

9th Workshop – “Lithium-Sulfur” Batteries

How much potential is hidden in next-gen battery technologies, and can they be successfully placed in the automotive market?

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Prepared for



Fraunhofer
IWS

Agenda

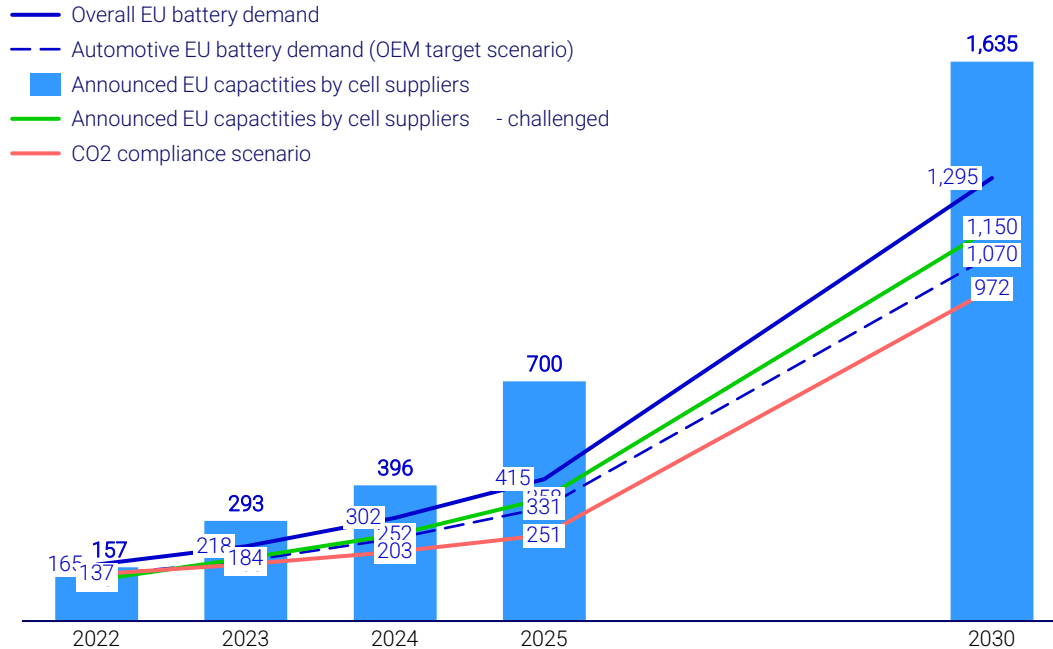
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|---|---|---|
| 1 | European Battery Market Forecast & Requirements | 3 |
| 2 | Trends in the LIB Market | 6 |
| 3 | Beyond LIBs - Assessment of Automotive Market Potential | 9 |

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1	European Battery Market Forecast & Requirements	3
2	Trends in the LIB Market	6
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Driven by vehicle manufacturer announcement to reach electrification rates above 70% by 2030 the European cell demand will 8-fold between 2022 and 2030 and push local establishment of cell production capacities

European battery supply and demand development [GWh/a]



Sources: P3 demand and supply-based market model (2022), European CO2 emission targets, OEM announcements, expert interviews
 Note: Ramp-up scenarios not considering vehicle manufacturer target feasibility assessment and correcting factors

Rationale

- Expected capacity growth in demand for battery cells will achieve > 1.2TWh until 2030 for OEM target scenario based on the **latest announcements of located OEMs in Europe**.
- Other segments such as **LCVs, Bus & Truck, stationary energy storage and others** are identified with **10% by 2030** of the battery cell demand due to lower market shares compared to passenger cars.
- Worst case** scenario is based on the **CO2 compliance case** considering vehicle manufacturing specific fleet emission targets and leads to **972 GWh cell demand in 2030**
- Ambitious announcements** of production capacities not only by **BIC cell manufacturers** but also, by **newcomers** are leading to partial oversupply expectations until 2030 by 10%.
- Unproven newcomers** suffer **severe setbacks** in terms of schedule and start-up/learning curve as the complexity of cell production was underestimated.
- European cell production capacities from **European newcomers or established Asian players** located in Europe will be able to **cover 90% of the demand by 2030**.

Automotive OEM requirements call for technological developments leading to the fact that innovation and new technologies on both, material and cell level, are necessary for successful products and competitiveness.

Main automotive push factors



LOW COSTS



HIGH ENERGY DENSITY



FAST CHARGING CAPABILITIES



LIFETIME

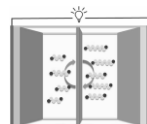
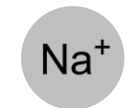
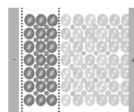
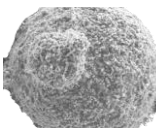
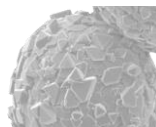


SUSTAINABILITY



SAFETY

TRANSLATION INTO
INNOVATIVE PRODUCTS



High nickel cathode active material

- Particle doping/coating

Silicon based anodes

- Advanced materials and specific compositions

Solid-state technology

- Fully solid-state hybrid or semi-solid-state approaches

Na-Ion technology

- Na-Ion as sustainable and low-cost alternative

Lithium-Sulfur

- Sulfur cathode and Li-metal as anode to increase energy density

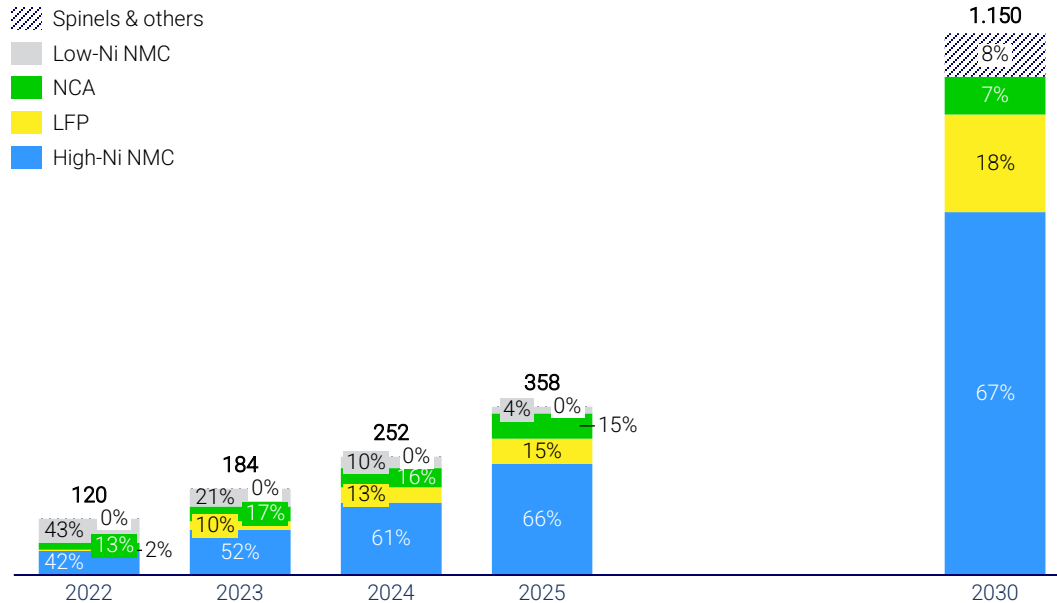
Beyond LIBs

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Technology roadmaps of cell manufacturers indicate that high-nickel materials will remain the leading cathode cell chemistry on automotive mass market in Europe.

Predicted CAM demand distribution in automotive applications EU [GWh/a]



Sources: P3 demand and supply-based market model (2022), European CO2 emission targets, OEM announcements, expert interviews
 Note: Ramp-up scenarios not considering vehicle manufacturer target feasibility assessment and correcting factors

Rationale

- Automotive **cost, lifetime and range requirements** are appropriately reflected in the **CAM roadmap** of corresponding cell suppliers in Europe.
- The demand in automotive industry and the announced technology roadmaps of cell suppliers display **NMC-811, with a share of 80% Nickel** or even higher, will dominate as CAM material already in **2024 due to energy density targets and cost reduction per kWh**.
- Due to **supply chain constrains and safety problems of high-Ni materials**, **LFP** is announced to be utilized by western OEMs and will be rolled out on a wider scale starting in **2030**. Currently, the **LFP market is dominated by Chinese cell manufacturers**.
- For 2030 it is expected, that **LFP** will have a market share of **18%**, while **NMC/NCA** are utilized in **74%** of deployed battery capacity.
- High-voltage CAM or Mn-rich material** technologies are pulled in the European market by players such as **SVOLT or Morrow** might reach up to **8% by 2030**.

Silicon-Anode Materials: The technologies are engaged in several automotive projects and offer drop-in solutions for existing cell manufacturing processes with potential to increase energy density and improvement of fast charging capability.

High-Silicon anode technology fit in the automotive market

Key Players



Performance

		Silicon	Graphite
	Low cost		
	Energy density		
	Lifetime		
	Fast Charging		
	Sustainability		
	Safety		

Rationale

- high-Silicon content anodes require special post treatment leading to higher costs **>30 EUR/kg compared to artificial graphite with 8-11 EUR/kg.**
- Silicon offers **fast kinetics due to 3D insertion** and alloy formation with Li. This enables opportunities for fast-charging applications.
- The disadvantages are the **large volume change** (up to 400%) during **charge and discharge**, accelerated aging effects and **limited lifetime of the battery.**
- Advanced nano-Silicon-carbon composites boost-up the energy density from **670 Wh/l for graphite to over 1100 Wh/l**
- In order to achieve **proof-of-concept in automotive application**, named players already enter development projects and form **alliances with large OEMs as BMW, Daimler or VW group.**
- Full replacement of graphite as active material by Silicon is likely considered in **premium automotive segment** related to more acceptance towards price premium or further **niche applications such as e-aviation.**

Key players either offering **Silicon material as drop-in solution** in LIB manufacturing process or **Silicon electrodes**, high Silicon content anodes offer potential for further **energy density and fast charging improvement**

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Solid-State Technologies: Technological limitations of ASSB cell chemistries will delay market entry in automotive segment up to 2035.

Solid-state technology fit in the automotive market

Key Players



Performance

		ASSB	LIB
	Low cost		
	Energy density		
	Lifetime		
	Fast Charging		
	Sustainability		
	Safety		

Rationale

- According to the **roadmaps of cell suppliers** and cells in development, **most targets for 2025 will be fulfilled** (incl. energy density) with next gen LIB cell technologies by implementation of advanced components and adjustments in cell design.
- Exemplary **improvement by StoreDot for fast charging** (with increased **silicon anode share**) can reach up to 8C – 5C targeted for 2025 already.
- Current technology maturity status of ASSBs shows a **moderate fit** between **corresponding capabilities and the automotive requirements**.
- The concept of solid-state technology has **clear hurdles** when it comes to **C-rate capability related KPIs** due to **limited kinetics of the cell chemistries**.
- Therefore, a market entry with significant shares is **not expected before 2035 in automotive segment**.

Large efforts are happening on the solid-state battery market including **strong engagement with players from automotive sectors** and **first prototypes for semi-solid-state technology** in China are already on the roads.. However, **performance hurdles** still need to be overcome to gain significant market shares.

Semi-solid-state has been accepted as a compromise technology by many OEMs. Main players are found in the US with corresponding invests of several hundred MUSD. Chinese players have already achieved platform integration with OEM partners as Nio or Dongfeng.



Sodium-Ion Technology: In terms of working principle and manufacturing, NIBs are mainly comparable to LIBs with limitation in energy density but outstanding power capability and sustainability and material cost advantage.

Sodium-ion technology fit in the automotive market

Key Players



Performance

		SIB	LIB
	Low cost		
	Energy density		
	Lifetime		
	Fast Charging		
	Sustainability		
	Safety		

Rationale

- Complementary technology with similar processes and cell construction requirements allows a **fast transition and adaption**
- Still in **early stage** /w **lacking industrialized solutions**. Several **start-ups** are working on development. **Fast ramp-up is expected**.
- Chinese Li-ion battery giant CATL**, announced last year a **first-generation NIB battery** with **160 Wh/kg** and nominal voltage of **3.0-3.2 V** to market by **2023**.
- Huge **sustainability and cost-saving potential** due to **Ni, Co and Li-free cathode material** (Prussian-blue Iron-based)
- Low energy density** might be a problem for application in EVs. Possible market segments to enter include mainly **LFP-driven applications** (stationary, power tools, low cost, short range and HEVs).

Key players in the market offer **solutions from cathode material to full cell set-up for stationary applications**, the technology overtakes LIBs in terms of **material cost, sustainability, power capability**

Lithium-Sulfur Flashlights: The increased pace of development in Li-S batteries has placed it as one of the most interesting beyond Li-ion technologies, expecting a technological maturity by the end of this decade

1,000-cycle lithium-sulfur battery could quintuple electric vehicle ranges

Energy • Electric Vehicles



Li-S Energy signs deal with Janus to power 400 electric trucks

Energy

November 23, 2021

This Prime Mover was converted by Janus Electric and is operating with a Janus Electric Motor and changeable 600KWh battery pack. Pic: Supplied

VTGMP secures licenses for lithium sulfur battery from KERI



Sep 28, 2021 - 01:47 pm

Lyten to launch Li-S battery for 2025/26

LG Chem's Li-Sulfur Battery Successfully Tested In High Altitude Aircraft

Lithium-sulfur batteries are considered as one of several next-generation technologies to significantly increase the energy density.



Lithium-Sulfur Battery, the Soaring Next-Gen Battery

2022.07.29 | R&D Story

NEWS RELEASE 30-JUN-2022

Two opposing approaches could give lithium-sulfur batteries a leg up over lithium-ion

Peer-Reviewed Publication
TSINGHUA UNIVERSITY PRESS

MAY 12, 2022

Next generation lithium-sulfur battery solves the loss of sulfur problem

by National Research Council of Science & Technology



Australian researchers announce lithium-sulfur battery breakthrough

Researchers from Australia's Monash University have created a new generation of lithium-sulfur batteries to provide a cheaper cleaner and faster-charging energy storage solution that outlasts lithium-ion alternatives and is rechargeable hundreds of times without failing.

MARCH 7, 2022

Former QuantumScape, Tesla Executive Joins Battery Startup Working on Nickel Rival

- Tesla veteran Mikolajczak departed QuantumScape last month
- Lyten making lithium-sulfur battery to offset metal shortage

GS Yuasa Achieves R&D Milestone in NEDO Advanced Aircraft System Commercialization Project –Successful demonstration of 400Wh/kg-class lithium-sulfur battery–

BUSINESS

Lithium-Sulfur batteries: Have gained attention over the last years as a key technology for future aerospace applications and for a possible future replacement of LIBs in automotive applications.

Lithium-Sulfur technology fit in the automotive market

Key Players



Performance

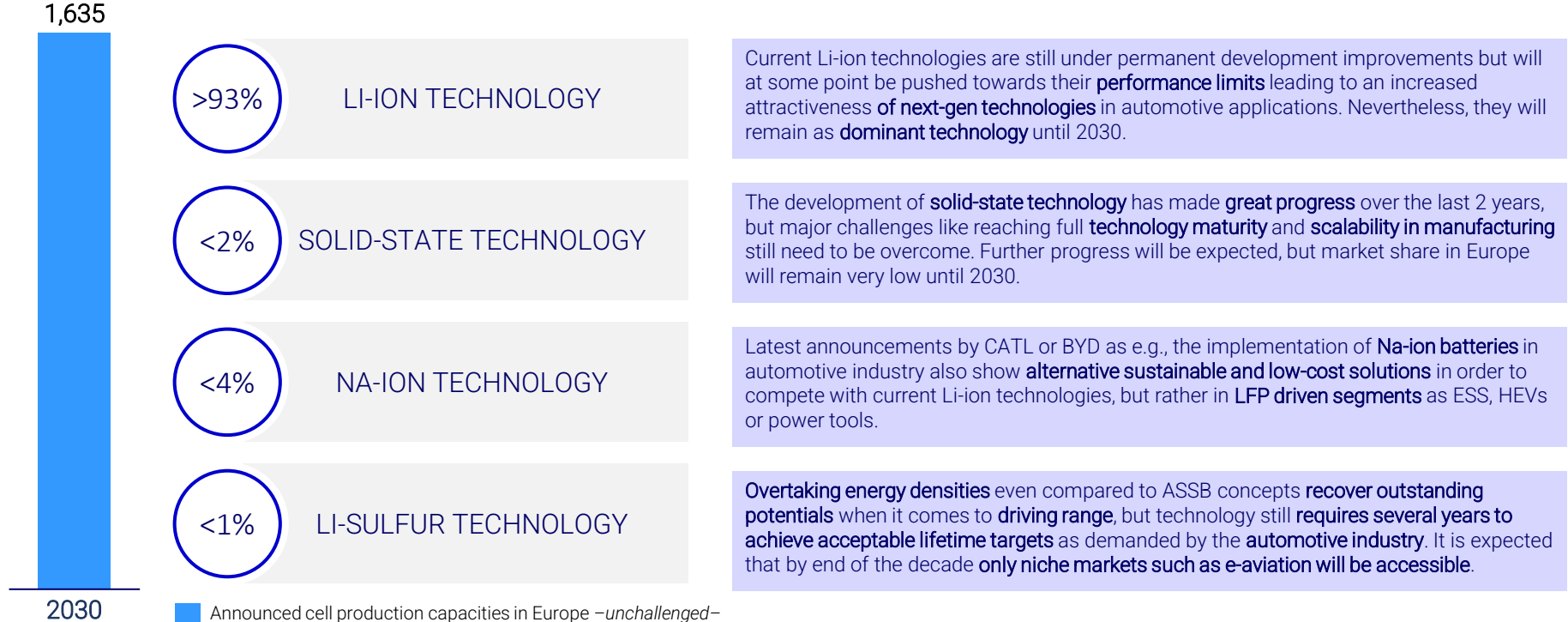
		Li-S	LIB
	Low cost		
	Energy density		
	Lifetime		
	Fast Charging		
	Sustainability		
	Safety		

Rationale

- **Lithium-sulfur batteries** with their **ultralight weight** can deliver **very high specific energy**, with values over **400 Wh/kg** (1.5-2 times greater than standard LIBs).
- **LiSBs** have enabled widespread use in **drones, satellites and military vehicles** so far and are expected to find a strong application into the **aviation sector** in the coming years.
- **Li-S batteries** has already a **high technology and manufacturing readiness** levels due to similar manufacturing process to LIBs.
- **Potential cost competitiveness** compared to LIBs, however, **specific treatment of Sulfur, implementation of Lithium metal and utilization of expensive Li-salts** are considered as key driver
- **Capacities and lifetime** of Lithium-sulfur batteries suffer due **shuttling of LiPS and instability of Li metal**.
- **Diffusion of intermediate polysulfide (PS) species** to the anode results in the **loss of CAM during cycling (PS shuttle)**, reducing energy density, rechargeability of the cells and cycle life.

Some players faced bankruptcy (Oxis Energy) and other players (Sion Power) changed their strategy due to the performance **issues of Li-S technology**. Nevertheless, some key players are still focused on the further development to achieve **technological maturity and possible commercialization** at the end of this decade.

LIB technology will dominate the electric passenger car market in the long term, advanced materials can partly be catch-up with next-gen technologies. Lithium-sulfur is expected to find application in high margin segments where weight is a premium.



Thank you for your attention!



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