BATTERY TECHNOLOGY

Battery Tech: From Lead to Lithium - and What's Next

A four generation review of chemistries, failure modes, critical minerals and the next gen pipeline.

Lead-acid 1859	Nickel-cadmium(NiCd) 1899	Nickel-metal hydride(NiMH) 1980s	Li-ion 1991

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WHAT'S INSIDE

THE EVOLUTION · WHY EACH CHEMISTRY GOT REPLACED

Every Chemistry Was Killed By Its Own Limit

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Lead-acid 1859 - now	Nickel-cadmium(NiCd) 1899 - 2009	Nickel-metal hydride(NiMH) 1980s - 2000s	Li-ion 1991 - now
Still alive Cheap and recyclable, but heavy with low energy density. Holds starter and backup duty.	**Killed by regulation** Cadmium is toxic. The EU banned it for consumer use and the chemistry never recovered.	**Killed by density** Lost the EV market to Li-ion on Wh/kg. Survives in hybrids and older tools.	**Current king** Best density at scale and falling cost, but not risk-free.

Regulation, then density, then cost, every ceiling was structural, not something incremental engineering could fix.

Li-ion's ceiling looks economic and geopolitical, not electrochemical, that changes what breaks it.

WHO CONTROLS THE MATERIALS

Li-ion Runs on Four Metals - One Country Dominates Three

Lithium

In 2024, Production by country : Australia 37% · Chile 20% · China 17%

Australia, the world's largest lithium producer, sent almost all its exports to China alone in 2023; In the midstream sector, approximately 65% of the world's lithium processing capacity is concentrated in China. Mining is diversified; conversion capacity is not.

Cobalt

In 2024, Production by country : DR Congo 76%

Chinese owned firms mine the majority of Congolese output.

Nickel

In 2024, Production by country : Indonesia 61%

One country now sets the price of class-1 battery nickel.

Graphite

In 2024, Production by country : China 78% mining · 97% anode grade synthetic processing

Graphite is the primary material used to make the anode (the negative side) in almost all standard lithium ion batteries. The tightest single chokepoint in the anode chain.

China's Dec 2023 graphite export licensing is the template for how fast access can be re priced.

WHAT'S STILL BROKEN IN LI-ION

Li-ion Solved Density. It Didn't Solve Risk.

01
Thermal Runaway
Flammable liquid electrolyte. Thousands of EV fire events were reported between 2020 and 2026.

02
Capacity Fade
Fast charging and heat degrade cells; lithium plating can seed internal short circuits.

03
Recycling Gap
A 50% EU recovery target for Li-ion after 2027 against 90% for lead-acid, genuinely behind in recycling process.

04
Value Chain Concentration
Cells, anode, electrolyte and recycled material refining all cluster in one country.

80%+
of global cell output

90%+
anode & electrolyte capacity

89%
Recycled material refining

China's share of the Li-ion value chain, the risk is concentration. Even if New tech solid state is considered as new normal, Lithium is still largely controlled by China.

No Single Successor - Two Bets Running at Once

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Solid-State
The density and safety bet

- **Target:** 400-500 Wh/kg vs 200-300 Wh/kg today
- **Players:** Toyota, Samsung SDI, QuantumScape, CATL
- **Ramp:** production mostly 2027-2030
- **Trade off:** scaleup and manufacturing cost unproven
- **Wins first:** premium EVs where range and safety pay

Sodium-Ion
The cost and independence bet

- **Materials:** no lithium, cobalt or nickel needed
- **Cost:** Sodium cheaper than Lithium
- **Ramp:** CATL targeting LFP cost parity by late 2026
- **Trade off:** lower density at 100-170 Wh/kg
- **Wins first:** grid storage, two wheelers, entry EVs

The density race and the cost race are separate bets, not sequential - expect each to win a different segment.

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