Alaska Hybrid Diesel Applications

High Renewable Energy Penetrations within Isolated and Remote Area Power Systems

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College of Engineering and Mines
Alaska Center for Energy and Power

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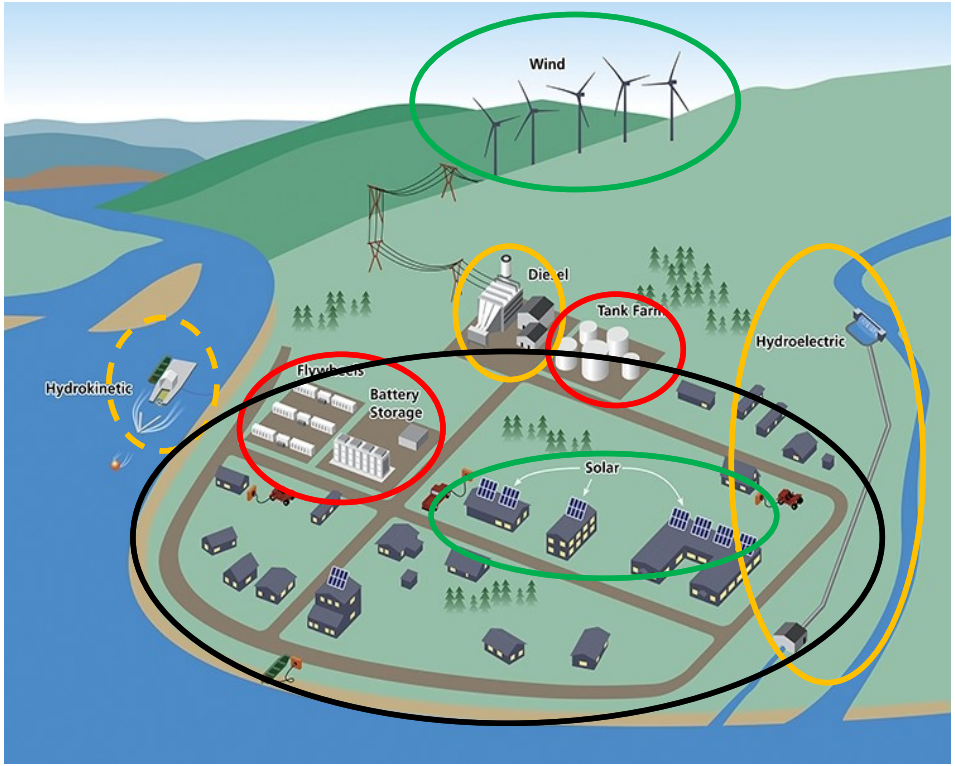
Presentation Outline

- Alaska Remote Islanded Microgrids (RIMs)
- Alaska/Arctic Renewable Integration
- Hybrid RE-Diesel Considerations
- Operational Systems
- Grid Bridging (Energy Storage)
- Pre-Deployment Development and Testing
- Takeaways

Pillar Mountain Wind - Kodiak

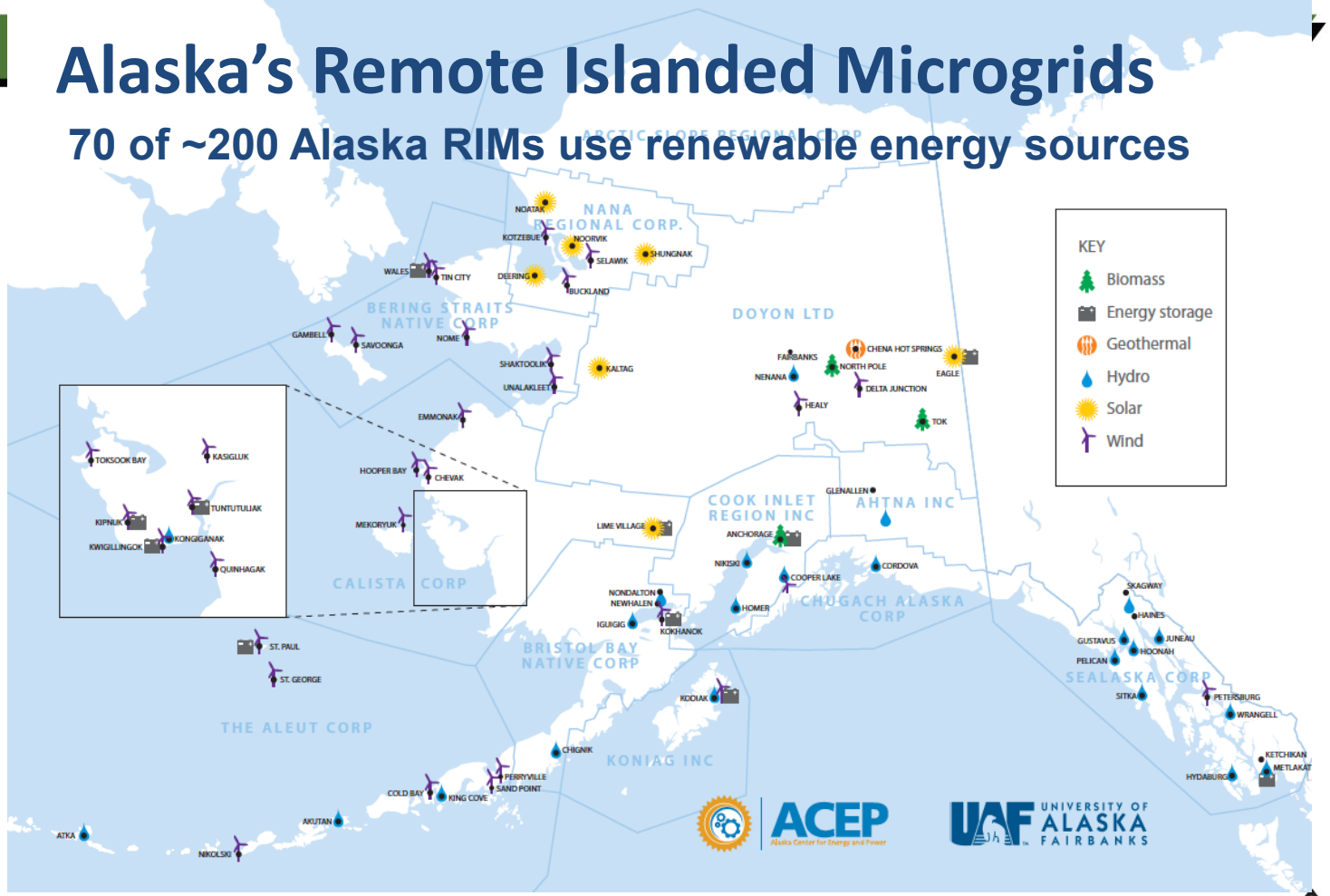
Remote Islanded Microgrids

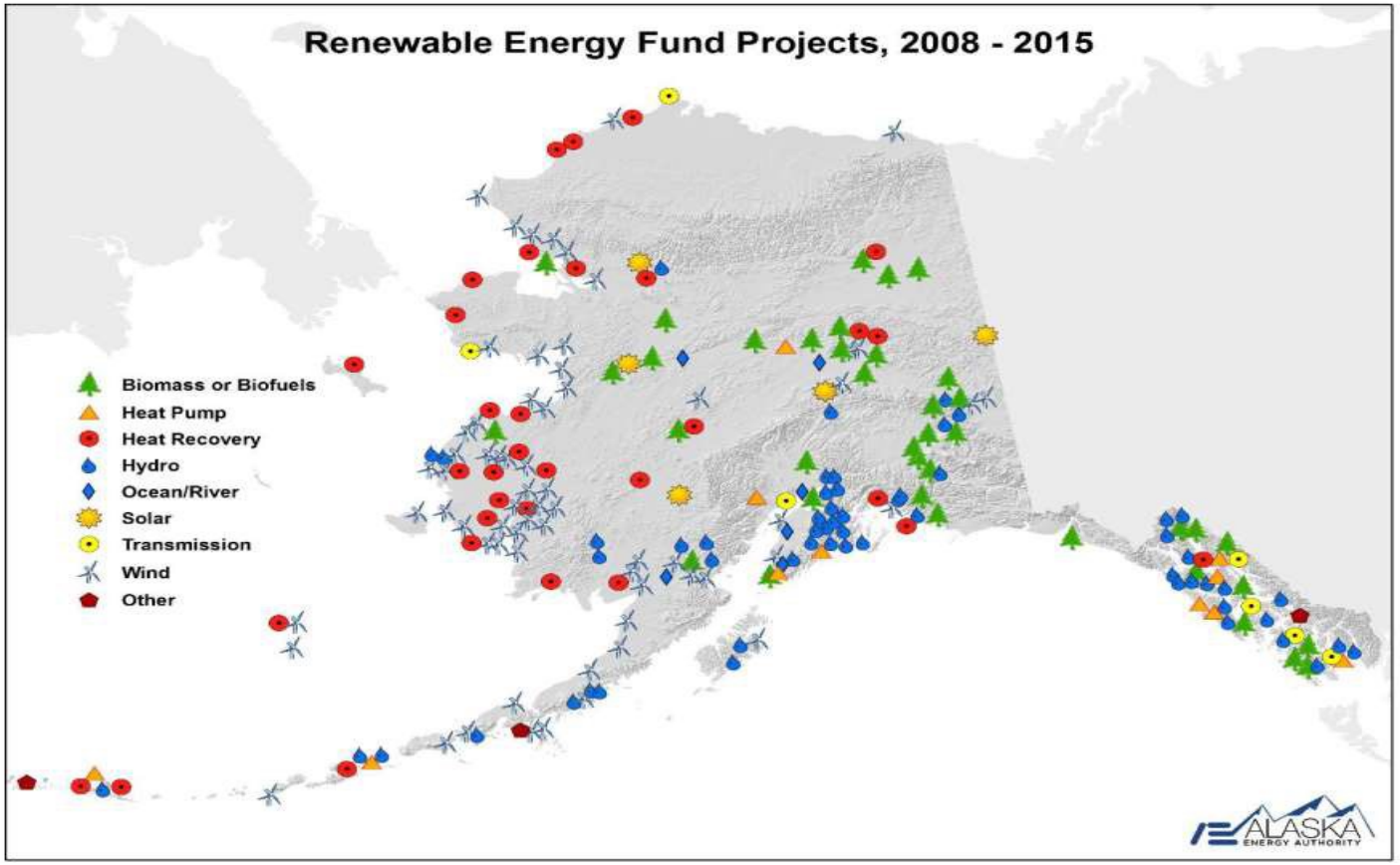


- Firm generation
- Intermittent generation
- Energy storage
- Demand Response

Alaska's Remote Islanded Microgrids

70 of ~200 Alaska RIMs use renewable energy sources



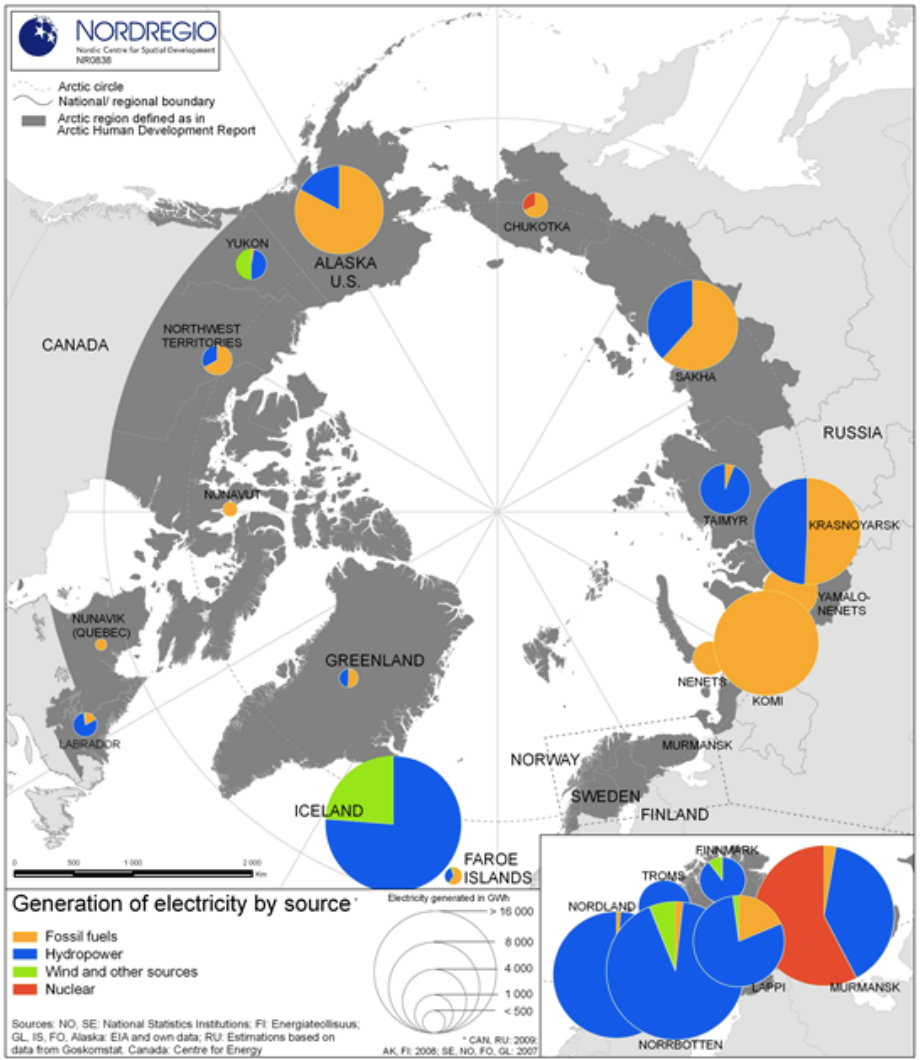


Alaska has ~12% of the worlds microgrids that incorporate grid scale renewable resources. *(data from Navigant Research)*

The Arctic region is a global leader in renewable energy development

- ✓ Finland (39%, biomass)
- ✓ Sweden (48%, hydropower, biomass)
- ✓ Norway (99%, hydropower)
- ✓ Iceland (100%, geothermal, hydropower)
- ✓ Greenland (70%, hydro)
- ✓ Alaska (12% of world's hybrid energy microgrids)

From http://www.nordregio.se/en/Maps--Graphs/05-Environment-and-energy/Generation-of-electricity-in-the-Arctic/



Alaska Islanded Grid Realities

- Harsh and changing climate
- End of supply lines
- Dispersed population
- Limited road network

Limited fuel delivery on ice roads

Erosion from fall storms - Shishmaref

Icebreaker supported fuel delivery to Nome

Alaska Islanded Grid Realities

- High energy costs (diesel fuel for electricity and heat)
- Fragmented electric grid
- Stranded resources

St. Paul Island Wind:
3-275 kW Vestas V17

Oil Stove:
Heating oil costs
$3.50 to $10/gallon
6- 18 kr./ liter

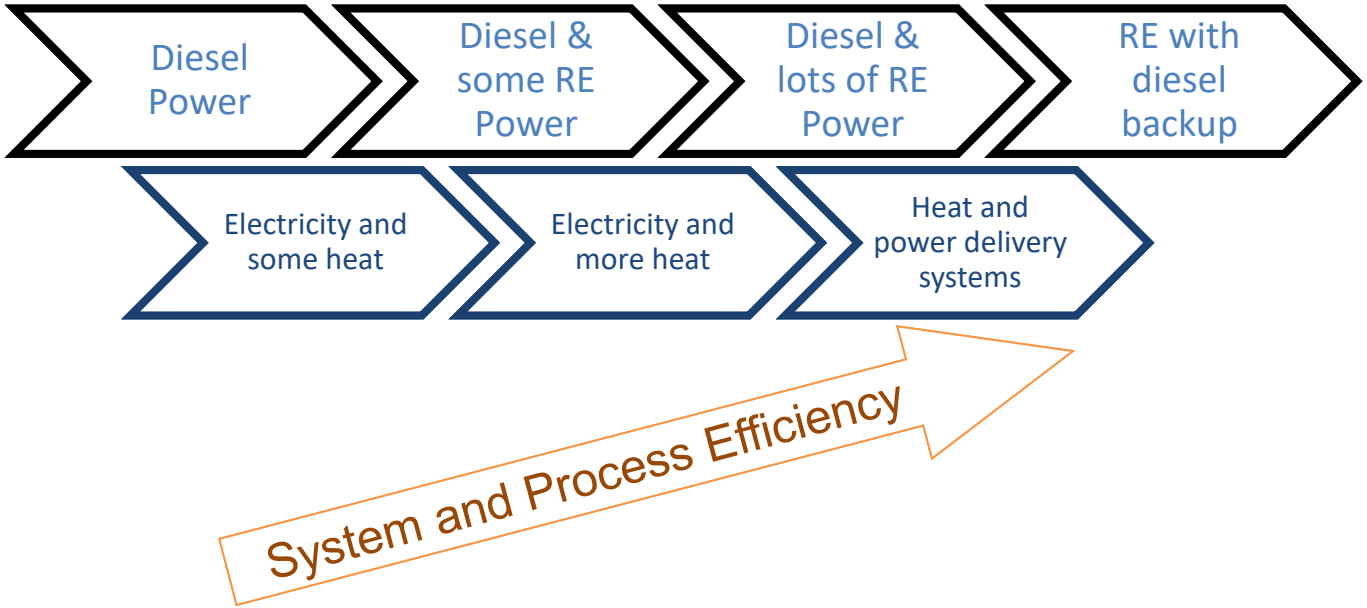
Diesel Generators:
Electric power in rural Alaska
costs $0.50-$1.50/kWhr
3,5-10 kr/kWh

Rural Alaska: Diesel Electric Generation

(add renewables to displace diesel fuel)

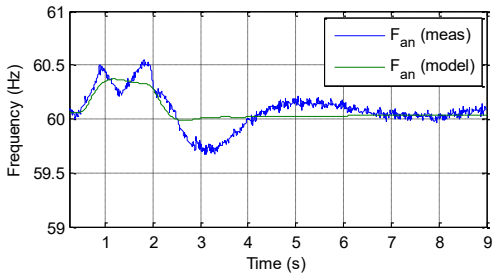
Renewable Energy Integration: Objectives and Trajectories

- Increase utilization of local resources
- Practical, cost effective, sustainable, reliable, resilient



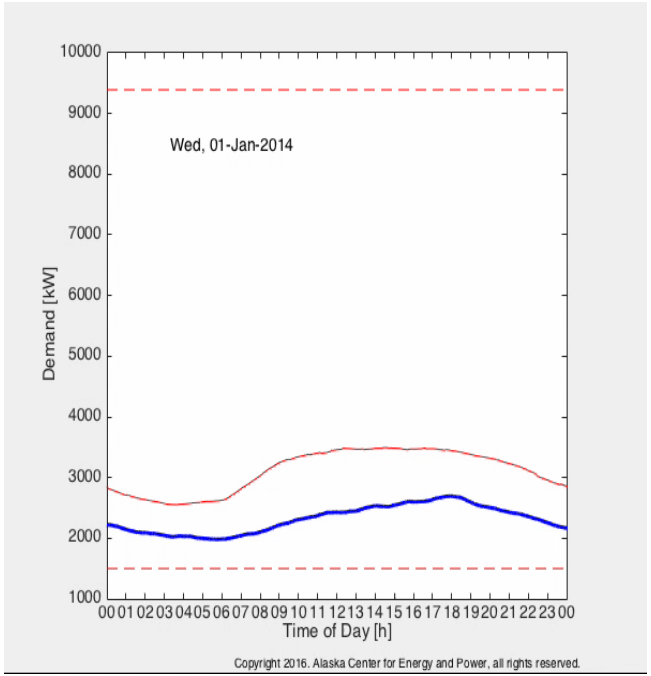
Hybrid RE-Diesel Considerations

- Variability of resources
- Demand swings
- High penetration
- Lost potential (wind curtailment, spilled hydro …)
- Load levelling & peak shifting
- Energy storage (?)



Wind Power Fluctuations

Seasonal Demand Swing – Cordova, AK



Cordova Energy Mix (2011):

18 GWh Hydropower

10 GWh Diesel

781,000 Gal Diesel @ $3.55/gal
= $2.77M Fuel bill = 18,82 mio. kr.

Cost of generation:
Hydro: ~$0.06/kWh - 0,4 kr./kWh
Diesel: ~$0.35/kWh 2,37 kr./kWh

Estimate: 3.8 GWh spilled hydro

Question: *Can some of the spilled hydro be recovered to displace diesel fuel?*

Answer: *Yes. July 23, 2019 (Cordova uses newly installed 1 MWhr battery/inverter system (isochronous) to operate in diesel-off mode for 12 hours with a >5 MW load)*

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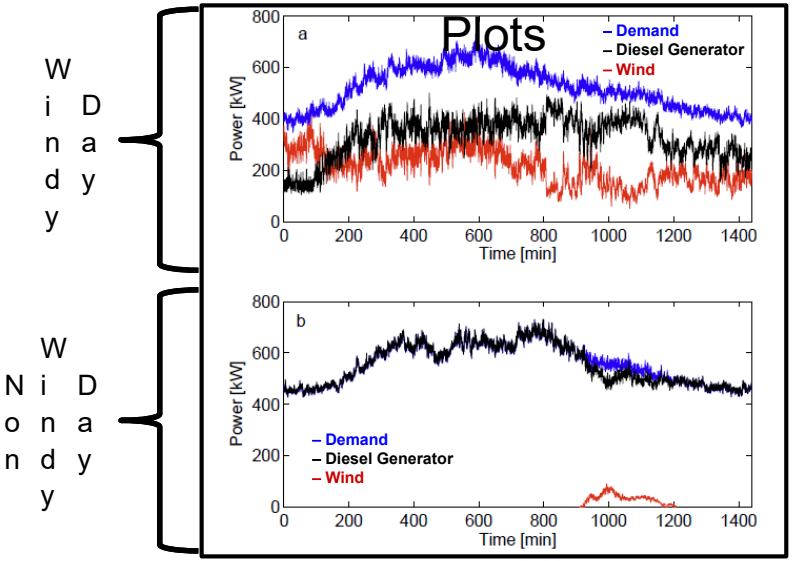
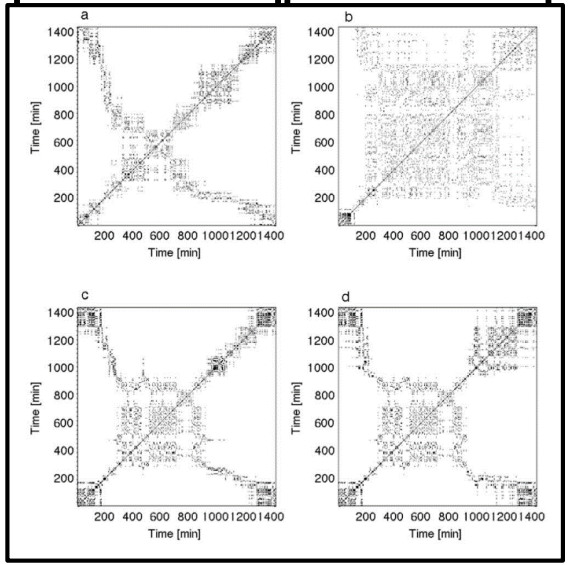
Unalakleet Wind Curtailment

- Issues:
  - Manual curtailment during high wind periods
  - 3 mile line @ 2.4 kV (reactive comp.?)

Time Domain Power Plots



Power State Recurrence Plots



(1-min averages, 5 kW threshold)

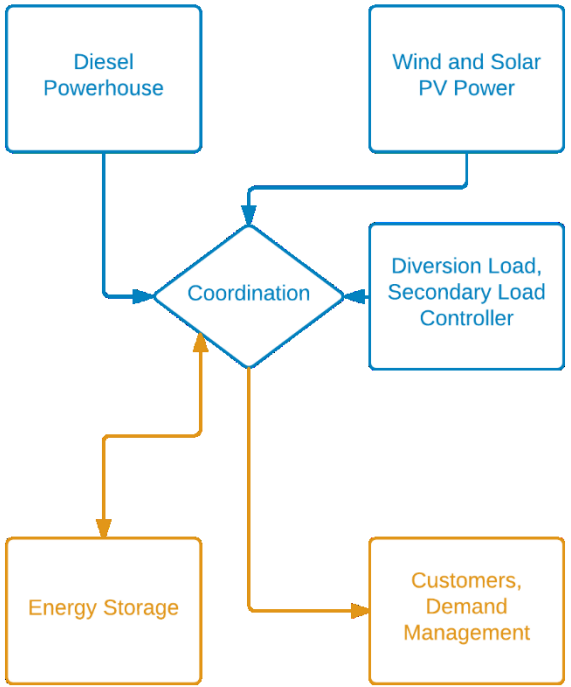
Diesel Limitations in Hybrid RE-Diesel

- Minimum optimal loading
  - 20% to 40%; nominal 30%
  - Low efficiency at low load
- Spinning reserve
  - Contingency for demand increase or RE power drop
- dP/dt limitations
- Minimum run-time
- Hot stand-by required for fast starts

Image source: http://www.dieselmarinegroup.com

RE Penetration in Hybrid RE-Diesel

- Low RE Pen. (Inst.: < 50%; Avg.: < 20%)
  - Considered as negative load
  - Diesels provide spinning reserve
  - RE output is often not controlled
  - Minimal stability and power quality issues
- Medium RE Pen. (Inst.: 50-100%; Avg.: 20-50%)
  - Requires diversion load and secondary controls
  - Diesels provide the grid
    - require minimum optimal load (MOL)
    - spinning reserve
  - Stability and power quality can be severely impacted
- High RE Pen. (Inst.: 100-400%; Avg.: 50-150%)
  - Diesels or energy storage form grid
  - Distributed demand management
  - Coordination and control is complex
  - Severe stability and power quality issues w/o energy storage



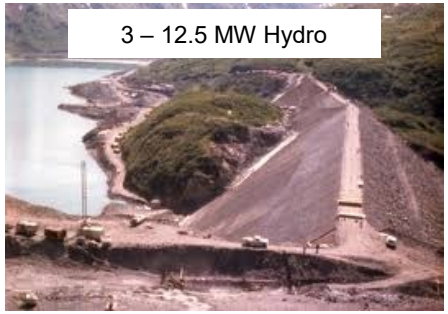
RE Only Operation (Diesel-Off)

- Requires alternative:
  - Voltage source
  - Reactive power-support
  - Inertia (synthetic)
- Energy storage
  - Spinning reserve (seconds)
  - Bridging (minutes)
  - Shifting (hours+)
- Significant transient stability issues

Unalakleet Wind (6-100 kW NPS)

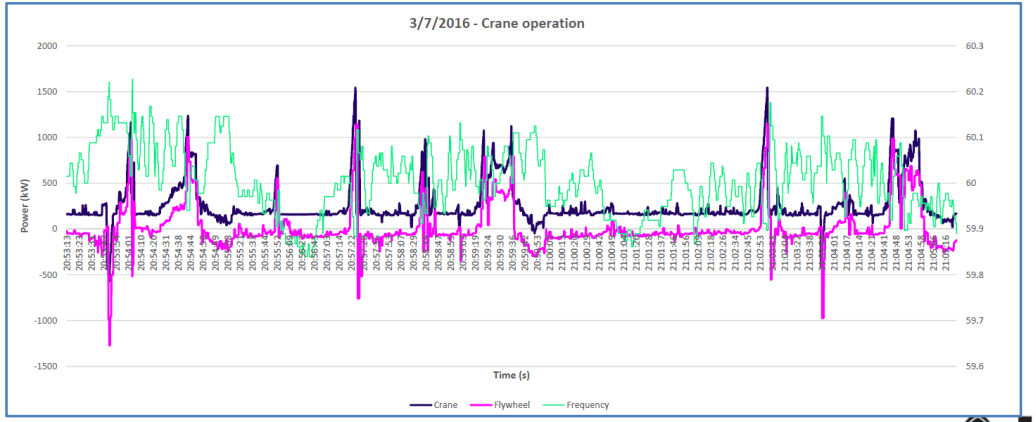
Kodiak Island: 100% renewable generation

Hydropower + Wind + Energy Storage (Battery and Flywheel)



Inverters 500– 1,500 kVA

18 MWs Flywheel



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Tuntiluliak, Kongiginak, Kwigillingok: Wind Heat System

Diesel off with wind + energy storage + distributed heating

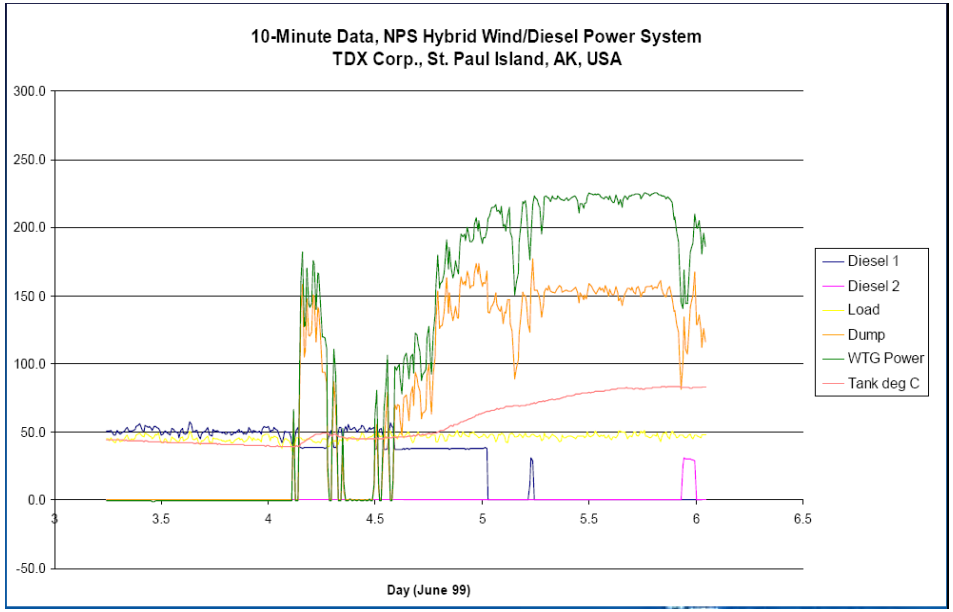
Images: Right: ***20+ thermal electric stoves installed in elder and low-income homes; Left: 5 – 95 kW Windmatic direct drive turbines (30-40% wind penetration annually)***

St. Paul Island

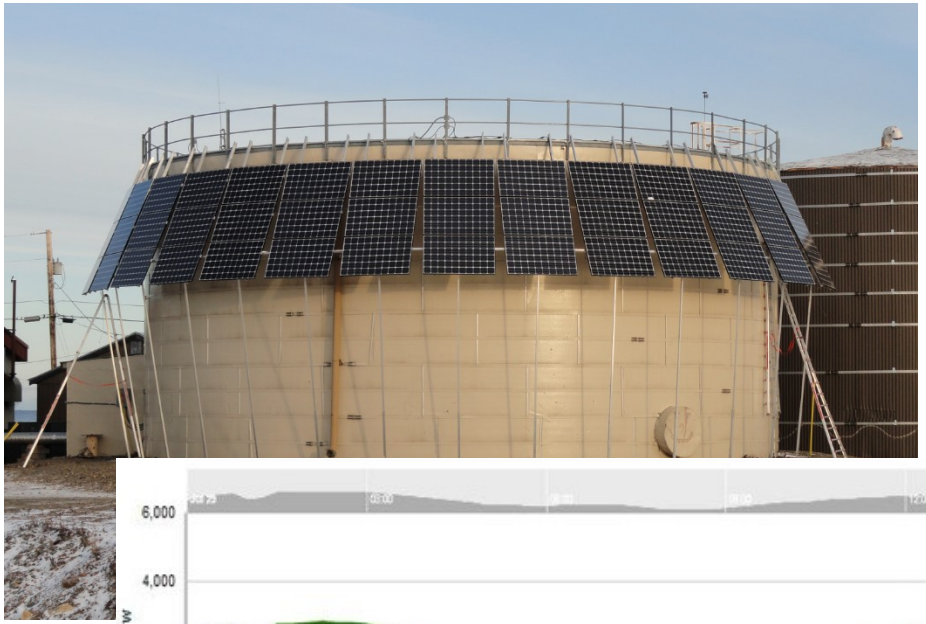
Diesel off – 17 years of operation

Wind + Diesel + Synchronous Condenser + Thermal dump loads

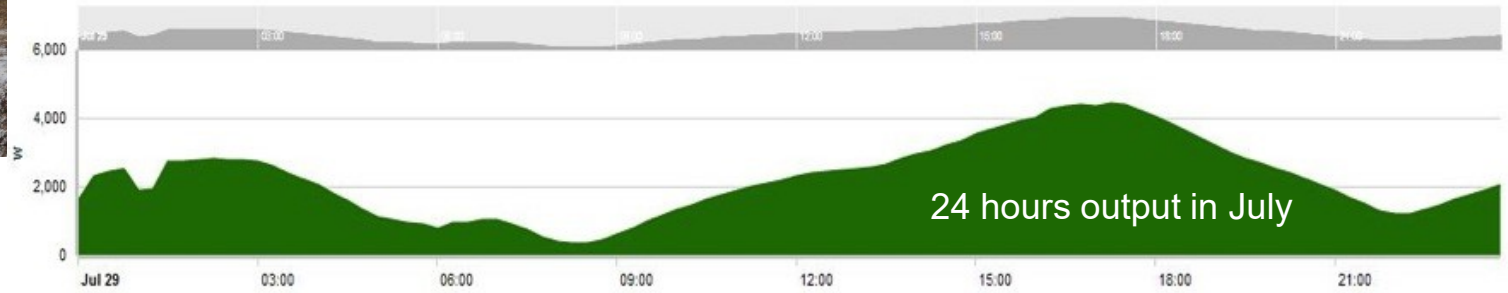
St. Paul Island Wind:
3-275 kW Vestas V17



Solar PV in Rural Alaska



Deering, Alaska
Population = 125 residents
10 kW Multi-directional array
Produces consistent power throughout day (and night)



Solar PV in Rural Alaska

Shungnak, Alaska Population = 262 residents, 10 kW array, provides up to 100% power to water and waste water treatment plant.

Noorvik, Alaska, Population = 683 residents, 10 kW array, installed with local labor.

Eagle Hydrokinetic Energy Project

25 kW system provided diesel off 100% power to Eagle Village

Igiugig Hydrokinetic Project

75 kW system from Ocean Renewable Power Company

Grid-Bridging Development

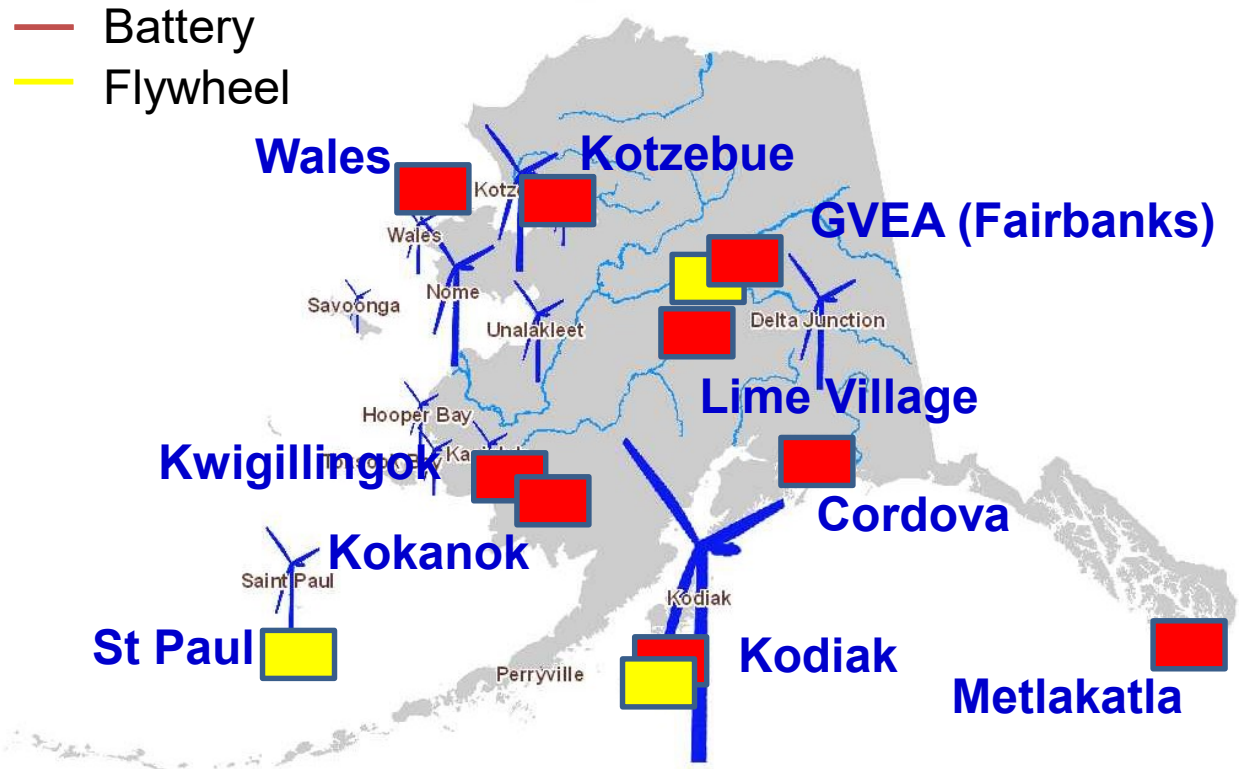
- Power bridge to absorb variations in hybrid-diesel systems
  - Adjust power generation and interruptible loads
  - Reduce spinning reserve (diesel use)
  - Energy storage with control

Flywheel (St. Paul)

Wind

Electric Thermal Storage

Existing Alaska Battery and Flywheel Projects

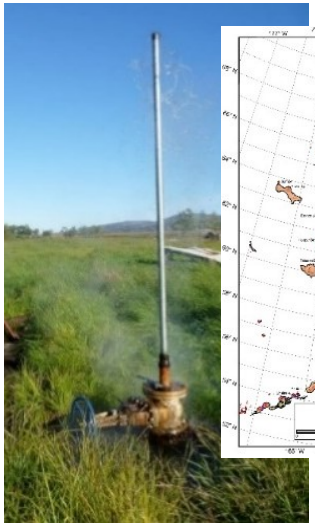


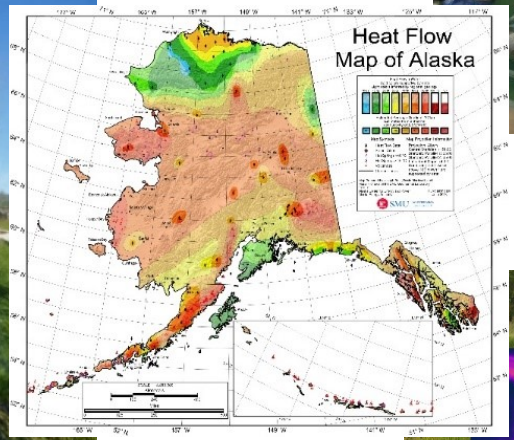
Prime Power RE Resources

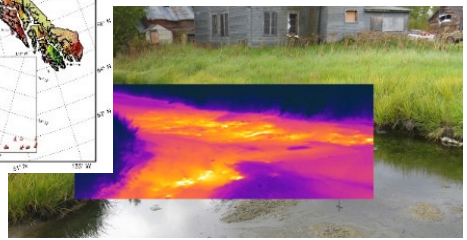
- Leverage local RE resources for prime power
  - Diesel off operation: use diesel genset as backup power
  - Enhanced system-level efficiency, reliability, and resilience
  - Ex: HKE and Geothermal Organic Rankine Cycles (ORC)

Hydrokinetic Energy (HKE)

Geothermal (ORC)



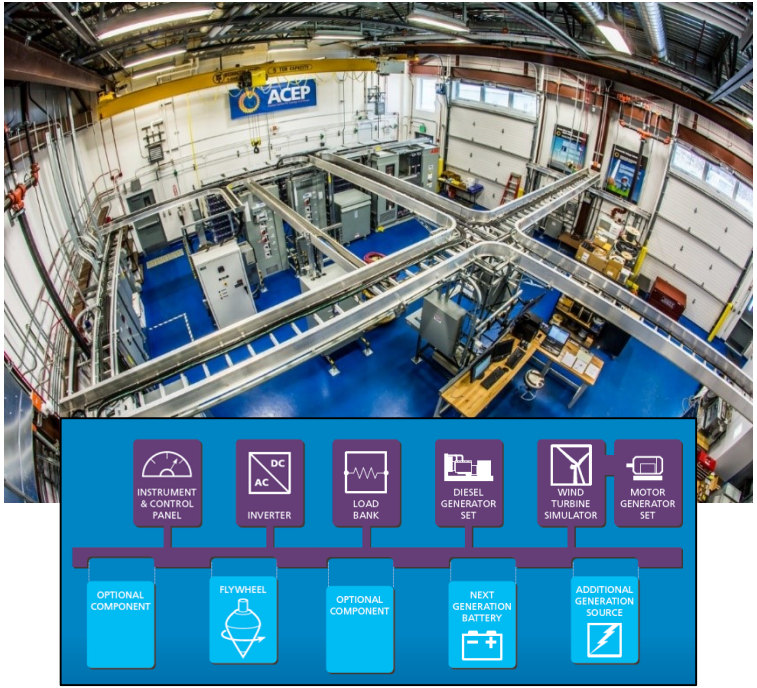




Power Systems Integration (PSI) Lab

Lab recreates an islanded microgrid at full power levels (500 kW)

- 320 kW Cat C-15 diesel, w/ Woodward EasyGen 3200
- 100 kW Wind Turbine Simulator (induction)
- 100 kW Solar PV Simulator w/ grid-tie Fronius Inverter
- 313 kW ABB PCS100 Inverter
- 540 VDC/1000 Ah Absolyte VRLA Battery
- Two reactive 250 kW LoadTech Loadbanks
- Fault Simulator
- 1000+ channel custom data collection



Example 1: Flywheel/controls Integration

Customer:

- Hatch Engineering (Canadian Company)

R&D and Testing of:

- Williams/KTSI 200 kW Flywheel
  - power quality mitigation strategies
  - power smoothing
  - Controls for dispatch and SOC management

Example 1: Flywheel/controls Integration

System has now been installed at the Raglan Mine in Northern Quebec (Canada)

Example 2: In-River Hydrokinetic Turbine

Customer:

- Oceana Energy

2-4 m/s

R&D and Testing of:

- 25 kW Oceana Turbine
- Ideal Power Inverter
- EnerDel Li-ion Battery

Takeaways

- Alaska's Remote Islanded Microgrids
  - Operation in harsh environments
  - Fragmented grid
  - High energy cost
- Renewable Integration Challenges
  - Increased grid instability with higher instantaneous RE penetration
  - Diesel
    - Minimum optimal loading (MOL)
    - Start and stop cycle limitations
    - Decreased efficiency at low load
  - Distributed control and storage required
- Pre-Deployment Development and Testing Required

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Visit us at http://acep.uaf.edu/facilities/power-systems-integration-lab.aspx

Thank you!