Looking Beyond Lithium-Ion -- How Soon?

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BUILDING CAPACITY

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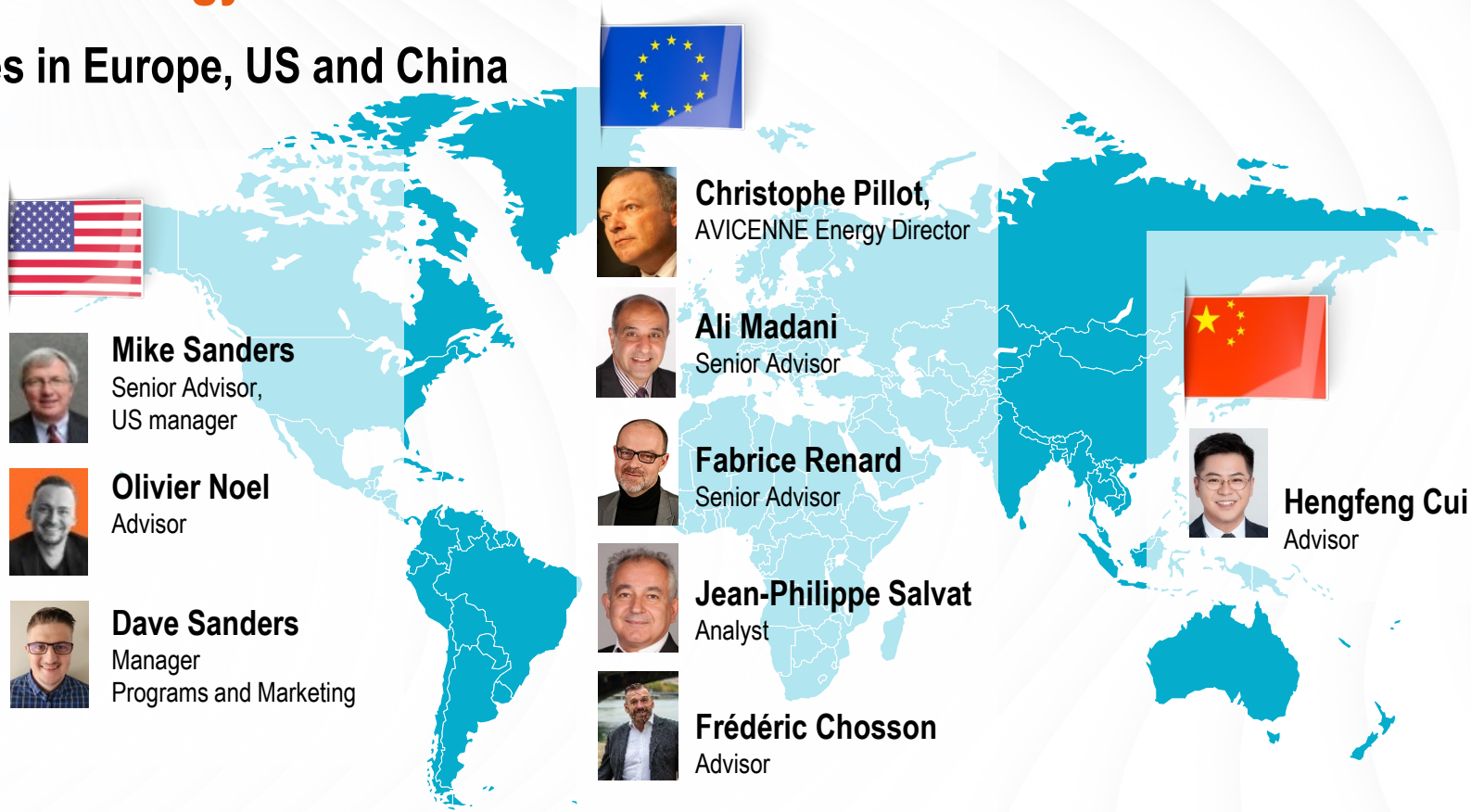

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Looking Beyond Lithium-Ion

Megatrends and Market Pressures

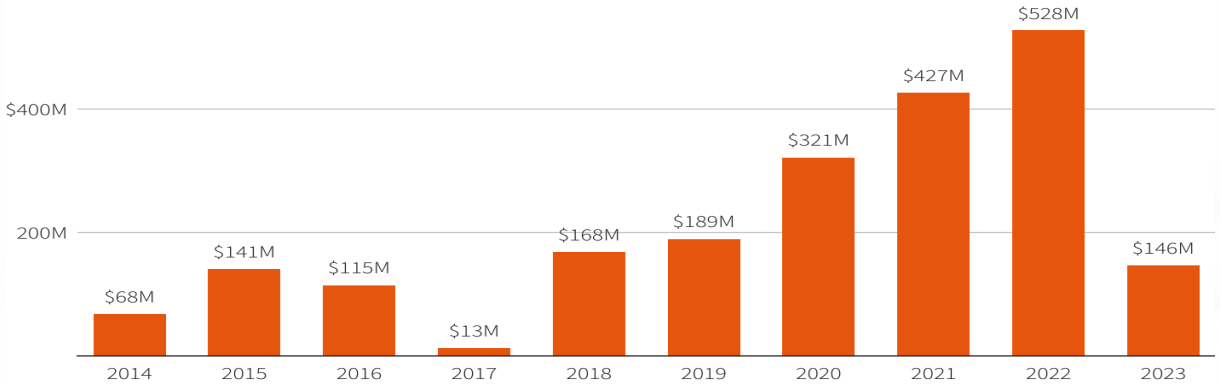
- **Lithium Ion is in the mass commercialization phase, along with price pressures, has strained emerging technologies for focus, resources and capital**
- **Solid State continues to have interest; however, many have gone through tech pivots, market focus changes and management turnover**
  - Semi-Solid State, move to consumer batteries, commercial launch promises now mainly in 2027 and beyond
  - Beijing forms national alliance in all-out effort to revolutionize the EV market
- **Sodium Ion made significant market splash with commercialization in CN**
  - West is mostly start-ups and promises to commercialize – but no significant capacity announcement outside CN
- **Lithium prices are expected to remain near market lows for next few years**
  - Good news for Lithium Metal and LIB
  - Bad news for Sodium Ion
- **Many technologies in development that could be interesting for what is next or to establish additional storage capabilities if Lithium, Nickel and Cobalt – have either pricing or supply issues**
  - Li-S, Mg Ion, Molten Sodium, Zinc-air, Iron-qir, Flow…

Looking Beyond Lithium

Solid State Investment Plunges – Rueters January 2024

Investment in solid-state battery start-ups plunges in 2023

Delays by companies developing solid-state batteries for electric vehicles after facing technical hurdles have dimmed appetite for venture capital investment in start-ups on disappointment that the potential for longer EV driving ranges and fast charging has not yet been commercialised.



Note: Millions of dollars in global venture capital deal activity in solid-state battery firms
Source: PitchBook | Reuters, January 2024 | By Eric Onstad

CATL, BYD, others unite in China for solid-state battery breakthrough

Beijing forms national alliance in all-out effort to revolutionize the EV market

China's battery and car makers have united as part of a government-led drive to commercialize all solid-state batteries, challenging Japan and the West in an area of technology that could revolutionize the electric vehicle market.

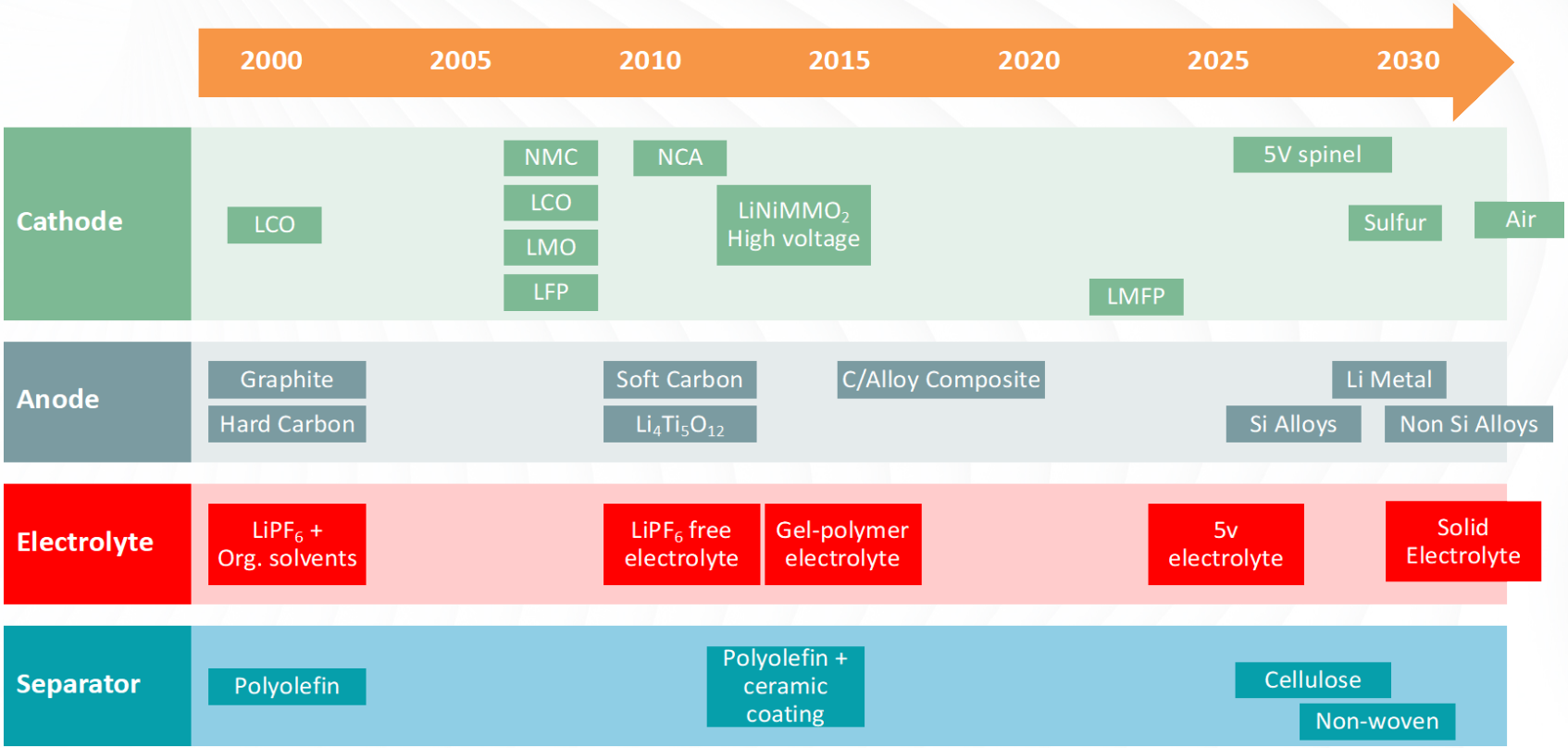
Aiming to build a supply chain for solid-state batteries by 2030, Beijing in January set up a consortium, the China All-Solid-State Battery Collaborative Innovation Platform (CASIP), which brings together government, academia and industry, including EV battery rivals CATL and BYD.

China is stepping up research and development of the next-generation batteries, leveraging artificial intelligence and other technologies.

Battery makers participating in the alliance include CATL, formally Contemporary Amperex Technology Co. Ltd., BYD subsidiary FinDreams Battery, CALB, EVE Energy and Gotion High-tech. Six of the top 10 automotive battery makers globally are taking part in the initiative, showcasing China's "all-star" lineup. Automakers, mainly state-owned enterprises, as well as private automakers BYD and Nio are also taking part.

Source: Nikkei Asia 2/12/24

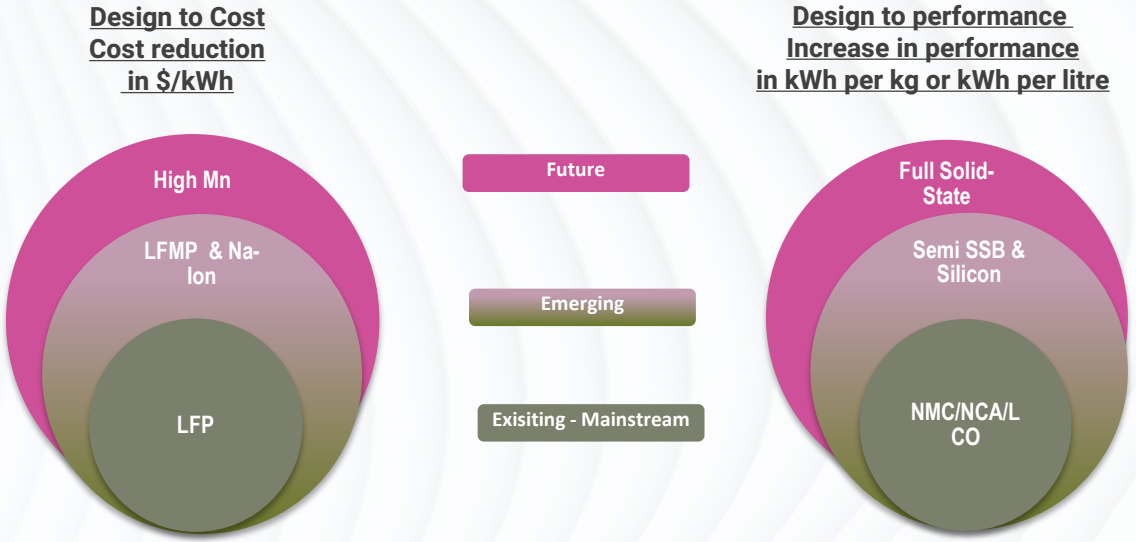
Technology roadmap



Source: Avicenne Energy 2023

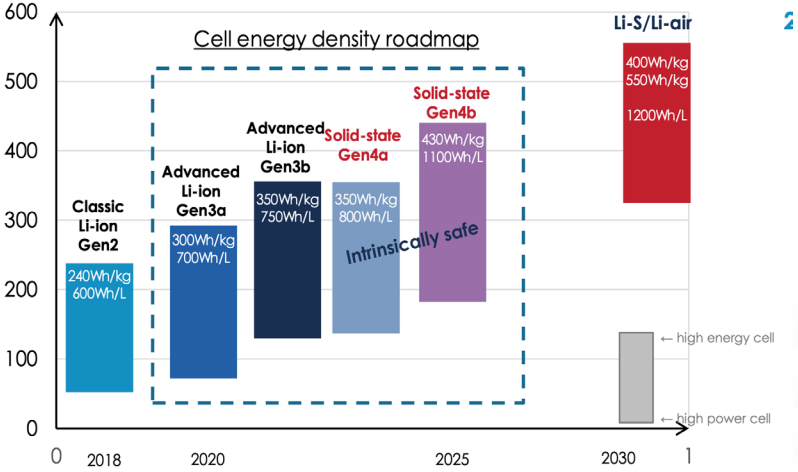
Technical Directions are split - Design to cost or Design for performance

Ideal would be both, but we have seen limited capability to deliver both cost and performance



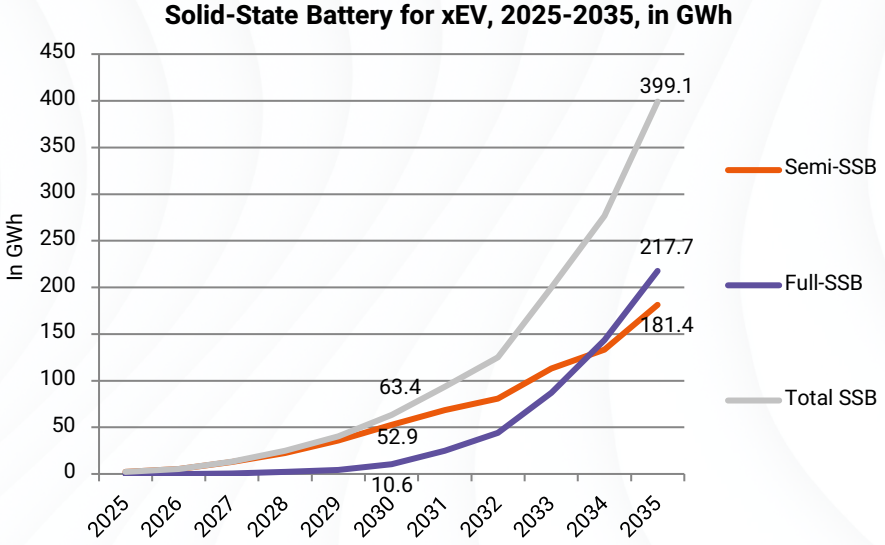
Solid-State battery for automotive: semi/hybrid versus all solid-state

- For large application like EV, the first generation **(Gen4a)** is called **semi-solid or hybrid solid state** and can be synthetically described as: **Lithium-Ion in which the electrolyte and separator are replaced by a solid/liquid electrolyte**; cathode and anode active materials **remain the same**; safety will be improved but not the energy performance

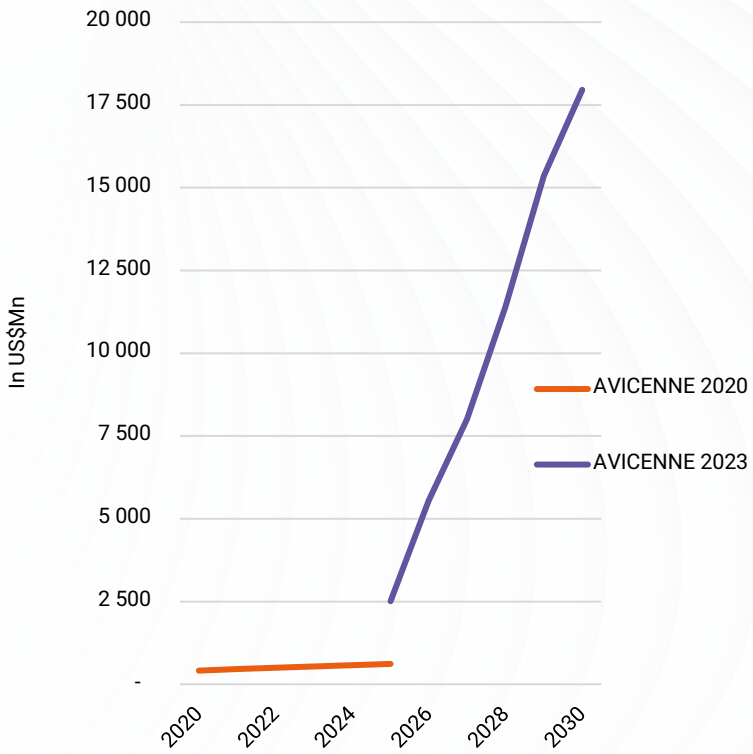


Source: Saft, based on internal expertise, EU commission, MIIT, NEDO, German VDA. Generation names aligned with EU commission roadmap.

- Second Generation **(Gen4b)** is **all solid-state battery** and can be synthetically described as: **Lithium-Ion in which the electrolyte and separator are replaced by a solid electrolyte**; graphite-based anode active material is **replacing by lithium**; safety and energy performance will be improved



Source: Avicenne Energy 2023



The Sodium-Ion battery market

Unexpected take-off three years ago
Major applications and participants

- **Market scope: Mostly LSEV and Budget Auto, ESS applications – Telecom, UPS and Renewables**
- **Market will remain smaller than for lead-acid and lithium-ion**
- **Mostly being developed by large CN Battery and mid-stage start-ups**
- **The sodium-ion battery market is mostly consolidated and limited to mid-stage start-ups making it challenging to forecast**
- **The key players in the market include CATL, BYD, Faradion, AGM, NGK, TIAMAT, HiNa, Altris, and Natron**

Electric truck development gets $131 million boost

Li-S viewed as winner in DOE funding, hydrogen funded but at lower level

The US Department of Energy's latest round of funding includes millions for truck OEMs like Cummins and Paccar to earmark for battery research and help drive lower electric truck battery prices and advance the cause of EVs in the transportation sector.

$60 million of the DoE funds will go to the United States Advanced Battery Consortium to further develop lightweight, lower-cost batteries for light, medium, and heavy-duty vehicles, as well as less expensive battery recycling processes.

The remaining $71 million is being split across 27 other projects, each focused on increasing driving range range, reducing battery costs, and advancing on-board EV charging systems and telematics. Among those projects, battery tech startups Lyten and Zeta Energy, as well as manufacturing company Coherent, stand out – because they're working on lithium-*sulfur* batteries.

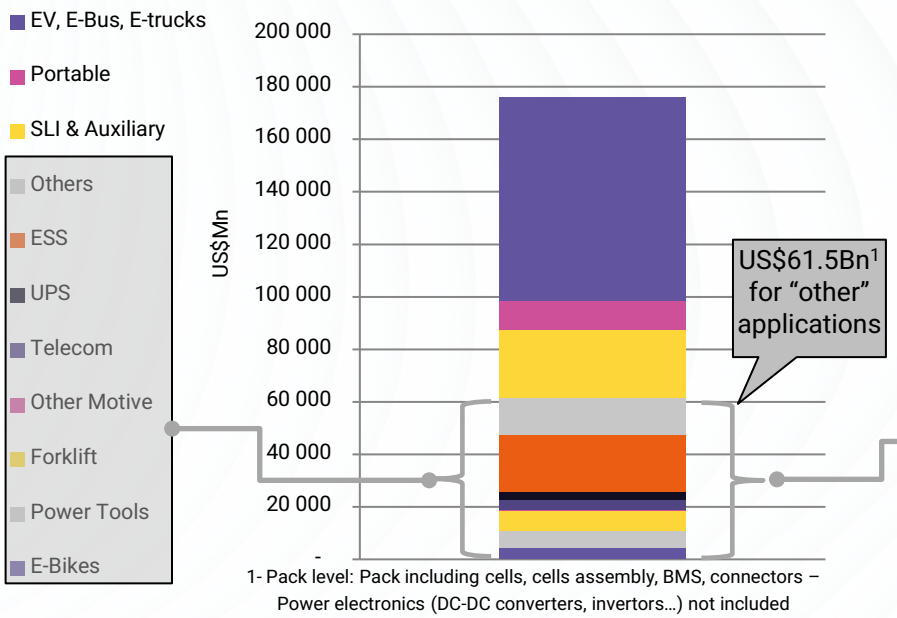
Each of the three companies received more than $3 million specifically to develop lithium-sulfur battery tech, which researchers at Argonne National Lab say could be more affordable to produce than ion-based batteries while also offering superior energy density to "conventional" li-ion batteries.

Source: Electek 1/24/24

The worldwide battery market in 2022

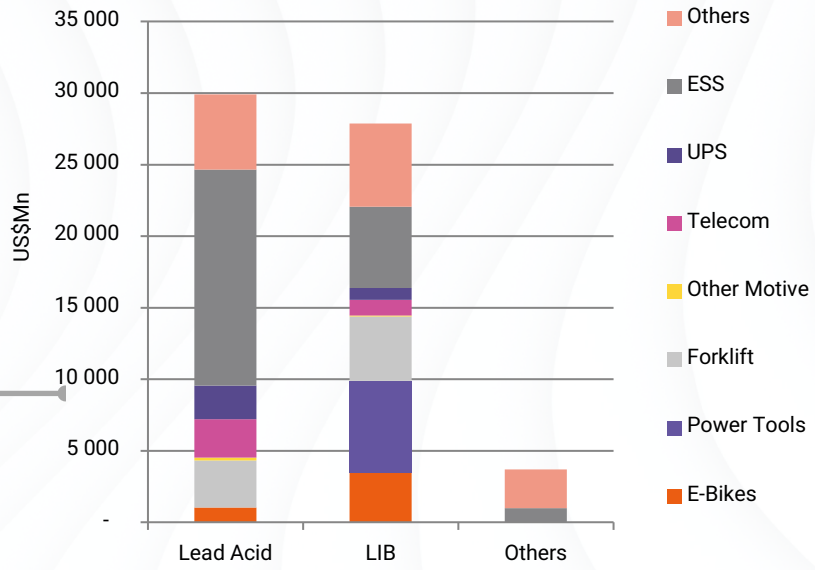
Beyond EV, Portable & SLI market, a lot of “other” applications are growing, representing an additional market of US$61.5Bn[1] in 2022

Worldwide battery Market split in applications, 2022, US$Mn



1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC-DC converters, invertors…) not included

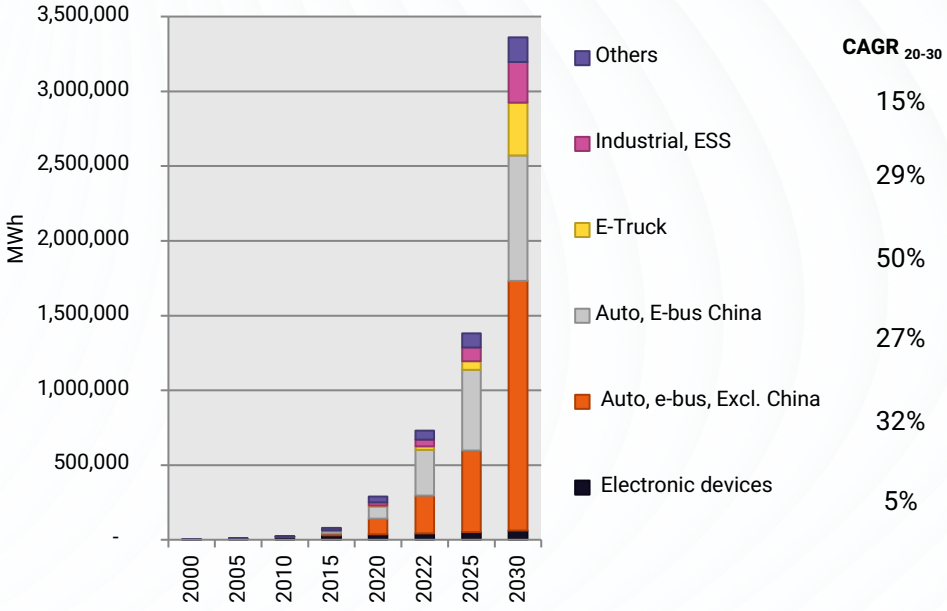
Worldwide « other » battery applications split in applications & chemistry, 2022, US$Mn



Li-ion battery market forecast

From 730 GWh in 2022 to 3.36 TWh in 2030 - $CAGR_{20-30}$: 28%

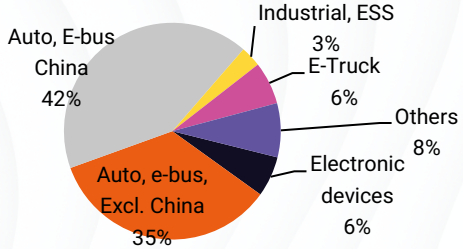
Li-ion Battery sales, Worldwide, 2000-2030, MWh



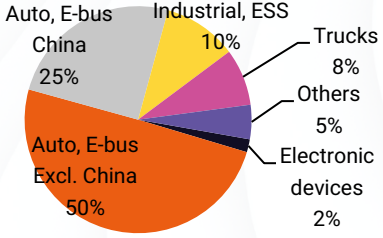
	CAGR 20-30
Others	15%
Industrial, ESS	29%
E-Truck	50%
Auto, E-bus China	27%
Auto, e-bus, Excl. China	32%
Electronic devices	5%

Others: medical devices, power tools, gardening tools, e-bikes…

2022: 730 GWh



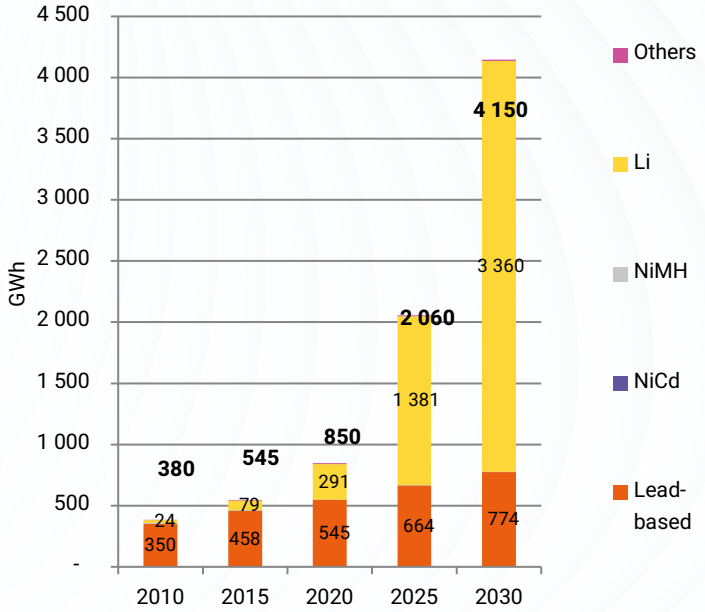
2030: 3,360 GWh



Worldwide battery market

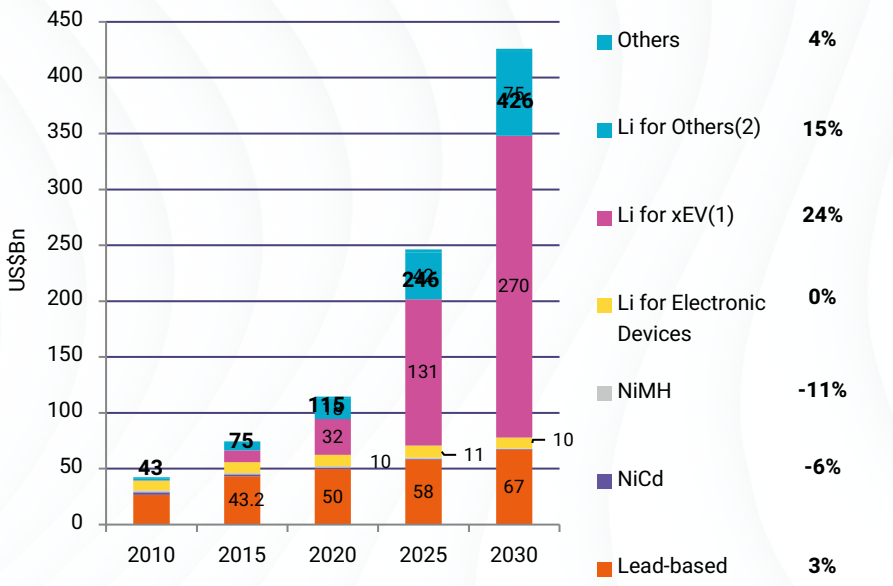
Lead-based and li-ion batteries will remain in 2030, the 2 most important markets and will reach 4.15 TWh & US$≈430Bn in 2030. The $CAGR_{20-30}$ in value is 14%

The worldwide battery market in value by chemistry, 2010-2030, GWh



(1) Pack level: pack including cells, cell assembly, BMS, connectors – power electronics (DC-DC converters, invertors, etc.) not included

Market value at Pack level[1], 2010-2030, in US$Bn



(1): Li for xEV including all kind of electric passenger cars HEV, PHEV & EV, E-buses, E-trucks, E-vans

(2): Others: automatic handling equipment, robots, forklifts, UPS, telecom, medical devices, residential ESS, grid ESS, drones, hoverboards, etc.

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