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Sodium Ion Batteries for Heavy Equipment

A Comparative White Paper: Sodium Ion vs. NMC and LFP

Introduction

The push for electrification in heavy equipment is driving demand for safe, robust, and cost-effective battery solutions. While NMC (Nickel Manganese Cobalt Oxide) and LFP (Lithium Iron Phosphate) dominate the market, Sodium Ion (Na-ion) batteries are emerging as a promising alternative. This white paper compares these chemistries with a focus on their suitability for heavy equipment, including cell specifications, pack design, and BMS requirements.

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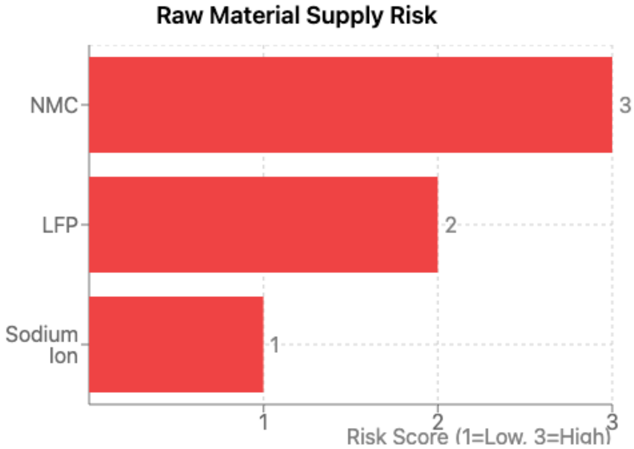
1. Chemistry Overview

Chemistry	Key Features	Typical Applications
NMC	High energy density, moderate safety	Mobile & compact equipment
LFP	High safety, long cycle life	Buses, heavy-duty, stationary
Sodium Ion	Abundant materials, cost-effective, robust safety	Emerging in heavy-duty, grid storage



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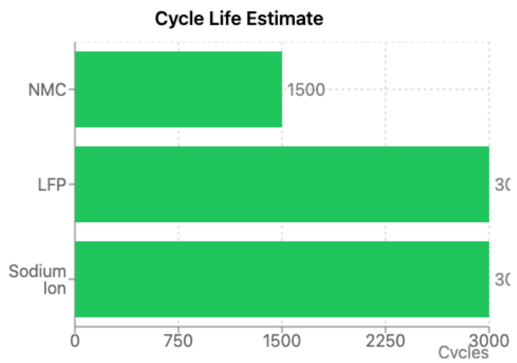
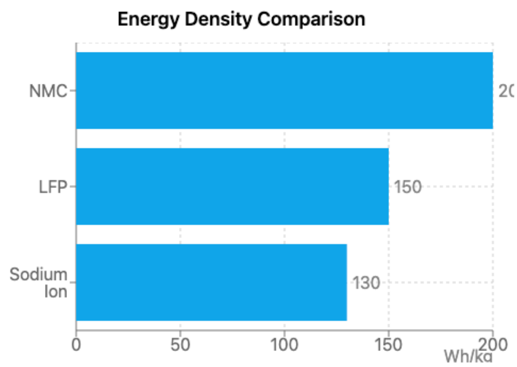
2. Pros and Cons for Heavy Equipment

Criteria	**NMC**	**LFP**	**Sodium Ion (Na-ion)**
Energy Density	180–230 Wh/kg	140–170 Wh/kg	100–160 Wh/kg*
Cycle Life	1,000–2,000	2,500–5,000+	2,000–4,000*
Safety	Moderate (thermal risk)	Excellent	Excellent
Operating Temp.	-20°C to 60°C	-30°C to 60°C	-30°C to 60°C*
Charging Speed	Fast	Moderate	Moderate
Cost	High	Moderate	Low (projected)*
Supply Chain	Cobalt/nickel/lithium	Lithium/iron	Sodium/iron/aluminum
Weight	Lightest	Heavier than NMC	Similar/heavier than LFP
Maturity	Mature	Mature	Emerging

*Based on current published data; performance may improve as technology mature





References:

- World Economic Forum: Is sodium the future of batteries?
- Battery University: Types of Lithium-ion Batteries
- Faradion Sodium-ion Technology

3. Cell Specifications & Calculations

Typical Cell Specs:

Parameter	NMC	LFP	Sodium Ion (Na-ion)
Nominal Voltage	3.6–3.7 V	3.2 V	2.3–3.0 V
Capacity (Ah)	30–100+	20–100+	10–100*
Gravimetric Energy Density	180–230 Wh/kg	140–170 Wh/kg	100–160 Wh/kg*
Volumetric Energy Density	500–700 Wh/L	350–500 Wh/L	200–400 Wh/L*
Typical Cycle Life	1,500	3,000+	2,000–4,000*

*Current Sodium Ion cells; expect improvement as tech matures.

Example Calculation: Sizing a 100 kWh Pack

- **NMC:** 100,000 Wh / 200 Wh/kg = **500 kg**
- **LFP:** 100,000 Wh / 150 Wh/kg = **667 kg**
- **Na-ion:** 100,000 Wh / 130 Wh/kg = **770 kg**

For a 100 kWh pack, Sodium Ion will be heavier and larger than NMC or LFP, but may offer cost and safety advantages. It also depends heavily on the applied safety measures and cooling applied in the pack.

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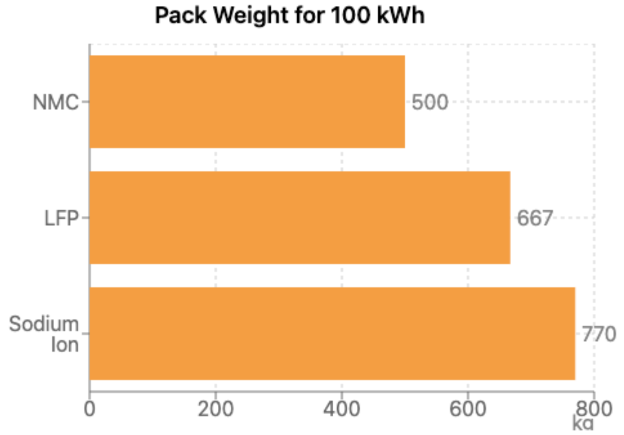
4. Pack Sizing and Design Considerations

Key Points:

- **Energy Density:** Lower for Sodium Ion, so packs will be larger/heavier for the same capacity.
- **Module Dimensions:** Sodium Ion cells may require more volume per kWh; important for equipment with tight space constraints.
- **Thermal Management:** Sodium Ion and LFP generate less heat and are less prone to thermal runaway, allowing for simpler cooling systems than NMC.
- **Mechanical Integration:** Extra weight may impact vehicle dynamics—critical for mobile or articulated equipment.
- **Scalability:** Sodium Ion's lower cost and abundant materials enable cost-effective scaling for large fleets or stationary assets.**Pack Design Example Table:**

Parameter	NMC	LFP	Sodium Ion
Pack Volume (100 kWh)	~150 L	~200 L	~250–300 L
Cooling Requirements	High	Moderate	Moderate
Integration Challenge	Low	Moderate	High (size)



5. BMS Specifications & Considerations

Key BMS (Battery Management System) Focus Areas:

Aspect	NMC	LFP	Sodium Ion
Voltage Window	2.7–4.2 V/cell	2.5–3.65 V/cell	1.5–4.0 V/cell*
SOC/SOH Accuracy	Standard	Requires tuning	Needs calibration*
Thermal Mgmt.	Critical (risk)	Moderate	Lower risk*
Cell Balancing	Important	Important	Important
Safety Features	Over-temp, OVP, UVP	Strong focus	Strong focus
Communication	CAN, Ethernet	CAN, Ethernet	CAN, Ethernet

*Sodium Ion BMSs must be tuned for the chemistry's unique voltage profiles and SOC (State of Charge) estimation, which can differ significantly from lithium-based cells.

Recommendations for Heavy Equipment:

- Use BMS with robust cell-level monitoring, especially for emerging chemistries (Na-ion).
- Ensure BMS supports wide voltage windows and can be reconfigured for new cell types.
- Implement advanced diagnostics (temperature, voltage, impedance) for early fault detection.
- Safety interlocks and thermal cutoff are critical in all pack designs.

6. Summary & Suitability

Sodium Ion Pros:

- Cost-effective (abundant sodium, no cobalt/nickel/lithium)
- Excellent safety and thermal stability
- Good cycle life, robust in harsh conditions
- Supply chain resilience

Sodium Ion Cons:

- Lower energy density (heavier/larger packs)
- Emerging technology (less field data, availability)
- May not suit highly compact or weight-sensitive machinery

References

- World Economic Forum: Is sodium the future of batteries?
- CATL launches sodium-ion battery
- Faradion Sodium-ion Technology
- Battery University: Types of Lithium-ion Batteries
- Clean Energy Institute: LFP Batteries

For further details, custom calculations, or to discuss your heavy equipment electrification project, contact PowerBattery.eu.