The True Cost of Energy Storage

BLUE PLANET
RESEARCH

How do we levelize the cost of storage?

What is Blue Planet Research?

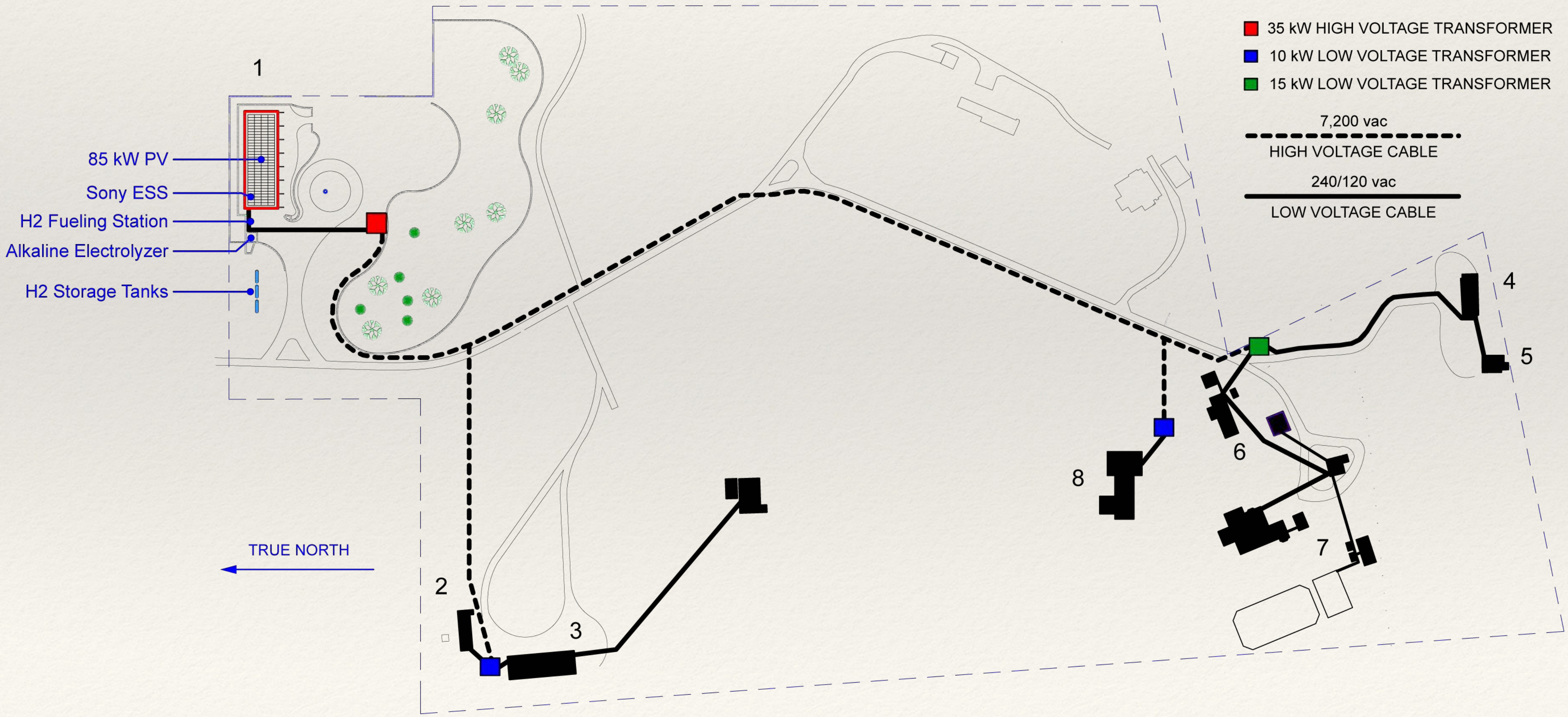
BPR is a private renewable energy research facility. We operate a 32 acre Micro-Grid that serves as a Testbed for storage technologies deployed in real world applications.

Our mission is to Change the Way We Power our World by Making Renewable Energy Work.

Blue Planet Research's Energy Lab located on the Kona Side of Hawaii Island

BPR Micro-Grid

(1) Energy Lab: Machine Shop, Laundry, Bathroom/Shower, 8 Work Bays, 3 One Bedroom Apts. w/1 1/2 baths & Full Kitchens
(2) Residence: 2 bedrooms, 1 Bath, Kitchen
(3) Wood Shop: Full Wood Working Shop, Mechanic Shop, 100 sf. Walk-In Cooler for Seed Bank
(4) Large A-Frame Guest Unit: Two Large Suites, Full Kitchen
(5) Small A-Frame Guest Unit: Two Bedrooms, One Full Bath, Kitchen
(6) 3 Guest Suites: Full Baths, Wet Bars
(7) Main Residence: 4 Bedroom Suites, Large Kitchen, 2 Guest Baths, Wine Cellar, Main Laundry
(8) Future Residence: 5 Bedroom Suites, Full Kitchen, Pool, Laundry, Large Office



What is Blue Planet Research?

BPR has multiple testbed locations in Hawaii. In addition to our own headquarters MicroGrid, we have technologies deployed in various applications around the state, including a NASA funded simulation habitat, several residential off-grid sites.

Blue Planet Research's Mars Habitat

Joint Venture Project with NASA/HI-SEAS/UH an Cornell Located on Mauna Loa Volcano

100 kW/110 kWh /2,400 amp dc Buss

20 kW/80 kWh /Vanadium Redox Flow Battery

Storage Technologies

- Pumped Hydro - Hi efficiency, but requires large CapEx
- Flywheel - Long life, but large footprint compared to capacity
- Batteries - High efficiency but many chemistries
- Hydrogen - Moderate efficiency, but very scalable
- Gravity Machines - Site dependent, large CapEx
- Compressed Air - Unique conditions required
- Thermal - Molten Salt, Hot Oil: specialized requirements

Storage Applications

Residential

- Off-Grid
- Customer Self Supply
- Time of Use / Arbitrage
- UPS for mission critical applications

Utility Scale

- MicroGrids
- Demand Response /Load Leveling

Storage Categories

- All but two of the previous examples are either kinetic or thermal.
- Batteries and Hydrogen are chemical.
- Batteries are the most available and compact solution that can be deployed anywhere over a wide range of scales.
- H2 has unlimited shelf life, but presents storage challenges, and round trip efficiencies are moderate but can have advantages of scale depending on application.

Cost or Affordability

These are not necessarily related, and cheap in not necessarily affordable!

Usual Metrics are:

- Capitol Investment
- Lifetime Production Expectation
- O&M Costs
- Hazmat Costs to Shipping
- Installation & Commissioning
- Climate Controls
- Warranty Costs
- Environmental, and End of Life Disposal

SAFETY FIRST

Industry Standard Destructive Testing (Nail Test) for Lithium Batteries

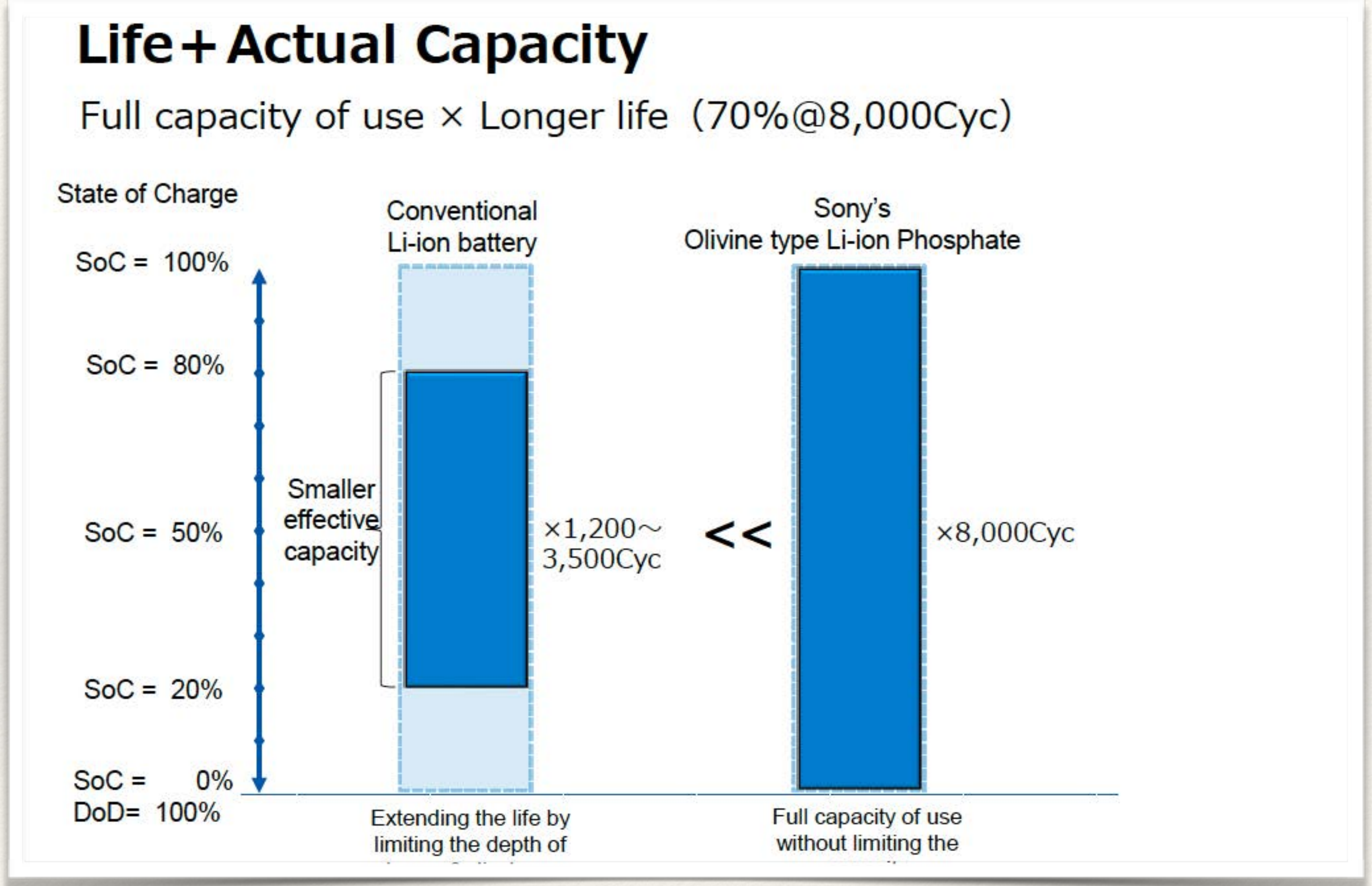
- LFP on top has organic solvent leaking
- Non-LFP violently explodes into flames

SAFETY FIRST

Industry Standard Destructive Testing (Burner Test) for Lithium Batteries

- LFP on top- organic solvent burning.
- Non-LFP on bottom- violently adding energy to fire.

Calculating Costs



- Capacity x Life expectancy

Calculating Costs

Lifetime cost comparison (Simulation)

Example comparing costs and lifetime capacity obtained from different batteries rated 10kWh ：

Lifetime cost of olivine is superior

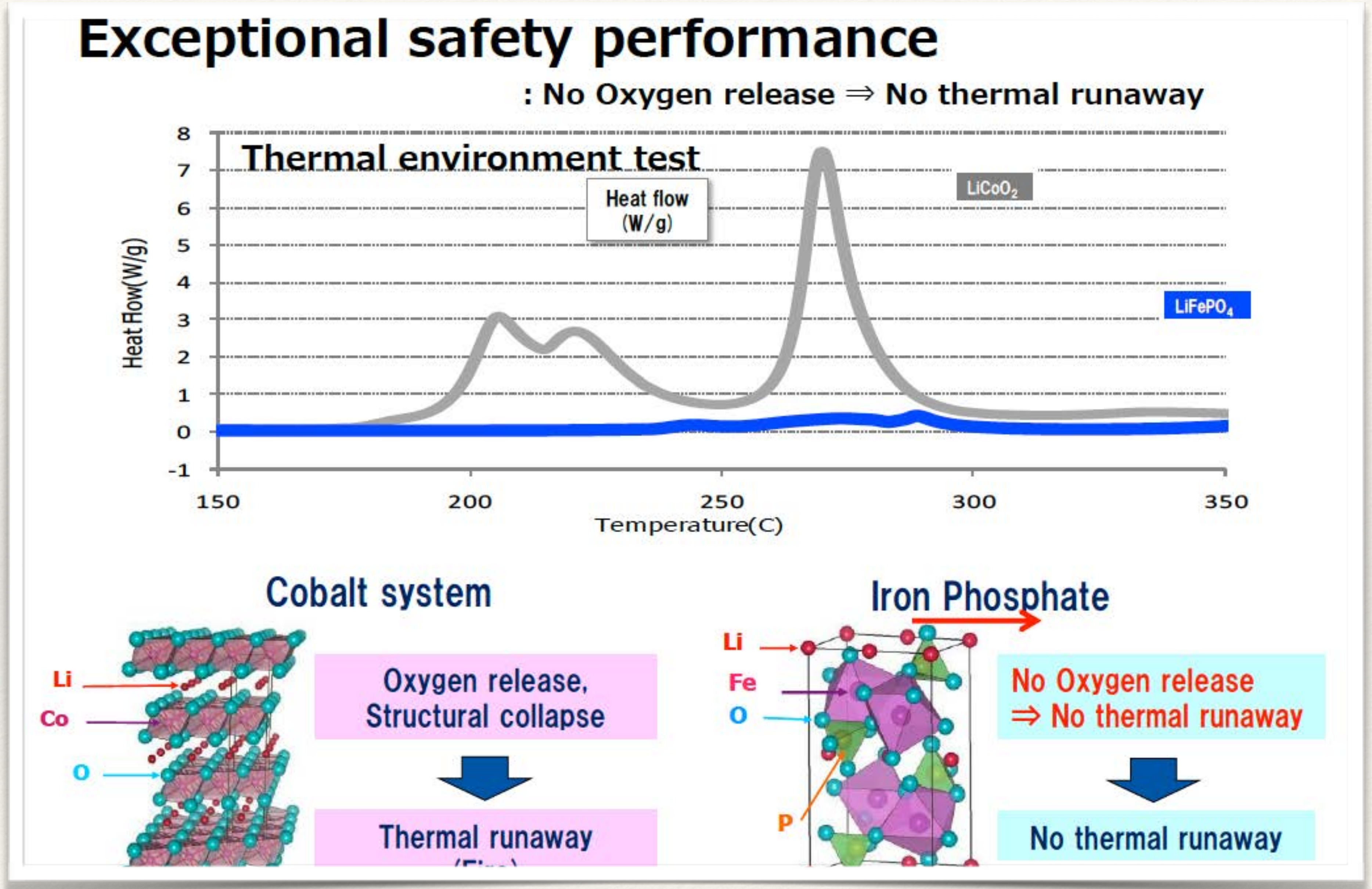
	Lead-acid	Li-ion	Olivine	Remark
Rating capacity(kWh)	10	10	10	
Unit cost @ capacity ($/kWh)	300	500	1000	Olivine looks expensive in terms only of the initial cost. The effective capacity and number of cycle have to be compared too.
Effective capacity(%)	50%	60%	100%	
Effective capacity(kWh)	5	6	10	
Number of cycle	3,000	3,500	8,000	
Lifetime capacity(kWh)	15,000	21,000	68,000*1	Olivine is actually cheaper than other types of battery.
Lifetime unit cost($/kWh)*2	0.20	0.24	0.15	

**1 Effective capacity x number of cycles. 0.85 of deterioration coefficient was applied only to Olivine for the 70% of capacity after 8,000 cycles*

**2 (Rating capacity x Unit cost) / Lifetime capacity. Battery part only. Actual cost may differ depending on the*

- Cycle Life & Cost/kWh of Different Chemistries

Calculating Costs



- Safety Factor Considerations

Conclusions

- Calculating LCOS is difficult as it depends on many assumptions & the specific application.
- In a rapidly growing market like energy storage, facts are sometimes obscured by marketing.
- Cost comparisons are very dependent on the LCOE in a particular locale.
- The true economics vary by Scale, Application, and Performance needed.