



Marine Battery Sizing

Canadian Ferry Association 2019

Overview



- Motivations
- Vocabulary
- Drivers
- Sizing
- Conclusions



Value Motivations



Size drives value proposition

- Motivation for electrification
- BEV, PHEV, HEV



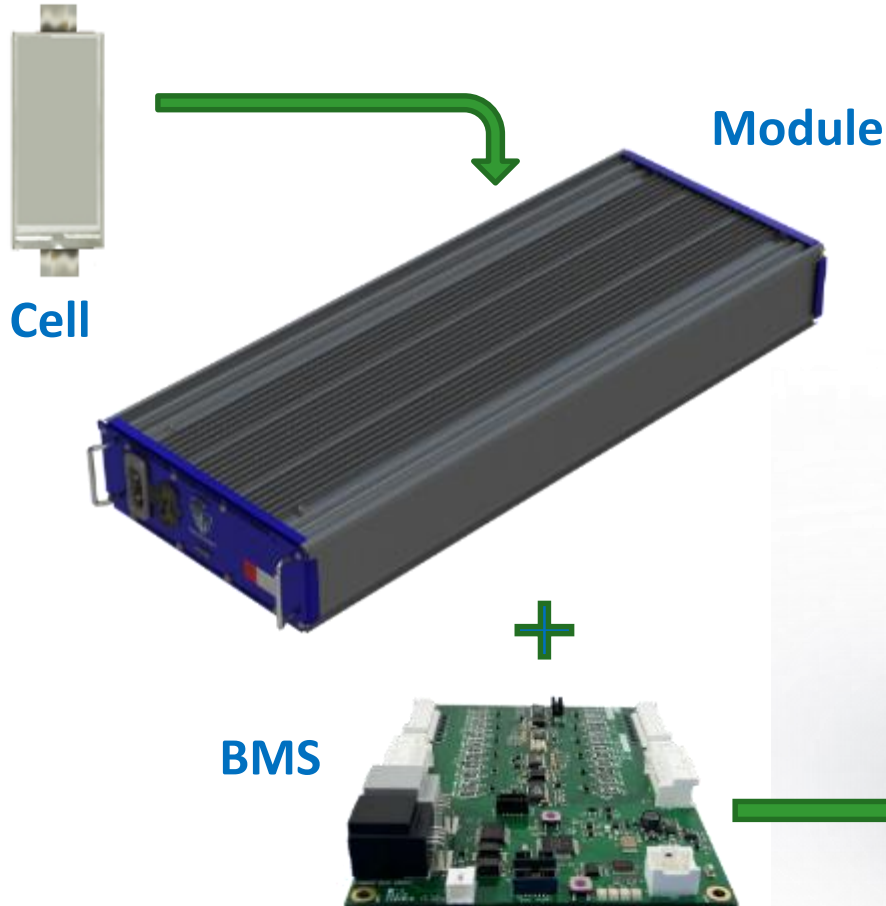
Stakeholder Motivations

All parties are motivated to make the battery as small, light, and cheap as possible

- Vessel owner is motivated by long term capital cost
- Battery vendor is motivated by competition and market perception
- Both parties also want a safe, durable battery



Terms



	ENERGY DENSITY	SPECIFIC ENERGY
Cell	414 Wh/L	205 Wh/kg
Module	136 Wh/L	115 Wh/kg
String	92 Wh/L	111 Wh/kg

Battery Life

The period of time over which the battery can complete its task

- Battery capacity is important to charge and discharge capability – limits defined by capacity
- Battery capacity declines over cycles, time, and other factors
- Power can also be a limit



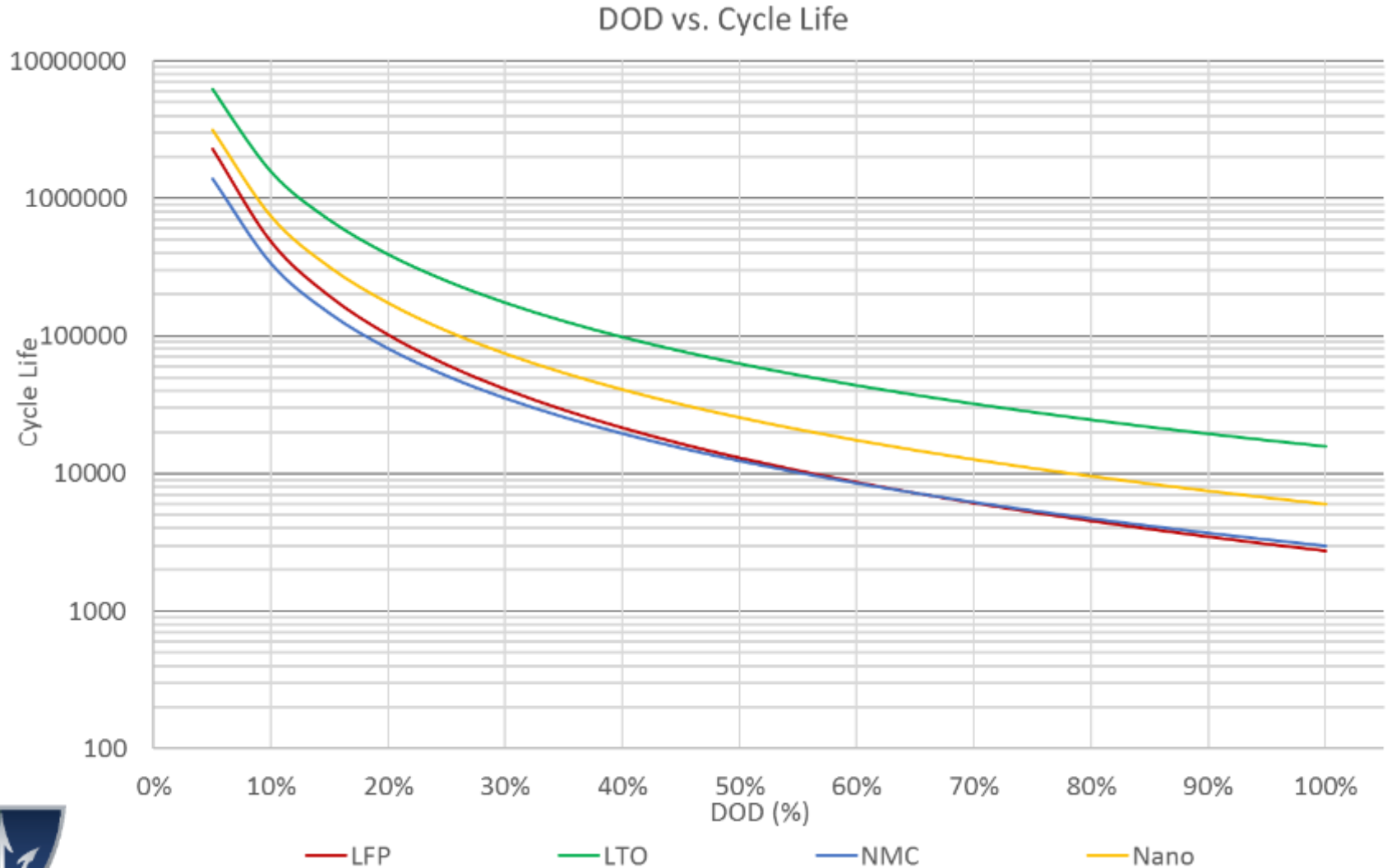
Lithium-ion



Lithium-Ion Chemistry	Cell-Level Energy Density	Cycle Life (at 80% DOD)	Recharge Time (0-80% SOC)	Advantages
Nickel Manganese Cobalt (NMC)	300-410 Wh/L	> 6,000 cycles	≥ 20 mins	<ul style="list-style-type: none"> • Highest energy density • Power/energy balance
Lithium Iron Phosphate (LFP)	200-250 Wh/L	> 6,000 cycles	≥ 20 mins	<ul style="list-style-type: none"> • Flat voltage response • Balanced chemistry
Lithium Titanate Oxide (LTO)	145-180 Wh/L	> 20,000 cycles	≥ 6 mins	<ul style="list-style-type: none"> • Highest cycle life • Highest continuous charge rates



Dynamic Aging



Dynamic Aging (only)

- **Passenger Ferry (full-electric):**
 - 100 kWh energy consumption each crossing (20 minutes in duration)
 - 10 minutes at the shore to charge battery system
 - Vessel operates for 15 hours/day = 30 cycles/day = 10,950 cycles/year
 - 7 year life desired → **76,650 cycles/life**



SOURCE: Green City Ferries

Typical Energy Consumed Between Charges	100 kWh
Number of Cycles (7 year life)	76,650
Maximum Allowable DOD	21 %
Minimum Embedded Energy	486 kWh



Static Aging

- **Complex Interaction**

- Temperature
- Average voltage
- Time



Conclusions

Battery sizing drives value

- Goal is to minimize cost and risk
- Cost of unexpected behavior much greater than initial capital delta
- Predictions and assumptions have to be made in order to move forward
- Distribution of risk produces the best economical case

