Considerations for Remote Battery Energy Storage Projects

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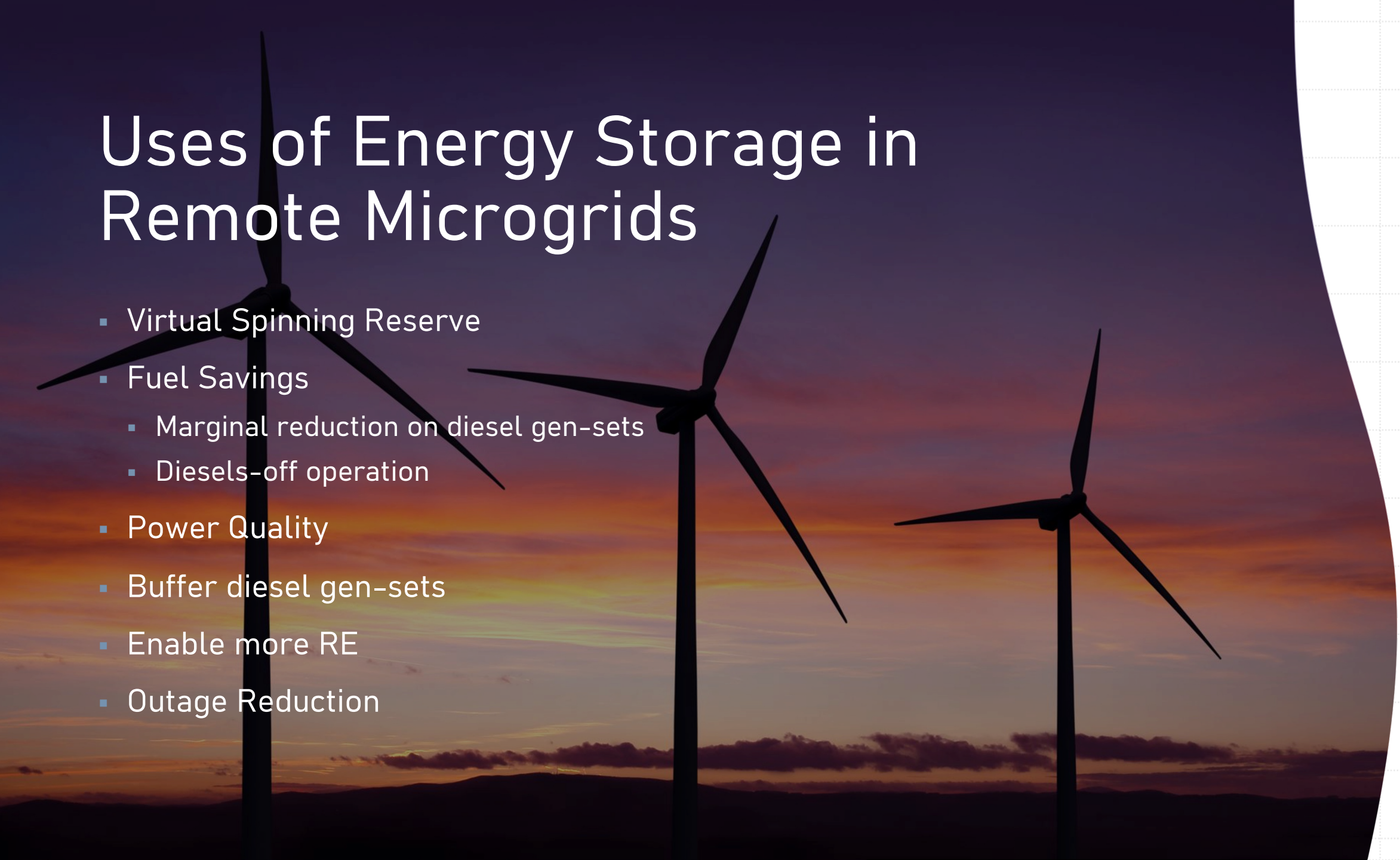
Alaska Wind Workshop
September 8, 2023

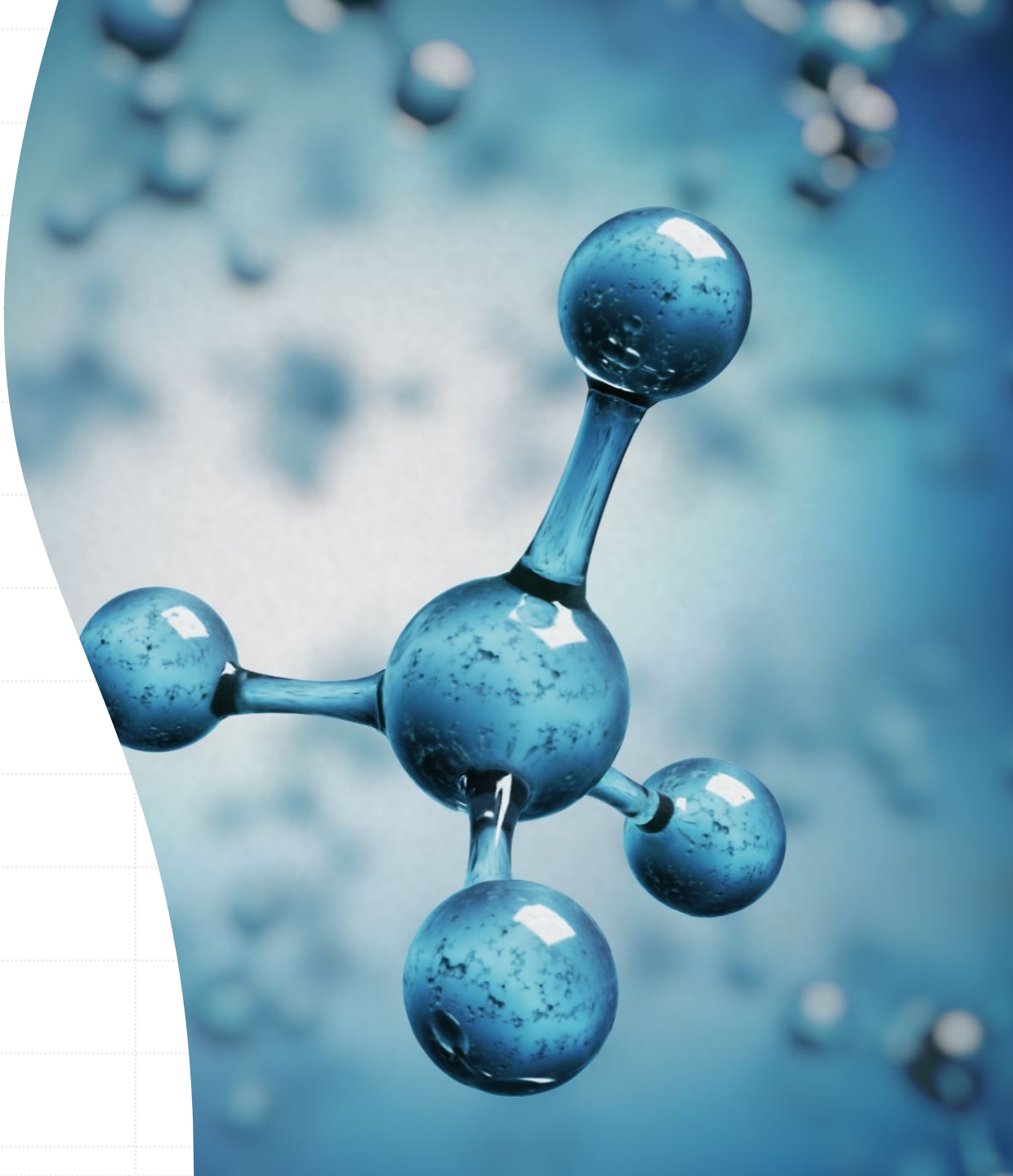
Uses of Energy Storage in Remote Microgrids



- Virtual Spinning Reserve
- Fuel Savings
  - Marginal reduction on diesel gen-sets
  - Diesels-off operation
- Power Quality
- Buffer diesel gen-sets
- Enable more RE
- Outage Reduction

Battery Chemistry

- Nickel Manganese Cobalt (NMC) very common and often lower up-front cost – more mfg capacity globally because of EV industry
- Lithium Iron Phosphate (LFP) allows for more depth of discharge, more life cycles, more thermal stability, but less energy dense and more expensive up-front
- Shipping costs: NMC more energy dense, so in remote locations this is an advantage
- Remote microgrid trends appear to be leaning toward LFP



Comparisons of NMC & LFP

Lithium-ion NMC , 1 MW, 2 hr
Costs & Performance Parameters

	2021			2030		
	Low Estimate	Point Estimate	High Estimate	Low Estimate	Point Estimate	High Estimate
DC Storage Block ($/kWh)	$196.84	$218.71	$240.58	$119.19	$143.12	$163.31
DC Storage BOS ($/kWh)	$40.29	$44.76	$49.24	$29.29	$33.42	$37.98
Power Equipment ($/kW)	$76.18	$84.65	$93.11	$63.21	$74.88	$78.04
C&C ($/kW)	$36.01	$40.01	$44.01	$26.18	$29.87	$33.95
Systems Integration ($/kWh)	$56.84	$63.16	$69.48	$49.24	$53.59	$58.23
EPC ($/kWh)	$70.01	$77.79	$85.57	$60.64	$66.00	$71.72
Project Development ($/kWh)	$84.01	$93.35	$102.68	$72.77	$79.21	$86.06
Grid Integration ($/kW)	$27.85	$30.94	$34.04	$24.12	$26.25	$28.53
Total Installed Cost ($/kWh)	$518.01	$575.57	$633.13	$387.88	$440.85	$487.55
Total Installed Cost ($/kW)	$1,036	$1,151	$1,266	$776	$882	$975
Fixed O&M ($/kW-year)	$3.10	$3.45	$3.79	$2.69	$2.93	$3.18
Warranty ($/kWh-yr)	$2.95	$3.28	$3.61	$1.79	$2.15	$2.45
RTE (%)	83%	83%	83%	85%	85%	85%
Cycle Life (#)*	1,520	1,520	4,805	1,672	1,672	5,286
Calendar Life (yrs)	13	13	13	13	13	13
DOD (%)	80%	80%	80%	80%	80%	80%

Duration hr
- (●) 2 hr
- ( ) 4 hr
- ( ) 6 hr
- ( ) 8 hr
- ( ) 10 hr
- ( ) 24 hr
- ( ) 100 hr

Power MW
- (●) 1 MW
- ( ) 10 MW
- ( ) 100 MW
- ( ) 1,000 M

* Cycle Life (#) represents available cycles until remaining energy is equivalent to average DOD (%).

Lithium-ion LFP , 1 MW, 4 hr
Costs & Performance Parameters

	2021			2030		
	Low Estimate	Point Estimate	High Estimate	Low Estimate	Point Estimate	High Estimate
DC Storage Block ($/kWh)	$164.04	$182.27	$200.50	$99.33	$119.28	$136.10
DC Storage BOS ($/kWh)	$38.14	$42.38	$46.61	$27.73	$31.64	$35.96
Power Equipment ($/kW)	$76.18	$84.65	$93.11	$63.21	$74.88	$78.04
C&C ($/kW)	$36.01	$40.01	$44.01	$26.18	$29.87	$33.95
Systems Integration ($/kWh)	$45.15	$50.16	$55.18	$39.10	$42.56	$46.24
EPC ($/kWh)	$55.08	$61.20	$67.31	$47.70	$51.92	$56.42
Project Development ($/kWh)	$66.09	$73.43	$80.78	$57.25	$62.31	$67.70
Grid Integration ($/kW)	$27.85	$30.94	$34.04	$24.12	$26.25	$28.53
Total Installed Cost ($/kWh)	$403.51	$448.34	$493.17	$299.49	$340.46	$377.55
Total Installed Cost ($/kW)	$1,614	$1,793	$1,973	$1,198	$1,362	$1,510
Fixed O&M ($/kW-year)	$4.54	$5.05	$5.55	$3.93	$4.28	$4.65
Recycling ($/kWh)	$2.21	$2.65	$3.09	$0.00	$0.00	$0.00
RTE (%)	83%	83%	83%	85%	85%	85%
Cycle Life (#)*	2,400	2,400	4,550	2,640	2,640	5,005
Calendar Life (yrs)	16	16	16	16	16	16
DOD (%)	80%	80%	80%	80%	80%	80%

Duration hr
- ( ) 2 hr
- (●) 4 hr
- ( ) 6 hr
- ( ) 8 hr
- ( ) 10 hr
- ( ) 24 hr
- ( ) 100 hr

Power MW
- (●) 1 MW
- ( ) 10 MW
- ( ) 100 MW
- ( ) 1,000 M

* Cycle Life (#) represents available cycles until remaining energy is equivalent to average DOD (%).

Source: Pacific Northwest National Laboratory – Energy Storage Cost & Performance Database

Form Factor & Thermal Management

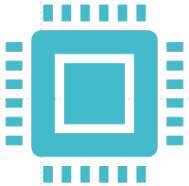
- Heat producing elements:
  - 1. Battery
  - 2. Power Conversion System
  - 3. Transformer (maybe)
- Container within a container?
- Additional considerations in powerplant if going diesels-off

Customer Service

Warranty requirements & costs

Technical Support

Responsiveness



Integration with Power Conversion hardware & software

Lessons Learned

- Diesels-off is not always desirable, or at least it's complicated
- Thermal vs Electric Storage
- Lowest price is not always least cost
- How to translate performance into cost savings
- Simplicity = More acceptance and use in villages