Integrated Microgrid Technologies

Alternatives to diesel generation – Systems perspective

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Terminology

- Islanded: not connected to a transmission grid.
- Microgrid: a small-scale power grid that can operate independently or in conjunction with the area's main electrical grid.
- Hybrid-Diesel: grid powered by diesel and other (renewable) power sources.
- Renewable Penetration: the fraction of renewable power (instantaneous penetration) or energy (average penetration) in the grid.
- Diesel-off: operation without (mechanical) synchronous generator.

Overview

- Alaska Context
- Alaska Center for Energy and Power
- Diesel generation
  - Services provided
  - Implications of Renewable Integration
- Renewable Penetration – function of system design
- Enabling technologies for high-penetration
  - What it takes to get off diesel
  - Energy systems perspective

Alaska Remote Power

- 250+ remote islanded microgrids in AK:
  - May exhibit renewable **power** penetration in excess of 300%
  - Have achieved >98% renewable **energy** penetration
  - Permanently islanded = millions of hours of `lower-48 emergency' operation
  - Function in challenging:
    - Technical conditions
    - Logistic conditions
    - Economic conditions
    - Human capacity conditions

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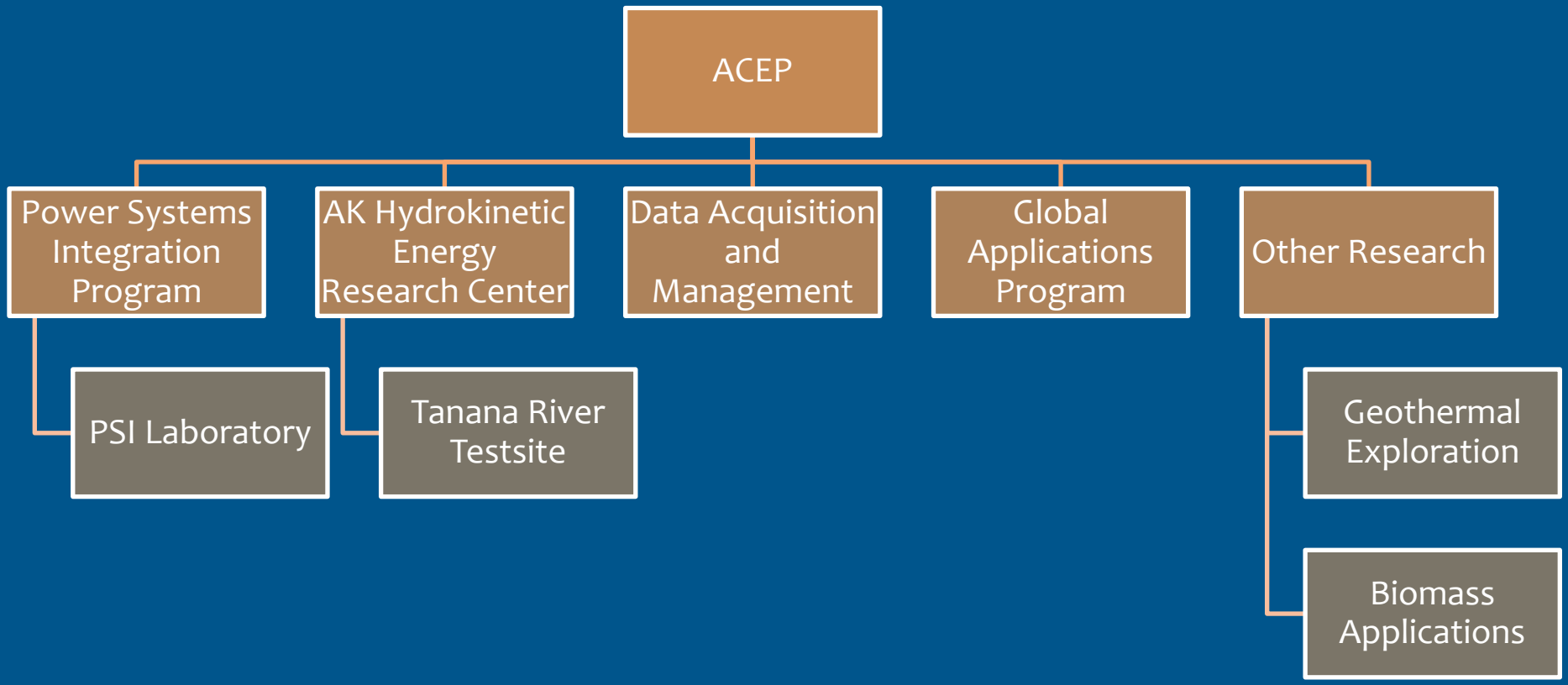
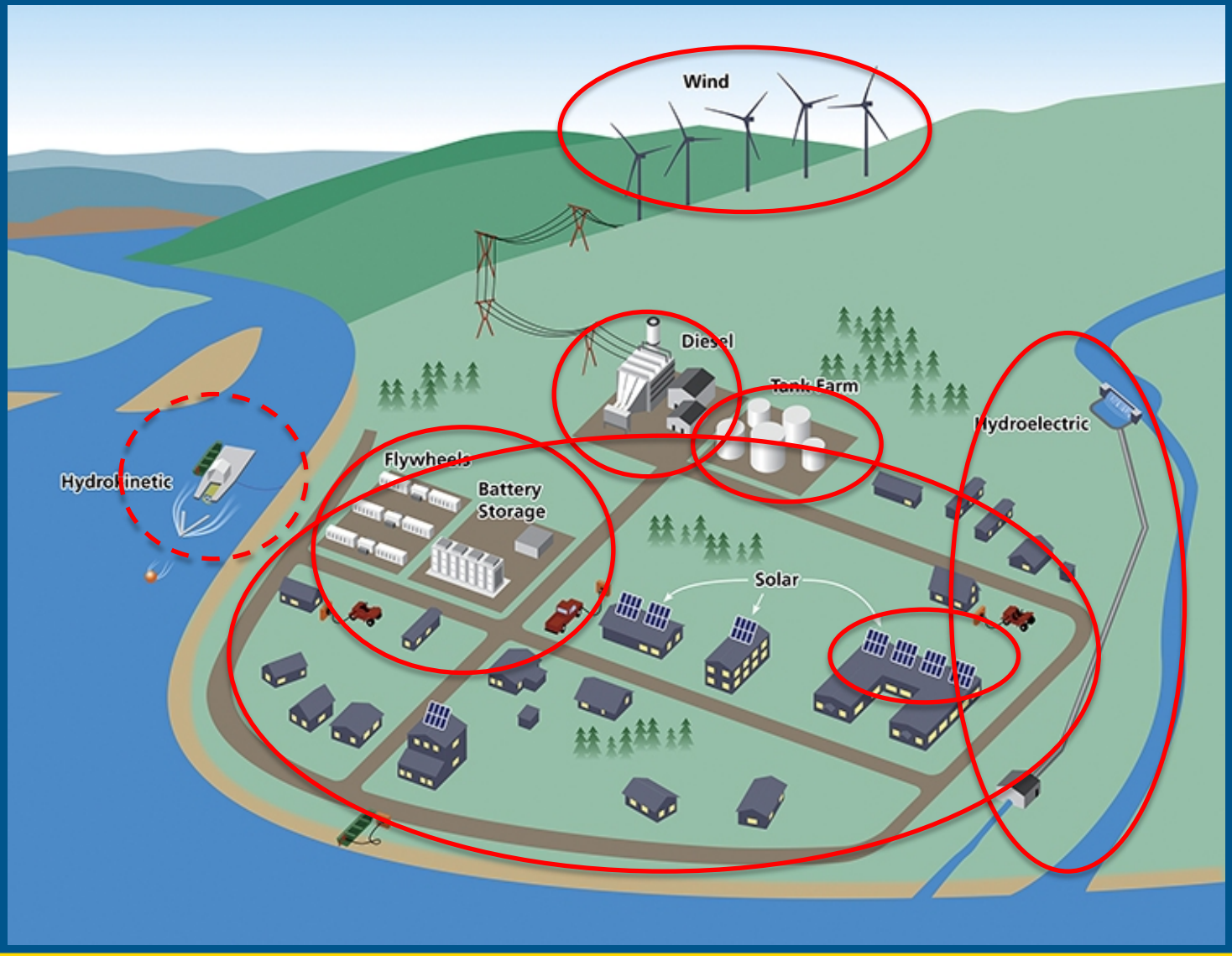
Mission: *Develop practical and cost effective energy solutions for Alaska and beyond.*



Remote off-grid microgrids

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



Services provided by diesels*

- 'Form the grid'
  - Provide Voltage and Frequency reference
- Inertia
  - Can ride through minor disturbances
- Provide spinning reserve capacity
  - Backstops drops in renewable power
  - Backstops increases in demand
- Fault current/clearing
  - Clear transient faults
  - Drive sufficient current to trip breakers
- Firm power source
- Waste heat

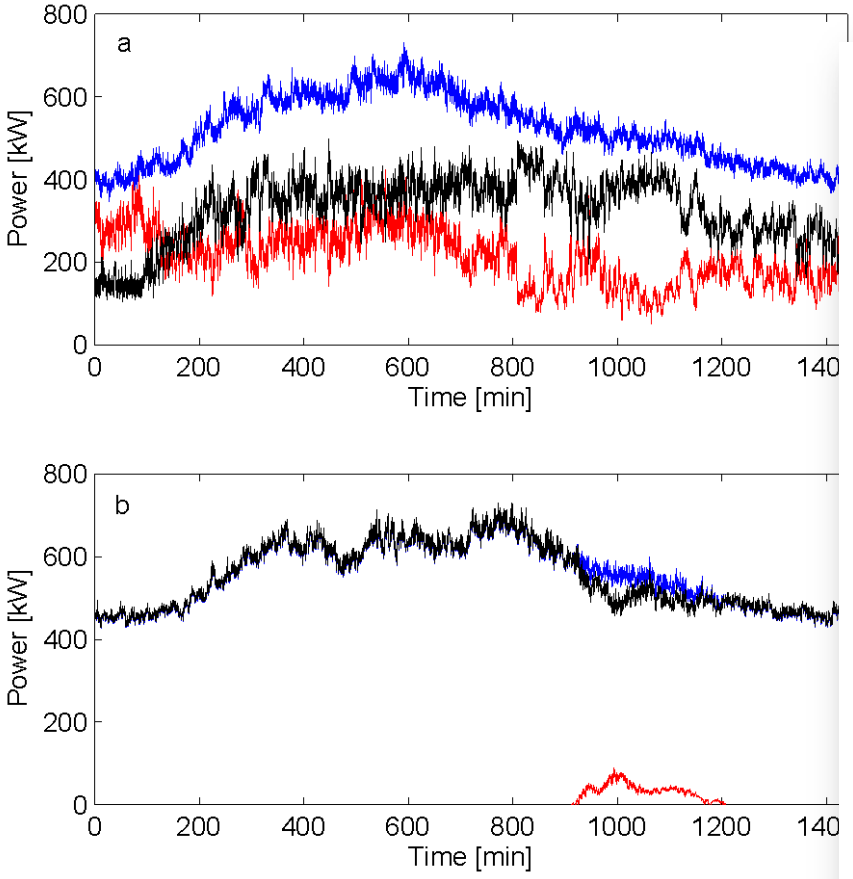
* Or other firm generation.

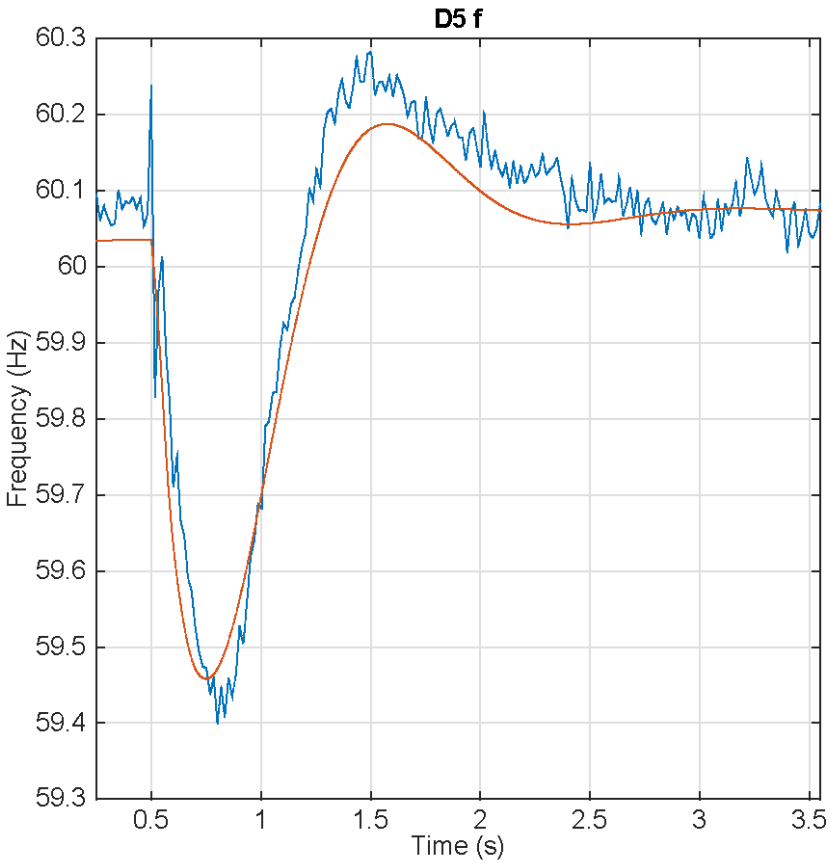
Diesel limitations

- Minimum optimal loading
  - 15% to 60%
  - 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

Spinning Reserve and Power Quality





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How much RE is possible?

- Firm RE: 100%
  - Assuming synchronous generation
  - Hydro, geothermal, hydrokinetic (?)
  - Issues:
    - PQ: intermittent RE
    - MOL: diesel

3MW hydro turbine, Cordova, AK.

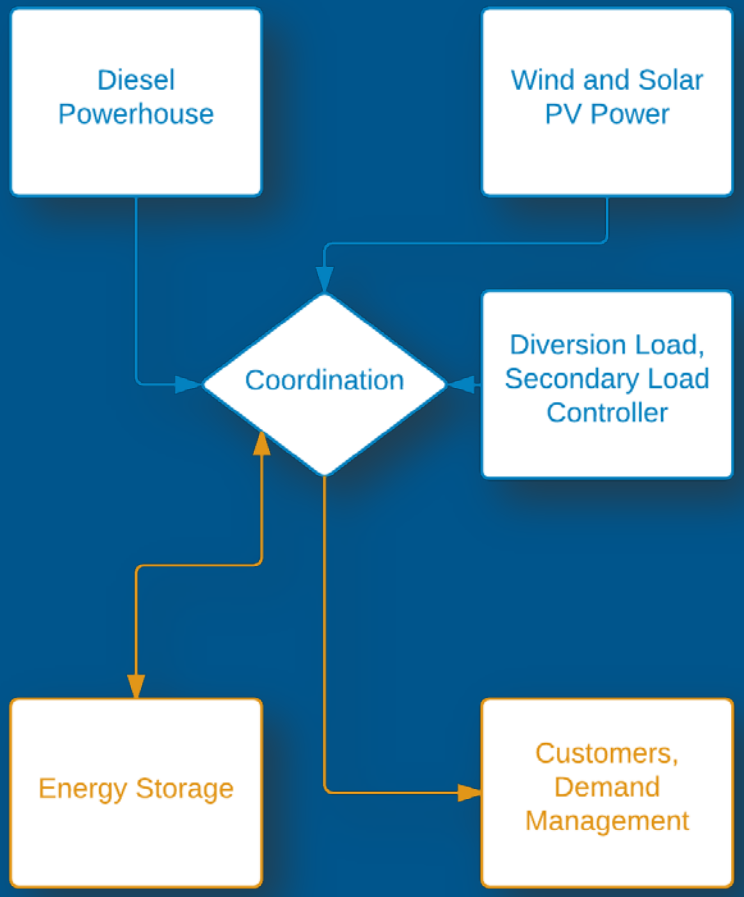
How much Intermittent RE?

Penetration Class	Operating Characteristics	Power Penetration	Energy Penetration
Very Low	No integrated control system	<60%	<8%
Low	Integrated controls curtail/dispatch RE; Simple managed loads	60 – 120%	8 – 20%
Medium	Sophisticated managed loads	120 – 300%	20 – 50%
High	Diesel-off possible; highly sophisticated controls; potentially energy storage	300 – 900%	50 – 150%

Empirical results based on Alaska wind-diesel systems compiled by I. Baring-Gould (NREL) and R. Stromberg (Alaska Energy Authority).

Limits without Energy Storage*

- Demand response only
  - Diversion loads
  - Secondary load control (PQ stabilizer)
  - Distributed controlled loads
    - Electrothermal



* One system operates in diesel-off w/o storage.

Conceptual Model

- Objective: corroborate empirical findings
- Consider:
  - 1 MW system
  - Various control options
  - Operational envelope of diesel power plant
- Ignore:
  - Specific variability of RE resource (diurnal, seasonal, stochastic)
- Results:
  - POWER Penetration result support empirical findings
  - Diesel sizing matters

Case	RE Power Penetration	Generator 1 [kW]	Managed Load [kW]	Classification
No control	0.50	480	-	Very Low
Curtail	0.54	440	-	Very Low/Low
Fixed DR	1.33	340	290	Low/Medium
Variable DR	1.55	340	270	Low/Medium

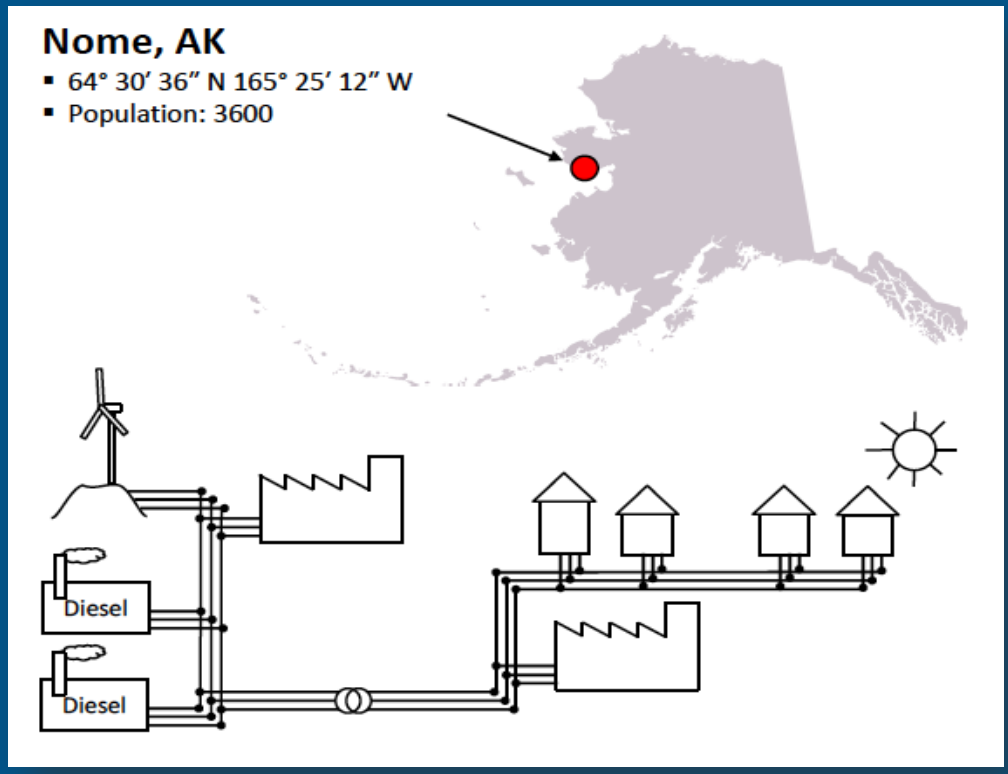
Energy storage applications

- Reduce fuel utilization:
  - Delay diesel starts (spinning reserve, short-term storage)
  - Load diesels optimally (medium/long-term storage)
  - Turn diesels off at times (grid-forming, short to long-term storage)
- Stabilize the grid
  - Improve power quality (short-term storage)

Energy Storage for Nome, AK

Objective: Avoid or delay diesel starts by providing spinning reserve capacity (SRC) with storage.

- Wind-diesel system
  - 4 MW average demand
  - 2.7 MW wind nameplate capacity
  - Diesels: 1.9, 3.6, and two 5.4 MW units
- Wind power diversion to boilers at times
  - Stability and minimum optimal loading issues



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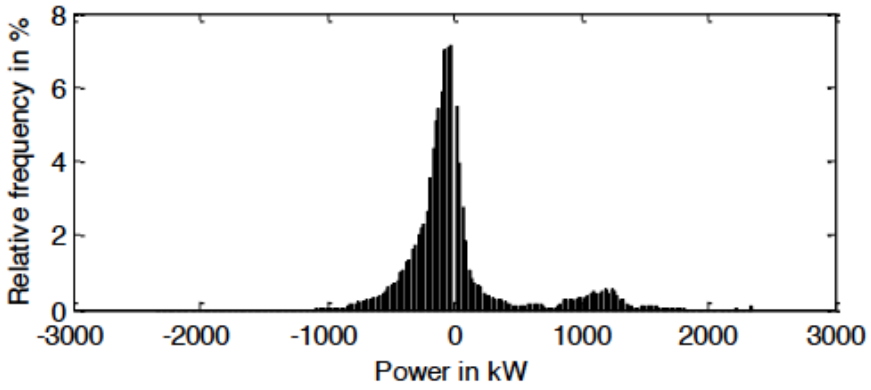
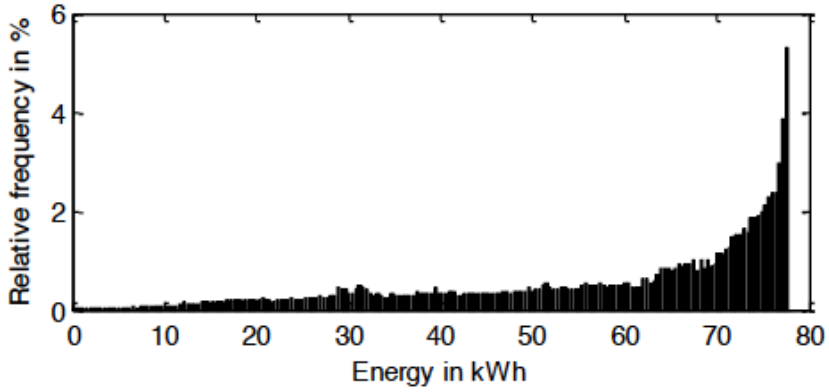
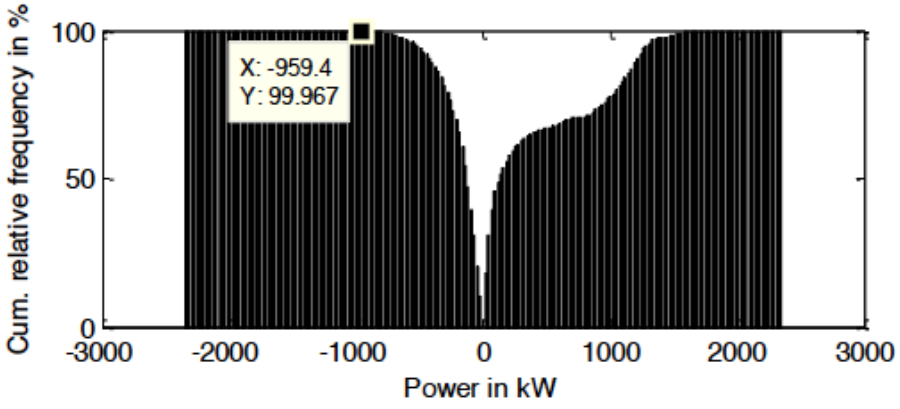
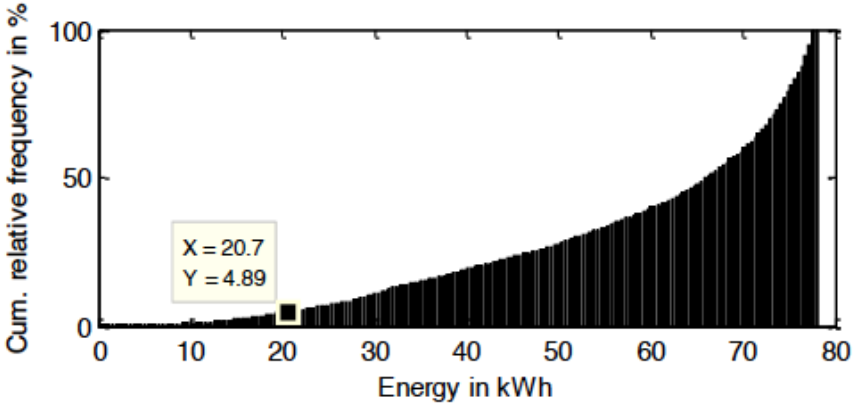
Nome, AK: Specification



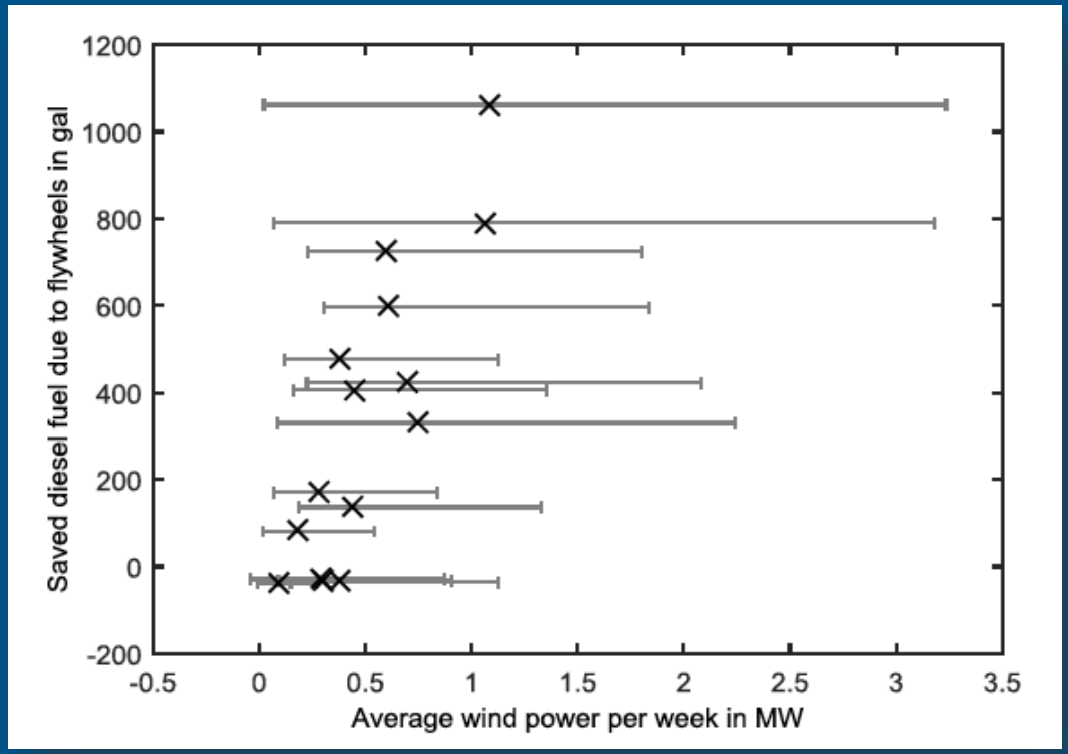






Nome, AK: Assessment

- Fuel savings with primary objective only:
  - 430 to 1150 gal/week (medium to high winds)
  - Slight increase in fuel use for stand-by operation
- Potential value add:
  - Diesel demand smoothing



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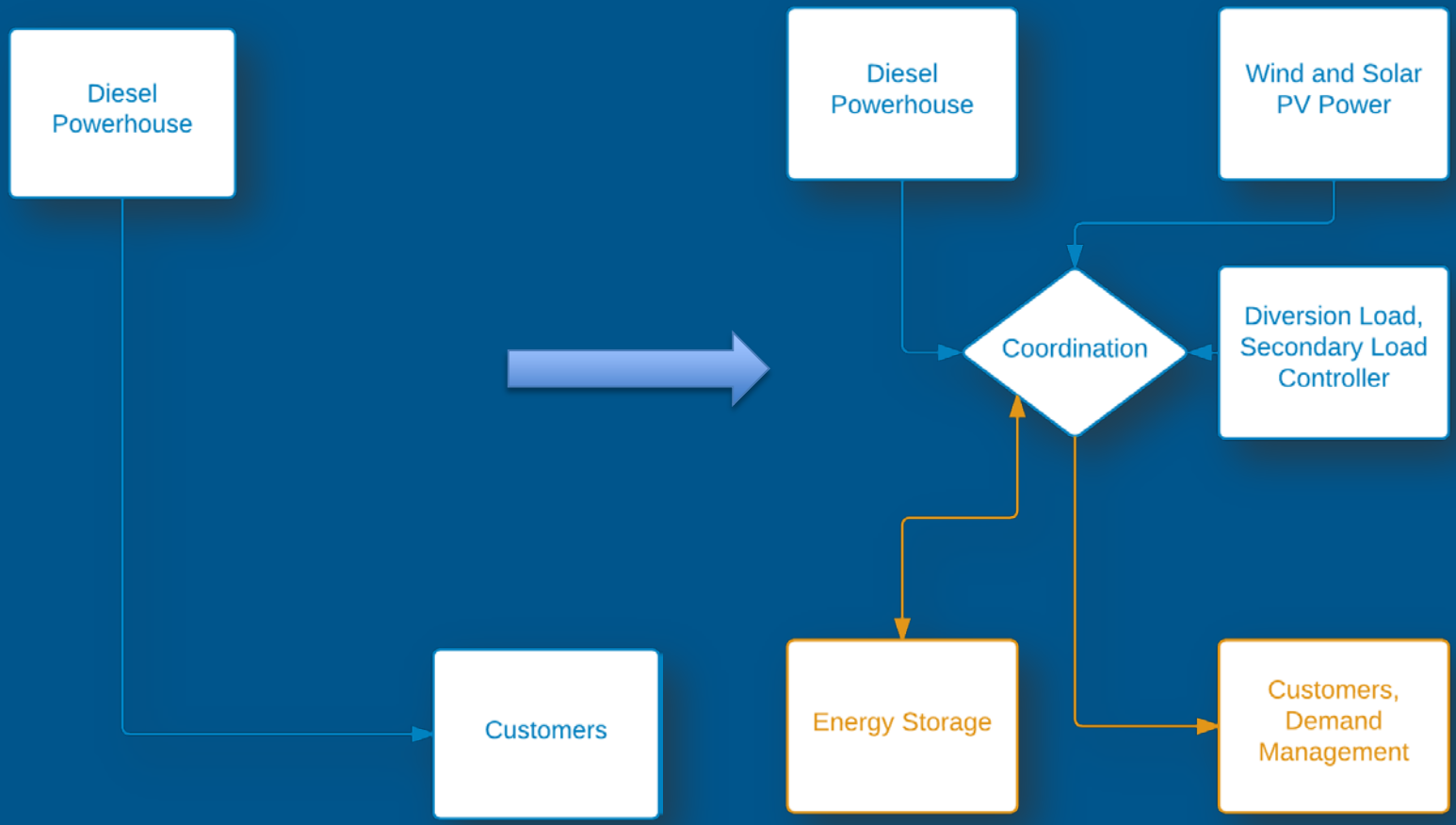
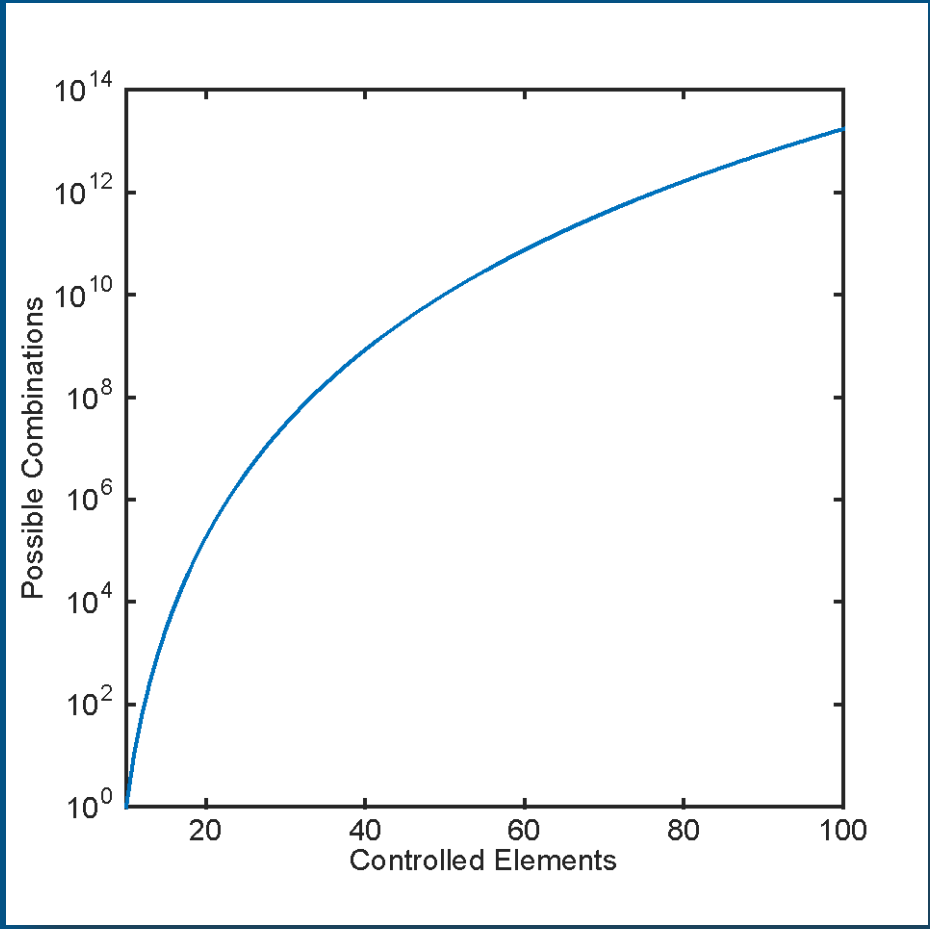
Increasing complexity



Improved optimal control needed

- More objectives:
  - Cheapest
  - Most reliable
  - Least diesel utilization
  - Equitable demand management
  - Maintenance schedules
  - …
- More resources
  - Renewable generation
  - Energy storage
  - Demand management
  - …



Future (near and far)

- Convergence of heat (thermal) and power systems
  - May provide maximum benefit at least cost
    - Minimize energy storage needs
    - Compete with residential fuel cost (higher than utility)
  - Missing:
    - Good data sets on heat utilization
    - Optimal control of distributed resources
    - Functional interfaces between various subsystem controls
- Supply-driven energy systems
  - Convergence with Internet of Things
  - Will need highly detailed data set on energy use
  - Will need to establish functioning ‘energy market place’ for islanded systems

Thank you!

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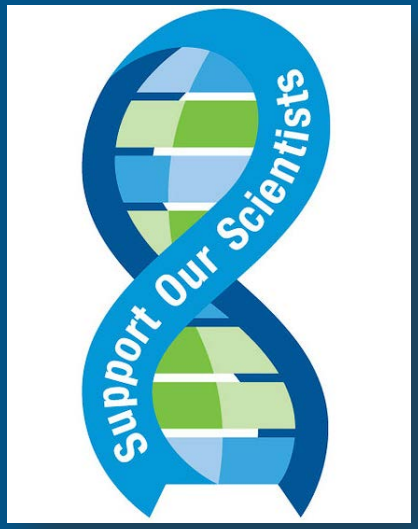

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