.
  - A large version of the battery in a semi-tractor trailer was delivered to Kotzebue Electric (KEA), integrated into the power plant, but was not commissioned at the request of Prudent. Prudent expects to accept the return of the battery to improve the design.
- Both sub-task lead Dr. Muhando and graduate research assistant M. Van Atta attended the 2011 International Wind-Diesel Workshop. Dr. Muhando also attended and gave presentations at the 2010 and 2011 Alaska Wind Working Group meetings.
- The sub-task lead, Dr. Muhando, attended several international conferences and made a number of presentations related to novel wind controls and flow battery research under Tasks 2.1-2.3, including the 2011 IEEE Power Systems Conference and Exposition, 2010-2012 IEEE Power and Energy Society Annual Meeting, 2010-2012 AWEA Conference and Exposition, 2010-2012 International Flow Battery Forum, and 2012 Arctic Frontiers.
- Dr. Muhando co-authored a peer review journal paper on ***novel wind control systems*** with Dr. Wies and is currently co-author on five peer review manuscripts with Dr. Wies and graduate research assistants E. Chukkapalli and M. Van Atta related to Task 2.
- A ***Wind-Diesel Best Practices Guide*** was authored by B. Muhando, K. Keith, G. Holdmann, and P. Lunsager. The guide can be downloaded at http://www.uaf.edu/acep/alaska-wind-diesel-applic/wind-diesel-best-practice-1/bpguide.pdf

Completed milestones, as proposed in work plan include:

Milestone	***Date of Completion***
Purchase of test bed equipment	7/2010
Completion of power electronics report	8/2010
Finalize layout and installation plans for wind-diesel test bed	3/2011
Construction and commissioning of test bed at temporary location	10/2011
Relocation and set up of test bed to UAF ETF	5/2012

The Task 2.1 subtasks are listed below with estimated percentage of completion:

Subtask	***% Completed***
Task 2.1-1: Improving understanding of the performance of existing wind-diesel systems and development of best practices guide	100%
Task 2.1-2: Construction of test bed and hardware testing	100%
Task 2.1-3: Field testing – it is anticipated that recommendations will be implemented as appropriate through a series of field trials with utility partner AVEC and Kotzebue Electric Association	ongoing

- Commissioning of the wind-diesel test bed at the UAF ETF was complete July 2012, after which a series of performance testing and converter control reprogramming tests addressed technical issues related to higher penetration of wind. At that time, research transitioned from purely computer simulations to physical emulation of an isolated wind-diesel power system. This enables use of suitable data, available from the field, for analysis of transient events (over/under-voltage, over/under-frequency, trip tests, harmonics, real and reactive load sharing, controlled battery charging/discharging, etc).

- Energy storage research via the flow battery energy system continued, with focus on deep cycling and performance in relation to intelligent adjustment of energy exchange with the utility grid.
- A research agenda is being developed with plans to acquire further funding.
- In addition, two conference papers have been submitted (IEEE PES General Meeting and AWEA WINDPOWER 2012).
- Three peer review journal publications based on the wind-diesel test bed and flow battery were submitted early in 3rd quarter 2012.

2.2.2 Phase I, Task 2.2: High-Penetration Operation of Hybrid Power Systems: Smart Grid Applications

Richard Wies

Overview:

This task looked beyond electric power generation applications for wind energy and considered the use of smart grid applications for demand side management, wind-diesel generation management, electric space heating, and electric transportation. In order to accomplish this task we identified potential smart grid applications and communities for high penetration wind-diesel systems and identified technical challenges related to using excess wind power for non-traditional applications. Based on this initial research, plans were developed to deploy and test strategies for smart grid applications.

Tasks Accomplished:

- During the initial months of the program, we sought to become familiar with and use MATLAB/Simulink® as platform to model and research high-penetration wind-diesel systems and smart grid applications.
- A dynamic MATLAB/Simulink® model of a high penetration wind-diesel system has been constructed to investigate smart grid controls. Testing with a synthetic load and wind data is on-going. Difficulties with the ineraction of the control models for the diesel governor and secondary load controller have only recently been resolved and we are currently working with original data from Unalakleet.
- Graduate research assistant, Diego Servan-Pozo, was hired in the Spring 2011 as an exchange student from Spain, and began modeling the wind-diesel system at Kongiganak, Alaska. This student completed some initial modeling and a final report in May 2011. D. Servan-Pozo also worked with Dr. Muhando and his graduate research assistant (Task 2.1) to coordinate initial model development to work with test bed generated data.
- Both sub-task lead Dr. Wies and graduate research assistant D. Servan-Pozo attended the 2011 International Wind-Diesel Workshop and presented a poster on wind-diesel modeling. Dr. Wies also attended the 2010, 2011 and 2012 Alaska Wind Working Group meetings and the 2011 Alaska Rural Energy conference.
- Graduate research assistant in Electrical Engineering, Eshwar Chukkapalli, was hired in May 2011 to begin efforts in dynamic modeling of wind-diesel systems to investigate control strategies for voltage and frequency regulation under Dr. Wies. He was fully funded from the EPSCoR program during the Summer 2011 and half time during the 2011-2012 academic year. He is fully funded from the EPSCoR program for the Summer 2012 with plans to complete his thesis in September 2012. E. Chukkapalli also worked with Dr. Muhando, Dr. Peterson, the other two graduate research assistants on Task 2.1 and 2.3 to coordinate model development for test bed generated data.
- Graduate research assistant in Mechanical Engineering, Maura Sateriale, changed projects from Task 2.3 to Task 2.2 in May 2011 to begin efforts in modeling electrothermal heating and storage systems as a means of

regulating high penetration wind-diesel systems. M. Sateriale is currently co-advised by Dr. Wies, Dr. Peterson and Dr. Muhando.

- The sub-task lead, Dr. Wies, has attended international conferences and made presentations related to hybrid wind-diesel models developed under Tasks 2.1 -2.3 (see Appendix D), including the 2011 IEEE Power Systems Conference and Exposition, 2010 2012 IEEE Power and Energy Society Annual Meetings, 2010-2012 AWEA Conference and Exposition, and 2012 Arctic Frontiers.

Dr. Wies co-authored a peer review journal paper on novel wind control systems and is co-author on five peer review manuscripts with Dr. Muhando and graduate research assistants E. Chukkapalli and M. Sateriale related to Task 2 (see Appendix D). Completed milestones, as proposed in work plan include:

Milestone	*Date of Completion*
Initial meeting with project personnel	9/2010
Identify communities and smart grid applications with Alaska wind-diesel systems	3/2011
Identify technical challenges of using excess wind power to supplement space heating and transportation	3/2011
Construct working dynamic models of wind-diesel systems in MATLAB/Simulink to explore smart grid applications	4/2012
Construct models of electrothermal space heating and storage devices in MATLAB/Simulink	4/2012

The Task 2.2 subtasks are listed below with estimated percentage of completion:

Subtask	*% Completed*
Task 2.2-1: Identify Smart Grid Applications and Communities for High Penetration Wind-Diesel Systems	100%
Task 2.2-2: Identify Technical Challenges of Using Excess Wind Power to Supplement Residential and Commercial Space Heating and Transportation	ongoing
Task 2.2-3: Develop Concept Plans & Economically Feasible Deployment Strategies for Smart Grid Applications	ongoing
Task 2.2-4: Deploy and Test Strategies	ongoing

- Graduate students E. Chukkapalli and M. Sateriale completed their master's degrees.
- Two peer review journal publications based on the wind-diesel and electrothermal models were submitted in 3nd quarter 2012.

2.2.3 Phase I, Task 2.3: High-Penetration Operation of Hybrid Power Systems: Advanced Modeling for High-Penetration Wind-Diesel Feasibility and Stability

Rorik Peterson

Overview

In order to improve the performance of existing and planned wind-diesel systems it is necessary to complete objective and detailed modeling of individual components and the system as a whole. In order to accomplish this, we compiled and evaluated the currently available power system data for model verification and assessment of currently available component and system models being used.

Tasks Accomplished:

- During the initial months of the program, we sought to become familiar with and use MATLAB/Simulink® and PowerFactory as platforms to develop advanced models of high-penetration wind-diesel systems. MATLAB/Simulink® was identified as the research modeling platform.
- This task has largely been integrated with Tasks 2.2 given the need to develop advanced dynamic models of wind-diesel systems in order to study smart controls and grid regulation mechanisms to maintain system voltage and frequency stability of high penetration wind systems under highly variable wind resources in islanded and unbalanced distribution grids. Graduate students from Task 2.1-2.3 have been working closely together since May 2011 and there have been regular monthly meetings of research participants on Task 2.
- Original data collection and management was identified early on as a major barrier to implementing our research plan. This task has moved forward with synthetic data during model development so both milestones can be approached simultaneously. Original data is being introduced as it becomes available. This was coordinated with Ginny Fay, the lead for Task 1.
    - A data collection working group was established in 2010 to work on collecting technical performance data for initial model verification.
    - A data manager was hired under Task 1 at UAA ISER.
    - A graduate intern, Marc Mueller-Stoeffels, recently turned Power Systems Integration Director, was hired under Task 2 at UAF ACEP to develop formats and protocols for collecting technical performance data. A data recorder developed at UAF ACEP is being used to collect data.
    - EPSCoR participants have worked closely with AEA, AVEC, Marsh Creek and IES to collect economic and technical performance data from a number of village power systems. Data has been collected from Unalakleet, Ugashik, and Kongiganak. Data from other systems including Banner Peak in Nome and Kokhanok has been promised, but is unavailable due to various system and data acquisition failures.
- A baseline MATLAB/Simulink® model of a single turbine/genset/battery has been constructed that is intended to be generic and easily modifiable for specific village power systems. Testing with a synthetic load and wind data is on-going. There have been difficulties with consistent convergence with varying parameters. This has setback working with original data.
- Graduate research assistant in Mechanical Engineering, Maura Sateriale, joined this sub-task during the Spring 2011. She began updating the scripted Homer modeling framework from NREL and subsequently moved to a project in May 2011 to model electrothermal heating and storage units for grid regulation under subtask 2.2 with Dr. Wies as a co-advisor. E. Chukkapalli also worked with Dr. Muhando, Dr. Peterson, the other two graduate research assistants on Task 2.1 and 2.3 to coordinate model development for test bed generated data.
- Dr. Peterson co-authored one working peer review manuscript with Dr. Wies and graduate research assistant M. Sateriale related to Task 2 (see Appendix D).

Completed milestones, as proposed in work plan include:

Milestone	*Date of Completion*
Initial Meeting with Project Personnel	9/2010
Review Existing power system data availability and applicability	4/2011
Review Existing models and platforms	8/2011
Develop working hybrid wind-diesel models	5/2012

The Task 2.3 subtasks are listed below with estimated percentage of completion:

Subtask	*% Completed*
Task 2.3-1: Compile currently available data	100%
Task 2.3-2: Assess quality and necessity of available power system data for model verification	100%
Task 2.3-3: Assess currently available and conventionally used models and modeling platforms	100%
Task 2.3-4: Develop new component and system models where necessary	100%
Task 2.3-5: Test and verify model performance	100%

- A baseline/standard Simulink® model of a single turbine/generator set/battery system was developed benchmarked with synthetic wind and load data. The model was compared with an analogous PSS/E model. The concomitant PSS/E model was not built as previously planned in 1st quarter 2012 because the graduate research assistant switched focus. The convergence issues with the baseline model was identified and fixed, enabling further testing with available real data.
- A deliverable in FY 2013 was an analysis of the effect of input uncertainty on output uncertainty to the model.
- Subtask lead, Dr. Peterson, will continue to work very closely with subtask 2.1 and 2.2 leads, Dr. Muhando and Dr. Wies. A new graduate research assistant at the PhD level is was recruited for work on this subtask in fall 2012.

2.3 Phase I, Task 3.0: Cold Climate Operation: Icing

Matt Cullin

Overview

The development of operational standards for cold climate wind turbines is vital to the successful expansion of wind power to arctic and subarctic regions. Research is needed that will address the technical challenges associated with cold climate operation and support the development of high-penetration wind systems. While there are a variety of issues which impact performance, the focus of this task was to analyze ice deposition on turbine blades. The first step towards solving the icing problems was to collect wind turbine performance and other icing data from a test site.

Tasks Accomplished:

- The EPSCoR funding has supported undergraduate research assistant Chris Chance under Task 3. Chris has worked with Assistant Professors Matt Cullin (M.E.) and Todd Petersen (E.E.) during this period to define and make progress toward three major goals:
    - Evaluate existing ice detection technology
    - Determine the effect of blade icing on wind turbine efficiency
    - Design novel ice detection sensors to address the shortcomings of existing technology
- The Task 3 team originally worked with industry partner Marsh Creek to develop sensors for the Vestas V17 wind turbine at St. Mary, Alaska. Due to project delays the team developed an alternative plan to test the icing sensors and de/anti-icing technology at an easily accessible, ice-prone site. The Banner Ridge wind farm in Nome, AK was chosen as a test site for the ice detection system.
- The sensor platform was deployed in October 2011 on a representative turbine at the Banner Ridge wind farm. Technical difficulties with the datalogger/internet/webcam interface and mobile internet connection prevented these components from being installed until early March of 2012. The decision was made to scrap the internet-based datalogger interface and manually retrieve the data from the datalogger for the strain gages, anemometers, and frequency-based icing sensors during summer 2012. The previously installed arctic specific unheated (propeller-type) anemometer had sustained an impact which broke off one of the propeller blades. However, this damage will not prohibit comparative analysis of unheated and heated anemometers for the purpose of ice detection.
- In addition to the standard icing sensors that were ordered, new sensors are in the developmental stage as part of a smart heating system. A grid of capacitance/inductance sensors are used to determine the location and thickness of ice deposition, and then de-ice the appropriate regions using a similar grid of resistance heaters. These smart heater/ice sensors are contained on a very thin, flexible printed circuit board with an adhesive backing. This design lends itself to retrofitting existing turbines. Preliminary testing and calibration of the capacitance sensors shows promising results.
- Subtask lead, Matt Cullin, presented work on task 3 at the 2011 International Wind-Diesel Workshop.

Completed milestones, as proposed in work plan include:

Milestone	***Date of Completion***
Initial meeting with project personnel	9/2010
Ice sensor platform installed	10/2011
Data logger installed	3/2012

The Task 3 subtasks are listed below with estimated percentage of completion:

Subtask	*% Completed*
Task 3.1: Collect wind turbine performance and other icing data from a test site.	100%
Task 3.2: The data collection system will be serviced and anti-icing measures will be installed on the turbine.	100%
Task 3.3: The final summer of the project was used to process the data and prepare a technical report and journal articles.	100%

- During the next year the technical difficulties encountered during the 2011/2012 winter season were resolved to allow for a full winter of icing data collection in 2012/2013 from the sensors deployed on the turbine at the Banner wind farm.
- The data collected during the spring was analyzed for useful information concerning the effect of icing on wind turbine efficiency.
- Several prototypes were completed and tested. Work to develop novel in situ, capacitance-based icing sensors continued during this quarter. Undergraduate research assistant Chris Chance and Dr. Todd Petersen (EE) plan to work on two different prototypes this summer. An appropriate LCR meter will be purchased in order to aid this endeavor.
- There are several deliverables which may result from this project. These include:
    - Journal Article on Existing ice detection systems (lessons learned and/or analysis results)
    - Journal Article and possible patent on Capacitance sensor #1
    - Journal Article and possible patent on Capacitance sensor #2
    - Best Practices Guide for turbine operators at ice-prone sites

2.4 Phase I, Task 4.0: Social, Economic, and Political Challenges

Steve Colt, Ginny Fay, Diwakar Vadapalli, and Terry Chapin

Overview

Successful development of wind resources in rural Alaska requires not only engineering solutions, but also the right mix of human capital, supportive policy and institutions, and local community capacity to operate and maintain sustainable wind systems, particularly the high-penetration systems that offer the greatest potential for lowering overall energy costs. In order to address these non-engineering aspects of successful project development we began the work of developing the capacity for assessing and improving the social/cultural/institutional factors affecting sustainable wind-diesel development.

FY13 work on Task 4 consisted of final data collection using a structured interview survey of some 80 stakeholders in several communities with existing or potential wind systems. The data was compiled and open-ended interviews were transcribed. The raw data is now saved as a usable research data set that has not yet been fully exploited for analysis of community capacity, attitudes, and their relationship to successful wind project development. The data are catalogued and available for use by interested scholars.

Tasks Accomplished:

- The Task 4 team developed a scope of work and was awarded funding for a project to specifically identify cultural, social, and institutional factors that impact sustainability of wind-diesel projects, and the potential cost savings and improved wind-diesel hybrid utility operations and training through alternative utility organizational structures.

- A report on power cost equalization was completed with Brian Hirsh at the Alaska NREL office. This comprehensive report features a review of the power cost equalization (PCE) program in Alaska under the current funding structure and discusses alternative PCE funding formulas considering the integration of renewables with diesel electric generation. The report can be downloaded at http://www.iser.uaa.alaska.edu/Publications/2012_03_14-NREL_PCEfinal.pdf.

- Diwakar Vadapalli, a new faculty member, was recruited and assigned the task lead. Work proceeded as shown below:
  - Step I - Through review of the literature, 'community capacity' was identified as an overarching concept to capture such social, cultural, and institutional factors of a community in sustaining a wind-diesel project. To solicit maximum participation from community members, community-based participatory research methodology was adopted. Through a partnership with community leaders, a series of relevant questions approved by the community was identified in each of the ten communities included in the study. Care was taken to replicate questions for meaningful comparisons. The methodology and the questions was tested and refined in the first two communities, during the pilot phase.
  - Step II – To construct the instruments, data collection was divided into three phases. The two phases constituted the pilot. Building on existing relationships through past work with Chaninik Wind Group, Kongignak was identified as the first pilot community. A team of two researchers visited Kongiganak in the month of May, 2012. A team of local leaders and the researchers identified key themes and questions relevant to wind-diesel project and its sustainability in Kongiganak. Several key local leaders and other citizens were interviewed. These interviews were transcribed. With a refined set of questions and several changes to our methods, we visited our second and final pilot community in July 2012. Owing to its population, unique institutional set up and funding structure, Unalakleet was identified as the second pilot community. Unalakleet is also a pilot community for the wind engineering data development so it could be used to test links across these two tasks.
  - Step III – Conclusion of the pilot after our visit to Unalakleet resulted in instruments that used in assessing community capacity in eight other communities across Alaska. The eight communities varied in their institutional structures, cultural and social practices in local management, and geography. Data collection proceed through the end of 2012.
  - Step IV – Analysis, conclusions and recommendations will follow data collection. We anticipate completion of the report by May-June 2013.

- Emeritus professor, Dr. Terry Chapin, co-PI of the UAF Resilience and Adaptation Program in the Institute of Arctic Biology and PhD level graduate research assistant Becky Warren worked closely with UAA ISER and UAF ACEP on the social, cultural, and institutional factors related to the development of sustainable Alaska Native communities. B. Warren's work in this area was funded through a combination of EPSCoR and UAF IGERT RAP programs.

Completed milestones, as proposed in work plan include:

Milestone	*Date of Completion*
Initial meeting with project personnel	9/2010
First graduate student dissertation underway	12/2010
Solicitation of applications for second graduate student dissertation	3/2011
Assigning of faculty member for task 4	8/2011
Initial visit to Kongiganak	10/2011
Institutional Review Board approval of the methodology for Phase I	04/2012
Pilot Phase I - Kongiganak	05/2012
Pilot Phase I – Kongiganak data transcribing and analysis Institutional Review Board approval for Phase II	06/2012

The Task 4 subtasks are listed below with estimated percentage of completion:

Subtasks	*% Completed*
Task 4.1: Mentor and support 2 graduate student(s) focusing on specific research questions	100%
Task 4.2: Develop and road-test several constructed variables measuring less-tangible factors affecting wind system	100%
Task 4.2.1: Literature review	100%
Task 4.2.2: Development of study methodology	100%
Task 4.2.3: Identification of pilot communities	100%
Task 4.2.4: Development of instruments	100%
Task 4.2.5: IRB Review	100%
Task 4.2.5: Completion of Pilot	100%
Task 4.2.6: Identification of the main sample	100%
Task 4.3: Applied economic and policy analysis focused on incentive structures	100%
Task 4.4: Empirical analysis of factors affecting success	10%
Task 4.5: Policy recommendations and additional proposals	10%

2.5 Phase I, Task 5.0: Project Management

Gwen Holdmann, Steve Colt, and Kat Keith

Overview

Energy is an interdisciplinary topic; as such, we assembled a team from numerous academic units throughout the University system spanning the engineering, economic, and social sciences. While most of the key participants have worked together in the past, effectively coordinating activities will be critical to successful implementation. An annual meeting among researchers was held to facilitate this type of interdisciplinary coordination during each of the three years.

Tasks Accomplished:

- Regular communication was held with team members to coordinate efforts across the tasks.
- An all-hands meeting was held for EPSCoR participants at the 2011 International Wind-Diesel Workshop to discuss challenges and share updates on progress within sub-tasks.
- An EPSCoR Halfway Review Meeting was organized and held in October 2011 at UAA ISER and attended by all EPSCoR team members and graduate students.
- WiDACs coordinator, K. Keith, resigned to take a position with WH Pacific. WiDAC was reorganized with three coordinators encompassing research, technical efforts, and outreach.
- An EPSCoR/WiDAC/Industry workshop was held in 2012 in Anchorage to refocus efforts and check in with industry.
- Regular meetings were held with team members to coordinate efforts across the tasks.
- A new strategic plan for WiDAC was developed after a reorganization of coordination.
- A revised plan for completion of all deliverables in FY13 and an application for renewal of the program for the period of 2013-2016 was developed based on meetings in summer 2012.

2.6 Phase I, Task 6.0: Education and Outreach

Gwen Holdmann and Julie Estey

Overview

This project built on Alaska EPSCoR's history of conducting successful outreach through developing strengths in our programs and partnerships to enrich education at every level, creating a pathway from early childhood to early career and drawing on the experience of Alaska Native elders to educate the next generation of researchers. Our outreach partners included Cooperative Extension Services at UAF, our rural campus participants (Bristol Bay and Chukchi), Renewable Energy Alaska Project, our rural utility partners, and the Alaska Energy Authority.

Tasks Accomplished:

The following activities are critical dissemination activities that helped us ensure we continued to meet stakeholders needs in rural Alaska and the international wind-diesel community. Some are still ongoing.

- ***International Wind-Diesel Workshops, involved annually since 2011:*** Approximately 175 people attended the 2011 Workshop from 11 different countries including Canada, Norway, Australia, and Mexico. In addition to the main workshop, a number of pre-conference workshops and sessions were organized free of charge and heavily attended. We have been involved in planning and hosting the workshop annually since then.
- ***Alaska Wind Working Group:*** The Alaska Wind Working Group meeting was held in Kotzebue on May 14-15th, 2012. We have remained involved since then. In addition, we have been involved in the development of analogous working groups for Biomass, Solar, Energy Storage, and Diesel.

- ***Wind-Diesel Academy:*** An identified need for the wind-diesel industry is the opportunity for education for traditional university-level students that may enter the workforce in the near future, or continuing education for technicians and engineers working on projects. Eight modules have been designed, although without identified funding we have delayed the program and are now considering initial release as a Webinar series. The goal is for participants to receive a certificate in wind-diesel technology. The Wind-Diesel Academy has been developed to emphasize knowledge-based development where the application of science, engineering and technology are of increasing importance for economic and social development. At present, we are heavily involved in helping to plan and execute the Arctic Remote Energy Networks Academy (ARENA). ARENA focuses on sharing knowledge and establishing professional networks related to microgrids and integration of renewable energy resources for remote Arctic communities, and has been endorsed by the Sustainable Development Working Group of the Arctic Council. About twenty participants, coming from across the Arctic, will be selected in late December to participate in the on-site program. (arena.alaska.edu)
- ***Wind-Diesel Best Practices Guide:*** We continue work on the evolution of the Best Practices Guide for Implementation of Wind-Diesel Systems in Alaska – a handbook that is a collaborative effort between ACEP and other wind industry players. We hope that in its final form it can serve as a textbook for future curriculum development centered on Wind-Diesel systems.
- ***Alaska Wind for Schools (AKWFS):*** Seven wind turbines have been installed at public schools under the Alaska Wind for Schools program. On April 27-28, Alaska Wind for Schools hosted a two day teacher training in Anchorage for the national NEED wind energy curriculum and a new corresponding Alaska-focused energy efficiency. Nineteen educators from around the state participated in one or both of the sessions.
  The last two quarters also saw a significant staffing turnover with many job and life changes for the limited Wind for Schools staff. The program is currently fully staffed and utilizing this opportunity to undergo an assessment of progress and effective use of resources. Due to unique circumstances of Alaskan geography, remoteness and harsh conditions, wind turbines installations represent a significant barrier to many schools who are interested in participating in the program. Current plans exist to equip schools with smaller points of entry (power predictors, anemometers, etc.) and connect them with the data from utility-scale turbines in or near their community.
  From a technical perspective, one common issue among our existing installations is the ability to interface with the turbine data in a more user friendly way for students. The program is currently focused on refining a new interface that utilizes a Raspberry Pi.
- ***Kid Wind Program:*** The Alaska Kid Wind Challenge is a wind turbine design challenge. Teams of 4 middle and high school students from throughout Alaska compete against each to create a turbine from the ground up. Teams design a base then determine the size, shape, material and number of blades to maximize the efficiency of their turbine.
  Turbines are tested in a wind tunnel and judged based on their performance, construction quality, material selection, and level of creativity and innovation. Students must also create a multi-media presentation explaining their process and key learning elements which is scored as a part of the competition as well.
  ACEP's Alaska Wind for Schools program held the 2012 competition in March and April. Over 20 schools from almost every region of the state participated. Competitions were judged and supported in person by ACEP education and engineering staff. That year's high school winner was from the St. Mary's High School, a small Yu'pik village of 500 people in the Yukon River delta of southwestern Alaska. Hoonah Middle School in southeast Alaska swept the top 3 places in the middle school competition. Winning teams were announced on May 1 and will receive team trophies, t-shirts and gift certificates.

The following activities are not directly funded through EPSCoR, but are critical dissemination activities that must be sustained to ensure that we continue to meet the needs stakeholders in rural Alaska and the international wind-diesel community.

- ***Annual International Wind-Diesel Workshop*:** We helped plan and host the Workshop in 2011, and have continued to be involved in the recurring annual workshop.

- ***Sesquiennial Alaska Rural Energy Conference***: The 8th Alaska Rural Energy Conference took place in Anchorage in April 2013. We continue to work with AEA to organize this conference every 18 months.
- ***AK Wind, Solar, Biomass, Energy Storage, and Diesel Working Groups***: We continue to provide updates on the programs developed under EPSCoR, provide input to and gain knowledge from these meetings to help improve our program.
- ***Wind-Diesel Best Practices Guide***: We plan to refine this into a textbook for wind-diesel curriculum.
- ***Wind for Schools***:
  - We continue to work with schools to permit, procure and install wind turbines.
  - We continue to provide technical support on the installed seven turbines.
  - We continue to provide programmatic support for teacher education and outreach.
  - ***KidWind***: The middle and high school student competition to design a wind turbine and test it in a wind tunnel will continue as part of the Alaska Wind for Schools program in AY 2012-2013.

2.7 Phase II, Task 1.0: Data Management: Overview

Phase II Task 1.0 focused on data collection, management, and dissemination.

2.7.1 Phase II, Task 1.1: Data Management: Energy Data Knowledge Network

Task Lead: Ginny Fay, Institute of Social and Economic Research, UAA

Task 1 included the development of a comprehensive energy data portal, the Alaska Energy Data Gateway (AEDG)—the first and only developed in Alaska. Development of the AEDG was critical to all other research completed through this program, since even the most basic data about energy systems in Alaska was either lacking, or not easily accessible. The AEDG is a multi-purpose data portal and warehouse to methodically organize and disseminate key data on energy consumption, production, costs, prices and usage in Alaska. Key components of the AEDG include:

- A limited access data warehouse to store and share data among agencies and academia.
- Reporting tools that agencies can use as part of their programmatic reporting requirements.
- A public web portal to disseminate timely and valuable actionable data to the general public and decision makers.

The AEDG public web portal was successfully launched in late 2013 and is quickly becoming the primary source of energy data in Alaska. The AEDG (https://akenergygateway.alaska.edu/) is housed at the University of Alaska's Arctic Region Computing Systems center at University of Alaska Fairbanks. The AEDG represents the first time comprehensive energy data has been made available online regarding Alaska energy projects and energy use for a wide range of stakeholders. In addition to the public data portal, the AEDG provides a controlled access data portal, or data "warehouse", for authorized researchers and agency users, primarily AEA staff, and academic collaborators including those at CSU, University of Texas, Technical University of Darmstadt (Germany), and Sandia National Lab. Considerably more data are available via the limited access data portal than is currently available via the public portal. The AEDG is a relational database comprised of linked tables. This is a link to the table layout to see how the public portion of the AEDG is constructed. https://akenergygateway.alaska.edu/static/schemaspy/relationships.html

The purpose of the data gateway is to make it easier for stakeholders—including industry, agencies, project developers, utility operators and researchers—to get the reliable and documented energy information they need to make informed and actionable decisions about energy production, use and affordability for Alaska communities.

The site provides data from many sources, in a user-friendly format and through a single access point with data available for download in a variety of file formats. It contains aggregated annual and monthly as well as higher resolution utility operations data. The higher resolution information is critical for validation and verification of models that provide insight into potential options for increasing renewable energy penetration levels. Furthermore, it provides a test-harness for adding more complex optimization controls and hardware configurations, prior to making potentially costly decisions.

Specific activities completed include:

- We worked with the Arctic Region Supercomputing Center (ARSC) to finalize the configuration of the ARSC server that will be the permanent home of the database and Web site. We then moved them from the development server housed at ISER, which will be retired, to the ARSC server. This is a significant milestone that comes with many benefits to the project.
- With the growing sophistication and use of the AEDG resulted in the need for the implementation of two virtual machines on the ARSC server to house the growing number of functions more efficiently. In particular this is required for the more advanced Django-based web programming as well as data mapping that are being added to the site. We are working with the Geographic Information Network for Alaska (GINA) to add mapping capabilities to the Alaska Energy Data Gateway. This will allow the visualization of data across the state with minimal technical expertise on the part of the user.
- The Alaska Energy Authority (AEA), Alaska's state energy office, established the AEDG as their primary repository of energy data and energy data management tool. We are working to develop a joint data management plan and Memorandum of Understanding for working across University of Alaska entities and the sharing of data. A component of the MOU includes that the AEDG will be transferred to AEA if for any reason UA can no longer provide the maintenance and support. The MOU will include a strategic plan to ensure continued availability, maintenance, and extension.
- The AEDG is expanding to provide data management for ISER and is cited as our primary data management tool in a proposal to the National Science Foundation.
- We worked with AEA to establish a Master Project Code for Renewable Energy Fund (REF) projects to unify REF application, grant, and project data that previously was not completely linked in a systematic way. This will streamline REF application evaluation, performance tracking, and reporting. We also worked with them to group and assign master codes to historical data.
- We worked with AEA to refine the set of REF variables, their definitions, and database relationships and conducted a training session for AEA program managers on data entry into the system.
- We have developed a data protocol document with AEA to document how data will be added to the AEDG, acquisition and inclusion of metadata and timing of data uploads.
- We have developed a web interface for renewable energy project developers to submit their required annual data reporting on-line. These data will be flagged to be checked by AEA program managers before being added to the database.
- We have prepared (and hope to soon deploy) a web interface to enable AEA field staff to enter powerhouse data on-line.
- We completed the fourth annual AEA Renewable Energy Fund projects performance report for the Alaska State Legislature using the AEDG (leveraged funding).
- We completed the 2012 Alaska Energy Statistics report using the AEDG for data reconciliation and review and reporting. For the 2013 report, we will refine the data reconciliation tool and train AEA staff to perform these tasks. Beginning in the 2014 reporting year, AEA staff will complete the Alaska Energy Statistics report using the AEDG (leveraged funding).
- We are developing a data sharing agreement with the Alaska Department of Labor and Workforce Development, Research and Analysis Section to provide regularly scheduled population and employment datasets for Alaska for upload into the AEDG.
- Similarly, we are developing a data sharing agreement with the Alaska Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs. We currently make available to them energy data for the Community On-Line Database and we link to each other's sites. They are a significant

driver of users to the AEDG.

- We have improved the data download functionality, allowing the user to select individual variables from the selected database table, as well as from related tables. This includes an interface for filtering based on data values.
- We created a system for generating temporary passwords that are required to be changed upon first login, streamlining user account creation and improving security.

Use statistics for the time period with analytics data (March 11th, 2014 through April 6th, 2015):

- There was a 40.3% increase in traffic in the last three months as compared to the first three months of the site being live. The Power Cost Equalization (PCE) Data dataset was the most popular (36% of downloads this calendar year) followed by the Alaska Housing Finance Corporation (AHFC) Fuel Survey at 8.7%.
- We had 5,485 visits estimated to last 6 minutes and 39 seconds per visit
- We had approximately 1066 downloads of methodology documents.
- 802 guided search dataset downloads
- 44,458 page views.
- An average of 8.7 actions (page views, downloads, outlinks and internal site searches) per visit
- 41% bounce rate (meaning users went to one page and then left)
- 68% (3,756) of our traffic are direct visits
- Usage around the US (88% of our traffic); 70% from Alaska (2.4% from Juneau); 2.4% from Washington State; 1.2% from Washington D.C.

2.7.2 Phase II, Task 1.2: Data Management: Develop and Implement Protocols for Robust Data Acquisition

Task Leads: Dr. Erin Whitney and Dr. Marc Mueller-Stoffels, ACEP, UAF

In addition to the type of data currently available through the AEDG, there is also a need to collect high temporal resolution engineering data to support Task 2 activities, which is almost entirely lacking for existing energy systems in the State. Data acquisition and data logging equipment are required to assess power systems in rural Alaska. This data is particularly necessary in distributed generation situations where renewable energy sources were added to the generation mix. Many smaller powerhouses throughout the state lack the capability to acquire or log high temporal resolution generation and demand data. As a result, ACEP has developed a data acquisition system, nicknamed the 'BlackBox', that is capable of logging hundreds of data channels that can provide an accurate picture about how the overall system is operating. The BlackBox prototype is a customized industrial computer built from hardened, off the shelf components wherever possible. Specific activities completed during this reporting period included:

- Development of a subsystem to allow for fast (<1 ms) mA-to-V signal conversion hardware. Available signal converters of acceptable robustness and cost lack the capability to directly convert current to voltage waveforms, but instead convert RMS signals. The nature of the core data acquisition computer requires voltage signals as inputs; but only secondary current measurements, mA-signals, are typically measured with acceptable noise and without delay with available current sensing technology.
- Two invention disclosures (system hardware configuration and software libraries; signal converter) were filed with the UAF Office of Intellectual Property and Commercialization and a patent review is currently underway for both.

A fully assembled BlackBox was finalized for systems testing in late July. Beyond the conclusion of the EPSCoR program, the BlackBox continues to be developed with funds from ShellWind, and a UAF Institute of Northern Engineering Innovation Award.

In addition to the Blackbox, ACEP has continued to develop the Data Collection and Management (DC&M) program, which represents a long-term institutional commitment to data collection and management. The data made available through the DC&M program is the foundation for other programs to provide targeted R&D, performance evaluation, and troubleshooting. The DC&M initiative has evolved through ACEP's ongoing data collection efforts in the Alaska Energy Authority (AEA) Emerging Energy Technology Fund (EETF) Program and the Denali Commission Emerging Energy Technology Grant (EETG) Program. For each program, ACEP has been the primary entity in charge of data collection and quality assurance. The goal for the DC&M program is to make high resolution, engineering data available via the AEDG. Specific activities completed during this reporting period include:

- Existing high resolution data sets have been acquired from partnering utilities with data archiving capabilities including Unalakleet, Nome, Yakutat, Ruby, and Cordova. These are being used to support Task 2 research.
- ACEP received a contract from NREL to support the Remote Communities Renewable Energy Partnership, specifically providing high resolution power and heating data from Alaska Communities to participating researchers at NREL and Colorado State University.
- A data storage, management (including quality assurance) and infrastructure plan has been developed and is being implemented to allow high resolution data to be stored on the Arctic Region Supercomputing Center, and made available through the AEDG.
- A data work flow has been created and demonstrated for real data, including standardization (unit conversion, naming conventions, time stamping standards, etc.) and correction of raw data, data filtering and quality control, and addition of relevant metadata to final data files.
- ACEP hired Erin Whitney, formerly with the National Renewable Energy Lab, to manage the program. Erin is originally from Alaska, and has a background in applied energy research, and while at NREL led the Dynamic Windows research group, managing technical assistance for a 2 MW Solar America Showcase project, and provided energy analysis for solar thin film technologies.
- ACEP has organized a Utility Manager's Advisory Group to inform these efforts and work to develop automated reporting tools as a feature of this program benefiting utility managers, to help them meet their agency and regulatory reporting requirements.
- DC&M Program Manager Erin Whitney traveled to Houston, TX to meet with researchers and project managers at Shell Wind, to better understand their data management and analysis processes to manage 22 active wind farms across the country.

ACEP has received funding to implement this high resolution data management plan using data from select projects funded through the Alaska Energy Authority Renewable Energy Fund.

2.8 Phase II, Task 2.0 Engineering Challenges: Overview

The goal of this task has been to find reliable and cost-effective renewable energy integration strategies for isolated hybrid-diesel microgrid systems with power and heating applications in remote Alaska communities. Our objective is finding economically and technically robust solutions for reducing reliance on diesel fuel, and improving grid resiliency (reliability, stability, and power quality) of Alaska village power systems with applications in similar isolated renewable energy (RE)-diesel based microgrids. This task included research related to the interaction of distributed renewable energy sources, various energy storage technologies, diesel generators, and loads within the isolated microgrid system through fundamental performance models and further development of the Power Systems Integration Laboratory grid-emulator at UAF. Specific activities completed during this reporting period are described below for each of 5 sub tasks.

- Task 2.1. Develop and implement local and distributed control system strategies for reliable and stable operation of isolated hybrid renewable energy systems.
- Task 2.2. Investigate common misconceptions regarding renewable energy-diesel operation with high-contribution of renewables and low-load or diesel-off mode.
- Task 2.3. Characterize energy storage applications including electrothermal, flow battery, and flywheels.
- Task 2.4. Develop smart dispatch/distributed generation strategies for power and heating applications.

- Task 2.5. Enhance Power Systems Integration test bed at UAF through the addition of a utility-scale fault simulator, improvement/replacement of the grid-forming inverter, and integration of other renewable energy sources and storage technologies leveraging external funds.

2.8.1 Phase II, Task 2.1: Engineering Challenges: Local and Distributed Control System Strategies

Task Lead: Dr. Rich Wies, Electrical Engineering, UAF

In remote islanded microgrid (RIM) systems with significant renewable penetration, diesel electric generator control and centralized load control strategies are generally employed to stabilize grid frequency and voltage, particularly during times of highly variable renewable generation. Generation control has traditionally consisted of varying the engine speed and generator voltage regulation, while load control has used centralized secondary loads (CSLs) to stabilize the grid frequency and voltage. In this task our work to date has consisted of investigating both local and distributed control strategies for these renewable-diesel RIM systems with the long-term goal of developing a plug-and-play distributed cloud control system. With this goal in mind the use of genetic algorithms for real-time control and optimization of local generation and the use of distributed grid interactive storage have been investigated as possible solutions in the development of an overall distributed cloud control system with inputs from Task 1 and outputs to Tasks 2.3 and 2.4. Specific work completed during this reporting period include:

Local Control Strategies (Genetic Algorithms for Generation Control): Local control strategies using genetic algorithms were implemented on the diesel speed controller in a dynamic wind-diesel model. The genetic algorithm improved the frequency regulation of the system by correctly compensating for the frequency swings from the variable wind generation. A peer-review conference paper was presented at the 2014 IEEE PES General Meeting in Washington, DC, and a master's thesis is pending based on the results of this work.

Distributed Control Strategies (Distributed Secondary Loads): A dynamic wind-diesel model of the ACEP Power System Integration (PSI) laboratory hybrid-diesel test bed was developed in MATLAB® Simulink® and used to implement a distributed secondary load (DSL) control scheme to investigate the optimal parameters for using DSL to assist in grid frequency regulation. Distributed secondary loads are distributed over the grid system and can be activated or de-activated as necessary to assist with regulating the grid. The purpose of the model is to analyze the effects of controller gain, design appropriate DSL capacity, switching time, coordination of DSL units throughout the grid, and element resolution on frequency and voltage regulation. The results have shown that when the system variables are set properly, the DSL network can effectively assist with frequency regulation by more than 30%. The optimal input parameters are specific to the system under investigation, although the trends apply to any hybrid-diesel system. DSL switching times of 0.005-0.025 ms are recommended for optimal frequency control. Though at the edge of existing technology, this level of performance is achievable with modern solid-state relays (SSRs). These findings have resulted in further research and development of DSL control system strategies, with ACEP-led proposals pending. A peer-review journal manuscript describing this work was submitted for review and potential publication in the IEEE Transactions on Sustainable Energy in December 2014. Two peer-review conference papers at prestigious ASME and IEEE conferences, one conference abstract, and one workshop lecture were presented related to this work.

2.8.2 Phase II, Task 2.2: Engineering Challenges: Common Misconceptions of Renewable Energy-Diesel Operation

Task Leads: Dr. Marc Mueller-Stoffels, ACEP; Dr. Rich Wies, Electrical Engineering, UAF; Dr. Daisy Huang, Mechanical Engineering/ACEP, UAF

Major efforts were directed towards investigating: i) impacts of high penetration renewable energy on diesel fuel efficiency; ii) principles of operating in "diesel-off" mode, *i.e.,* without mechanical synchronous machines to provide frequency and voltage support; and iii) performance requirements for equipment such as energy storage and secondary load control to boost high penetration RE systems to even greater levels of penetration, ultimately aimed at enabling "diesel-off" operation of a grid system. This subtask had the side benefit of providing baseline analysis and modeling to inform developments in other task 2 areas, as well as utilize information developed in those tasks to further general understanding of RIM operation at high penetration RE. In addition, under this subtask additional 'myths and rumors' were explored, and where possible less complicated data analysis and reports were provided to stakeholders. Specific examples of work completed during this reporting period include:

1) System sophistication as a determinant of maximum RE penetration: A model hierarchy of controls was developed to discover the maximum achievable RE penetration that can be expected in a system based on overall control system sophistication, data visibility, and integration of auxiliary equipment. This work has further refined definitions of 'very low', 'low', 'medium', and 'high penetration' systems previously put forward by NREL and AEA based on empirical data. As such, the results can be utilized as a benchmark for system performance and provide design and RE system sizing envelopes for hybrid systems (e.g., PV Assessment for Galena, AK, see Task 2.4). The work has also shown that optimal sizing of diesel generators, demand response requirements, and energy storage systems varies significantly with the desired RE levels and availability of demand response, which is an important consideration in system design. A paper is in preparation by Dr. Mueller-Stoffels and will be submitted in Summer 2015.

2) Diesel fuel efficiency vs. system fuel efficiency: *In-situ* data from 12 diesel generators ranging from 320 kW to 5.2 MW in size was analyzed to understand and validate diesel fuel efficiency under various load scenarios. This dataset provided the basis for determining a general performance envelope for diesel generators ranging from 50 kW to 5 MW, which is an important tool in the assessment of impacts of RE penetration on system efficiency (e.g., see Nome Impact Assessment, Task 2.4). The analysis demonstrates that the addition of RE power is generally detrimental to one part of the hybrid system, diesel engine efficiency. This can be due to reduced loading or utilization of oversized or smaller diesel generators However, the benefit to the complete hybrid system efficiency (actual kWh produced per liter of fuel consumed) generally outweighs the effect of poorer diesel engine efficiency. This research demonstrates the importance of properly sizing the renewable and diesel engine components of a hybrid system. Paper in preparation by Mueller-Stoffels, Maker, Huang, and Light submitted Fall 2015.

3) Principles of operation in diesel-off mode: the initial phase of this EPSCoR award saw the testing of a Sustainable Automation GRIDFORM (voltage source) inverter for diesel-off operation of hybrid-diesel microgrids, in conjunction with a VRLA battery. The results from this product test were disappointing and suggested that a synchronous condenser is required to stably operate a grid system without a diesel online to provide frequency and voltage support. However, an extensive survey of information from manufacturers of voltage source inverters identified some products that do not appear to require support from a synchronous machine. An RFP was issued to purchase a new voltage source inverter with the intent to: a) provide added functional capabilities to the laboratory; b) confirm that a hybrid system can be operated in diesel-off mode with the appropriate technical capabilities incorporated into the system; c) develop operational paradigms for testing; and d) further the knowledge of design and integration of power conversion systems to include energy storage and advanced control systems. Initial evidence from a flywheel energy storage integration project (see Task 2.3) suggests that the new inverter may be capable of forming a stable grid without a synchronous machine. A further extensive test campaign is planned for May 2015 when the inverter will be operated together with a VRLA battery and custom controls.

4) Myth and rumors example: Snow-shedding of PV arrays: Discussions with stakeholders uncovered a wide variety of opinions regarding the shedding of snow of PV arrays in the Alaskan climate, and the impact on snow events on PV power production. With additional funding from the UAF Undergraduate Research and Scholarly Activity office a study was designed to acquire quantitative data throughout a winter in Fairbanks, AK. Study results from 8 emulated (black plywood) PV panels were scaled-up to provide power production and O&M cost estimates for a 1 MW array, showing that PV panels generally self-clear snow very quickly, and manual snow clearing is not economical since power production losses are marginal.

2.8.3 Phase II, Task 2.3: Engineering Challenges: Energy Storage Characterization (Electric Thermal Storage, Battery and Flywheel Testing)

Our team focused on three specific examples of energy storage to support

1) Electric Thermal Storage (ETS): An Electric Thermal Storage (ETS) masonry heating/storage device was modeled in MATLAB® Simulink® to determine the value of using excess wind generation in distributed ETS for heat storage to

displace heating oil. The results presented in a Master's thesis illustrated that the cost-to-benefit ratio of using excess wind to ETS for heat is largely dependent on the system configuration, the outside ambient temperature, the wind regime, and ultimately the price of heating oil in each community. Simulations were conducted on two Alaska remote communities which employ wind generation with a high percentage of excess wind generation. At the time of the analysis (October 2012- March 2013) the break-even point was in the neighborhood of $6-$7 per gallon for heating oil (which is not an uncommon pump prices in Alaska rural communities) and the cost of electricity over $1 per kW-hr (also not an uncommon price in many remote communities). Simply making use of excess wind with distributed ETS offers an additional method of storing wind energy which would otherwise be lost due to curtailing wind generation.

Centralized secondary loads generally consist of an electric thermal load with resistive heating elements that incrementally add or remove load based on the level of system voltage or frequency deviations. An alternative method has been proposed and is currently under development by the Steffes Corporation to use a series of grid-interactive distributed electric thermal storage (GETS) devices that sense frequency at the local level and respond by adding incremental load that distributed throughout the system (as opposed to centralized). A masonry ETS unit (Steffes 2102) with a GETS control designed to assist in grid frequency regulation was tested at UAF in fall 2013 under a Denali Commission Emerging Energy Technology Fund grant, "Small Community Self-Regulating Grid." The results showed that the controller was able to respond to deviations in system frequency above 60 Hz by proportionally switching on four equally resistive heating elements based on the programmed set point for frequency deviation. Similarly, when the unit was loaded and the frequency dropped below 60 Hz, the controller responded by switching the load back off. The response time of the GETS control and the solid state relays was determined to be longer than the response time required to achieve optimal frequency regulation. The development of the GETS control system with an updated solid-state switching circuit to improve the response time is currently under development as a result of these findings.

A finite-element numerical model of a typical ETS unit (Steffes 2102) has been created in Comsol Multiphysics® that describes the transient conjugate heat transfer within the masonry material and between the advecting air. The purpose of the model is to study the effects of thermal gradients, material properties, air flow characteristics and core geometry. Based on these results, it will be possible to (1) optimize the storage material properties, geometry, and charge/discharge behavior for improved state of charge characteristics, and (2) create a simplified and generalized charge/discharge model that can be applied to a wide range of potential ETS units. The broader impact of this model will be for future electrical system designers who wish to implement ETS units in a community to utilize excess power (e.g. wind) for thermal use and/or improve overall power quality through distributed secondary loads. A paper describing this work is in preparation for submission to ASME Journal of Heat Transfer in January 2015.

<u>2) Liquid Metal Battery (LMB):</u> A project funded under an AEA Emerging Energy Technology Fund Grant, and lead by ACEP: Reliable Infrastructure for Secure Electricity (RISE) in Alaska will see an Ambri CORE™ liquid metal battery deployed in ACEP's PSI lab late in 2015. At the PSI lab, the 17.5 kW/35 kWh CORE will be integrated with a 3-phase, 480 VAC power converter to match the needs of remote Alaskan powerhouses. The CORE will undergo rigorous testing in general operation, versatility of electricity storage application from regulation services, and load following and peak shifting within the fully operational wind-diesel microgrid of the PSI lab. If the performance evaluation of the Ambri CORE warrants it, an Ambri Energy Pod (50 kW/100 kWh) will be deployed in conjunction with an existing PV array in the remote community of Eagle, AK for further testing and control development for peak shifting during the Summer of 2015.

<u>3) Flywheel Energy Storage System (FESS):</u> Inverter integration, testing and controls development of a flywheel energy storage system developed by Williams for Hatch Engineering for frequency and voltage support in hybrid renewable-diesel RIM systems in remote communities and mines was conducted in the ACEP PSI Lab from September 2014 to January 2015. For this project, ACEP developed the inverter specification (the flywheel was originally designed with a DC frontend); provided design modifications for flywheel foundations that are easily built on-site; provided design and specification reviews, and offered suggestions for improving the control interactions between the flywheel, inverter, wind generator, and diesel generator; collaborated on commissioning and test protocols; operated the PSI lab hybrid-diesel system throughout testing; provided high fidelity data collection on over 1000 channels; and provided baseline

data and reviews of economic and performance assessments. Hatch Engineering furnished a report to the Alaska Energy Authority in February 2015.

Additional Flywheel Energy Storage System (FESS) analysis and sizing studies were performed by ACEP in collaboration with Sandia National Lab (see Cordova Energy Storage and Demand Response Assessment, Task 2.4) and the Institute for Mechatronic Systems at the Technical University Darmstadt, Germany (see Nome Hybrid-Diesel Studies, Task 2.4).

2.8.4 Phase II, Task 2.4: Smart Dispatch/Distributed Generation Strategies

Nome Hybrid-Diesel Studies: Nome operates a 6 MW medium to high penetration wind-diesel power system with 2.7 MW wind power capacity and a fleet of diesel generators that range from 600 kW to 5.2 MW. Exploration at a nearby the geothermal site of Pilgrim Hot Springs (led by ACEP) indicated the potential of adding 2 MW of non-load following, Organic Rankin Cycle derived, low-temperature geothermal power for the Nome grid. Two years of 1 Sample/s data from the Nome grid) was collected and used to develop a time-series energy balance model which included detailed dispatch schedules for diesels and secondary loads. The model was used to study the impact on wind power utilization if a geothermal resource ranging from 500 kW to 5 MW were to be integrated into the grid. The study found that: a) there is a clear cutoff in benefits under current operational paradigms should the geothermal resource exceed 2.3 MW capacity; b) there was a cost of 1 kWh of wind power diverted or curtailed for every 10 kWh hours of diesel power displaced by geothermal power; c) suggestions were made for the addition of a 1 MW diesel generator to achieve higher operational flexibility. A Master of Science thesis (Vandermeer, 2014) was authored based on this research. A journal paper by Vandermeer and Mueller-Stoffels is in preparation.

With the recent increase of wind power capacity from 900 kW to 2.7 MW, Nome Joint Utility Systems (the local utility) reported power quality issues at times of high wind power output. NJUS currently addresses this issue via curtailment and diversion of wind power into an electric boiler. In collaboration with researchers from the Institute for Mechatronic Systems at the Technical University Darmstadt, Germany, an energy storage sizing study, based on the time-series energy balance model mentioned above, and additional dynamic modeling, was conducted to provide insights into an optimally sized energy storage system for grid stabilization. Ancillary services, such as fuel savings by smoothing power demand on the diesel generators, was explored. Results of this study are published in Schaede, et al., 2015.

Galena PV Integration Study: In the Fall of 2013 ACEP researchers were invited to participate in a summit organized by FEMA to assess options for the village of Galena, AK. The village infrastructure had been severely damaged during a severe flood that thrust ice floes in excess of 30 tons through the village. The FEMA summit saw a breadth of opinions regarding the optimal size of a PV system to supplement power production by the very basic diesel power plant. Based on the data available, and research described in Task 2.2, ACEP developed a recommendation for the maximum PV capacity to be installed under current conditions, as well as recommendations for data collection, system upgrades and the further addition of PV power should recommended upgrades to the utility system be made. A technical report was furbished to the City Council of Galena, and to the Alaska Energy Authority (Mueller-Stoffels, 2014).

Cordova Energy Storage and Demand Response Study: In Fall 2013, Cordova Electric Corporation (CEC) requested technical assistance in understanding the value proposition of a flywheel energy storage system (FESS) for the hydropower-diesel system. Due to the lack of water storage (run-of-the-river hydro) and growing demand, CEC often has to supplement hydropower with diesel generation during the peak fishing season when processing facilities are driving demand. This is significant because hydropower is estimate by CEC to cost $0.06/kWh to produce vs. $0.40/kWh for diesel power. Through a collaboration between ACEP and the Clean Energy States Alliance (CESA) a team of ACEP and Sandia National Labs (directed by the DOE Office of Energy Storage and later by DOE Indian Energy) was able to provide an initial data analysis that showed that a FESS would not be economically feasible for CEC. However, during the course of the study a significant potential for demand response was uncovered. At night, when demand is low, CEC 'spills' an average of 1 MW of water, i.e., does not run it through its hydropower turbines. At an interruptible rate of $0.075/kWh this equates to a total of $750,000/year of foregone revenue. Currently, additional work is underway to further assess technical implementation of centralized and distributed demand response in the CEC grid. Intermediate reports were furbished to CEC in 2014.

2.8.5 Phase II, Task 2.5: Hybrid Wind-Diesel-Storage Test Bed Enhancement

Voltage source inverter: Testing of the Sustainable Automation GRIDFORM voltage source inverter on the ACEP PSI lab wind-diesel test bed was completed in December 2012 under Task 2.1 with a report issued in 2013. Testing of the GRIDFORM inverter as the interface buffer between the wind simulator, diesel electric generator, battery bank, and loads proved the functionality of the device as a grid "following" inverter requiring reactive compensation from the diesel generator to maintain the grid in wind-battery mode. In addition, the power conversion system in the ACEP PSI lab wind-diesel test bed was upgraded to a 313 kVA ABB PCS100 to improve capabilities for testing energy storage and renewable energy technologies. See Task 2.2 for further information.

Additional laboratory capabilities:

- As a synergy with the 'BlackBox' project (Task 1.2) a high fidelity automated data acquisition system was developed for the PSI Lab. This system is capable of automatically detecting all online data sources and initializing data collection at a rate of 5 Samples/s from utility-grade power meters automatically, and varying collection rate from other meters, e.g., power quality analyzers, and fuel flow meters. Currently, up to 1200 channels of data collection are available in the PSI lab. An invention disclosure was submitted for the data collection system and management libraries were developed for this project.
- The Alaska Center for Microgrid Technologies Commercialization funded a proposal through the U.S. Economic Development Administration i6 Challenge for procurement and installation of a PV simulator (100 kW), and the development of fault simulation capabilities for near and far phase to phase, and phase to ground faults. Both of these have now been built, and there is significant interest in these capabilities by our Australia utility partners, Power and Water Corporation, Darwin, Australia, for testing PV and energy storage inverter fault ride-through capabilities.
- A proposal was submitted to the NSF Major Research Instrumentation Solicitation (15-504) to develop an R&D environment (mechanical and power electronics) for slow-speed electric generators as they are found in hydrokinetic and wind turbines. It was not funded, but a conceptual design for this system exists, and we are still seeking funding.
- In summer 2015, two interns with ACEP's Power Systems Integration program developed a Demand Response Emulator (20 single phase circuits, about 30 kW capacity total) and a Demand Response Simulator (>500 phase-balanced three phase devices, up to 250 kW capacity by controlling a load bank) based on equipment provided by Saturn South, Hobart, Australia. This system provided the hardware and simulation basis for massively distributed demand response control and coordination system development (Concept paper submitted to ARPA-E NODES).

2.9 Activities and Accomplishments Toward Program Sustainability

The following five objectives relate to long-term program sustainability:

1) *Collaborate with international hotbeds of research across all tasks to form long-term institutional and individual research partnerships.*

   We have continued to invite researchers and students from other regions of the world to UA in order to share expertise and knowledge. Similarly, we have sent a number of UA researchers to other research institutes including NREL, SNL, Shell Wind, Power and Water Corporation (Australia), South Africa, and Hydro Quebec (upcoming visit planned). This has resulted in a number of strong partnerships that have formed the basis for joint research proposals, publications, and projects. In addition, we have joined several organizations to enhance sharing of information in this area, including the Clean Energy State Alliance (CESA), United Nations Practitioners Group, and the Islanded Grid Resource Center (Advisory Council Member). In addition, our project PI Gwen Holdmann was selected to receive an Arctic Fulbright Scholarship to continue research in the areas of islanded microgrids pertaining to the arctic.

2) *Further develop meaningful relationships with national labs, especially the National Renewable Energy Laboratory (NREL) and Sandia National Laboratory (SNL).*

   We substantially increased collaborative projects between these labs. We have been a partner with Colorado State University in the NREL-led RCRE project, and together with SNL were jointly funded to collaborate on energy storage assessments, data analysis, and model development for Cordova (SNL was funded through the DOE Office of Indian Energy and DOE Office of Energy Storage). These projects both resulted in researcher exchanges that have significantly deepened our ties and researcher-to-researcher relationships we anticipate will continue well beyond the conclusion of this EPSCoR program.

3) *Collaborate directly with DOE offices to foster these relationships and ensure that our program is relevant to broader DOE objectives.*

   We believe it is critical to engage directly with DOE offices, so they are familiar with the unique challenges and opportunities afforded by the Alaska microgrid market. We continue to have regular engagement with the following DOE offices: Office of Electricity Delivery and Energy Reliability; Wind Program; Office of Indian Energy; ARPA-E; Geothermal Technologies Program; and the Technology to Market Program. In addition, our team has worked closely with DOE on the *National Strategy for the Arctic Region* 10-year plan to develop renewable energy resources in the Arctic region, participated in the DOE Quadrennial Technology Review December 4-5th, 2014 in Washington DC, and hosted Secretary Moniz in our testing laboratory (developed in part with support through EPSCoR) August 17th, 2014.

4) *Increase the number of peer-reviewed publications.*
   Our primary objective during Phase 1 was to develop work products targeted at industry and communities; in Phase 2 we placed a greater emphasis on traditional academic publications. Nonetheless, this is still a weakness of our program and a metric we continue to work to improve. Over this reporting period, we have developed 16 publications (journal articles and published technical report). During this same time period, we have developed: 1 book chapter, 15 conference papers and proceedings, and 7 conference presentations.

5) *Increase involvement with industry groups*.
   One strength of our Phase 1 work was close collaboration with industry. We have significantly increased activity in this area, both by deepening existing partnerships, as well as developing additional ones. Our network of collaborators has provided us with excellent opportunities to leverage EPSCoR funds, as well as, providing a viable avenue for sustained program support beyond this program. ACEP researchers are now often invited to be project partners, not only on research projects with academia and national laboratories, but also on competitive bid projects lead by the private sector. For the latter, we are generally tapped to provide consulting, analysis and modeling of the more complicated systems integration project specifics.

3 Community Outreach

3.1 K-12 Outreach

ACEP views student outreach as a valuable way to inform the community about energy-related topics. ACEP has partnered with the Renewable Energy Alaska Project (REAP) to leverage expertise and funding for implementing DOE's Wind for Schools program and for developing the "AKEnergy Smart" curriculum for use within the state of Alaska.

The Wind for Schools Program which capitalizes on Alaska's investment in wind energy technology to generate interest among students for science, technology, engineering and mathematics (STEM) coursework and to inform them of possible career options after graduation, especially in energy-related fields. The program has developed an energy-related teaching curriculum tailored for Alaska known as "Energy Smart" and has conducted teacher trainings throughout the state and provides on-line curricula and other resources, and ACEP and REAP staff will come into the school to help implement hands-on learning for students in K-12.

ACEP also facilitates the KidWind Challenge in Alaska, partially funded by a grant from Shell and DOE/NREL. It is a student-oriented wind turbine design contest for students in grades 6 through 12. Students learn about wind energy through designing and constructing their own wind turbines.

ACEP has reached almost 300 students through the Wind for Schools program and the KidWind Challenge: Wasilla Girl Scouts-Women of Science (60 students); Emmonak (40 students); Alaska Summer Research Academy for high school (15 students); Watershed School (20 students); Eielson AFB School (120 students); Angoon (20 students); Sitka (20 students); Alaska Summer Research Academy for Middle School (15 students); Randy Smith Middle School in Fairbanks (120 students);

3.2 Additional Community Outreach Activities

- **Community Partnership for Self-Reliance (CPS):** In response to feedback from the mid-project review, ACEP has worked to increase direct feedback from communities to inform our research agenda. As such, ACEP has been a founding member of the UAF-based CPS program, which is organized around a novel "in-reach" paradigm for researcher engagement with Alaska communities. In collaboration with the Alaska Native Science Commission (a tribal NGO), native communities, not university academics, identify the topic(s) and methodology for research in support of community-selected projects to enhance their self-reliance and sustainability. This program has now been piloted with four communities (Igiugig, Koyukuk, Newtok, and Nikolai) in rural Alaska.
- **ACEP in the Community:** EPSCoR resources are being complemented by a grant received from the Shell Foundation in 2014 to provide financial support for the ACEP in the Community program executed by UAF's Alaska Center for Energy and Power (ACEP). This program focuses on sharing information and technical expertise to help communities identify their energy-related opportunities and priorities. ACEP researchers integrate outreach presentations and small group discussions wherever possible in their travels across Alaska. On annual basis, ACEP team members visit on order of 60 communities; conducting resource evaluations, visiting schools and working to develop projects.
- **Global Applications Program (GAP)**: Multiple ACEP interns, staff and affiliated faculty have collaborated to assess the global opportunities for knowledge export economy using Alaska-rooted experience with energy systems in islanded grids to facilitate development of solutions and strategies for removing barriers to affordable, cost-stable, reliable, and secure energy in areas facing challenges similar to those encountered in Alaska. Trade studies, focus area detailed assessments, surveys and industry interviews were used to identify potential market areas and engagement options. Interactions are underway with various government and non-government organizations that have global focus areas for energy initiatives. Examples include the Power Africa program at the United States Agency for International Development (USAID), and the United Nations' Sustainable Energy for All initiative. ACEP assisted Navigant Consulting to evaluate Alaska microgrids per the criteria used by Navigant for their industry assessment, allowing Alaska systems to be included in the 2015 update of their microgrid market assessment report for the first time since they began such market assessments. Finally, ACEP is preparing to initiate discussion sessions with a cross-section of Alaska microgrid companies. The discussions will focus on developing concepts for establishing an industry consortium that will serve as the basis for implementing the United Nations University model in Alaska with respect to microgrid training, and to develop worldwide business opportunities for Alaska's expertise to be shared in other parts of the world.
- **Scenarios Analysis:** EPSCoR resources were used to provide partial funding for an energy-related scenarios planning workshop in Yakutat, AK, using the ScenLab software tool co-developed by UAF research faculty member Marc Mueller-Stoffels, Harriet Watts, and Erik Gauger. Because of this and other scenario work, Mueller-Stoffels is also participating in the NSF ArcSees-funded Northern Scenarios Alaska Project lead by faculty member Amy Lovecraft, Political Science, UAF.
- **Georgetown University Energy Prize competition**: ACEP identified the Georgetown University Energy Prize

(GUEP) competition (www.guep.org) as an opportunity for UAF to engage with its host community and neighbors in the Fairbanks North Star Borough (FNSB). Our initiative led to development of a steering committee with members from the local government, utilities, school district, local non-profits and the university, and the submittal of a successful application to participate in the national competition.

- **Industrial Energy Efficiency Audits:** UAF ACEP-affiliated personnel participated in energy efficiency assessments at three seafood processor facilities in conjunction with a DOE Industrial Assessment Center team from Idaho.
- **Renewable Energy Conference:** ACEP has partnered with the Alaska Energy Authority to plan and sponsor the Renewable Energy Conference which is held every 18 months. This event was held in September 2014 in Fairbanks and attracted over 500 participants from throughout Alaska. This conference provides a unique opportunity for village and tribal leaders, utility operators, and agencies to gather in one location to learn from each other about what technologies are working, and not working, from all corners of the state.
- **Technical Workshops:** ACEP is sponsoring a series of technology workshops on a variety of renewable energy projects. The aim of the series of workshops is to provide a venue for technology providers to meet with the technology adaptors learn from each other. The first workshop will occurred at the end of April 2015 and addressed the integration of PV with an islanded microrid.

4 Cost Share and Budget

The project was on budget. Inception to date and the available balance for the Tasks are listed in the table below.

BUDGET TOTALS (60 months)					
	Budget	Inception to Date	Commitments	Available Balance	% of Budget Spent
Task 1 & 4 (ISER)	686,143	686,143	0	0	100%
Task 2	2,414,689	2,414,688	0	0	100%
Task 3	151,772	151,772	0	0	100%
IAB (Sustainable AK Native Communities)	54,778	54,778	0	0	100%
Totals	3,307,382	3,307,382	0	0	100%

Our DOE cost share has been committed by the Alaska Energy Authority through the Department of Energy Wind Energy Program. The Institute of Arctic Biology (IAB) budget was originally allocated in collaboration with faculty at UAF Resilience and Adaptation Program (RAP) program with expertise in rural community sustainability to assist technical and economic research components of the program. UAF IAB Professor Emeritus of Ecology, Terry Chapin, a co-PI on the UAF RAP program who was working with the EPSCoR team has retired. Two PhD level graduate students associated with the RAP program and Integrative Graduate Education and Research Traineeship Program (IGERT) continue to work under Task 1 and 4.

Appendix A. Students, Faculty, and Visiting Researchers Supported

A-1. Students:

Student	Affiliation	Role	Expected Date of Graduation
Diego Serván Pozo	ACEP, UAF	Masters student, Mechanical Engineering, full funding on Task 2	completed
Alejandra Villabos-Melendez	ISER, UAA	Masters student, economics, employed on Task 1	completed
Nataliya Fedorivna Udovuk	ISER, UAA	Masters student, economics, employed on Task 1	completed
Richard Stevens	ACEP, UAF	Masters student, computational physics, employed on Task 1 and 2	completed
Marc Mueller-Stoffels	ACEP, UAF	Continuing as Post-doc beginning in April, 2012	completed
Maura Satierle	ACEP, UAF	Masters student, Mechanical Engineering, full funding on Task 2	completed
Mathew Van Atta	ACEP, UAF	Masters student, Mechanical Engineering, full funding on Task 2	Left the program
Chris Chance	SOE, UAA	Undergraduate Student, Mechanical Engineering, student researcher on Task 3	completed
Eshwar Chukkapalli	ACEP, UAF	Masters student, Electrical Engineering, full funding on Task 2	completed
Benjamin Saylor	ISER, UAA	Masters student, employed on Task 1	completed
Becky Warren	ACEP, UAF	PhD student, Natural Resource Management, fully funded on Task 2/4	Health issues delayed completion of PhD.
Dominique Pride	ACEP, UAF	PhD student, Resource Economics, partial funding on Task 2	Expected 2017
Daisy Huang	ACEP, UAF	PhD candidate, ME, employed on Task 2	Completed
Nick Janssen	ACEP, UAF	PhD student, employed on task 2	Expected 2017

Jeremy Vandermeer	Carl von Ossietzky Univ	Task 2. Initially worked as unpaid intern, now hired by ACEP	Completed
Henrique Fiche	Universidade Federal de	MS Intern to conduct initial market analysis associated with the *Global Applications Program*	Completed
Nathan Green	ACEP, UAF	MS Electrical Engineering (Task I and Task II)	Expected 2015
Haley McIntyre	UAF	MS, Natural Resource Management	Expected 2015
Brita Mjos	UAF	MS program student (Civil Engineering)	Expected 2016
Daniel Talbot	ACEP, UAF	Undergraduate student (Mechanical Engineering)	Completed
Anastasi Thayer	ACEP, UAF	MS Resource Economics	2015

A-2. Faculty and Post Docs:

- The state approved two new tenure track engineering faculty lines at UAF, providing two half-time joint appointments split between the College of Engineering and Mines (CEM) with state funds and ACEP with EPSCoR funds. One of these appointments was filled in 2014 by an ACEP research assistant in mechanical engineering, Daisy Huang, after the completion of her Ph.D., while the other position in electrical engineering was cut due to recent budget shortfalls at UAF.
- UAF/ACEP has hired three additional research faculty at UAF, supported in part through EPSCoR. Each has made substantial contributions to our team, and increased the breadth and depth of our research capacity. These include:
    - Erin Whitney, PhD Physical Chemistry, formerly with the National Renewable Energy Laboratory where she specialized in solar energy research.
    - Antony Scott, PhD Energy Economics, formerly with the State of Alaska where he managed the commercial division for the Division of Oil and Gas, and has also served as the lead economist for the Regulatory Commission of Alaska.
    - George Roe, Mechanical Engineer, formerly with Boeing where he focused on energy storage (flywheel and batteries) for aircraft based electric microgrids as well as fuel cells.
- A postdoctoral fellow, Marc Mueller-Stoffels, hired by ACEP in May 2012 to continue work on the data acquisition systems hybrid test bed under Tasks 1 and 2 of Phase II transitioned to an INE research faculty position and is currently the director of the ACEP PSI Laboratory and associated PSI Program.

A-3. Visiting Researchers:

- We have implemented an industry/university exchange between Power and Water Corporation, the sole utility for the Northern Territory in Australia (experienced in high penetration PV-diesel systems) and UAF bringing researcher Phil Maker to UAF for two 4 week periods in February 2013 and March 2014 on Task 2 activities related to the hybrid-diesel test bed, model development and data acquisition software development. Maker was recently appointed to affiliated faculty status at UAF. UAF researcher Marc Mueller-Stoffels travelled to Australia for 6 weeks in March/April 2013 to work with their team on developing models for high penetration wind systems for the 75 remote, islanded communities they service, provide content for a PV-Diesel Minigrid Handbook, and review and test models.
- Jeremy Vandermeer initially visited ACEP as a visiting researcher for 6 months to conduct research for his MS thesis at the Carl-von-Ossietzky University, Oldenburg, Germany. After his MS was granted Vandermeer joined the ACEP team as a research engineer.
- Researchers from Sandia National Laboratories (Abbas Akhil, Benjamin Schenkman, Richard Jensen) have visited ACEP for 1 and 2 week periods in Spring 2014 and Fall 2014 to collaborate on energy storage assessments, data analysis and model development for Cordova, AK. Akhil's visit was funded by ACEP, while Schenkman and Jensen received funding through DOE Office of Indian Energy and DOE Battery Storage Program.
- Hendrik Schaede formerly with the Institute for Mechatronic Systems at the Technical University Darmstadt, Germany, will spend three months with ACEP starting late April 2015. This visit will include a one-month deployment to our utility partner in Cordova, AK, to provide on-the-ground support for data analysis and design of a demand response system. ACEP and the German Academic Exchange Service funded Schaede's visit.
- Daisy Huang visited the National Renewable Energy Laboratory for a 4 week period in Summer 2014. This visit was part of the DOI Remote Community Renewable Energy Project. Huang worked on the development of performance markers for remote islanded microgrids, and collaborated on model development and refinement to provide better model performance for remote Alaskan thermal and electric systems.

Appendix B. Papers, Technical Reports and Presentations

B-1. Peer Review Papers (developed since the review in September 2012):

- Janssen, N. T., R. W. Wies, and R. A. Peterson. Dec 2014. Frequency Regulation by Distributed Secondary Loads on Islanded Wind-Powered Microgrids, *IEEE Transactions on Sustainable Energy*, vol. PP, no. 99, pp. 1-8, 2016.
- Janssen, N. T., R. A. Peterson, and R. W. Wies. Generalized Heat Flow Model of a Forced Air Electric Thermal Storage Heater Core. *ASME Journal of Heat Transfer*, in preparation.
- Chapin, F. S, III, Knapp, C. N., Brinkman, T. J. and Bronen, R. Community-empowered Adaptation for Self-reliance and Sustainability. *Global Environmental Change*, submitted.
- Vandermeer, J., and M. Mueller-Stoffels. Geothermal Integration Study for the Wind-Diesel Microgrid of Nome, Alaska. *IEEE Transactions on Sustainable Energy,* in preparation.
- Mueller-Stoffels, M. System sophistication as a determinant of maximum RE penetration. *IEEE Transactions on Sustainable Energy,* in preparation.
- Maker, P., M. Mueller-Stoffels, D. Huang, and D. Light. Energy efficiency considerations in hybrid-diesel power systems. *IEEE Transactions on Sustainable Energy,* in preparation.
- Muhando, B. E. and R. W. Wies. 2011. Nonlinear H_∞ Constrained Feedback Control for Grid-Interactive WECS Under High Stochasticity. IEEE Trans. on Energy Conversion. vol. 26, no. 4, pp. 1000-1009.
- Fay, G. and N. Udovyk. 2012. Factors Influencing Success of Wind-Diesel Hybrid Systems in Remote Alaska Communities: Results of an Informal Survey. submitted to *Renewable Energy*. Under review.
- Wies, R. W., E. Chukkapalli, and B. E. Muhando. 2012. Novel Voltage Stability and Frequency Regulation Control Models using Secondary Load Controllers for Wind-Diesel Microgrids. IEEE Trans. on Power Systems. In preparation.
- Wies, R. W., M. Sateriale, and B. E. Muhando. 2012. Development of Models for Evaluating the Optimal Use of Electrothermal Heating and Storage in Wind-Diesel Microgrids. IEEE Trans. on Energy Conversion. In preparation.
- Muhando, B. E., R. W. Wies, and G. Holdmann. 2012. “Re-engineering the wind-diesel industry: integration of energy storage and power electronics for grid-forming and system fidelity,” IEEE Trans. Energy Conversion. In preparation.
- Muhando, B. E., R. W. Wies, T. H. Johnson, and G. Holdmann. 2012. “Coming of age: redox flow battery storage systems – a practical solution for wind-diesel power system operations in cold climates?” IEEE Trans. Sustainable Energy. In preparation.
- Muhando, B. E., M. van Atta, R. W. Wies, and G. Holdmann. 2012. “Dynamic models and grid-form test bed – a functional analysis for stability of wind-diesel power systems with integrated storage,” IEEE Trans. Power Systems. In preparation.

B-2. Book Chapters (developed since the review in September 2012):

- Wies, R. W., R. A. Johnson, and A. Agrawal. Mar 2012. Energy-Efficient Standalone Fossil-Fuel Based Hybrid Power Systems Employing Renewable Energy Sources, Fossil Fuel and the Environment, Dr. Shahriar Khan (Ed.), ISBN: 978-953-51-0277-9, InTech.

B-3. Conference Proceedings (since the review in September 2012):

- Wies, R.W., N. T. Janssen, and R. A. Peterson, Distributed Self-Sensing Secondary Loads for Frequency Regulation in Wind-Powered Islanded Microgrids, Proceedings of the 2015 IEEE Power and Energy Society General Meeting, Denver, CO, 2015.
- Janssen, N. T. , R. W. Wies, and R. A. Peterson, Improved Frequency Regulation on Hybrid Wind-Diesel Microgrids using Self-Sensing Electric Thermal Storage Devices, Proceedings of 2014 Australian Universities Power Engineering Conference (AUPEC), Perth, WA, Australia, 2014.
- Wies, R. W., E. Chukkapalli, and M. Mueller-Stoffels, Improved Frequency Regulation in Mini-Grids with High

Wind Contribution using Online Genetic Algorithm for PID Tuning, Proceedings of the 2014 IEEE Power and Energy Society General Meeting, Washington, DC, 2014.

- Janssen, N. T., R. W. Wies, and R. A. Peterson, Development of a Full-Scale-Lab-Validated Dynamic Simulink© Model for a Stand-Alone Wind-Powered Microgrid, Proceedings of 2014 ASME Power Conference, Baltimore, MD, 2014.
- Wies , R. W., N. T. Janssen, and R. A. Peterson, Evaluation of Grid-Interactive Electric Thermal Storage (GETS) Heaters for Islanded Renewable Energy-Diesel Microgrids in Cold Regions, Improved Frequency Regulation in Mini-Grids with High Wind Contribution using Online Genetic Algorithm for PID Tuning, Proceedings International Conference on Cold Climate Technology, Narvik, Norway, 2014.
- Janssen, N. T., R. W. Wies, and R. A. Peterson. Sep 2014. Improved Frequency Regulation on Hybrid Wind-Diesel Microgrids using Self-Sensing Electric Thermal Storage Devices, *Proceedings of 2014 Australian Universities Power Engineering Conference (AUPEC)*, Perth, WA, Australia.
- Wies, R. W., E. Chukkapalli, and M. Mueller-Stoffels. Jul 2014. Improved Frequency Regulation in Mini-Grids with High Wind Contribution using Online Genetic Algorithm for PID Tuning, *Proceedings of the 2014 IEEE Power and Energy Society General Meeting*, Washington, DC.
- Janssen, N. T., R. W. Wies, and R. A. Peterson. Jul 2014. Development of a Full-Scale-Lab-Validated Dynamic Simulink® Model for a Stand-Alone Wind-Powered Microgrid, *Proceedings of 2014 ASME Power Conference*, Baltimore, MD.
- Wies, R. W., N. T. Janssen, and R. A. Peterson. May 2014. Evaluation of Grid-Interactive Electric Thermal Storage (GETS) Heaters for Islanded Renewable Energy-Diesel Microgrids in Cold Regions, Improved Frequency Regulation in Mini-Grids with High Wind Contribution using Online Genetic Algorithm for PID Tuning, *Proceedings International Conference on Cold Climate Technology*, Narvik, Norway.
- Schaede, H., M. Schneider, J. Vandermeer, M. Mueller-Stoffels, and S. Rinderknecht. March 2015. Development of kinetic energy storage systems for islanded grids. *Proceedings of the 9th International Conference on Renewable Energy Systems (IRES2015).*
- Mager, M., B. E. Muhando, D. Witmer, and G. Holdmann. "Independent third party battery testing and verification for the Alaskan Market," The International Flow Battery Forum (IFBF'10). Vienna, Austria. June 15-16, 2010.
- Muhando, B. E. 2010. High penetration operation of hybrid power systems. Joint Renewable Energy Alaska Project (REAP) and the Wind Working Group Meeting). Nome, Alaska, USA. November 11-12, 2010.
- Muhando, B. E. 2011. Reliability and performance of WECS by full-state feedback and independent blade pitch regulation. IEEE Power Systems Conference & Exposition (PSCE'11). Phoenix, Arizona, USA. March 20-23, 2011.
- Muhando, B. E., G. Holdmann, M. Mager, and K. Keith. 2011. Advanced battery storage testing at ACEP – a practical solution for power networks in cold climate operations. The International Flow Battery Forum (IFBF'11). Edinburg, UK. May 4-5, 2011.
- Muhando, B. E., G. Holdmann, K. Keith, and T. H. Johnson. 2011. Practical assessment of advanced battery storage technology for power systems in Alaska. Pacific Region AAPG & Western Region SPE. Anchorage, Alaska, USA. May 9-11, 2011.
- Muhando, B. E., K. Keith, T. H. Johnson and G. Holdmann. 2011. High-penetration wind-diesel systems in Alaska: diesel-off operation and advanced battery energy storage research," America Wind Energy Association (AWEA) WINDPOWER 2011. Anaheim, California, USA. May 22-25, 2011.
- Muhando, B. E. 2011. Nonlinear $H\infty$ constrained feedback control for grid-interactive WECS under high stochasticity. 2011 IEEE Power & Energy Society General Meeting. Detroit, Michigan, USA. July 24-29, 2011.
- Wies, R. W., B. E. Muhando, and E. Chukkapalli. 2012. Reduced Fuel Consumption in Standalone Wind-Diesel Systems in Remote Arctic Communities using Smart Grids. 2012 Arctic Frontiers Conference: Energies in the High North. Tromsø, Norway Tromsø, Norway. January 22-27, 2012.
- Wies, R. W., R. Peterson, and M. Sateriale. 2012. Optimization of Electrothermal Loads in Standalone Wind-Diesel Microgrids in Remote Arctic Communities. 2012 Arctic Frontiers Conference: Energies in the High North.

Tromsø, Norway. January 22-27, 2012.

- Muhando, B. E., K. Keith, M. van Atta and G. Holdmann. 2012. Toward sustainable utilization of energy resources in the high North: addressing off-grid Alaska communities' energy challenges via wind-diesel power systems with integrated storage. 2012 Arctic Frontiers Conference: Energies in the High North. Tromsø, Norway. January 22-27, 2012.
- Muhando, B. E., T. H. Johnson, K. Keith, and G. Holdmann. 2012. Grid-scale rampable dispatchable storage: cascaded use of advanced battery technology to increase energy security in Alaska. 2012 Arctic Frontiers Conference: Energies in the High North. Tromsø, Norway. January 22-27, 2012.
- Muhando, B. E. 2012. Redox flow battery testing at ACEP – performance analysis and validation for wind-diesel integration in cold climate operation. 2012 Arctic Frontiers Conference: Energies in the High North. Tromsø, Norway, January 22-27, 2012.
- Muhando, B. E., R. W. Wies, T. H. Johnson, and G. Holdmann. 2012. Grid-Scale Rampable Dispatchable Storage: Cascaded Use of Advanced Battery Technology to Increase Energy Security in Alaska, 2012 IEEE Power and Energy Society Annual Meeting. San Diego, CA, July 22-27, 2012.
- Pacific Northwest Economic Region Annual Meeting – Anchorage, AK / July 2013: UAF research professor George Roe chaired a panel titled *Microgrids: Policy Implications and Challenges for Utilities*, with panelists from Alaska Village Electric Cooperative, Kodiak Energy Association, and Northwest Territories Power Corporation.
- ARPA-E Innovation Summit – Washington, DC / February, 2014: PI Gwen Holdmann and UAF research faculty members Marc Mueller-Stoffels and George Roe hosted an information booth in the technology showcase, and participated in multiple discussions with ARPA-E, DOE, industry, and other academia personnel at the event. Topic areas included microgrid energy systems, renewable energy integration, energy storage, and technology transition-to-market.
- LeHigh University – Bethlehem, PA / February, 2014: UAF research professor George Roe served as an invited guest lecturer, sharing a presentation titled *Energy in Alaska "North to the Future*" at a student-faculty seminar, touring the LeHigh campus and laboratories, and discussing possible collaborations in the area of thermal energy storage.
- Energy Storage Peer Review – San Diego, CA / October 2013 and Washington, DC / September 2014: UAF research professor George Roe attended the peer reviews for information gathering and research collaboration explorations with other participants from government, industry and academia.
- Clean Technology Showcase – Seattle, WA / June 2014: UAF research professor George Roe served as a member of the event's steering committee at the inaugural offering of this industry information and hardware display forum, hosted by the Washington Clean Technology Alliance.

B-4. Technical Reports

- Mueller-Stoffels, M. 2014. Adding PV Capacity – Initial Assessment and Recommendations for Galena, Alaska.
- Wies, R. W. and N. T. Janssen. 2014. *Review and Testing of Steffes Electric Thermal Storage Unit with Grid-Interactive Frequency Regulation*, prepared for Intelligent Energy Systems, LLC, funded by Denali Commission Emerging Energy Technology Grant Fund #7310049: Small Community Self-Regulating Grid.
- Mueller-Stoffels, M., D. Light, G. Holdmann, and B. Sheets. 2013. *GRIDFORM Inverter – Tests and Assessment*, funded by Denali Commission Emerging Energy Technology Grant Fund #01233.
- Roe, G., D. Benoit, and C. Pike. 2015. *Study of Direct Use Options for Hot Springs in Adak, Akutan & Atka*, funded by AEA Grant Fund #TBD and Aleutian Pribilof Islands Association grant fund #TBD.
- Fay, G., K. Keith, and T. Schwörer. 2010. Wind-Diesel Systems in Alaska: A Preliminary Analysis. Anchorage: ISER.
- Muhando, B. E., K. Keith, G. Holdmann. September 2010. Power Electronics Review. Evaluation of the Ability of Inverters to Stabilize High-Penetration Wind-Diesel Systems in Diesel-off Mode using Simulated Components in a Test Bed Facility. 54 pp. Technical Report submitted to the Denali Commission under the Emerging Energy Technologies Grant Fund. Available at http://energy-alaska.wdfiles.com/local--files/high-penetration-hybrid-power-system/Phase%20I%20-%20Power%20Electronics%20Review.pdf.

- Muhando, B. E., D. Witmer, T. H. Johnson, K. Keith, G. Holdmann. March 2012. Advanced Battery Storage Systems testing at ACEP: The Prudent Energy VRB-ESS. Characterization and Assessment of the Flow Battery Concept for Energy Storage and Ancillary Services in Isolated Wind-Diesel Power Networks in Alaska. 51 pp.
- Fay, G., B. Hirsch, A. V. Meléndez, and T. Schwörer. 2012. Power Cost Equalization Funding Formula and its Impacts on Renewable Energy Incentives, National Renewable Energy Laboratory. Available at http://www.iser.uaa.alaska.edu/Publications/2012_03_14-NREL_PCEfinal.pdf.
- Muhando, B. E., K. Keith, G. Holdmann. High Penetration Hybrid Power Systems Research: Evaluation of Grid-Forming Inverter for Wind Turbine Simulator. Hybrid Wind-Diesel Test Bed to Assess Smart Grid Technology for Distributed Power Systems in Isolated Communities in Alaska. (Due for release June 2012).

B-5. Presentations:

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B-6. Best Practices Guide

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Appendix C. Proposals Submitted and Proposals Funded

C-1. Proposals Submitted

We continue to submit proposals to federal (USDOE, NSF, USDOI) and state (Denali Commission, Alaska Energy Authority) agencies, and private industry (ShellWind) to support ongoing work.

- Real-time Optimization of Islanded Microgrids. Apr 2014. DOE EPSCoR Office of Science, DE-FOA-0001087, $4,194,298.
- Evolutionary Real-Time Multi-Objective Control of Islanded Microgrids with Distributed Renewable Energy Generation. Nov 2014. NSF Energy, Power, Controls and Networks Open Solicitation, $399,411.
- Transforming Remote Islanded Microgrids Science and Technology Center – TRIM STC. Dec 2014. Pre-proposal to NSF Program Solicitation 14-600 Science and Technology Centers: Integrative Partnerships, $23,797,006. In collaboration with University of Texas at Austin and George Mason University, UAF lead.
- Project DREAM – Demand Response via Evolutionary Algorithm Methods. Concept paper to ARPA-E NODES Program, Concept paper No. 1289-1580. March 2015. $1,300,000. In collaboration with Herriot Watt University, UK. UAF lead.
- Evaluation of Energy Storage and Grid Integration. Full submission to ARPA-E CHARGES Program (DE-FOA-0001078). February 2014. $4,000,000. In collaboration with Idaho National Laboratories and Boise State University. INL lead.
- Development of a slow-speed electric generator grid-integration R&D environment. January 2015. NSF Major Research Instrumentation Solicitation 15-504. $649,017.
- Cultivating High Achievement: Rural Grant for Energy-based Professional Development (CHARGE PD). March 2014. NSF Solicitation 14-158, proposal no. 1440920. $1,448,193.

The following proposals were submitted in FY12 and are complimentary to the EPSCoR scope. These are pending proposals currently under consideration by the associated funding agency.

- NSF Sustainable Energy Pathways SEP: Ensuring Power Stability and Reducing Price Volatility of Isolated Grids – Real Time Simulator Analysis for Hybrid Wind-Diesel Systems. $637,818.00
  - The objective of this research is to establish the efficient management of high penetration wind-diesel systems with integrated storage through advanced control to effect diesel-off operation, as well as ascertain the economic benefits of implementing such a system in isolated grids in Alaska.
- "Wind-Diesel Academy", Alaska Department of Labor, $100,000.
  - This will provide funding for curricula development and short-course wind-diesel seminars.
- "Assessment of Low-Head Archimedes Hydrodynamic Turbine Operation in Cold Climates-*with Focus on Diesel Hybrid Integration Issues*". DOE, $380,000.
  - Among other tasks this proposal will look at more aspects of diesel integration and control schemes.
- "Comparative analysis of major renewable and nonrenewable energy options for Alaska," under discussion with NREL, $50-70k.
  - This project will assess the comparative economics of large hydro, smaller hydro, wind, geothermal, and other options using common assumptions/level playing field.
- "Experimental Modular Prototype Construction for Isolated Hybrid Energy Systems in Alaska." AEA Emerging Energy Technology Grant Program. Marsh Creek, LLC. *Subaward $147,000.*

- o The proposed effort with Marsh Creek is to construct a modular prototyping platform together with the associated set of test procedures needed for the validation of the design of a complete hybrid power plant, including its full dynamic and fault mode characterization.
- "Self-Regulated Grid using Electrothermal Storage ETS." AEA Emerging Energy Technology Grant Program. Intelligent Energy Systems. *Subaward $30,978.*
- o The proposed effort with Intelligent Energy Systems is to develop controls for electric thermal storage units (ETS) to regulate the frequency of a village wind diesel grid.
- "High Voltage Direct Current Transmission System for Rural Alaska Applications: Phase III – Converter Technology Demonstration Project." AEA Emerging Energy Technology Grant Program. Polarconsult. *Subaward $223,288.*
- o Polarconsult and PPS propose to continue development and demonstrate real-world operation of an HVDC converter for rural Alaska with third party testing and validation at UAF Energy Technology Facility.

C-2. Proposals Funded

- Independent High-Resolution Data Acquisition and Recording Equipment for Rural Alaska – Phase I: Initial BlackBox Deployment – Shell Wind Energy, $50,000 (donation, no proposal was submitted to Shell).
- Wind-Diesel Systems Reanalysis - in discussion with the Denali Commission, Alaska Energy Authority, DOI, and NREL, $480,500.
- Wind-Diesel Academy, Alaska Department of Labor, $100,000.
- Assessment of Low-Head Archimedes Hydrodynamic Turbine Operation in Cold Climates-*with Focus on Diesel Hybrid Integration Issues*. DOE, $380,000.
- Comparative analysis of major renewable and nonrenewable energy options for Alaska notice of award. Final funding is under discussion with NREL, but $50,000 to $70,000 is expected.
- Small Community Self-Regulating Grid. AEA Emerging Energy Technology Grant Program. Intelligent Energy Systems, LLC, Denali Commission Emerging Energy Technology Grant Fund, Grant #7310049. Subaward $20,000.
- Hot Springs Direct Use Awards. March 2014: $15,000 from AEA and $10,000 from the Bureau of Indian Affairs to examine the use of geothermal hot springs for district heating.
- Alaska Center for Microgrid Technologies Commercialization. November 2014. Economic Development Administration, EDA-HDQ-OIE-2014-2004219, $499,000 awarded. (Total project, including match, is $998,500). This is a collaboration with the University of Alaska Anchorage, and is led by UAF.
- UAF Institute of Northern Engineering Innovation Award for further development of BlackBox fast signal conversion subsystem. $10,000.
- Project Reliable Infrastructure and Secure Energy (RISE) in Alaska. AEA Emerging Energy Technology Grant Program. ACEP in partnership with Ambri, Inc. Grant #7310204. $1,533,616.
- AEA Data Collection RSA
- Remote Community Renewable Energy Project, Phase I. DOI appropriation to NREL. NREL subaward No. RGS-4-42156. $60,000. In collaboration with NREL and Colorado State University. NREL lead.
- Capital Improvement Projects, Alaska State Legislature, various funding summing to $2.5 million, of which $745,000 is for support of ACEP's Power Systems Integration Lab to support the evolution of hybrid renewable-diesel technologies.
- Rural Energy Conference, AEA, $60,000. (Conference is primarily funded from sponsorships and registration fees amounting to considerably more than $60,000.)

The following is a list of funded proposals to date that are complimentary to the EPSCoR scope.

- “Alternative Utility Management Structures”. Contract with Intelligent Energy Services. $60,000.
    - This contract will look closely at alternative utility structures and propose potential strategies for increasing project sustainability.
- “Remote System Performance Monitoring and Stranded Renewables Assessment.” National Renewable Energy Laboratory. $30,000.
    - This contract will look at developing community energy solutions using locally available resources.
- “Battery Analysis for Chukchi Campus” Contract. $35,000.
    - Gather information on Prudent Energy Flow Battery System and perform testing at the Alaska Center for Energy and Power’s lab facility.
- “Kotzebue Electric Association Flow Battery Energy Storage System” Emerging Energy Technology Grant Program. Subaward, $75,000.
    - Gather additional information on advanced battery technologies and testing and demonstration projects around the country.
- “Development/Deployment of Supervisory Controller and Secondary Load Controller for Wind-Diesel Hybrid Systems”, Emerging Energy Technology Grant Program. Marsh Creek LLC. *Subaward $90,000.*
    - This project with Marsh Creek develops and deploys a Hybrid Power System Supervisory Controller and a Secondary Load Controller to be incorporated into the simulator test bed.
- Emerging Technology Fund Data Collection and Analysis for:
    - “Wales High Penetration Wind-Diesel System Upgrade.” $25,000
    - “Kotzebue Electric Association Flow Battery Energy Storage System.” $25,000
- Utility rate structures and incentives and their impact on renewable energy development and project sustainability:
    - Alternative Power Cost Equalization program structures, National Renewable Energy Laboratory. $25,000.
    - All-Alaska rate, Alaska Senate Finance Committee. $25,000.
- “Database development for assessing performance of Alaska renewable energy projects”. Contract with Alaska Energy Authority. $30,000.
    - This contract will develop a database system for assessing system performance and fuel savings from Alaska Renewable Energy Fund grant program projects.
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Appendix D. ACEP Power Systems Integration Laboratory Equipment and Communications Interfaces

D-1. Overview

The ACEP Power Systems Integration Laboratory emulates an isolated hybrid-diesel grid at up to 500 kW of permanently installed capacity and potential capacity of sev- eral MW. The basic bus infrastructure is a 12 station switchgear at 480 VAC and 600 A continuous capacity. Particular grid configurations are achieved by manual configura- tion via circuit breaker switching. Automated scheduling of generation, energy storage and load assets is controlled via contactors or motorized breakers.

D-2. Diesel generators

The lab provides a flexible infrastructure to test diesel engines from 50 kW to several MW nameplate capacity. The built-in cooling and exhaust systems can receive gener- ators up to 400 kW nameplate capacity. Larger generators require their own cooling system.

Two generator options are available as part of the laboratory: a 400 kVA Caterpillar C-15 and a 156 kVA Detroit Series 50.

Caterpillar C-15

Capacity	Controller	Protocol	Switching	Status
400 kVA	EasyGen 3200	Modbus TCP/RTU, CAN, Hardwire	Motorized CB	Operational

The Caterpillar C-15 is installed in a mobile package with Arctic modifications to ensure operability down to −30° C. The engine is directly managed by a Caterpillar ECM, and the electric generator is controlled by a Basler digital voltage regulator. Both systems can be adjusted and modified via available software tools. On top of these generator controls operates a Woodward EasyGen 3200 controller that acts as the interface to laboratory controls and data acquisition. A ProconX Esenet CAN- to-Modbus TCP interface is installed to enable Modbus TCP communications. This module preserves the Modbus RTU addressing scheme provided by Woodward for the EasyGen 3200. In addition, direct integration into the CAN bus or to hardwire I/O by additional controls is possible.

Capacity	Controller	Protocol	Switching	Status
156 kVA	EasyGen 3200	Modbus TCP/RTU, CAN, Hardwire	Motorized CB	Overhaul

Detroit Series 50

Engine/AVR controls TBD. On top of these generator controls operates a Woodward EasyGen 3200 controller that acts as the interface to laboratory controls and data acquisition. A ProconX Esenet CAN-to-Modbus TCP interface is installed to enable Modbus TCP communications. This module preserves the Modbus RTU addressing scheme provided by Woodward for the EasyGen 3200. In addition, direct integration into the CAN bus or to hardwire I/O by additional controls is possible.

D-3. ABB PCS100 ESS

Capacity	Controller	Protocol	Switching	Status
313 kVA	ABB AC800M PLC	Modbus TCP, Hardwire	Motorized CB	Operational

A 313 kVA ABB PCS100 line-up is used as the power conversion unit for energy storage systems. The line-up is comprised of six PCS100 modules which are directly controlled and coordinated via CAN bus and a control computer. The interface for basic HMI, interaction with battery management systems, and external control is pro- vided by an ABB AC800M PLC via Modbus TCP. This PLC coordinates AC and DC motorized breakers, provides top-level controls and status, as well as coordination for various protective settings. The PCS100 modules are of the high DC voltage type, and designed to achieve nominal AC output voltage (318 VAC) between 450 VDC and 1100

VDC. Grid voltage is achieved via 318 to 480 VAC Delta-Wye isolation transformer. The inverter can be operated at voltages between 250 VDC and 450 VDC. At these lower DC inputs it only achieves 254 VAC, additional tabs at the isolation transformer allow stepping this voltage up to the required 480 VAC grid voltage.

Currently, the ABB PCS100 is integrated with a valve-regulated lead acid (VRLA) battery (540 VDC/1000 Ah) with a usable capacity of 270 kWh. The PCS100 control PLC interacts with a battery management system to retrieve DC voltage, current, state-of-charge, available charge/discharge current, and available capacity. The BMS is runs on an ABB AC500 PLC, with Modbus TCP communication.

D-4. Wind Turbine Simulator

Capacity	Controller	Protocol	Switching	Status
125 kVA	NI LabView	Modbus TCP	Contactor	Operational

The wind turbine simulator (WTS) is comprised of a VFD-controlled 200 HP in- duction generator that mechanically drives a 100 kW induction generator. The drive- motor is powered by the utility grid, while the generator is connected to the PSI Lab grid. The WTS system is controlled via a NI LabView software tool that controls the VFD power output based on either power set points, or based on a power curve and wind speed time-series. The control software acts as the Modbus TCP control in- terface for the WTS. This allows for start/stop commands and power output limiting (curtailment).

D-5. LoadTech Load Banks

Capacity	Controller	Protocol	Switching	Status
2 x 313 kVA	LoadTech	Proprietary TCP/Serial	Contactor	Operational

Two 313 kVA reactive load banks on separate feeders are available. Both load banks can be controlled in 5 kW/3.75 kvar load steps and can operate down to 0.8 power factor at full load.

The older load bank operates at 208 VAC and is couple to the grid via Delta-Wye step down transformer. This load bank can be controlled via an HMI panel or via a software tool with RS-232 connection. Efforts are underway to decode the communi- cations protocol and place an RS-232 to Modbus TCP decoder as the main communi- cations interface.

The newer load bank operates at 480 VAC and is directly coupled to the grid. This load bank can be controlled via an HMI panel or via a software tool with TCP com- munication. The TCP communication has been decoded such that the load bank can be controlled via ACEP-custom developed software. This will also allow to simulate demand management with this load bank. An auxiliary connection is available on this feeder to connect a 55 kW manually operated load bank such that moderate phase unbalances can be created for testing.

D-6. ABB MGC600 Distributed Control System

A DCS system was purchased from PowerCorp in 2011, but never finalized. The con- trol hardware has been installed to the extent possible from generic drawings and ad- ditional information received. The software on the individual CPUs is not configured for interoperability with equipment currently available in the lab.

D-7. Hardware

Hardware currently on site is: six control CPUs (IDC-CPU), six digital output modules (IDC-DO8), six digital input modules (IDC-DI8), three analog I/O modules (IDC- AIO22), and a data recorder (Yawarra NET5510). In addition, six Schneider PM800 power meters are on site and connected to one control CPU respectively via Modbus RTU.

Hardware was designated as: Gen1 (CPU, DO, DI), Gen2 (CPU, DO, DI), Wtg1 (CPU, DO, DI), Bat1 (CPU, DO, DI, AIO), Feeder1 (CPU, DO, DI, AIO), Slc1 (CPU, DO, DI, AIO). This can easily be reconfigured as needed.

D-8. Data Acquisition

Data from over 1000 channels is permanently logged when the laboratory is in op- eration. This data ranges from basic electrical measurements to all available diesel generator data, and independent fuel consumption measurements. Generally, data is logged at about 5 S/s using FieldTalk Modbus TCP C++ libraries and custom data han- dling and visualization software. All data is stored in daily files, one per channel, in netCDF format.

Meters

Meters used for general data acquisition from all energy sources and sinks are either Electro Industries' Shark 100 B and T, or Elkor WattsOn. All meters communicate via Modbus TCP. The meters provide data at a rate of about 5 S/s.

In addition to the standard utility-grade meters, an Elspec GS4300 BlackBox power quality analyzer is permanently installed on the feeder to the 480 VAC load bank. This meter provides permanent logging of voltage and current waveforms at 1024 S/cycle and 512 S/cycle respectively.

Other Equipment

The laboratory LAN is managed by a Netgear FSV318G router. Additional ports are made available via several switches. A WAN connection can be made available via an eWON Cozy router and eWON's VPN software.

Time keeping for data acquisition and control is provided by a Tekron NTP server. Data acquisition is driven by a PC with Fedora Linux OS and data is routed to a Buffalo TerraStation, striped and mirrored RAID, network attached storage drive with four physical hard-drives.

D-9. Protection

Primary protection is provided by main manual circuit breakers with adjustable trip units. These CBs are sized to match equipment capacities. Limited over/under-voltage protection is available and wired into CBs shunt trip circuits. All power sources are further protected by secondary CBs and software protections, e.g., EasyGen 3200 re- verse power protection, etc. Secondary software protections generally actuate motor- ized CBs or contactors rather than trip units.

D-10. Fault Simulator

A fault simulator for phase-to-ground and phase-to-phase faults has been identified as a key additional components. A fault simulator should provide options for simulation for faults near the power source and far in the distribution system. This equipment has been conceptually specified and a design is anticipated to be finalized by Fall 2015.

D-11. PV Simulator

To simulate power produced by PV panels a DC power supply with PV-like character- istics (PV simulator) is required. Several quotes have been procured and it is planned to purchase a 50 to 100 kW module as soon as a project requires it. This will enable testing of various PV inverter options. Currently available as permanent laboratory equipment are SMA Sunny Island, and Aurora PV inverters.

D-12. Demand Management Simulator

Demand management hardware has been procured from Saturn South. This equip- ment will be integrated into an physical demand management emulator (20 kW, to be designed). In addition, a software simulator for further Saturn South devices will be developed to study behavior of controls managing a large fleet of these devices. The simulated portion of the system will control load steps at one of the load banks to emulate behavior of switching a number of devices at once, while the physical de- mand management emulator will provide finer resolution switching. The design for this system will be finalized by August 2015.

D-13. Slow-speed Electric Generator Test Stand

A funding request for a slow-speed electric generator test stand has been submitted to the National Science Foundation. This test stand is intended to provide the capability of testing typical direct-drive electric generators as they are found in modern wind turbines and hydrokinetic turbines. The conceptual design and budget request are targeting the construction of a system that can accommodate generators up to 100 kW.

Appendix E. Notes from Internal Project Review Meeting

MAKING WIND WORK FOR ALASKA
EPSCoR Halfway Review
Meeting Summary
Oct 6-7, 2011

The co-Principal Investigators for this EPSCoR project are Gwen Holdmann and Steven Colt. They called a meeting of all project participants, including industry stakeholders, in order to review progress to date for each task, provide feedback to task managers, and to identify areas that require further discussion in order to meet the EPSCoR objectives and project timelines.

October 6th, 2011 EPSCoR Day 1
Ms. Holdmann began the meeting by providing a history of the EPSCoR project for the benefit of those who may not have been involved from the beginning. She explained that the concept for the Wind-Diesel Application System (WiDAC) grew out of discussions between the Alaska Energy Authority, National Renewable Energy Laboratory, and the Alaska Center for Energy and Power in late 2008 during the International Wind-Diesel Workshop held in Girdwood, AK. Following those discussions, two proposals were prepared and submitted to various funding bodies, but were not selected for an award. A third proposal, Making Wind Work for Alaska, was submitted to the DOE EPSCoR program managed by DOE's Office of Basic Science. This proposal was selected, in part, because of its emphasis on combining engineering that address various technical challenges associated with integrating wind and diesel power with social components that are also directly related to providing affordable and reliable power in challenging environments.

<u>Summary of Presentations</u>
Day 1 of the two day review was primarily for the benefit of receiving stakeholder feedback, and began with the task leaders presenting the status of their projects:

Task 1: Wind Energy Database. Joint Presentation from Ginny Fay (ISER), Ben Saylor (ISER) and RJ Stevens (ACEP)

- Making significant progress toward creating an energy database that can easily be shared across Universities and with the power industry.
  - Database will include power performance statistics, economic data from the systems, demographics, and other relevant information.
  - Key challenge is developing a structure for linking engineering data with economic data.
- Economic and technical operating data has been collected in the past by various entities for various purposes, and basically abandoned resulting in orphaned data bases.
  - This task group is working to establish a long-term repository with protocols and documentation to encourage continued use of this database into the foreseeable future.
- There was quite a lot of discussion from the stakeholder group making the following observations: Much of the historical data collected in the past is useless today because of inadequate documentation. One of the objectives of this task is to collaboratively develop a data management protocol and process in which all institutions can work together to achieve a common process for data across entities.

  - There are differing attributes associated with data collected and reported for analysis. A key challenge in analyzing the data is understanding the associated factors which are not always well documented. For example is the data collected from power generating equipment high resolution (collected a closely spaced time intervals) or low resolution data (collected at time intervals that are not closely spaced)? Is it collected over an hour and then the average is reported? Are periods for which no data is collected reported as zero, or removed from the dataset? Is the data reported actually measured, or is it derived from other sources.
  - Quality of available data may not necessarily be guaranteed. For example, PCE data may not be an accurate source of data for a community. It often depends upon the veracity of the local records keeper. Determining what is reliable data and what is not can be a difficult task. In other instances, vendors may not wish to make data available for reporting.
- Collecting data from remote systems often presents its own set of challenges. Assuming successful implementation of data recording devices and protocols, just getting the data offsite can be a challenge, especially in areas with limited band-width. One possible solution is installation of on-site data collection and storage capacity capable of collecting and storing several years' worth of data. Such a system has been developed by ACEP and was displayed by RJ Stevens during this presentation. For the moment, the system has been dubbed the Black Box. The Black Box has not been deployed at any site so far, although discussions are taking place that could lead to its installation in a village served by AVEC.
  - For locations with adequate bandwidth, the data can be compiled and uploaded when needed.
  - If no bandwidth, but a phone line is available, the Black Box and be called when needed for data dumps.
  - Raw data can be stored in the netCTF format which is an open source standard that can be used with any programming language. The data can be stored and made available from any public domain. The cost of assembling the Black Box was approximately $2,300. The Black Box was over-built as a prototype unit. Future versions should be cheaper.
- ACEP is currently collecting and analyzing data from Ugashik and Unalakleet in order to demonstrate that it is practical to collect high resolution data from remote locations. The locations are currently used as test cases for determining the data points to be collected.

Task 2.1: Technical Issues Associated with High-Penetration Systems. Billy Muhando.

- In wind-diesel integrated applications, technical problems arise when running in a diesel-off mode. Task 2.1 is split into two phases. Phase 1 is complete and was comprised of a review of power electronics, energy storage, and control strategies that effect diesel-off operations, and to use that information to help design the wind-diesel test bed. Phase 2 involved development of the WiDAC test bed which has been commissioned at the March Creek facility in Anchorage during the fall of 2011, and will be relocated to a permanent home at the University of Alaska Fairbanks once the new energy technology test lab facility is completed in December 2011.
- The presentation reviewed the differences in power quality between diesel-on and diesel-off states and the role of energy storage in moderating swings in power quality as well as in prolonging the period in which diesel-off mode can be sustained. In particular, this presentation discussed the performance of the 20kWh Prudent Energy flow battery in Fairbanks that will be integrated into the wind-diesel simulator test bed after it is relocated to Fairbanks.
- The stakeholder group observations included the following:

  - One of the concerns is that is engines are shutdown, then they will cool, thus increasing wear and tear because they will not have been kept warm. Currently, if one engine is running, then the operating engine provides heat to the non-operating engines via a heat loop which make instantaneous starting much more palatable.
  - One of the questions to be answered is whether there is an optimal time period for diesel-off operation and how to accommodate for transient events.

Task 2.2. Demand Side Management. Richard Wies

- Demand side management essentially means balancing the existing loads with electrical supplies. The common, short-hand, reference for this is "smart-grid." In order to determine smart-grid feasibility, a good model is required. Dr. Wies has two students working on developing a good model for the utilities in Kongiganak and Unalakleet.
- Data collected at the local utility can be reproduced within the WiDAC test bed, thus helping assess the potential effects of implementing various changes to the supply and demand of power.
- Stakholder questions were mostly about whether we are close to developing electric 4-wheelers and snow machines (or transportation uses in general) that can be incorporated into the smart-grid modeling and planning concept. It was mentioned that such transportation advances for village application is still not fully developed beyond a novelty machine here and there.

Task 3. Cold Climate Operations of Wind Turbines. Matt Cullin

- Loss of wind turbine performance due to icing has been an unknown variable that frequently lead to major damage. Even a thin build-up of ice causes loss of performance. This task addresses ice detection and mitigation.
- An approach to ice detection has been identified and will be deployed this winter at the Banner Wind Site in Nome. The detection system will be observed and analyzed over the next year, and mitigation strategies could be deployed in time for the start of winter in late 2012. The data logger includes heated electronics along with a micro-logger that has been tested to -40°C. Data reporting to UAA will occur via internet and will transmit high resolution images in addition to traditional climatological data.
- Several methods of ice detection will be tested:
  - Vaisala (heated) anemometer and weather station will be compared to an RM Young Alpine (unheated) anemometer system.
  - The Goodrich icing sensor is a vibrating cylinder that is capable of sensing changes in resonant frequency caused by icing. Ideally, this device can be used to determine the rate at which ice accumulates during an icing event based on the changing frequency.
  - A high resolution camera will be deployed. Specifically, the Mobotix dual-night M12 high resolution camera with night vision and an independent network interface will be tested.
  - The BDI 35- ohm strain gauge will theoretically detect additional load on the structure due to ice accretion.

- Stakeholder questions included the following points:
  - A cost comparison analysis between sensors to evaluate accuracy versus cost would be helpful. The PI confirmed that is a component of the research.

- A comparison of a lattice tower verses a monopole in terms of ice accumulation and associated stresses would be helpful.
- One stakeholder inquired how the camera will be kept ice free? The PI indicated they may incorporate a heating bulb to keep the camera ice free and that they are trying to determine the heating interval for when the bulb is turned on and off.
- Some concern was raised about the capability of the vibration sensors to deal with tower vibration was raised. The PI indicated that this is indeed a big part of the analysis, but suggested that the sensors will be well insulated from tower vibration.

Task 4. Socioeconomic Factors for Project Sustainability. Diwakar Vadapalli.

- The PI is attempting to measure the "community capacity," which he defined as the interaction of human capital, organization resources, and social capital existing within a given community. It may operate through informal social processes and/or organized effort. Factors include formal and informal institutions; local technical capacity; local policy and long term planning for energy sustainability; local government structure; available leadership; a sense of ownership and responsibility. The PI plans to identify and visit eight sites with varying structures. Deliverables over the next one and one-half years includes development of a dataset and a qualitative analysis technique.
- Stakeholder comments included the following:
  - There is a notion that more diesel reduction is better through higher penetration systems. However, there might be a certain level of fit with respect to how much integration with renewables can occur within certain villages depending on community types.
  - Perhaps this research can lead to a checklist of sorts of needed programs/policies/documents that must be instituted in a community prior to the state investing in a "high-end" utility system in a particular community. There should be some demonstration of commitment to make an integrated system work in a community, but how that commitment can be measured is a good question.

<u>Stakeholder Input</u>

After the presentations were completed, each stakeholder was asked for general observations about whatever aspect of the EPSCoR project they cared to comment upon. Are there areas we are doing particularly well in? Are there areas being overlooked? Are we addressing issues of value from the stakeholder's perspective?

- Rich Stromberg, Alaska Energy Authority, stated that the bulk of his work is affiliated with implementing the Renewable Energy Fund and all the EPSCoR research has direct impact on those projects. Rich was wondering how the information collected through EPSCoR can beused by AEA to inform the grant selection process –which is outside of the typical engineering model (HOMER). One other question that Rich has for down the road is what is the minimum size community to have a typical NW100 with gen-sets diversion load? What is the best model from smaller communities in the 40-60 kW average load community, perhaps they should have a centralized utility? These are practical, real-world questions, that perhaps EPSCoR research will be able to help answer. More specifically, Rich would like to follow up with Rich Wies on the heat recovery aspects of his work in villages. He also sees the usefulness of the "Black Box" data collection tool introduced during this meeting and sees potentially AEA supporting further development and deployment of that technology.
- Brent Petrie, Alaska Village Electric Cooperative, also observed that data collection, synthesis, and utilization is a very large problem for AVEC. Basic operational data is easy to obtain, but historical trending requires large data

storage. AVEC also doesn't have the time or the capacity to analyze it. Hooper Bay has seen a large data dump recently and Brent offered to make that dataset available to EPSCoR for analysis and for proof of concept in terms of formatting kinks and manipulation. Another helpful item, as we look towards higher wind penetration systems, we should look at storage to allow diesel off and low diesel cycling. If we use batteries, AVEC, would like to use batteries that are mass produces (with hybrid vehicles such as the Chevy volt) that would allow us broader access to servicing and replacement parts. He suggested that ACEP could help examine what relatively common batteries are available in the markets today, and what might be most appropriate for an AVEC community. As for turbine manufacturers, thereis now enough of a fleet of NW100 models in the state that Northern Power has hired an Alaska-based technician who rotates throughout all of the sites performing maintenance. AVEC would also like to see a 40kW turbine which could meet the community's needs. This balanced with the larger 900 kW machine-could meet our state's growing needs well. His final observation was that the work done by Matt Cullin in terms of ice build-up and ice-shedding may be useful, and he made EPSCoR researchers aware of a National Rural Energy Cooperative Association project that is looking at a hydrophobic material coating for transmission lines that may be useful in a wind turbine application.

- Brian Hirsch, National Renewable Energy Laboratory, is interested in the wind-diesel test bed and learning more about the facility. He noted that NREL is currently focusing on development of the Island Region Wind Working Group. NREL trying to provide support to share lessons learned. The lessons learned from the group can be of value to these other communities. He sees EPSCoR as a valuable source of information for other islanded grid systems. He also mentioned that there are issues with respect to modeling turbulence, basically that it is difficult. Perhaps the wind-diesel test bed can assist with such modeling in addition to other technical matters.
- Jenny Spegon, USFWS, observed that there are great resources at the University and there is a need for a bird mortality survey specific to Alaska. Currently, such data does not exist in for Alaska, although it is being collected throughout the lower-48. This sparked a conversation about possibly incorporating the Wind for Schools program (also administered by ACEP separately from EPSCoR) to bring school children out to their community's wind turbine (assuming they have one) to make observation. The Alaska Bird Observatory might be another partner in this endeavor.
- Connie Fredenberg, March Creek (formerly with TDX), was pleased to hear that electric transportation is still being considered. (It was mentioned in Rich Wies' presentation earlier in the day.) In TDX, an electric four-wheeler, Barefoot, was purchased, but experienced problems. Recently, one was purchased from Polaris, and they have been happy with it to date.
- Steve Drouilhet, Sustainable Power, asked if there is a way to focus the "soft data" to ensure that value will be obtained at the end of the time period. He suggested surveying numerous developers to determine what human factors are necessary in order to successfully deploy their technology. For example, what are the maintenance requirements and will the village population have the necessary skills? Many power systems are now fully automatic, and the local operator will probably have the capability to fully maintain the system if something were to happen. He observed that often what is needed no is an operator who will serve as their eyes and ears on the ground so that as actions are taken to manipulate a system from a remote location, then there will be somebody on the ground who can verify this or that piece of equipment is operating. A power plant operator should be in email contact with the outside world and should include cell phone contact. This is not always achievable in a remote setting.
- Jodi Fondy, Denali Commission, was glad to see that the smaller funding amounts that the Denali Commission has provided for wind-diesel systems has gone a long way to leverage great work.
- David Lockard, Alaska Energy Authority, noted that AEA is inserting a due diligence process in project selection. One example was a community, who received funding for a high penetration wind project, but they hadn't paid the fuel vendor, they haven't paid taxes, and there are a plethora of other problems. Perhaps the Rural Energy Fund (a program that helps pay for energy projects in villages) could gain insight from Diwaker's work, and

maybe some of the experiences from Rural Energy Fund projects (good projects and bad projects) could provide useful information for his studies.

The first day then ended with a reception for the researchers and stakeholders sponsored by Marsh Creek. It also provided an opportunity to demonstrate the Wind-Diesel Test Bed that is newly commissioned as a result of the EPSCoR project.

October 7th, 2011 EPSCoR Day 2

Day 2 was an opportunity to hear from the student researchers, followed by a discussion of where this EPSCoR project should head next.

Student Presentations:

Aligning Energy Policies in Alaska, Alejandra (Alex) Villalobos-Melendez, ISER.

Her project explores the possibility of reducing high costs of from fossil fuels by providing new policy incentives for renewable energy development in rural Alaska through implementing changes in the way that the Power Cost Equalization (PCE) program is implemented in Alaska. There is a long history of PCE in the state, and a correspondingly rich history of analysis by state agencies, ISER, and independent analysts. The Renewable Energy Fund provides funding for renewable energy projects in communities. Often, communities support such infrastructure initiatives in the hope that it will reduce their high electric bills. Although implementation of a renewable project often competes favorably with diesel powered generation, the consumer does not always see such a reduction in their monthly electric bill, and this is thought to be because of the PCE calculations that subsidize consumer power costs. Alex's project will try to identify if changes to the PCE rate structure can be identified so that the consumer's bills reflect the fuel savings from implementing renewable power in a community.

Modeling of Kongiganak and Unalakleet for Smart-Grid application. Eshwar.

The objective of this project is to develop a MATLAB/Simulink® model of the wind-diesel system in a village and analyze the system in terms of voltage, frequency regulation, etc. An important component of this task also includes creating a GIS map of each building connected to the electric grid and determine the distributed load patterns as accurately as possible. The ultimate goal is to apply demand side management tools and load control and load following technologies. It seems that a small Alaska village would make for a logical test case for implementing smart grid technologies.

Working on Converting Excess Electricity to Thermal Loads, Maura

Home heating is a huge household cost. In communities where wind turbines are installed, there can be excess electricity generated during high wind occasions. How to handle those jumps in electrical generation can pose a problem for a community. One solution is to utilize that excess electricity into a device that heats water or heats conditioned space, thus displacing heat derived from diesel generation. Two candidates for thermal loads include hot water heaters and masonry heaters. Maura's project will use models developed for *Kongiganak, Unalakleet, and Ugashik* to determine the economics of which may be better, heating water, or using masonry heaters. This also includes understanding what portion of a household budget goes toward water heater, and how much toward home heating

Facilitated Discussions about the future direction of EPSCoR, Brent Sheets, ACEP

The first topic of discussion is the role of the Wind-Diesel Application Center (WiDAC) with respect to the renewal application. Its development was the center of the original EPSCoR application and the question is whether it should remain the focus of the renewal application, or whether is should be one component of the renewal application rather than the focus. Several opinions were expressed, and it was ultimately decided that the co-PI's need to have a strategic discussion about this matter.

The next topic was a discussion about the effectiveness of our collaboration across campus' and disciplines. It was generally agreed that we can always do better with respect to communications, but widely acknowledged that this EPSCoR structure is effectively bringing researchers and students together to look at issues holistically. There was some discussion about developing a protocol document with respect to seeking information from stakeholders. It turns out that on occasion the Engineering School will sometimes go to the same people as the Economicis School and both are looking at roughly the same problem. We could do a better job of coordinating external communications to avoid burdening our mutual stakeholders.

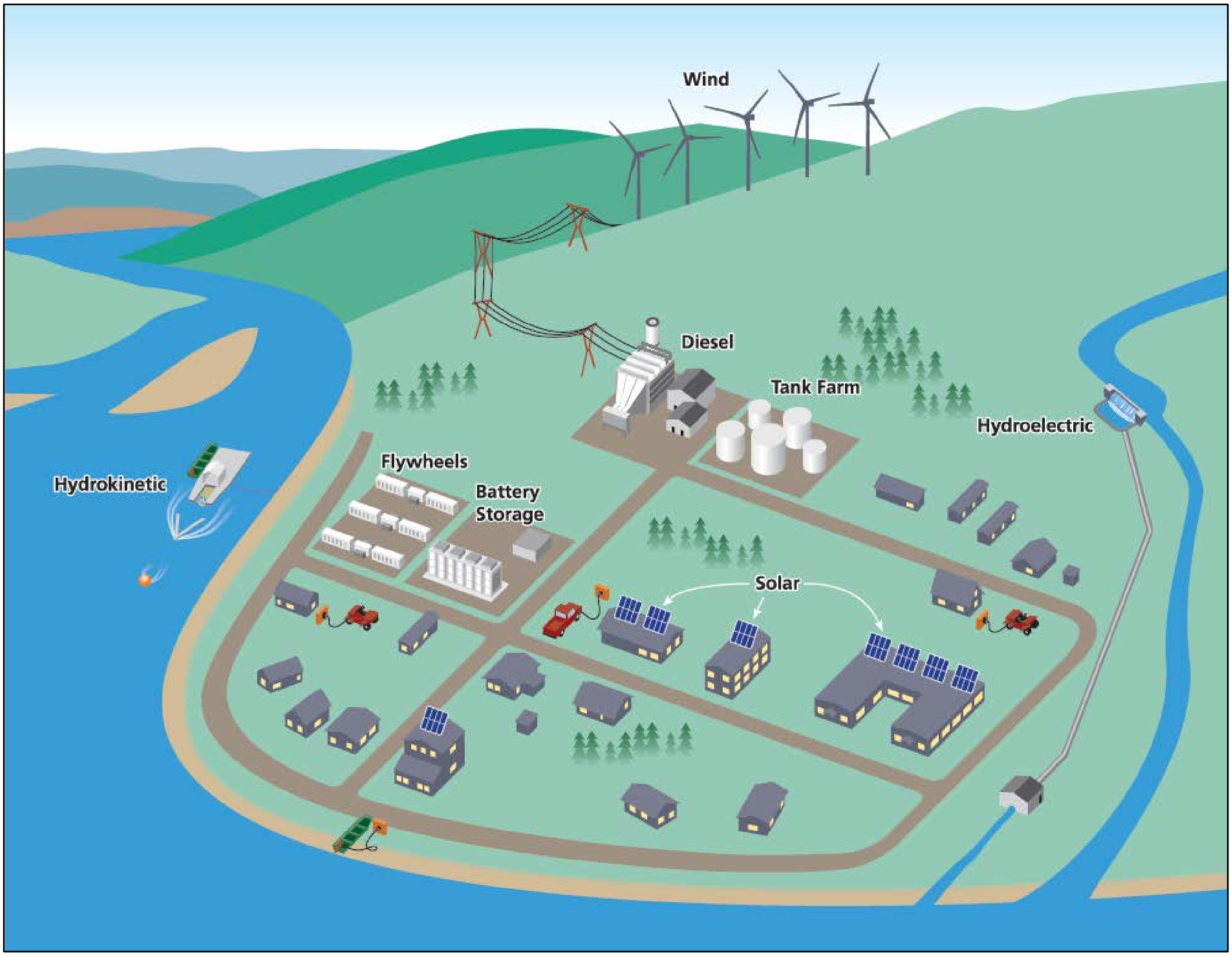
Finally, a list of topics was identified for potential paper topics. The list will be circulated and honed, but include the following:

a. A paper relating how we developed the database that incorporate sociological, economic and engineering data, where will it be stored, and what its uses.
b. Recommended performance standards for isolated power systems.
c. Diesel genset construction.
d. How far can models take us:
    i. Comprehensive descriptions of village load distribution.
    ii. How reliable/available is the data we're using in the models?
    iii. Operating in diesel off mode.
e. Incentives/disincentives of socio economics and how do they tie into planning and operation.
f. How low of a load can you go in terms of running diesel's at low levels before it negatively impacts maintenance, emissions, etc.
g. From village perspective, what is the trade-off between lowering your energy costs and altering your lifestyle? Are designers/installers engaged in finding out what matters to them. What is it that people demand of their power in the village setting? What is their willingness to pay for conventional power generation in such a "brutal setting?"
h. Effect of ampies on villages—immediate and long term.
i. How to incorporate societal factors into screening criteria for who receives state-supported generators.
j. Dumping extra wind energy effectively/efficiently.
k. Carbon reduction.
l. Case for high resolution data acquisition in remote communities.
m. Power quality in outmoded systems…what are the current and emerging issues related to deploying emerging technologies.
n. Financial analysis of performance loss due to icing.
o. Comparative study of different methods of community engagement and decision making.
p. Developing indicators of community capacity to sustain complex energy systems.
q. Need a few case studies: Unalakleet, black box location.
r. Bird Strikes/Wildlife impacts…using wind for schools for monitoring bird strikes.

s. Free energy at any price?: Optimal levels of wind penetration (depending on the circumstance)
t. Evolving role of the operator…

Not all of the above are likely to become papers, but they do provide ideas for teams address.

Appendix F. Depiction of a Hypothetical Alaska Village-Scale Microgrid



Depiction of a hypothetical Alaska village-scale microgrid, including a variety of renewable and non-renewable generation sources, energy storage in the form of batteries and flywheels, and load management capability represented by plug-in electric vehicles.

Appendix G. Images of EPSCoR Program Activities

Figure 1. Halfway project team review meeting for EPSCoR. Held in Anchorage at UAA in October 2011.

Figure 2. EPSCoR team picture taken during project review meeting.

Figure 3. Ground breaking for the new research facility constructed at UAF to permanently house The Wind-Diesel Hybrid Test Bed and other research programs when it is completed in October, 2011. Construction is funded through the State of Alaska.

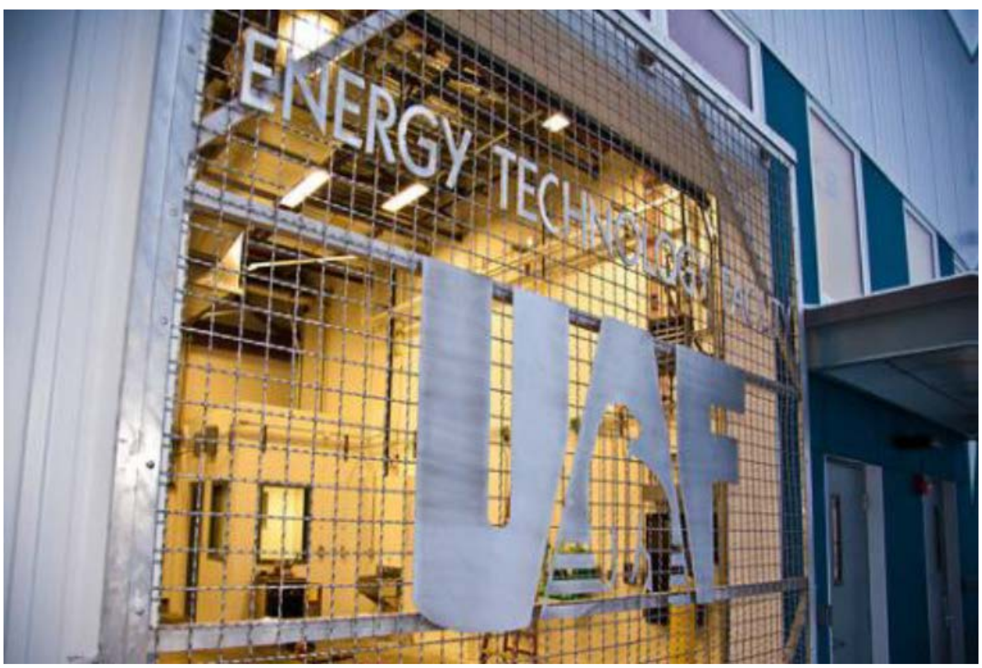


Figure 4. The new Energy Technology Facility which opened at UAF in October, 2011 and permanently houses The Wind-Diesel Hybrid Test Bed and other research programs.

Figure 5. Ribbon cutting of new ETL lab facility.

Figure 6. Moving diesel generator into new facility.

Figure 7. The Wind-Diesel Hybrid Test Bed at its temporary home at the facility of Marsh Creek, LLC in Anchorage.

Figure 8. Explaining function of wind-hybrid test bed to stakeholders.

Figure 9. The Wind-Diesel Hybrid Test Bed at its permanent home in the University of Alaska Fairbanks Energy Technology Facility.

Figure 10. Grid forming inverter undergoing testing at UAF.

Figure 11. 5kW Prudent Energy Vanadium Redox Flow Battery undergoing testing at ACEP.

Figure 12. Installation of Premium Power battery system in Kotzebue.

Figure 13. The International Wind-Diesel Workshop was hosted by WiDAC in Girdwood, Alaska.

Figure 14. During the Wind-Diesel Workshop, EPSCoR participant Per Lundsager received the lifetime Achievement Award.

Figure 15. The Wind-Diesel Workshop attracted 175 registrants from 11 countries including Australia, Norway, and Scotland.

Figure 16. The EPSCoR team and participants attend a tour of the 4.5 MW Kodiak Wind Project, the largest wind project currently installed in Alaska.

Figure 17. EPSCoR researcher Billy Muhando provided a tour of the ACEP test bed facilities in Fairbanks to Russell Cahill, Powercorp Australia, and John Lyons, Marsh Creek to discuss opportunities for industry/University collaboration through EPSCoR.

Figure 18. EPSCoR team members tour the BESS Battery in Fairbanks.

Figure 19. Tom Johnson, ACEP, and Matt Bergan, WH Pacific in Wales analyzing the high-penetration wind-diesel system.

Figure 20. Site visit of team members to the Kokhahok Wind-Diesel Hybrid System.

Figure 21. Site visit of team members to the Kongiganak Wind-Diesel Hybrid System.

Figure 22. The Mat-Su College installed a 2.4 kW Skystream Wind Turbine as part of the Wind for Schools program.

Figure 23. 1-credit Department of Labor funded wind training curriculum.