

LUX RESEARCH - CONSULTING PRIOR WORK EXAMPLE

Battery technology landscape for a leading power tool manufacturer

Delivered value:

The project provided our Client with a clear understanding of the energy storage options with recommendations integrated into their new product development strategy and roadmap.

Problem to be solved:

A leading power tool maker identified that its competitors are moving to battery-operated power tools and that advancements in battery technology are resulting in broader adoption. They hired Lux to help them catch up to their competition in the power tool market.

Lux Solution:

Lux built a landscape of 80+ emerging technologies at the component or cell level covering chemistry, miniaturization, and modularization aspects of Li-ion, solid state, and Li-sulfur batteries.

Lux aggregated the advancements and prioritized them by taking into account power tool user needs and performance metrics resulting to three leading battery architectures.

Lux provided key milestones and directional guidance on when the high-priority battery architectures will likely meet the desired increase performance criteria on the path to fulfilling our Client's ambition.

NMC offers greatest balance between specific energy and stability while providing a platform for future improvement

Technology and differentiators:

- Lithium nickel manganese cobalt oxide (NMC) chemical formula of $Li(Ni_xMn_yCo_z)O_2$ is one of the cathode materials for Li-ion batteries. The good balance between stability, cost, and specific energy.
- The ratios of Ni, Mn, and Co are tunable to customize for different performance. Developers are looking to increase the nickel content to capture more ions.

Challenges and future work:

- Different molar ratios and the crystallographic structure are being researched. The layout of the cathode and anode is a dispute over such. The final design will affect which players need to license from who to move forward with NMC technologies, although a preliminary ruling.

Production estimates:

- The demand for NMC-based cathodes will grow with the electric vehicle market; it is anticipated that 28 GWh by 2025 in just this application space.

Scoring criteria were chosen based on the application in question and key assumptions made

Main research trends: Increasing nickel content

3) A high level battery calculator was created and used iteratively to formulate scoring criteria per each metric. Assumptions were made regarding the application, tool and battery pack design factors.

Scoring criteria representing the low, medium, and high score were assigned to each metric. The scoring rubric allows for a vast analysis of key performance metrics, but also applicability factors that can influence adoption.

Energy Grade	Low (100-120)	Medium (120-150)	High (150-200)
Specific energy (Wh/kg)	<150	>150	>200
Voltage (V)	< 3.5	> 3.5	> 3.8
Current density (A/kg)	< 1000	> 1000	> 1500
Specific current (A/kg)	< 1000	> 1000	> 1500
Power density (W/kg)	< 3000	> 3000	> 5000
Specific power (W/kg)	< 3000	> 3000	> 5000
Discharge rate (C-rate)	< 1.5	> 1.5	> 2.0
Energy density (Wh/L)	< 400	> 400	> 600
Operating Temperature	< 10K and > 40C	> 10K and > 40C	> 10K and > 40C
Self-Discharge (pA/g)	< 100	> 100	> 200
Cell cost (\$/kWh)	< 400	> 400	> 500
Cost per cycle (\$/kWh)	< 0.1	> 0.1	> 0.2
Safety	High thermal runaway resistance, better components	Low thermal runaway resistance, better components	No thermal runaway risk or hazardous reaction
Stage of development	Lab	Introduction	In scale

Assumptions:

- 28550 cylindrical cell
- 80% eff. electric motor
- Single module battery pack (5 cells)
- 37% nominal cell efficiency to account for capacity fade, internal resistance, and safe design.

Power tool battery pack has followed a trend of voltage step changes by subsequent steps of increased capacity

Pack design needs to take into consideration emerging >4.2V and >3.5Ah battery cells.

With jumps in battery pack voltage more and more high power tools are electrified.

- As individual cell energy density increases, runtime improves, and more "space" is made available in the pack for cells, and thus "additional" voltage.
- As higher voltage and higher charge capacity electrodes are produced these jumps can be realized within required weight and cost limits.
- Emerging flexible voltage and capacity settings through power electronics increases flexibility.
- Therefore, it is critical to design the tool overall, and battery pack specifically, in ways that increases in voltage and capacity are anticipated and designed for.