Alaska High Penetration Wind Diesel Systems

Katherine Keith

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High Penetration Wind Diesel Systems

Ultimate Objective:

Reduce diesel consumption

Optimizing system performance

Reduce capital cost

Definition:

Peak Instantaneous (kW) 100-400%

Annual Average (kWh) 50-150%

Ability to enter diesel off mode

Review of Wind-Diesel Classes

High

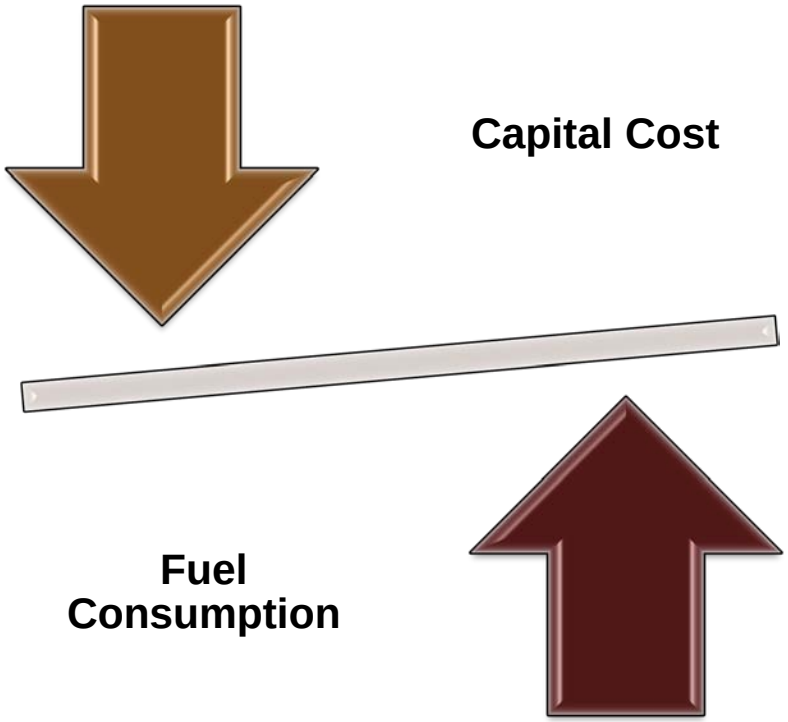
- 50-90% fuel savings
- Capital Cost-High

Med

- 15-50% fuel savings
- Capital Cost-Mid

Low

- Up to 15% fuel savings
- Capital Cost -Low



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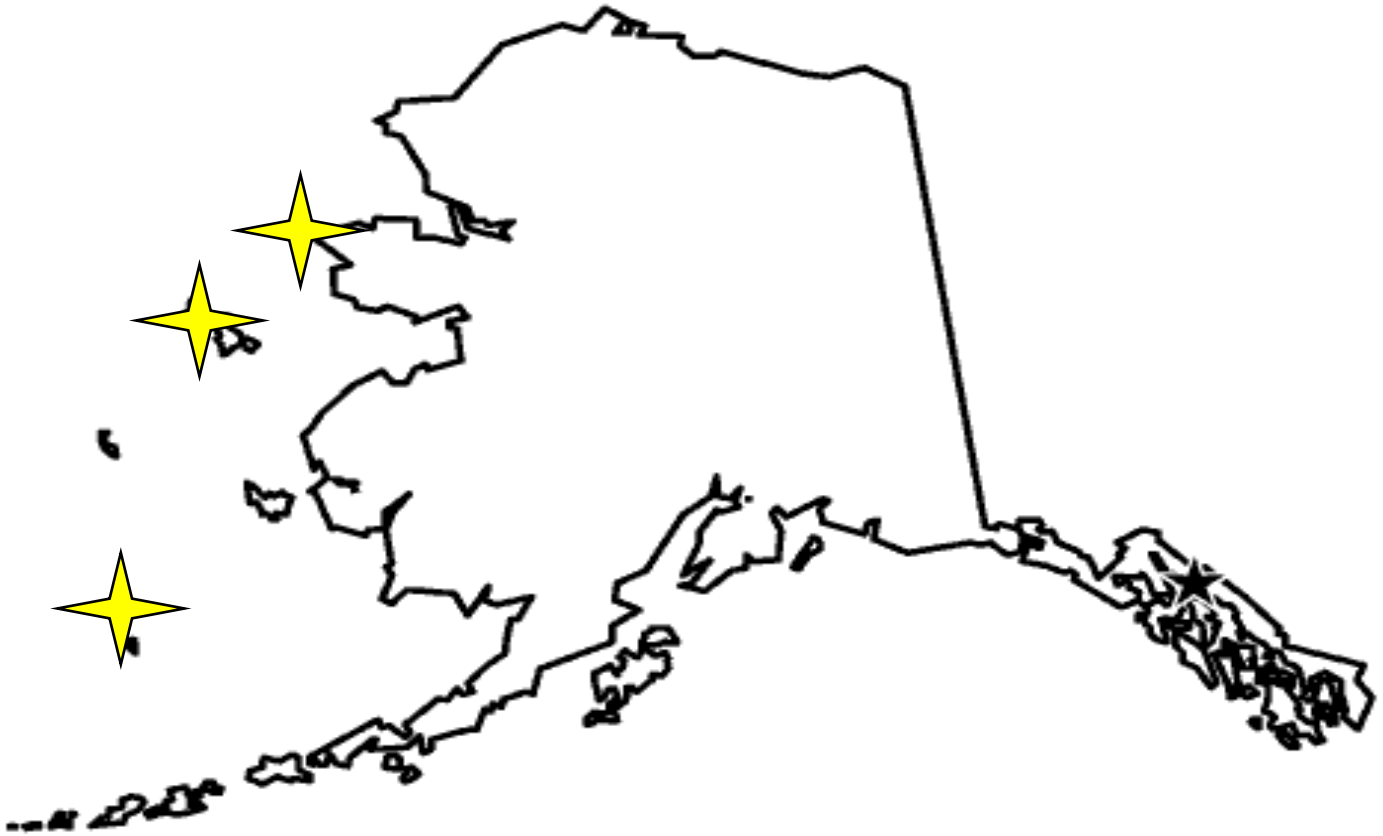
Existing High Penetration Wind Diesel



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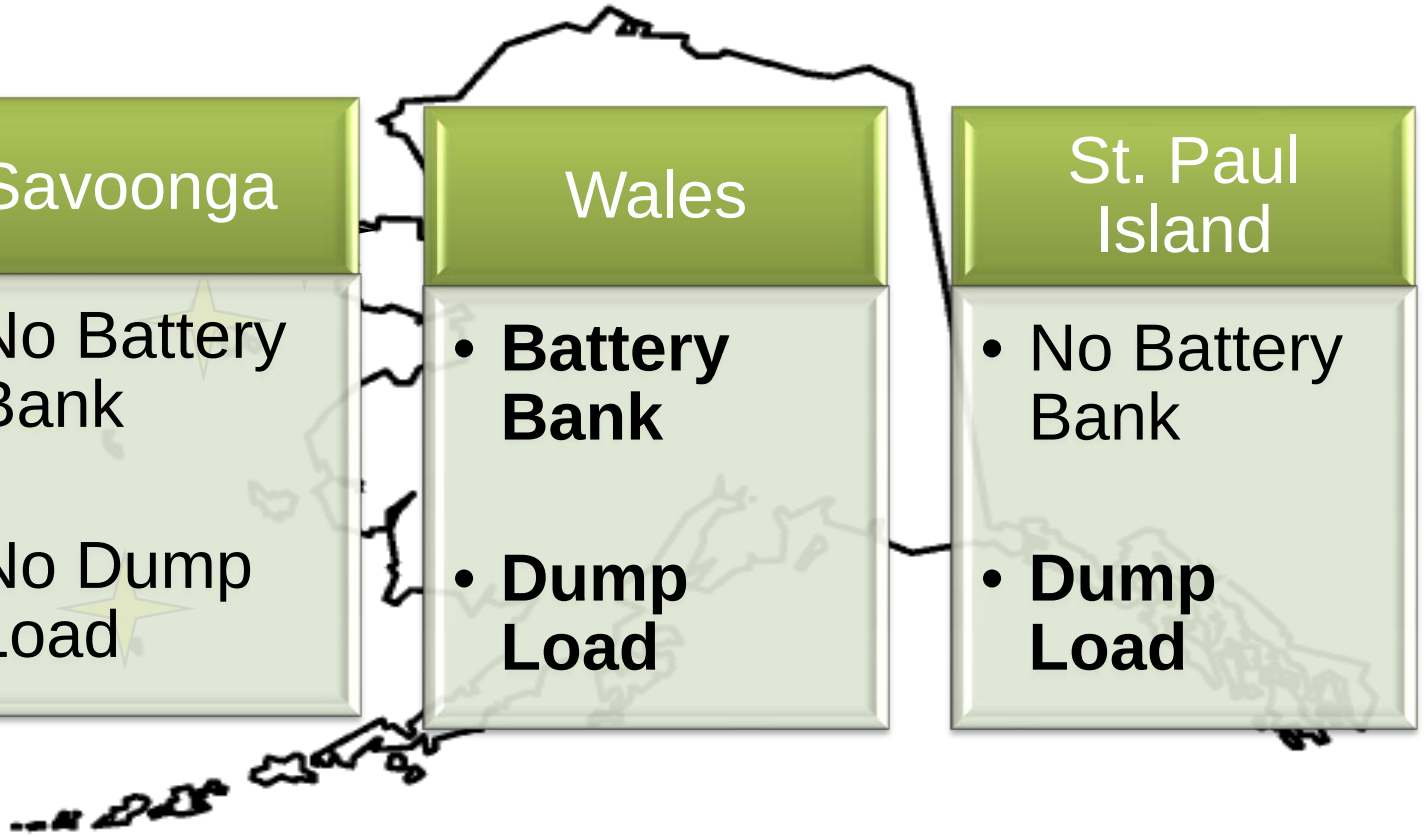
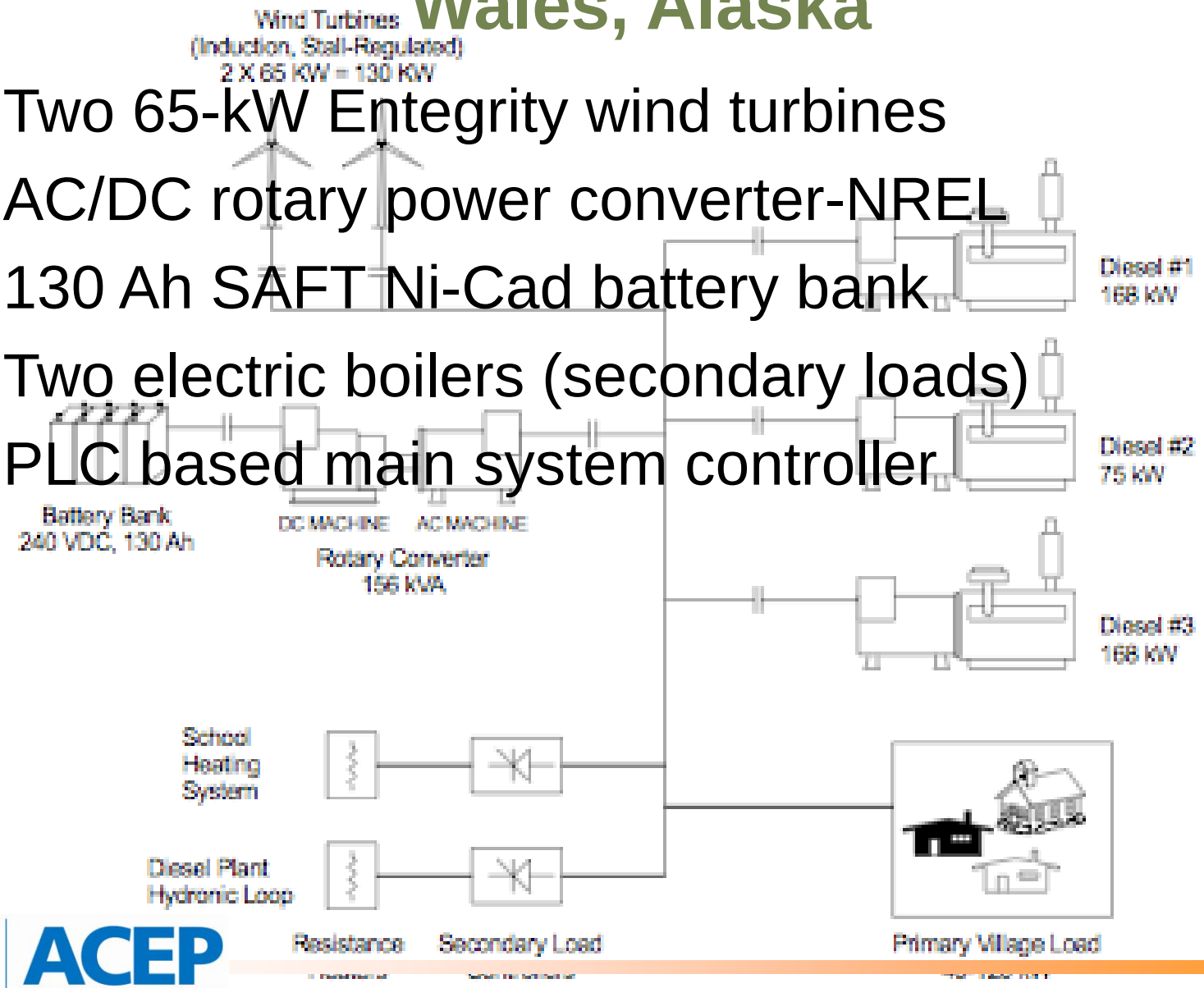


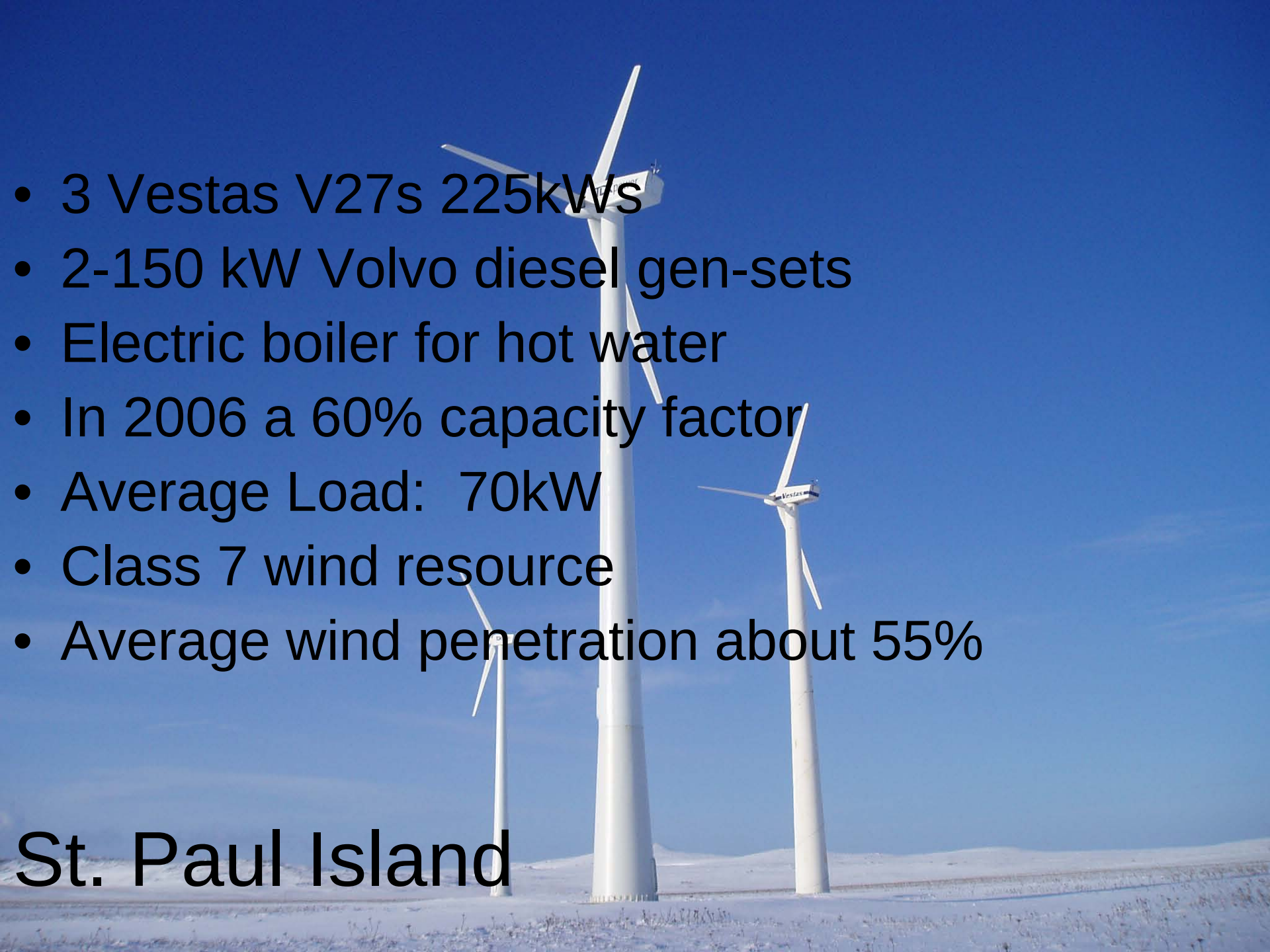
Savoonga, Alaska

- Two NW100 installed October 2008
- Up to 90% instantaneous penetration during low loads (at night in summer)
- No secondary load
- 18% average wind penetration during first few months

Wales, Alaska

- Two 65-kW Entegrity wind turbines
- AC/DC rotary power converter-NREL
- 130 Ah SAFT Ni-Cad battery bank
- Two electric boilers (secondary loads)
- PLC based main system controller

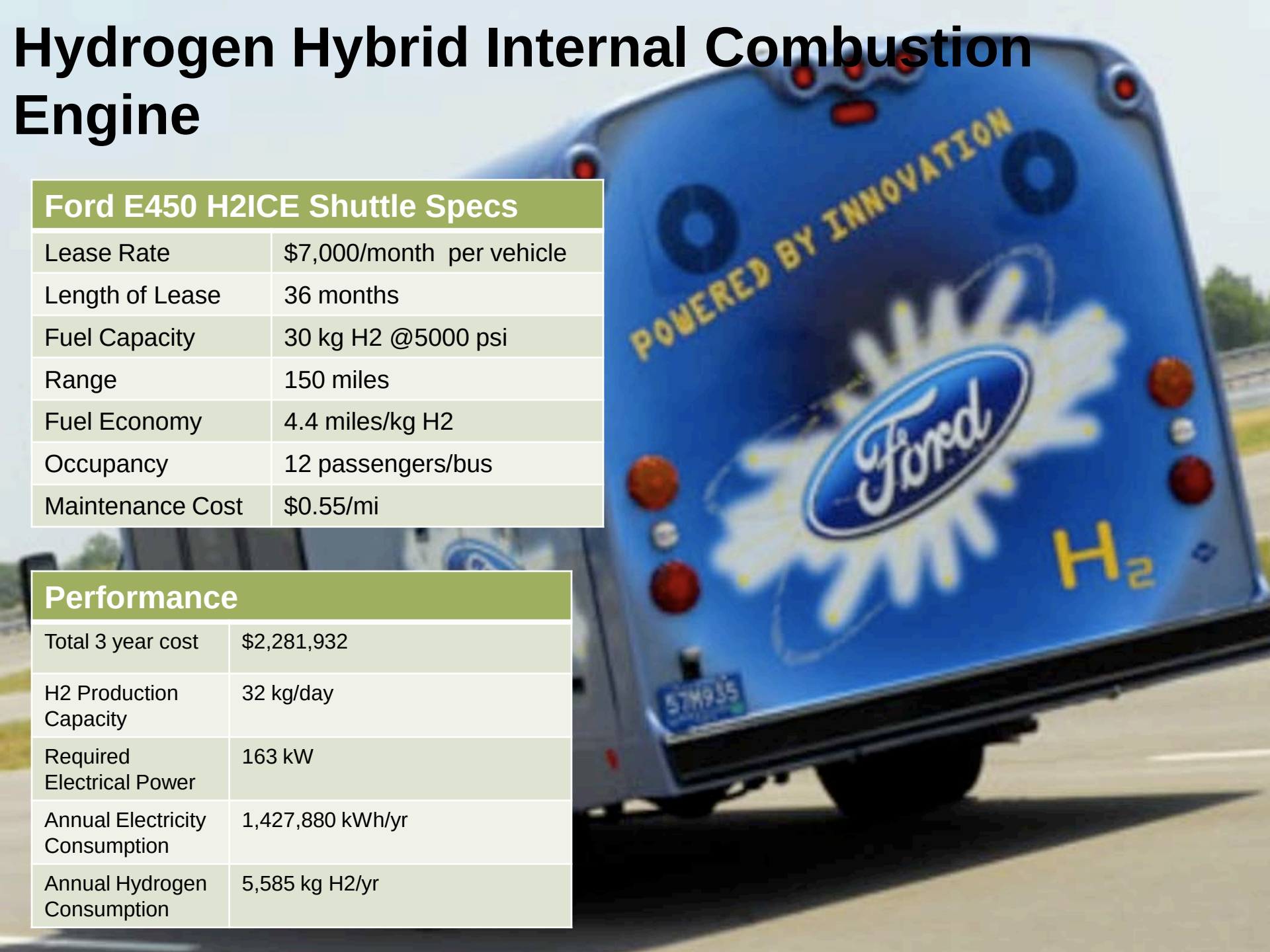




- 3 Vestas V27s 225kWs
- 2-150 kW Volvo diesel gen-sets
- Electric boiler for hot water
- In 2006 a 60% capacity factor
- Average Load: 70kW
- Class 7 wind resource
- Average wind penetration about 55%

St. Paul Island

Hydrogen Hybrid Internal Combustion Engine



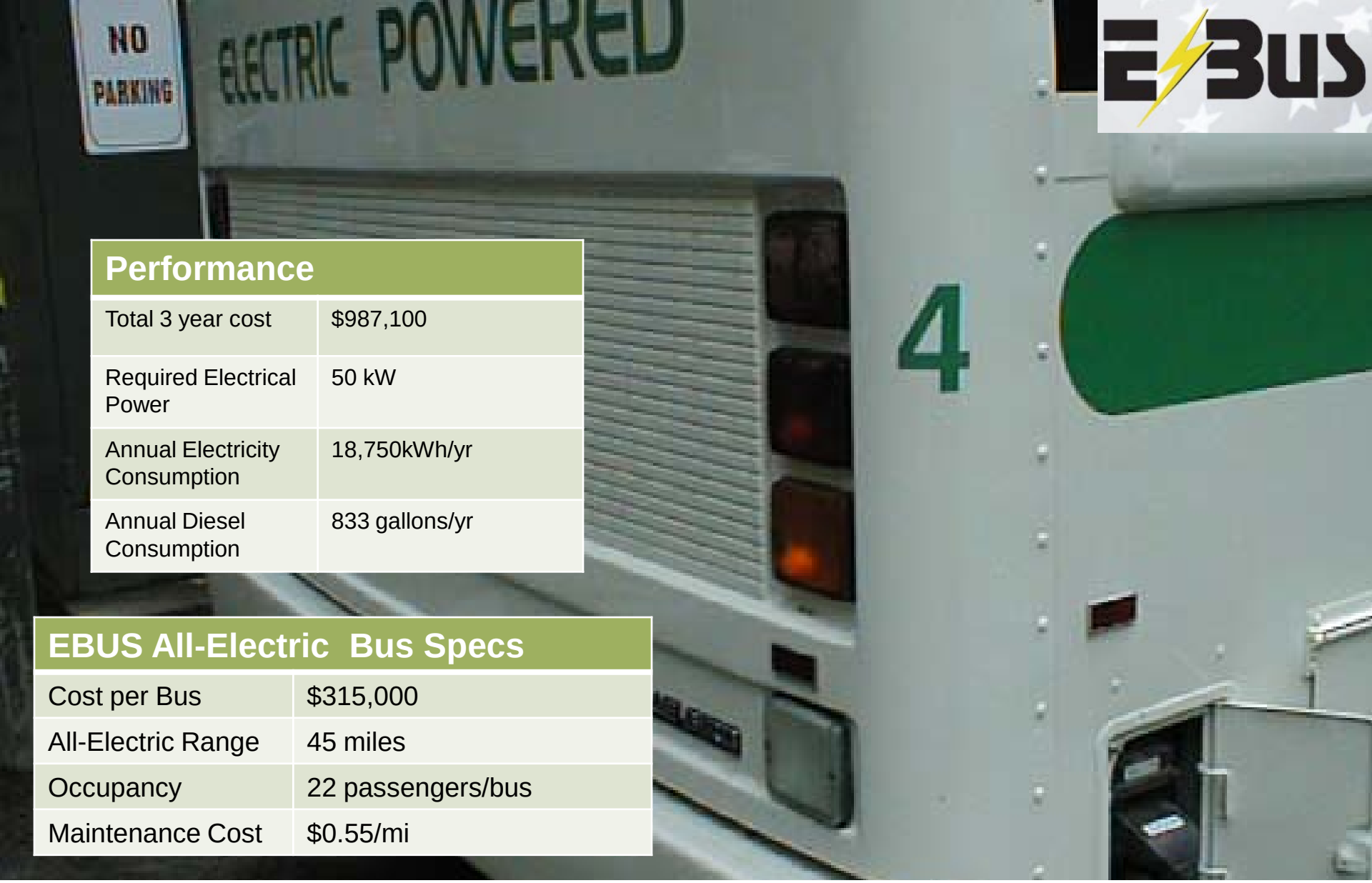
Ford E450 H2ICE Shuttle Specs	
Lease Rate	$7,000/month per vehicle
Length of Lease	36 months
Fuel Capacity	30 kg H2 @5000 psi
Range	150 miles
Fuel Economy	4.4 miles/kg H2
Occupancy	12 passengers/bus
Maintenance Cost	$0.55/mi

Performance	
Total 3 year cost	$2,281,932
H2 Production Capacity	32 kg/day
Required Electrical Power	163 kW
Annual Electricity Consumption	1,427,880 kWh/yr
Annual Hydrogen Consumption	5,585 kg H2/yr

Plug-In Hybrid Electric Vehicles

Champion/Odyne PHEV Specs	
Cost per Bus	$243,301
Battery Capacity	35 kWh
All-Electric Range	12 miles
Charge Sustaining Fuel Economy	9 miles/gallon diesel
Occupancy	22 passengers/bus
Maintenance Cost	$0.55/mi

Performance	
Total 3 year cost	$1,312,571
Required Electrical Power	20 kW
Annual Electricity Consumption	4,500kWh/yr
Annual Diesel Consumption	1,378 gallon/yr



Performance	
Total 3 year cost	$987,100
Required Electrical Power	50 kW
Annual Electricity Consumption	18,750kWh/yr
Annual Diesel Consumption	833 gallons/yr

EBUS All-Electric Bus Specs	
Cost per Bus	$315,000
All-Electric Range	45 miles
Occupancy	22 passengers/bus
Maintenance Cost	$0.55/mi

Electric Vehicle plus Diesel ICE

Wind to Hydrogen

Project Specifications

Occupancy	15-20 passengers/bus
Tour Route Mileage	100 miles -100 days a year
Residential Route Mileage	40 miles year round
Total Annual Mileage	24,600 miles/year

Resource Assumptions

Available Wind Energy	1,500 MWh/year
Estimated Cost of Diesel	$8.00/gallon
Wind Resource	Class 7
Average Power Density	440 kg/m^3

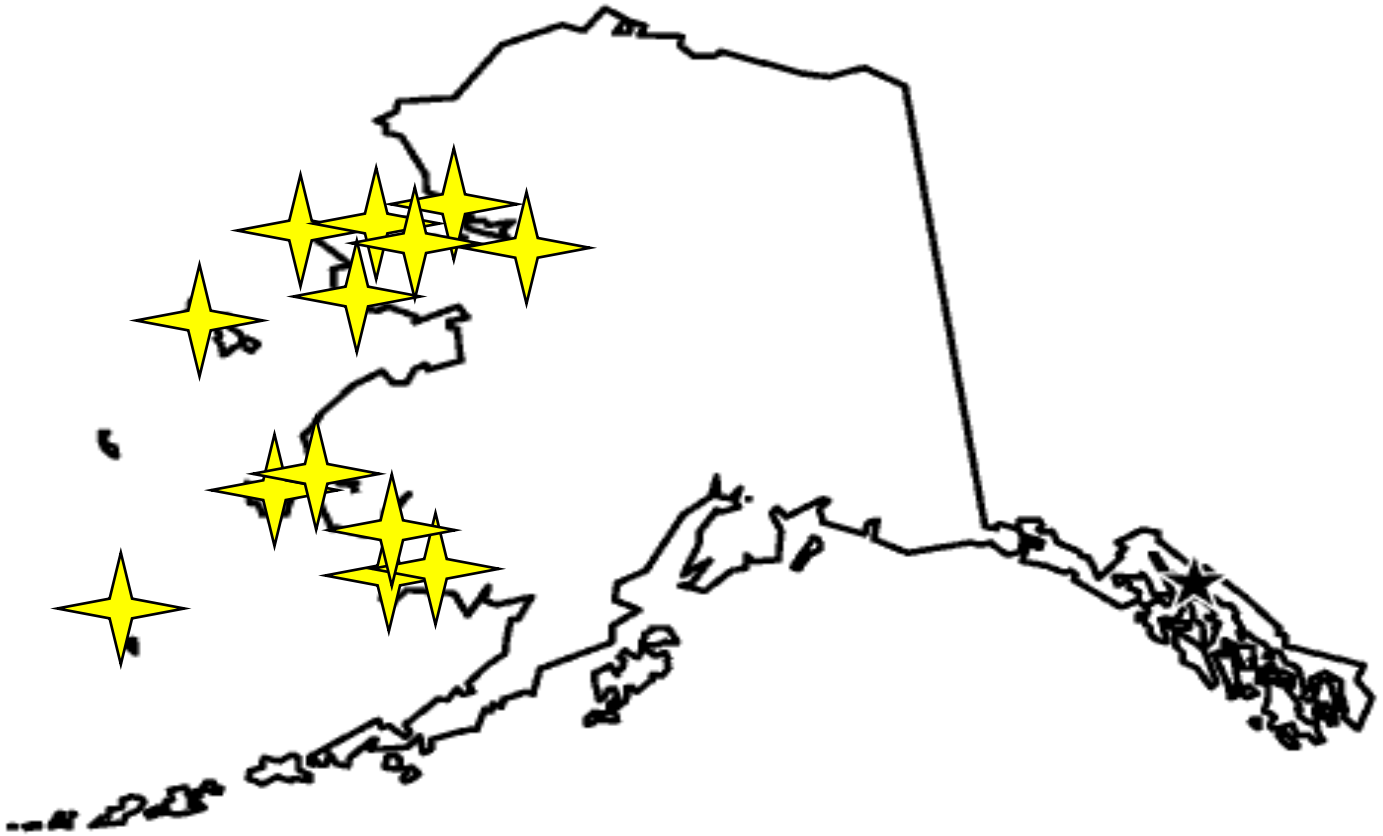
Vehicle Assumptions

Ford H2ICE Shuttle available only on 3 year lease	2 vehicles at $7,000/month each
Fuel economy and Capacity	4.4 mi/kg H2 30kg H2 @ 5000psi
Maintenance Cost	$0.55/mile
Annual Electricity Consumption	1,425 MWh
Annual Hydrogen Consumption	5,585 kg/yr

H2 Assumptions

Hydrogenics Hystat-30 Electrolyzer Efficiency	67%
System Components	$1,355,000
H2 Production Capacity	32 kg/day
Required Power to Electrolyzer & Compressor	162kW
Hydrogen LHV	33 kWh/kg

Proposed High Penetration Wind Diesel



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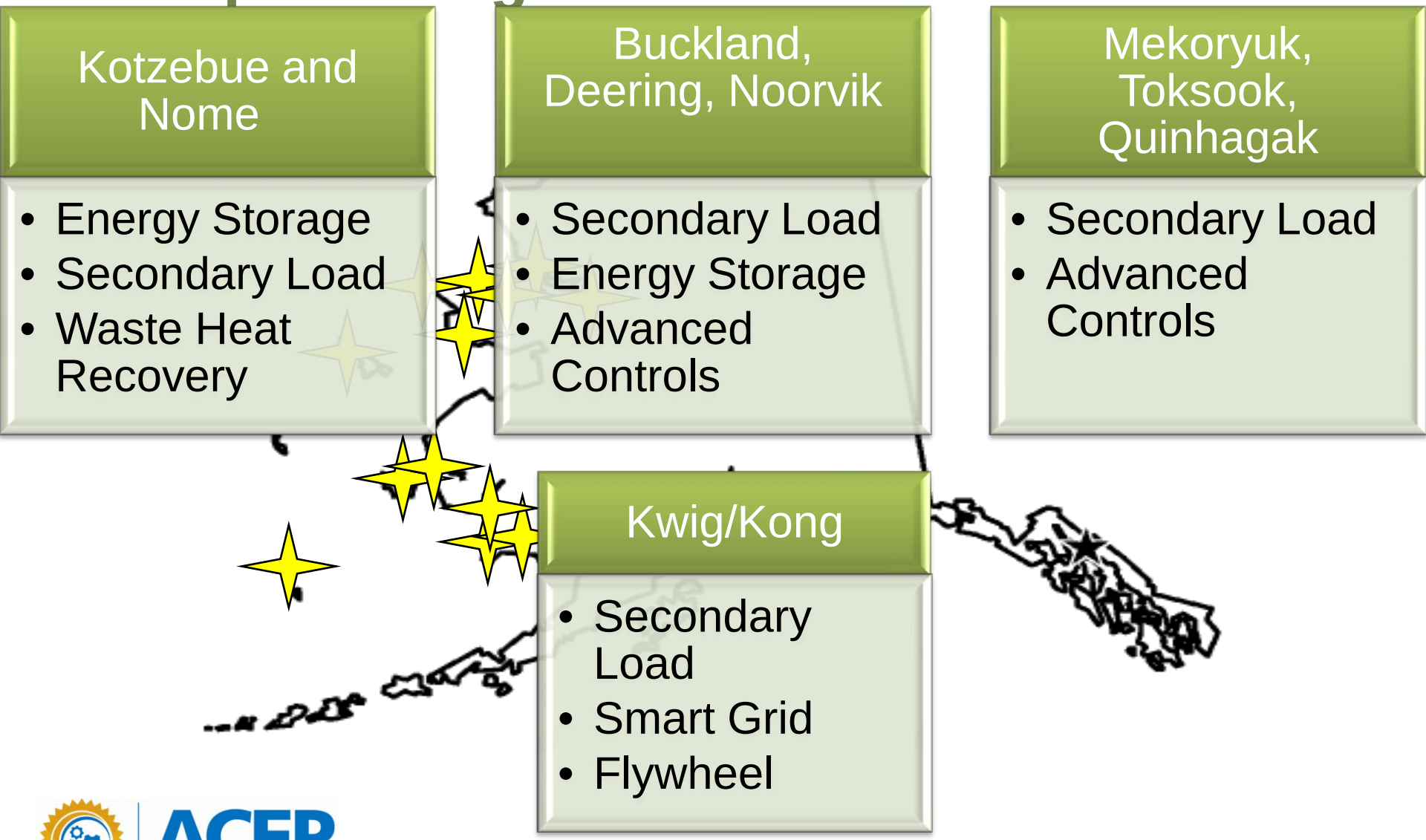

Kotzebue and Nome

- Energy Storage
- Secondary Load
- Waste Heat Recovery

Buckland, Deering, Noorvik

- Secondary Load
- Energy Storage
- Advanced Controls

Mekoryuk, Toksook, Quinhagak

- Secondary Load
- Advanced Controls

Kwig/Kong

- Secondary Load
- Smart Grid
- Flywheel

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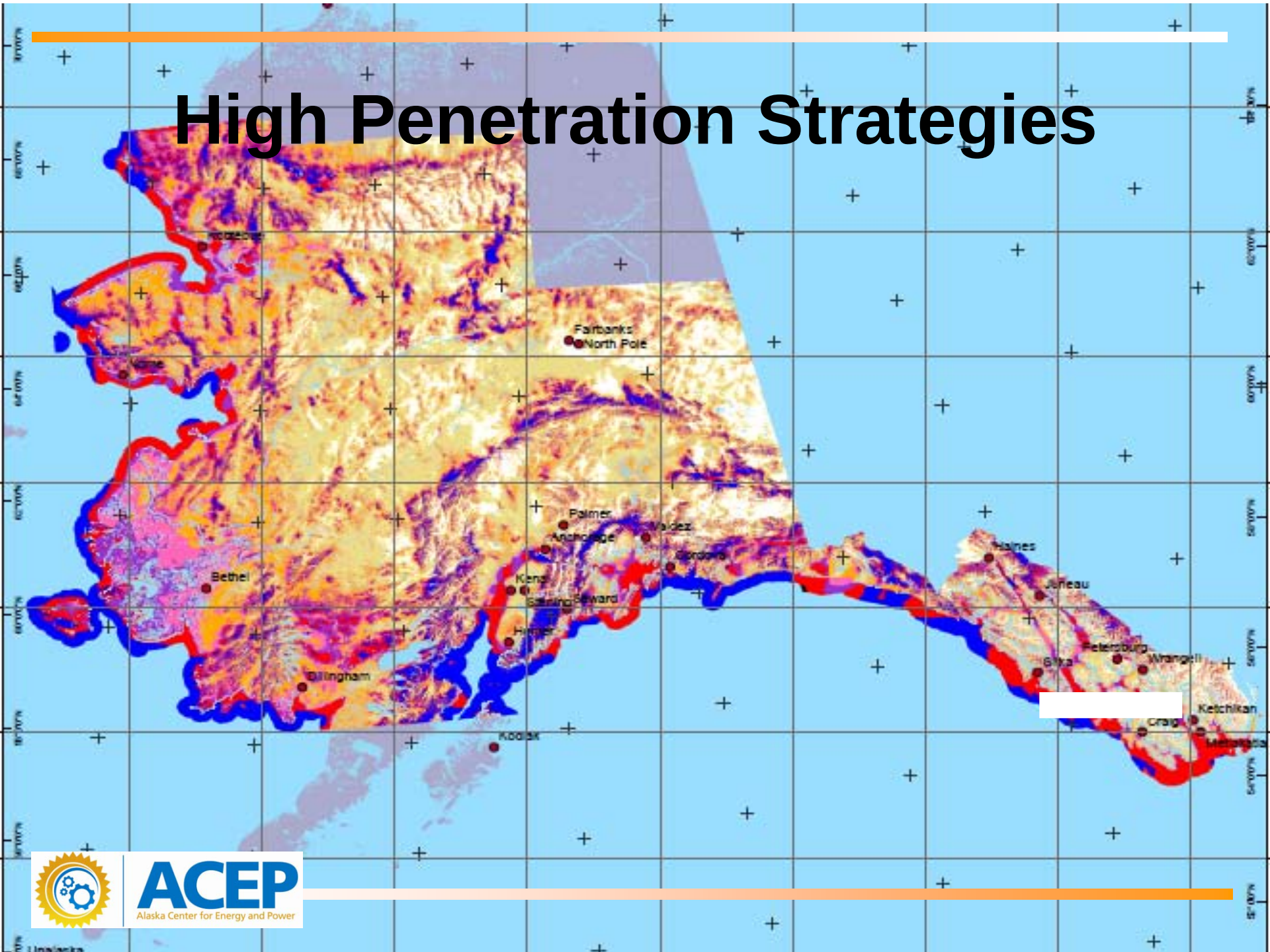
High Penetration Strategies



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Secondary Loads/Energy Storage

- Energy Storage
  - Batteries/Pumped Hydro/Compressed Air
  - Hydrogen
- Thermal Uses
  - Space Heating
  - Water Heating
  - Power Generation (ORC/Ammonia Power Cycle)
  - Absorption Chilling (Ice making-Air conditioning)
- Transportation
  - Plug-in Hybrid Electric Vehicles (PHEV)
  - Electric Vehicles: ATVs and Mass Transit
  - Hydrogen Internal Combustion Engine

Kotzebue

- Average Load 2500kW
- Installed Wind Capacity 1.14MW (Annual average 8% total kWh)
- Plans to increase wind capacity to 4 MW
- Vanadium Red-ox Flow Battery from Prudent Energy
  - Phase One: Battery Power 600kW and Battery Storage 1800kWh
  - Phase Two: Battery Power 1200kW and Battery Storage 2700kWh
- Waste Heat Recovery with 150kW Ammonia Power Cycle Power Plant

600 kW x 3 hr with Increased Wind	
Metric	**Value**
Present Worth	$12,661,682
Annual Worth	613,802/yr
Return on Investment	82.90%
Internal Rate of Return	81.10%
Simple Payback	1.23 yrs
Discounted Payback	1.31 yrs

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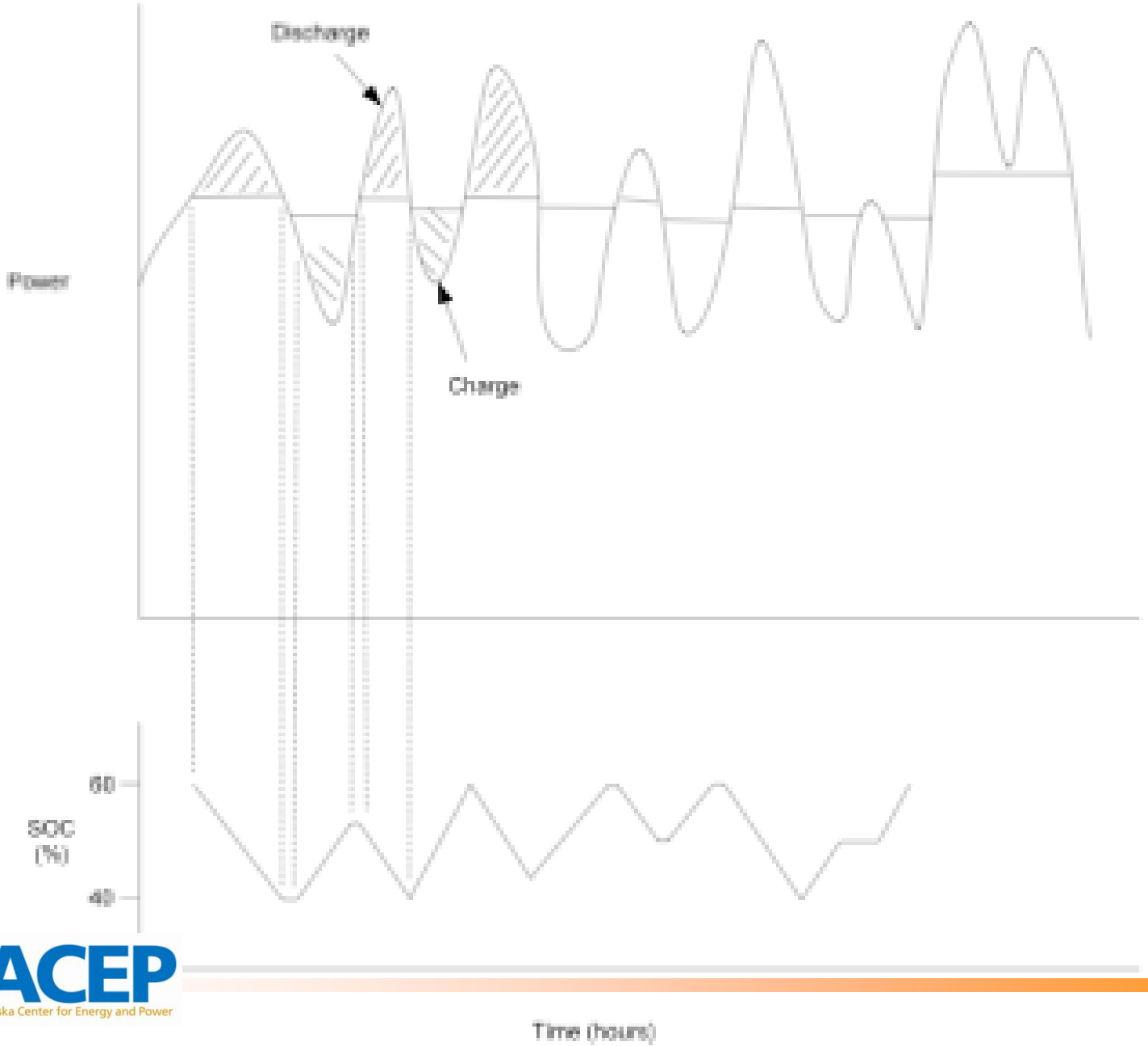
System	Initial capital cost	COE ($/kWhr)	Renewable Fraction (%)	Estimated diesel usage (liter/year)
2400kW x 0.66hr = 1800kWhr	$6.877M	0.396	19%	5.630M
1200kw x 1.50 hr = 1800kWhr	$4.697M	0.398	20%	5.612M
No VRB-ESS	$0	0.440	19%	6.179M



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Northwest Arctic Borough

- Average Load 250kW-2010
- Install NW100s
- Zinc Bromide Battery from Premium Power with Secondary Dump Load
  - Battery Power 50 kW
  - Battery Storage 50 kWh

	Deering	Buckland	Noorvik
Average annual wind speed	7.2 m/s	6.8 m/s	5.8 m/s
Wind plant capacity factor	29.1%	25.9%	18.0 %
Total installed wind capacity	200-kW	300-kW	300-kW
Annual wind energy generated	510 MWh	682 MWh	473 MWh
Total generated in FY2007[3]	710 MWh	1423 MWh	1992 MWh
Transmission line length	1.5 miles	5 miles	0.5 mile
Transmission line cost	$525,000	$1,750,000	$175,000
Total installation cost	$1,926,100	$3,597,275	$1,812,800
Equity payback	11.6 years	13.6 years	11.8 years
Benefit-cost (B-C) ratio	1.72	1.27	1.68

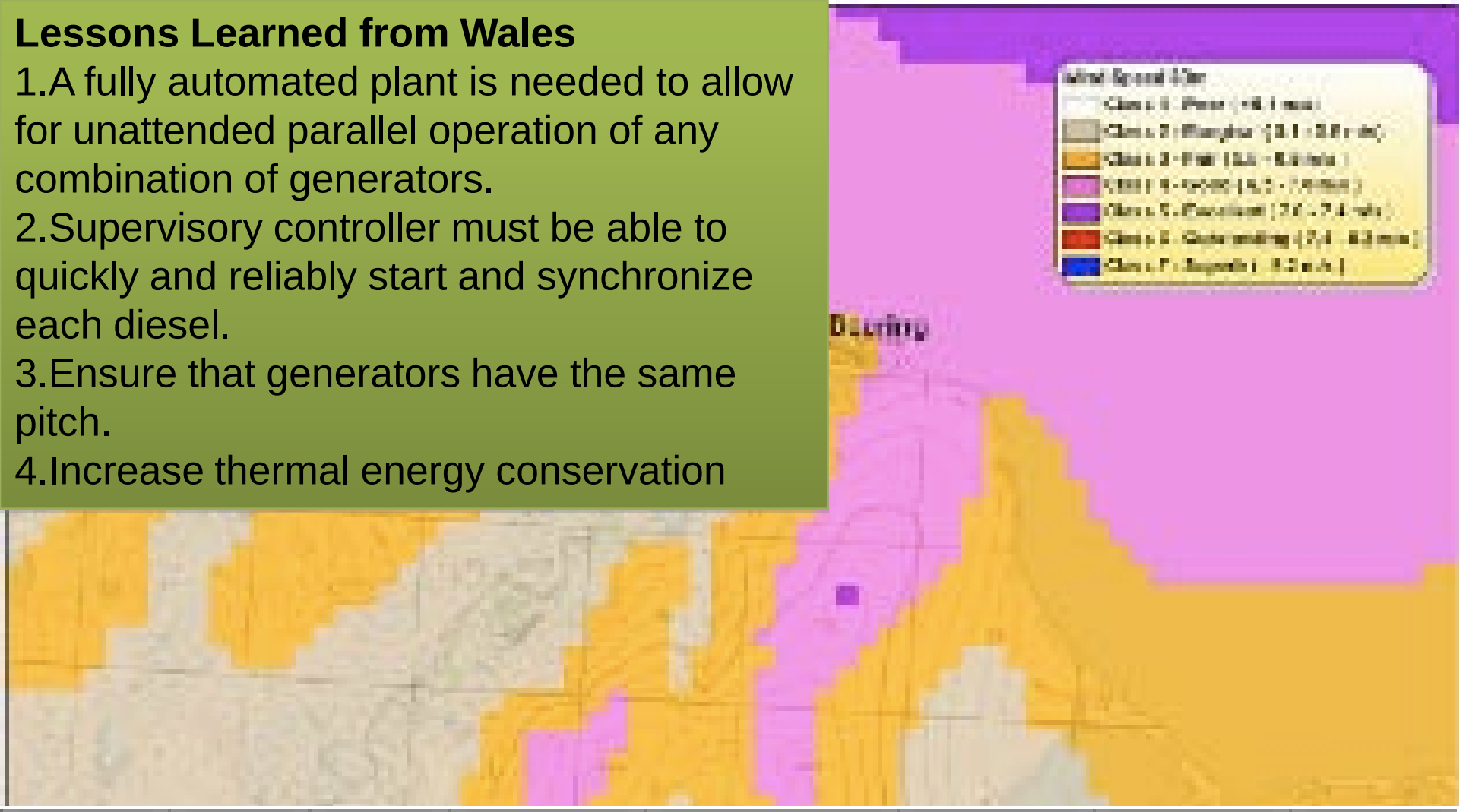
Lessons Learned from Wales

1.A fully automated plant is needed to allow for unattended parallel operation of any combination of generators.

2.Supervisory controller must be able to quickly and reliably start and synchronize each diesel.

3.Ensure that generators have the same pitch.

4.Increase thermal energy conservation



	No. of Tur-bines	kWh/Yr	Equiv. Diesel Gallons	FY2007 Diesel Gallons Used for Power Generation	Reduction in Diesel Fuel/Yr.	Cost of fuel	Avoided Cost/Yr.
Buckland	3	682,000	54,560	118,708	45%	$4.25/Gal	$231,880
Deering	2	510,000	40,800	62,878	65%	$4.25/Gal	$173,400
Noorvik	3	473,000	37,840	149,669	25%	$4.25/Gal	$160,820

Quinhagak, Mekoryuk, and Toksook

- AVEC villages-installed summer 2009
- Average Load 250kW
- Install NW100s
- No Energy Storage
- Secondary Loads-Boilers

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Alternate Energy Storage: St. Paul Island and Kodiak

- St. Paul- Hydrogen
- Kodiak Electric Assoc. Pumped Hydro

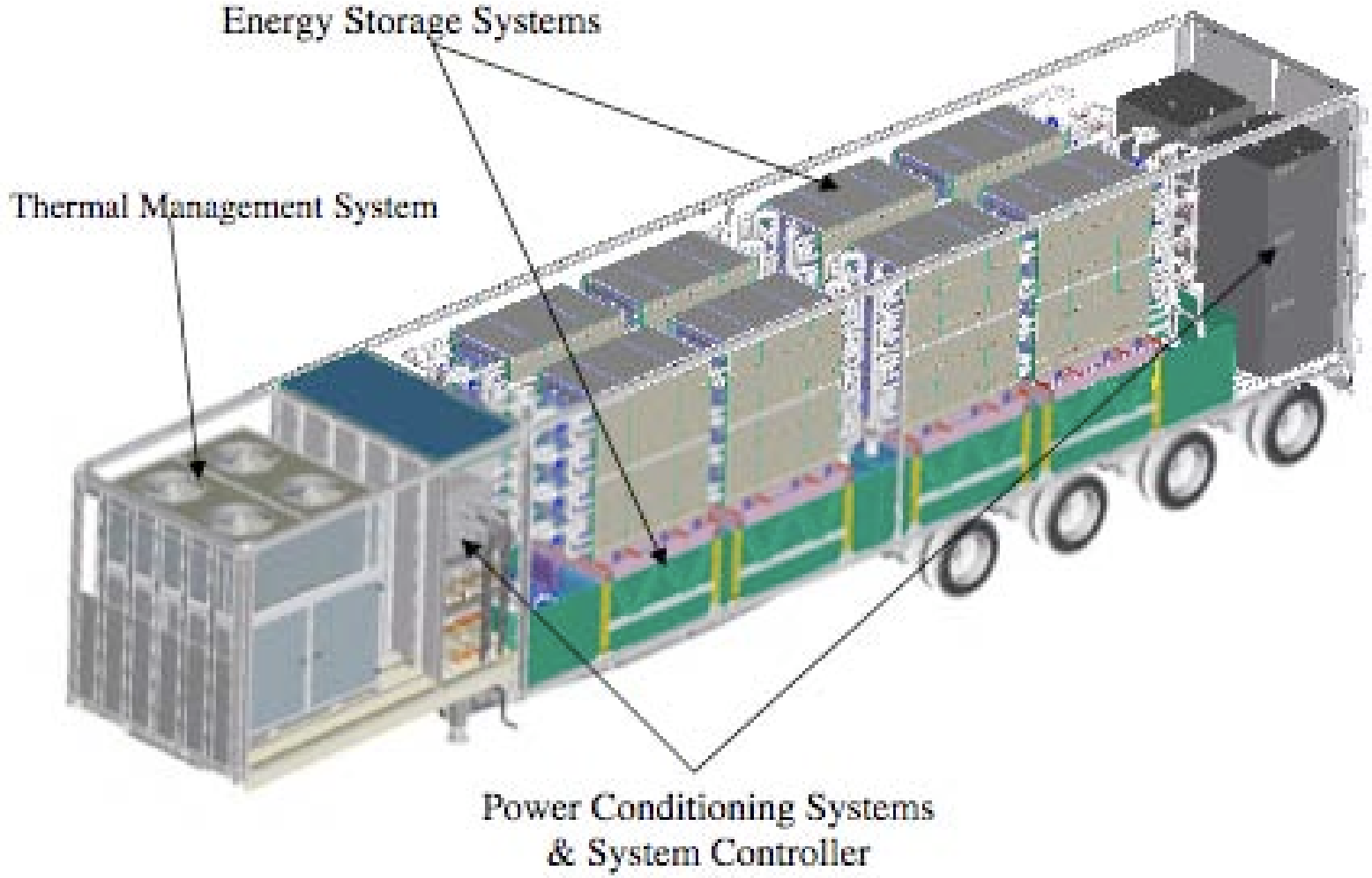
Energy Storage (kWh) Comparison

Method	$/kWh	Power (MW)	Efficiency	Lifetime (hours)	Discharge Time (hrs)
Pumped Hydro	250-260	20-2,400	76-83%	11,000+	10
Compressed Air	550-650	110-290	50-75%	11,000+	10
NaS (NGK)	2,500-4,500	.05-50	70-80%	3,000+	7
Ni-Cad	610-1,700	.01-27	60-65%	1,000+	4
Premium Power	350-400	.5	70%	30 years	5
ZBB	1,070	.5	77-78%	+2,000 cycles	varies
Prudent Energy	1637	Varies	85%	10,000+ cycles	varies

Power Stability (kW) Comparison

Method	$/kW	Power (MW)	Efficiency	Lifetime (hours)	Discharge Time (min)
Lead Acid	1,050-1,890	.01-10	70-75%	250+	15
Flywheels	2,500-4,000	.5-1	90-95%	500,000+	15
Super Capacitors	n/a	.003-.01	90-98%	500,000+	Seconds
NaS Batteries	3,000-4,000	.05-50	70-80%	3,000+	300
Li-Ion Batteries	1,000-4,500	.005-1	90-95%	20,000+	15
Lead Acid	1,050-1,890	.01-10	70-75%	250+	15

Premium Power-Zinc Bromide



TransFlow 2000 – Main Subsystems

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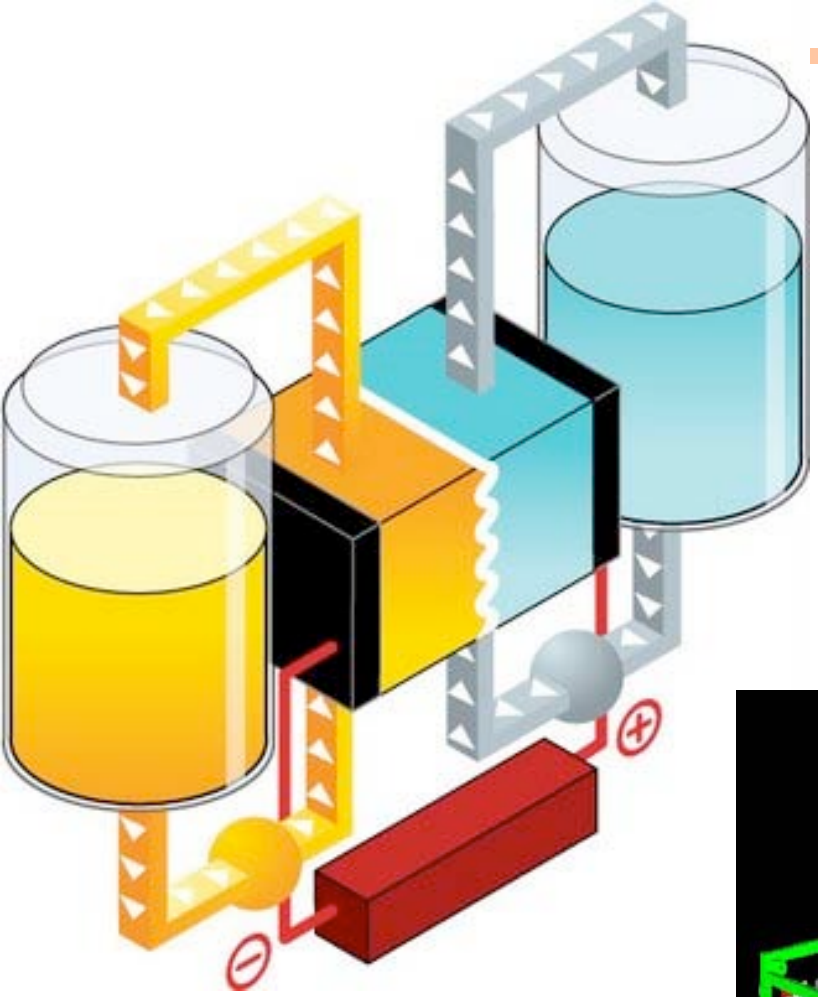
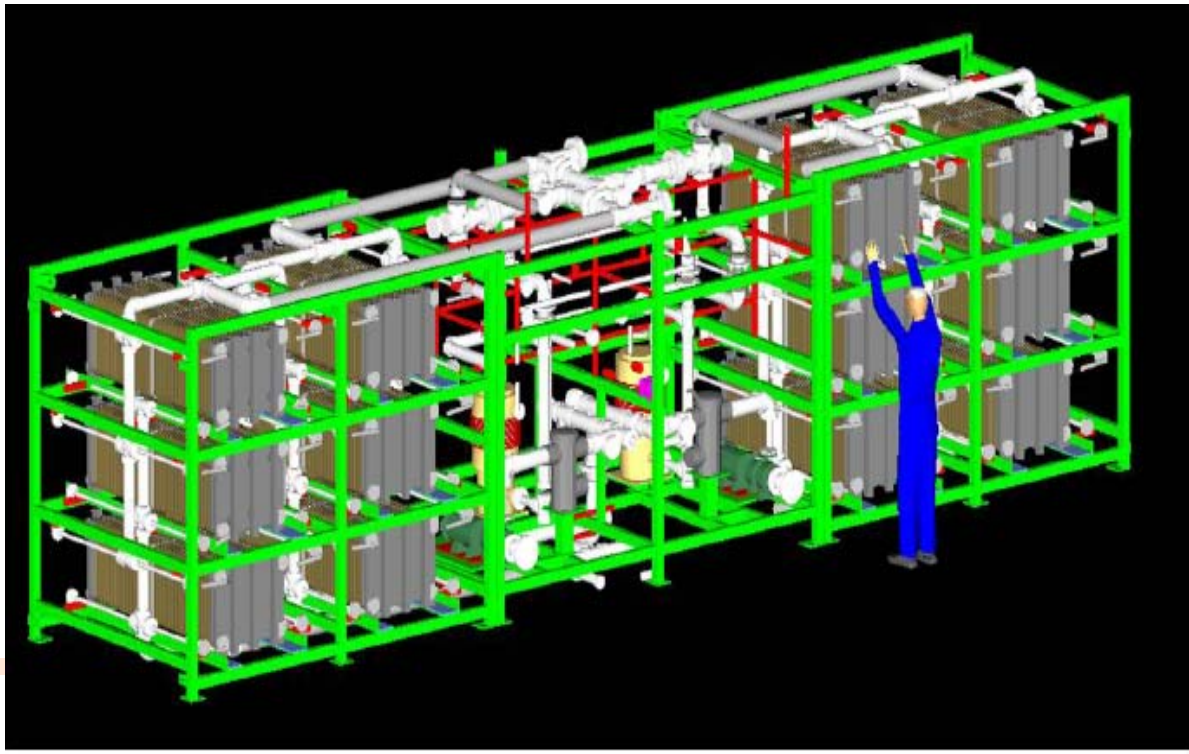
Zinc Bromide
ZBB Energy

Prudent Energy Vanadium Red-ox Flow Battery





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VRB Power Systems

Sodium Sulfur Batteries, NGK

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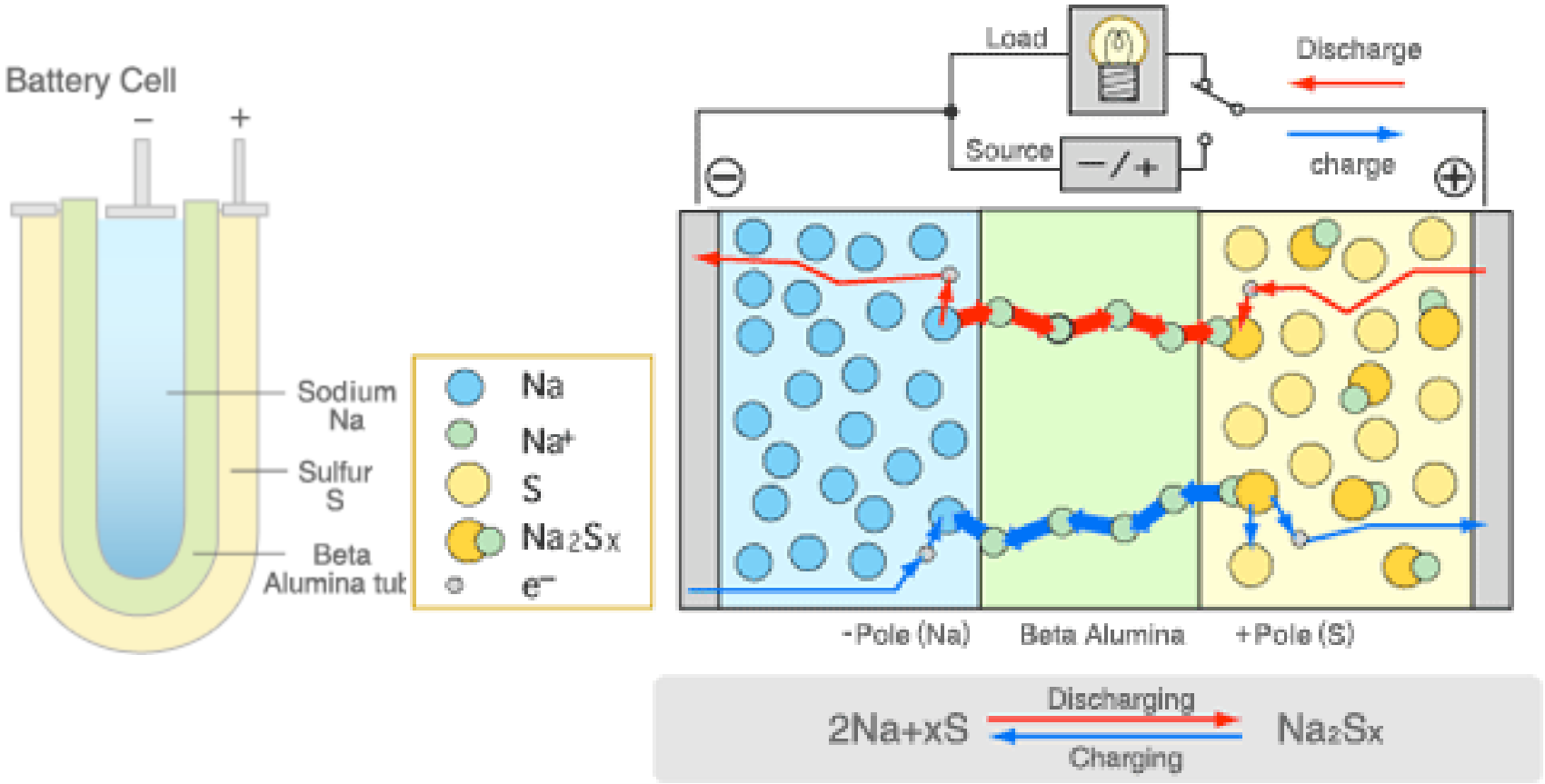
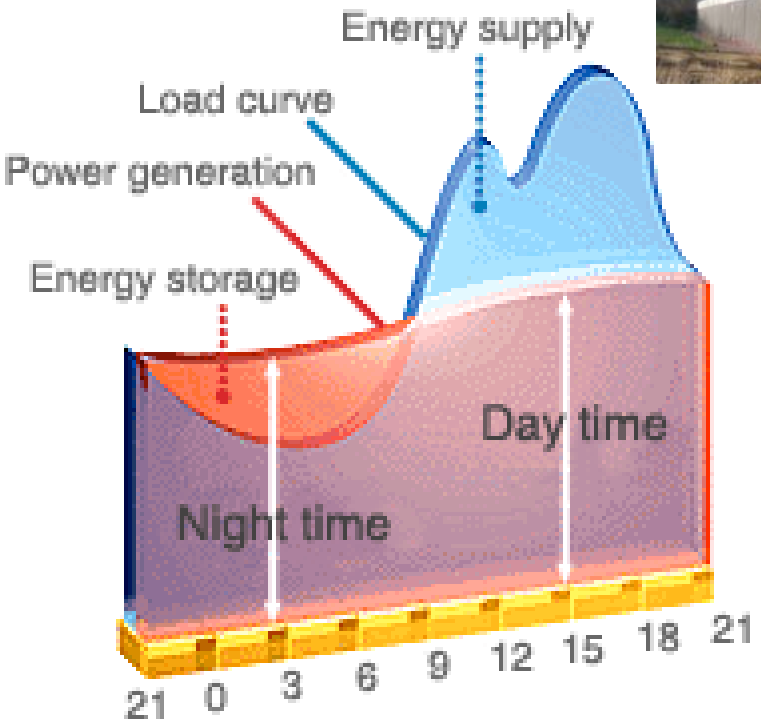
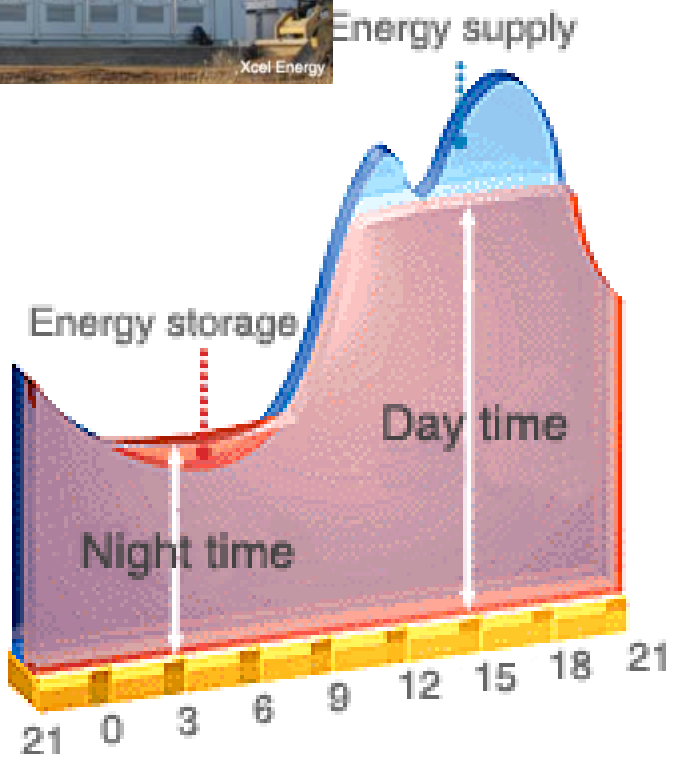
Sodium Sulfur Batteries, NGK



Sodium Sulfur Batteries, NGK

- Electric power demand
  - Load leveling





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Katherine Keith
Wind Diesel Application Center
Alaska Center for Energy and Power
University of Alaska
kmkeith@alaska.edu
907-590-0751