Realizing Reliable and Robust Energy Systems for the Arctic

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Sandia National Laboratories

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ACEP Alaska Center for Energy and Power

Sandia National Laboratories

Albuquerque, New Mexico

Livermore, California

Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

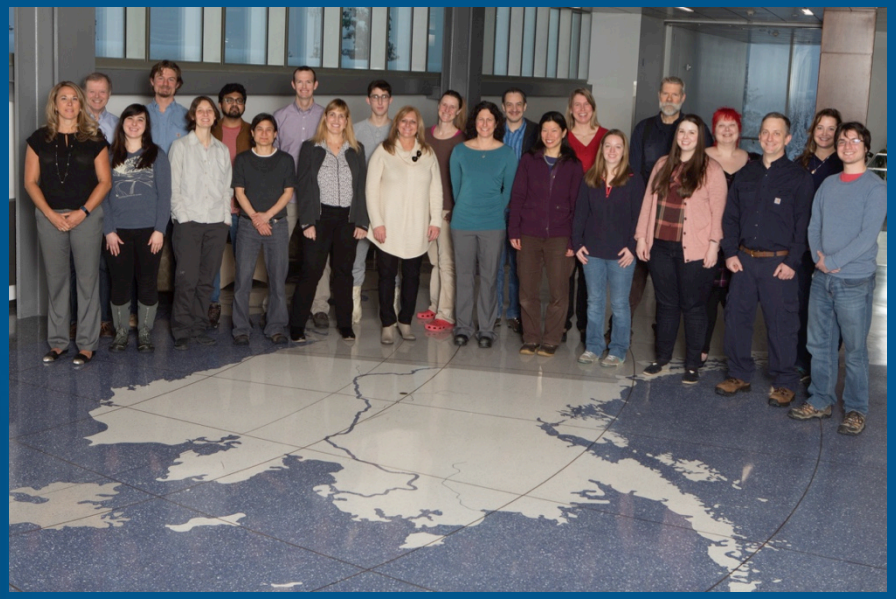
Pantex Plant, Amarillo, Texas

Tonopah, Nevada

Alaska Center for Energy & Power

Mission: Fostering development of practical, innovative and cost effective energy solutions for Alaska and beyond

- Applied energy research program
- Technology testing & optimization
- Energy systems modeling & analysis
- Knowledge network creation
- Commercializing energy innovation



- Industry
- Utilities
- Policy makers
- Communities
- Practitioners
- Students
- Department of Defense

Energy for arctic operations

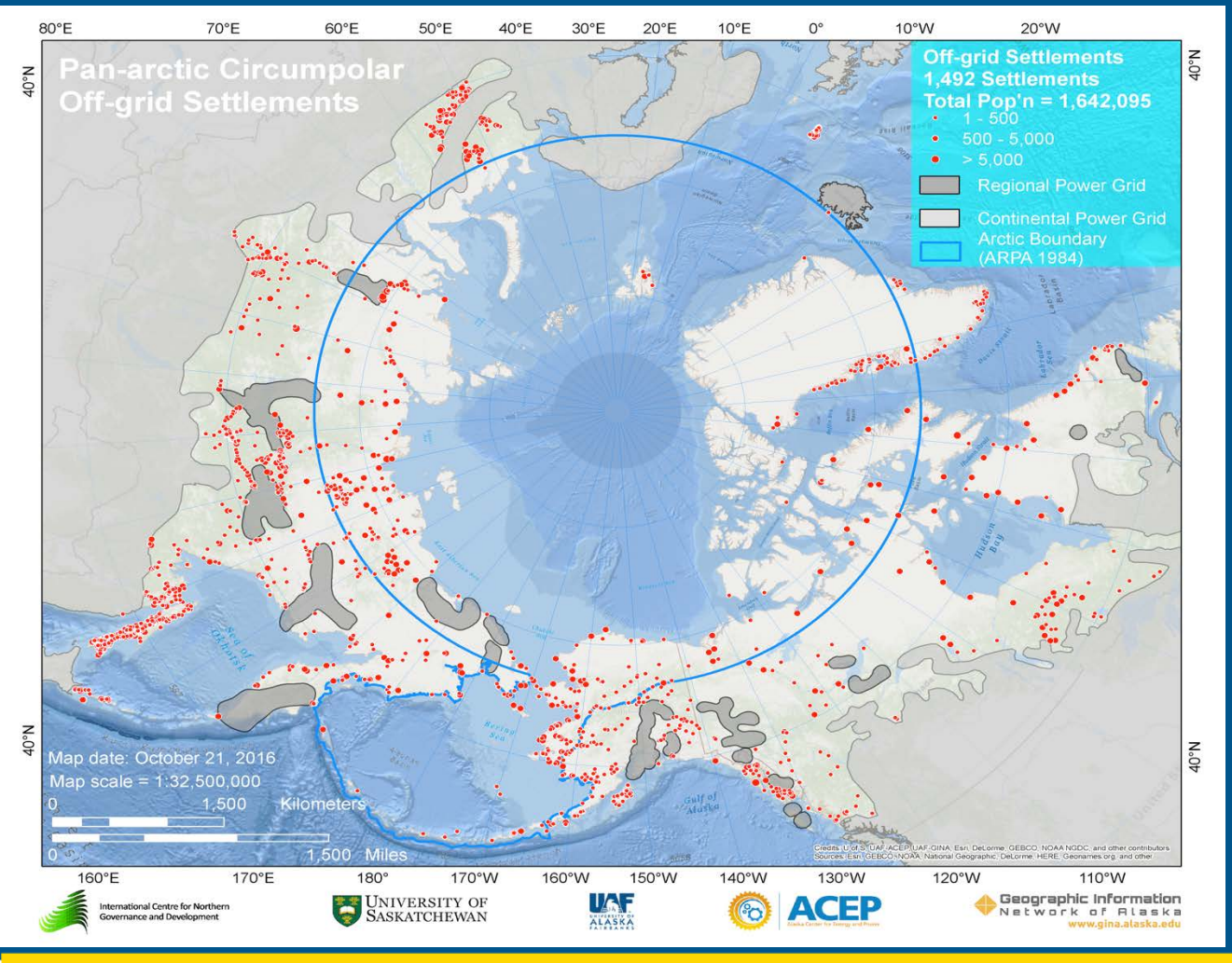
- Broadly shared energy requirements
  - Heat – space, water
  - Power – shelter, equipment, tools
  - Transportation – people, systems, supplies
  - Robust - Reliable – Resilient – Deployable
- Rich experience base - university, utility, industry, community, defense sites
- Many capability / affordability synergies

Alaska Realities

- High energy costs
- Fragmented electric grid
- Harsh & changing climate
- End of supply lines
- Stranded resources
- Dispersed population
- Limited road network
- Challenged economy

In rural Alaska:
- Electric power: 0.50-1.50 $/kWhr
- Heating fuel: 3.50-10.00 $/gallon

Off-grid settlements in the North



Nearly 2 million people living in the Arctic.

About 80% without connection to the energy, gas, and often even the roads of their neighbors to the south.

Note: preliminary / in-progress (10/21/2016)
Credits: University of Saskatchewan, University of Alaska Fairbank

Alaska & hybrid energy microgrids

250+ remote systems & 70 communities renewable-diesel systems

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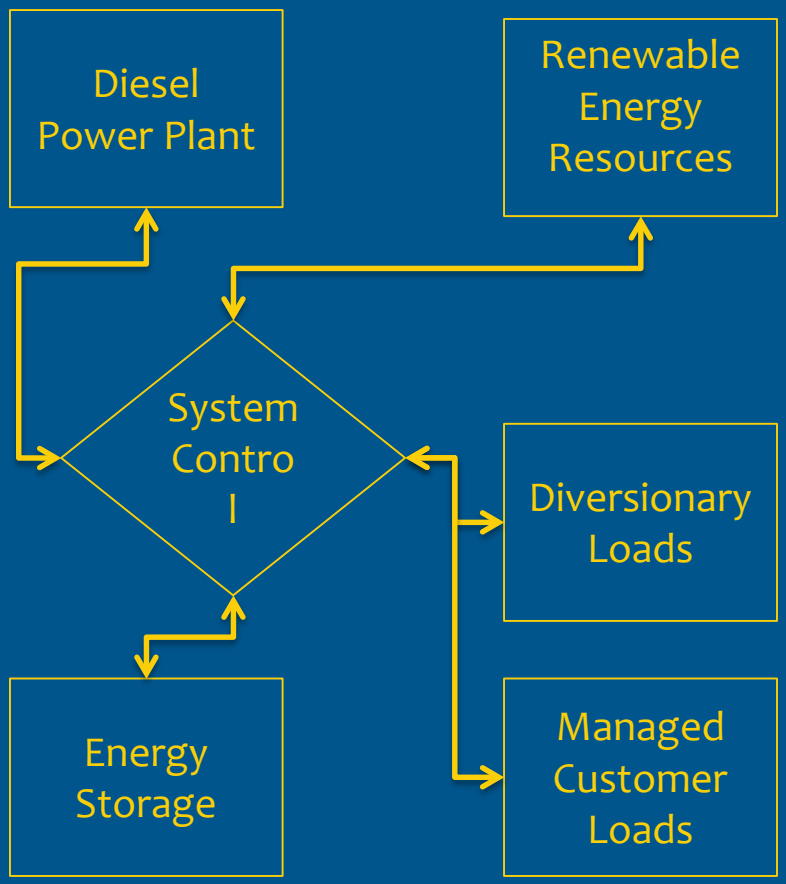
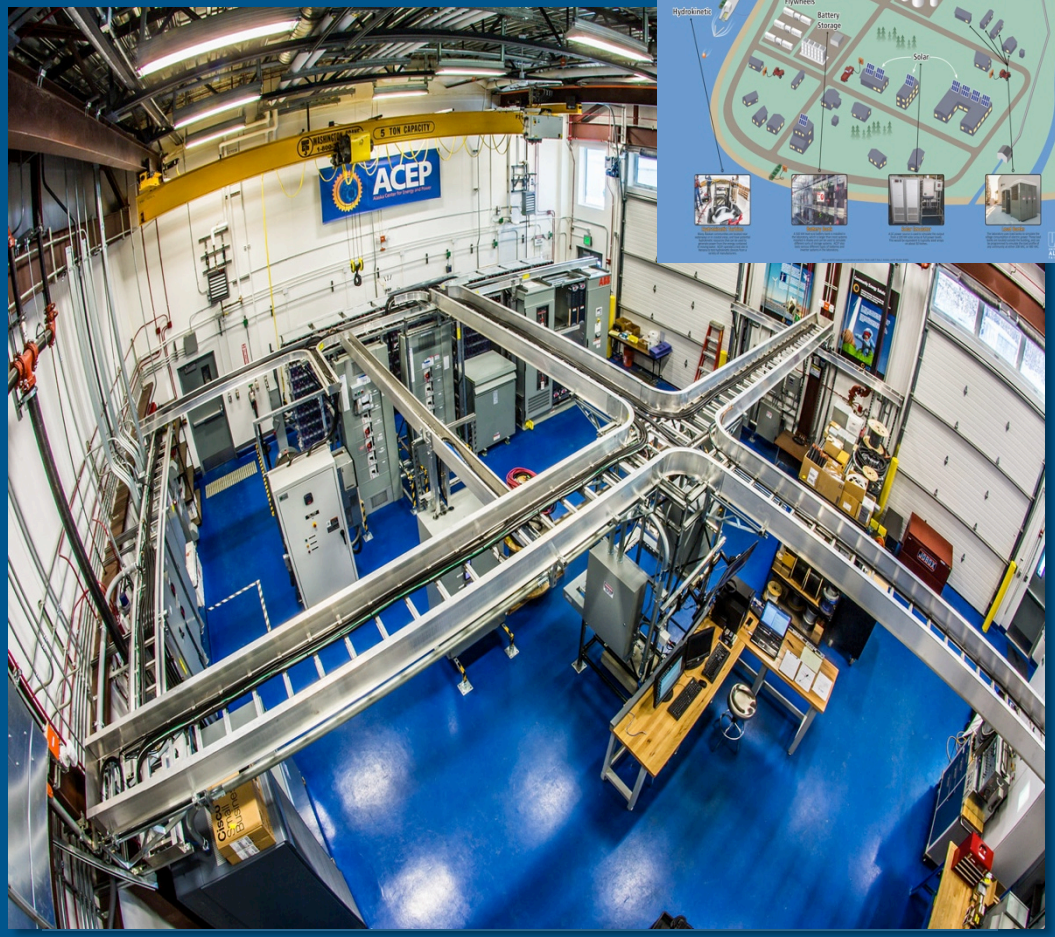
Microgrids … integrate & manage diverse, distributed assets

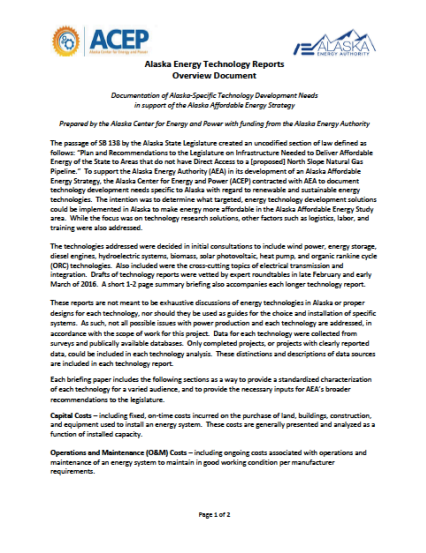




Lab recreates a microgrid at full power levels (500 kW)

Facilitating technology transition

Technology Needs



ACEP

ALASKA ENERGY AUTHORITY

Alaska Energy Technology Reports
Overview Document

Documentation of Alaska-Specific Technology Development Needs
in support of the Alaska Affordable Energy Strategy

Prepared by the Alaska Center for Energy and Power with funding from the Alaska Energy Authority

The passage of SB 138 by the Alaska State Legislature created an uncodified section of law defined as follows: "Plan and Recommendations to the Legislature on Infrastructure Needed to Deliver Affordable Energy of the State to Areas that do not have Direct Access to a (proposed) North Slope Natural Gas Pipeline." To support the Alaska Energy Authority (AEA) in its development of an Alaska Affordable Energy Strategy, the Alaska Center for Energy and Power (ACEP) contracted with AEA to document technology development needs specific to Alaska with regard to renewable and sustainable energy technologies. The intention was to determine what targeted, energy technology development solutions could be implemented in Alaska to make energy more affordable in the Alaska Affordable Energy Study area. While the focus was on technology research solutions, other factors such as logistics, labor, and training were also addressed.

The technologies addressed were decided in initial consultations to include wind power, energy storage, diesel engines, hydroelectric systems, biomass, solar photovoltaic, heat pump, and organic rankine cycle (ORC) technologies. Also included were the cross-cutting topics of electrical transmission and integration. Drafts of technology reports were vetted by expert roundtables in late February and early March of 2016. A short 1-2 page summary briefing also accompanies each longer technology report.

These reports are not meant to be exhaustive discussions of energy technologies in Alaska or proper designs for each technology, nor should they be used as guides for the choice and installation of specific systems. As such, not all possible issues with power production and each technology are addressed, in accordance with the scope of work for this project. Data for each technology were collected from surveys and publically available databases. Only completed projects, or projects with clearly reported data, could be included in each technology analysis. These distinctions and descriptions of data sources are included in each technology report.

Each briefing paper includes the following sections as a way to provide a standardized characterization of each technology for a varied audience, and to provide the necessary inputs for AEA's broader recommendations to the legislature.

Capital Costs – including fixed, on-time costs incurred on the purchase of land, buildings, construction, and equipment used to install an energy system. These costs are generally presented and analyzed as a function of installed capacity.

Operations and Maintenance (O&M) Costs – including ongoing costs associated with operations and maintenance of an energy system to maintain in good working condition per manufacturer requirements.

Page 1 of 2

- Biomass
- Diesel Generator
- Energy Storage
- Heat Pump
- Hydroelectric Power
- Integration
- Organic Rankine Cycle
- Solar Photovoltaic
- Electrical Transmission
- Wind Power

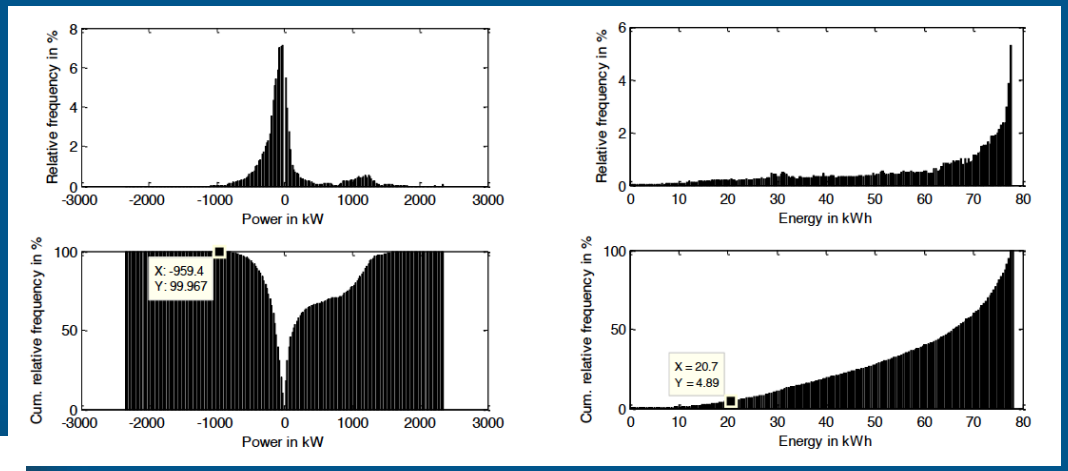
- Summary
- Technology trends
- Gaps and Barriers to Successful Project Development & Operation
- Recommendations

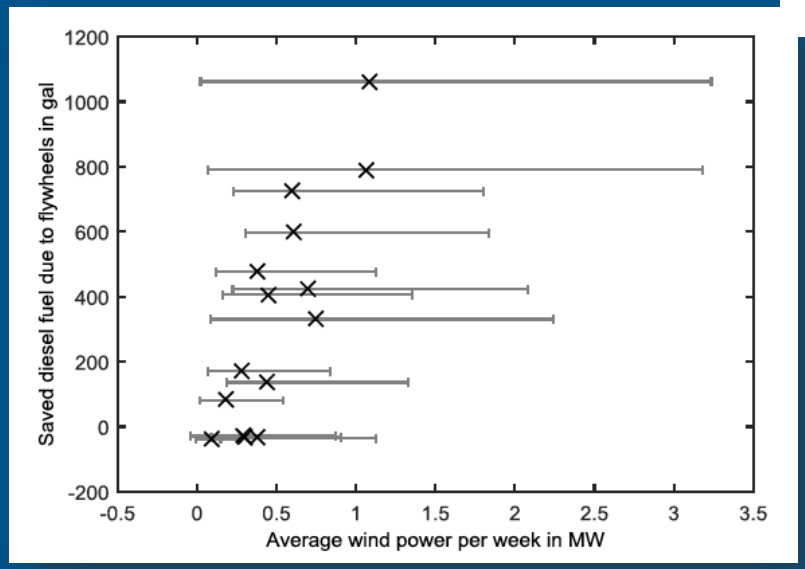
Feedback? Updates? Usage?

Helping communities define needs

Required for meeting objective 99% of times:

- 959 kW power capacity
- 58 kWh energy capacity
- High cycle life





Fuel savings for primary objective:

- 430-1150 gal/wk (med-high wind)
- Slight increase in stand-by fuel

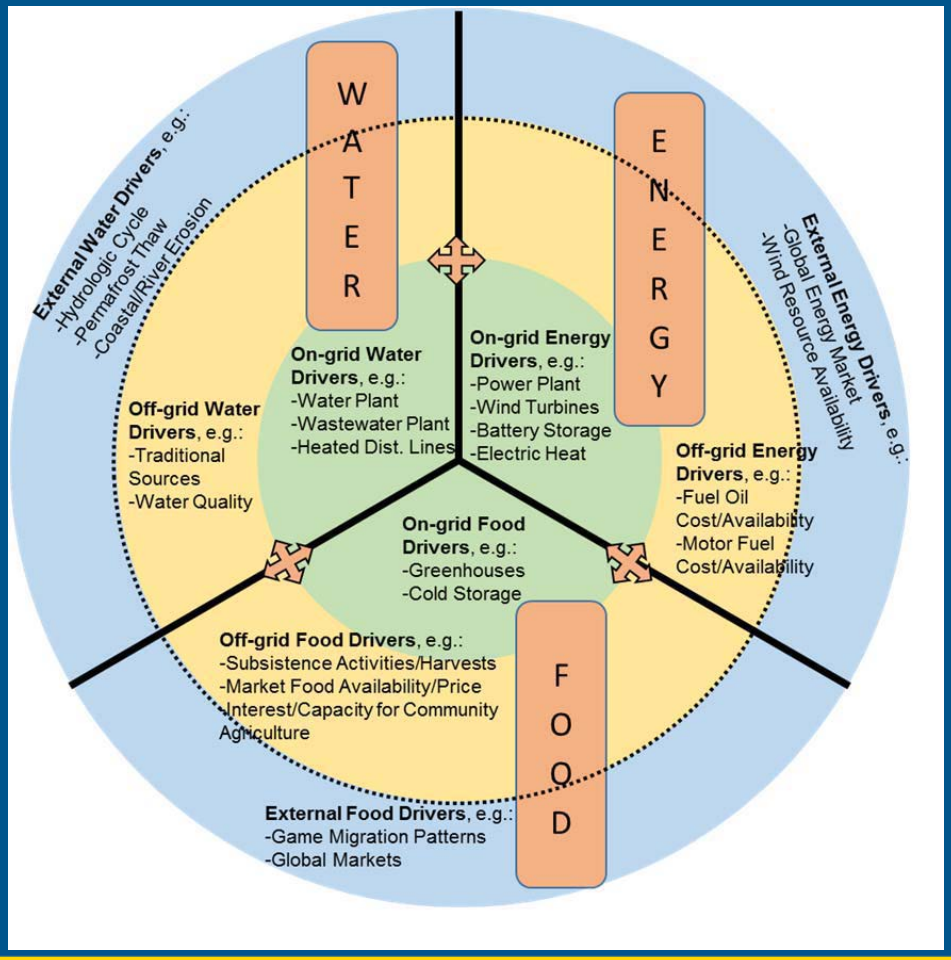
Potential value add:

- Diesel demand smoothing

AK Center for Microgrid Technologies Commercialization (ACMTC)

- Economic Development Administration i6 Challenge award
- 500K$ EDA / 500K$ UA, July 2015 – July 2018
- Providing technical and business assistance to accelerate commercialization, and implementation, of technologies for affordable and reliable microgrid energy systems.

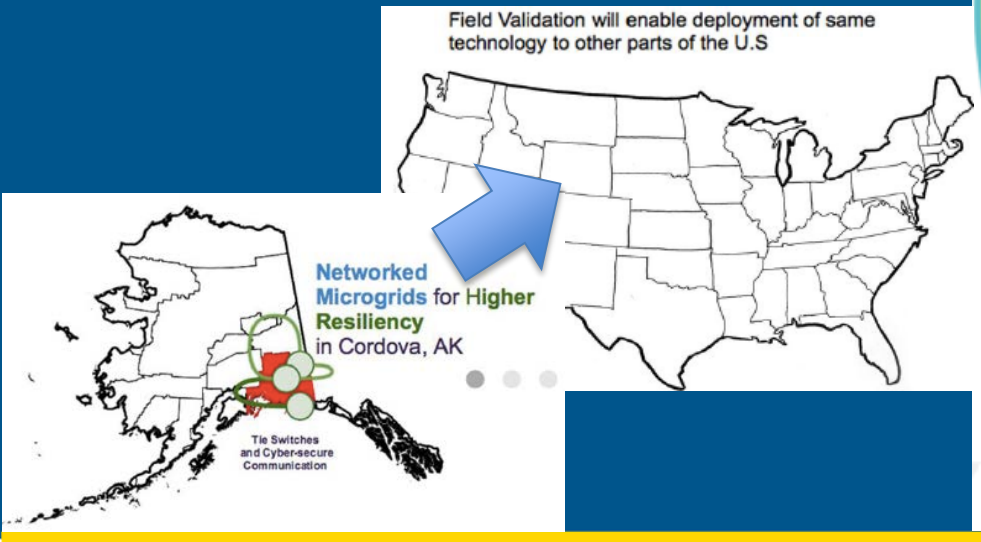
Food-Energy-Water nexus



- NSF grant / 3.5 years
- What are the linkages between renewable energy generation and the local food, energy, and water (FEW) security in Arctic and Subarctic communities?
- To what extent can combinations of renewable energy generation and FEW-related energy loads be optimized to enhance FEW security in these communities?

Resilient Alaskan Distribution system Improvements using Automation, Network analysis, Control, and Energy storage (RADIANCE)

- Resiliency Enhancement Methods
- Resilience Metrics Framework
- Cyber-security Architecture
- Rapid Prototyping of Controls
- Multiple Networked Microgrids
- Field Validation



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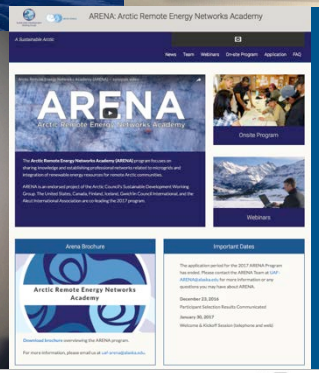
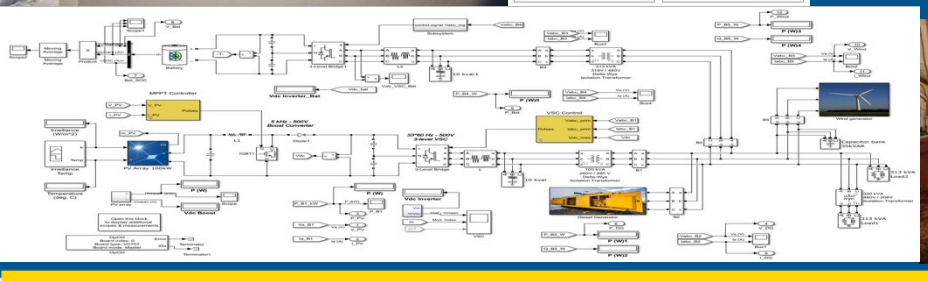
Additional microgrid research areas





- Grid fault emulator
- Fuel meter
- Line loss & inertia
- Real time simulator (RTS)
- Genset with heat recovery
- Training & workforce development
- Grid bridge system
- Asynchronous generator functionality
- Combined heat & power
- Model validation
- PV bi-facial arrays
- Hydrokinetic resource & integration

• • •

Thermal energy storage - applications

- Vehicle heating – interior, battery, engine
- Wind-to-heat buffering
- CHP & exhaust heat recovery optimization
- Season-shifted space heating
- Container refrigeration & cold storage
- Process heat resource
- …

Fuel & stranded renewables

- Electrical grid connecting resource to loads not always economically viable
- What mix of technologies could allow conversion, delivery, & use as fuel?
  - Safety?
  - Efficiency?
  - Environmental Hazard?
  - Compatibility?
  - Affordability?
  - Carbon Footprint?

Convert → Transport → Store → Consume

Waste-to-Energy (W2E)

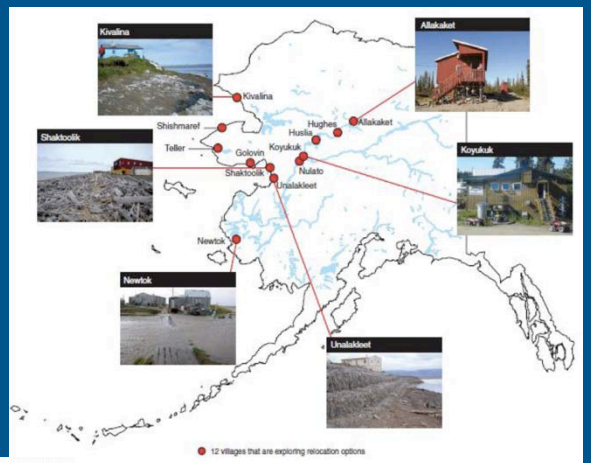
- Community, industry & defense applications
- Multiple issues & feedstock options
- Defense & industry investments in transportable W2E technology
- Heat as preferred energy off-take

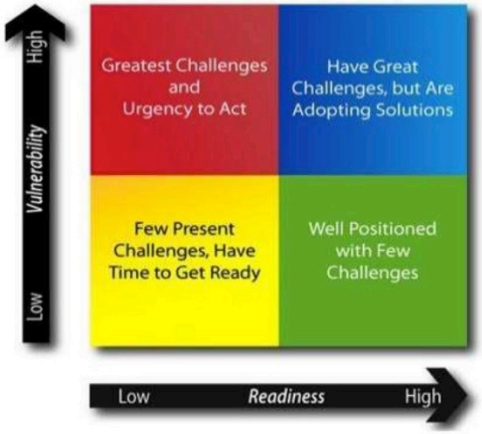
Joint Deployable Waste to Energy Initiative

Priorities: waste management & community health

Re-location as business catalyst?

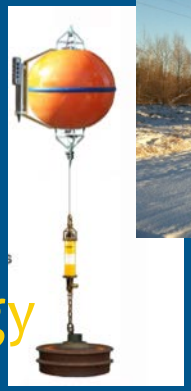
- Resource assessment
- Community development
- Modular infrastructure
- Affordable
- Resilient
- Sustainable
- Replicable
- Scalable





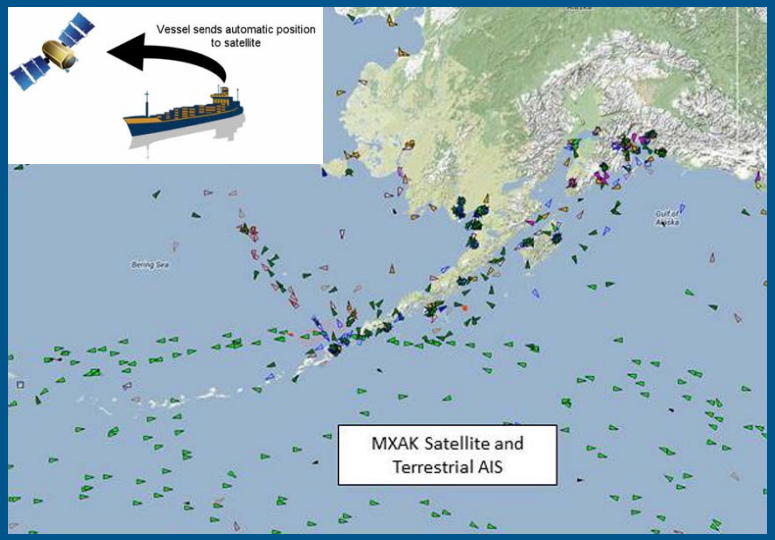
Alaska & Electrical Energy Storage Opportunities

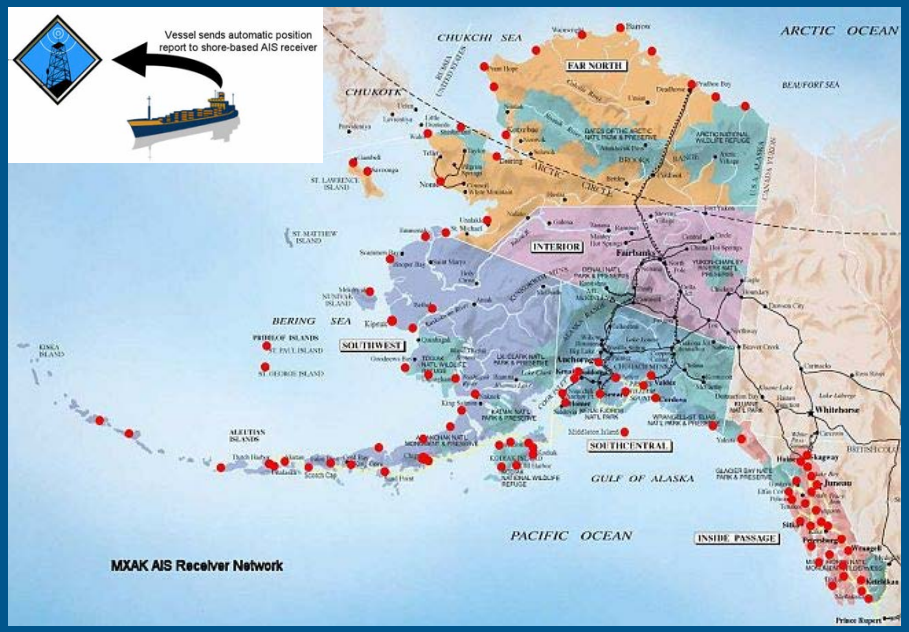
- Geophysical sensors
- Border security
- Communication systems
- Tools & displays
- Off-grid renewable energy
- Diesel-off facilitation
- Uninhabited vehicles
- Transportation



Navigation & communication

http://www.mxak.org



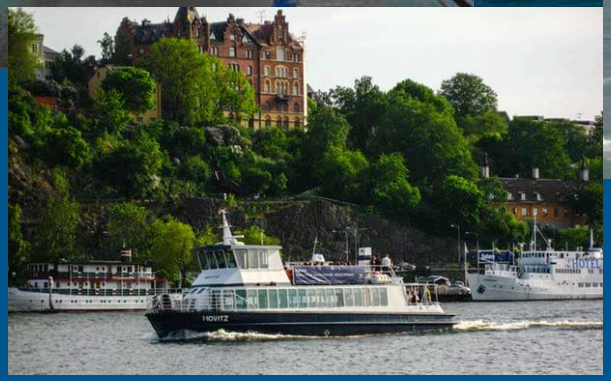


- 10,000 commercial vessels <u>currently</u> sail the 33,000 miles of Alaska coastline every year
- Changes in maritime traffic could drive requirements for additional AIS terrestrial stations with high reliability Internet

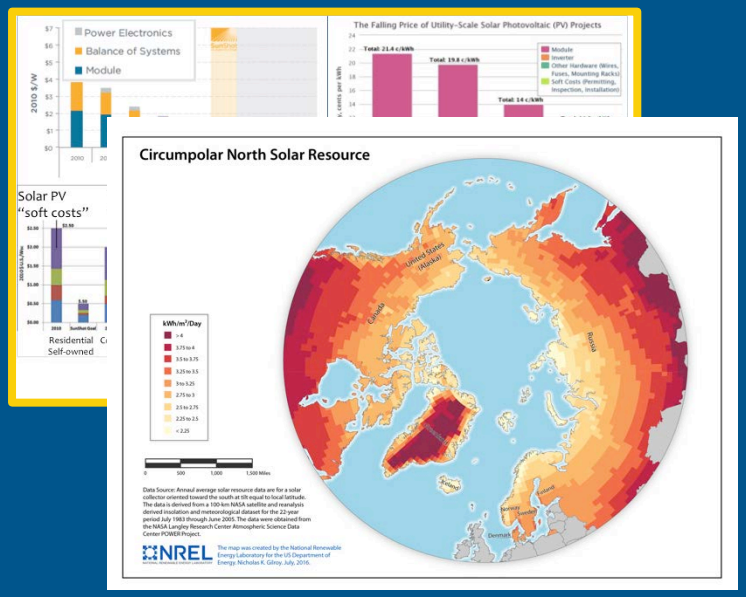
Emergency response

- Economics are event-driven
- Equipment: containment boom, skimmers, vessels, barges, tanks & bladders, ground vehicles, aircraft, buildings, communications

Electric maritime



Northern region solar initiative?



- Local & regional resource analysis
- Solar panel & hardware = commodities
- "Bundled" customers for market scale
- Regional / state expertise collaboration
  - System financing & contracting
  - Permit, interconnection, inspection
  - Installation hardware & skills
  - Operations & maintenance

- What size market is needed?
- How low must the soft costs be?
- Community / military "Solarize"?
- Veteran work force leverage

S&T synchronization opportunities

- Lessons learned from Alaska operations of energy, shelter and water systems at remote and austere locations, including failure modes, recommended practices, and areas of need of advances in engineering.
- Cold-weather performance characteristics of renewable energy technologies, communications, sensing and battery components.
- Engineering to address electrical and thermal functionalities as part of integrated design for energy, water and shelter systems.
- Research to mitigate challenges and requirements for extreme temperature range operations (from -60F to 90F) to include battery performance, fluid protection, space heating, mechanical systems, inspection and service provisions, equipment temperature regulation.
- Component and system test standards (conditions, criteria, apparatus and procedures) to evaluate reliability and robustness for arctic conditions (e.g., temperature, humidity, resource, load profiles)
- Shared collaborative knowledge base for component and system design, testing, operations and maintenance.

Alaska National Lab Day - Fairbanks 5/30-31

5/29: Research center open houses

- Climate science, geosciences, natural resources and engineering

1 International Arctic Research Center
Akasofu lobby
IARC supports Arctic research, coordination and communication to help the nation and the world understand, prepare for and adapt to the impacts of climate change in the Arctic and beyond.

2 Alaska Center for Unmanned Aircraft Systems Integration
Sign up for a guided tour in Akasofu lobby
ACUASI develops, tests, and exploits emerging unmanned aircraft technology and its uses to create a positive economic and social benefit to Alaska, particularly the Arctic and sub-Arctic.

3 Alaska Satellite Facility
Sign up for a guided tour in Elvey lobby
The satellite facility has supported research through acquiring, processing, distributing and archiving remote-sensing data for Earth observations since 1991. ASF makes remote-sensing data accessible.

4 Alaska Earthquake Center
Elvey suite 301 (turn right off the elevator)
The earthquake center works to reduce the impacts of earthquakes, tsunamis and volcanic eruptions in Alaska by providing information to the public, emergency managers, scientists and engineers.

5 Alaska Volcano Observatory
Elvey suite 310 (turn left off the elevator)
AVO monitors and studies Alaska's 52 active volcanoes to predict and record eruptive activity, and to mitigate volcanic hazards to life and property.

6 Wilson Alaska Technical Center
Elvey suite 506 (turn right off the elevator)
WATC conducts research and operates numerous seismic and infrasound stations across the globe to support nuclear treaty monitoring.

7 College of Fisheries and Ocean Sciences
O'Neill 2nd floor
CFOS researches the most pressing issues in fisheries, marine science and changes in the Arctic. The college has a dozen locations around the state that focus on research from coastal to deep ocean regions.

8 Institute of Arctic Biology-Toolik Field Station
Irving I lobby (west entrance)
IAB and TFS support research and education that creates a greater understanding of the Arctic, its ecological structure and function, and their relationship to the global environment.

9 Alaska Sea Grant
Murie lobby
Alaska Sea Grant is a partnership between CFOS and NOAA. Its mission is to enhance the sustainable use and conservation of Alaska's marine and freshwater resources through research, outreach and education.

10 Institute of Northern Engineering
Murie lobby
INE offers expertise in renewable power and microgrids, modeling and testing of mechanical systems, environmental engineering and hydrology, Arctic landscape processes, infrastructure, mining, and petroleum development.

11 Agricultural and Forestry Experiment Station
Arctic Health 1W05 (use entry on NW side of building)
The Agriculture and Forestry Experiment Station works to solve issues relating to food security and natural resources management, including forestry and forest management, tourism, resource economics, and renewable energy.

Questions? Email hrmcfarland@alaska.edu or call (907) 474-6286.

5/30: Plenary sessions

- Alaska as a living lab
- What is a national lab?
- Alaska industry and energy
- University / lab collaboration

5/31: Breakout panels

- 6 Arctic research themes
- UA, DOE, Industry, community

Developing locally and globally relevant energy solutions

Navigating the changing Arctic

Exploring and accessing the energyfield of the future

Natural hazards and defense / aerospace

Enabling and empowering the energy of Alaska's entrepreneurs

Energy and defense systems in the North

6/1-3: Local & remote site tours

- Poker Flat Research Range
- Arctic energy systems
- Evidence of climate change
- Barrow environment & atmospheric research sites
- Toolik Point / Prudhoe Bay

https://aknatlabday.org/

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Energizing the Arctic

Sandia National Laboratories and the University of Alaska-Fairbanks Alaska Center for Energy and Power (UAF-ACEP) partner to research, develop, and demonstrate renewable energy and microgrid technologies

Thank you for your attention.
We look forward to speaking with you more!
Please join us during the poster session.