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MARKET INTELLIGENCE REPORT

COBRA

KEY TECHNICAL, POLICY AND MARKET DEVELOPMENTS INFLUENCING THE ELECTRIC VEHICLE BATTERY LANDSCAPE

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SOLID-STATE ELECTROLYTES

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INTRODUCTION

Solid-state batteries (SSBs) have been dubbed by many as *the holy grail* of energy storage. Researchers and industry alike believe that transitioning from liquid to solid electrolytes can lead to a **breakthrough in battery KPIs**, such as energy density, safety, fast-charging capabilities, and cost. While many of these benefits have only been proven on paper or in the lab so far, huge investments have been put in place to make this new technology a reality. Not only because of its promising properties, but also because the SSBs give hope to European and US companies looking to **disrupt the electrolytes market**, almost entirely dominated by Asian manufacturers at the moment. This is particularly important considering recent efforts to domesticate battery supply chains. Where do SSBs outperform batteries based on liquid electrolytes? When will they become price-competitive? Which companies are closest to commercialisation? This Market Intelligence Report investigates different solid-state electrolyte concepts, comparing both their electrochemical performance and market potential. Moreover, with the support of COBRA's partner Solvionic we explain how difficult it is to **switch from liquid to solid electrolyte production**, present key R&D challenges, and discuss promising innovations that will help to bring SSBs to the market.

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ELECTROLYTES CLASSIFICATION

ROLE OF ELECTROLYTES IN EV BATTERIES

In a conventional (Li-ion) battery, the main components are the anode, the cathode, and the electrolyte with a separator. The two electrodes are made of different materials and have different potentials and charge differences that cause the movement of electrons from one to the other – thereby charging and discharging the battery. Simultaneously, as the electrons move, ions migrate from the same electrode to the other through the electrolyte. A good electrolyte typically exhibits **high lithium-ion conductivity**, has a **high energy density** and **low resistance** at the electrode interfaces during cycling. Like the veins in our body, the electrolyte conducts the necessary substances from one place to another, to achieve the necessary energy output. As the role of the electrolyte is of such high importance, it is crucial to pick an electrolyte with good properties that will improve the overall quality of the battery. To do so, one can choose between liquid state, quasi-solid state, and solid-state electrolytes. As displayed in Figure 1, the **morphology** of the different battery types varies, where the main difference is the solid-state electrolyte, and solid-state electrolyte composite electrodes are used in the solid-state batteries. For ease of property comparison, the following section compares solid and liquid-state electrolytes.

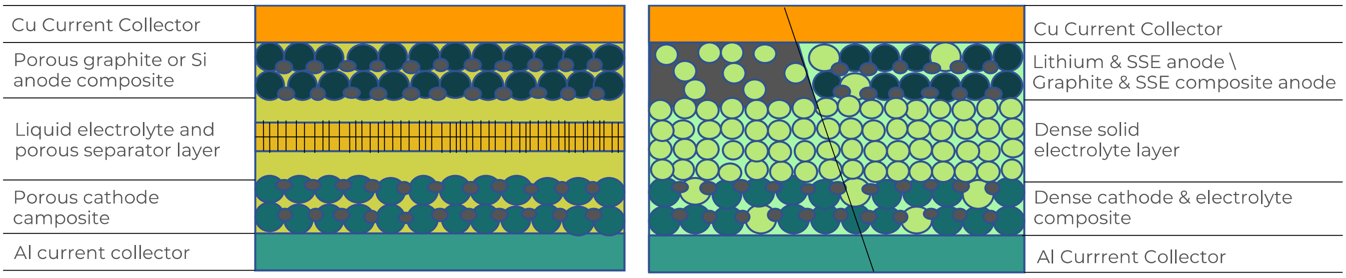

Figure 1: Comparison of a liquid-state battery (left) and a solid-state battery (right) with a graphite anode or Li-metal anode (based on [1])

LIQUID-STATE VS SOLID-STATE PROPERTIES

It is possible to divide Li-ion batteries into three different categories based on the state of the electrolyte: **liquid state**, quasi-solid state, and solid-stat. In this report, solid-state batteries will be compared to conventional liquid-state batteries. While the working principle of the battery is the same, the electrolytes exhibit different properties, resulting in different advantages and disadvantages. In this section, the liquid-state electrolyte will be compared to the solid-state electrolyte.

In general, the most important property of electrolytes is **ionic conductivity**, this can be explained as the ease with which the electrolyte carries positive Li charges from one electrode to another. The electrolyte can be compared to a river where a counter-current makes transportation harder, resulting in lower ionic conductivity. A co-current, on the other hand, can transport more substances in the same time window, giving higher capacity and less energy loss, which is desirable.

Conventional liquid-state batteries are highly valued in EV applications due to their high energy density (up to 270 Wh/kg) **[2]**, wide electrochemical stability window, high ionic conductivity, and power density. These features enable longer driving range, higher power output per cell, and fast-charging abilities. However, the biggest disadvantages of conventional liquid-state batteries are the **risk of thermal runaway** and **dendrite formation**. Both are well-known modes of battery degradation and can lead to short-circuiting, battery fires and explosions [3], [4]. Liquid electrolytes are commonly separated into ionic liquids and organic solvents, with the main difference being that ionic liquids are non-molecular and solely consist of ions [5].

Solid-state batteries (SSBs) solve some of the main issues related to conventional liquid-state batteries regarding safety and stability. SSBs can be divided into **sulphides**, **oxides**, and **polymers**. Unlike the liquid state, the electrolyte also works as a separator, which opens the possibility for denser battery packs, resulting in higher energy densities. Moreover, due to the absence of liquids, the degradation of SSB is slower, leading to higher stability, lifetime, and safety. Some drawbacks of SSBs are the limited ionic conductivity, the volume change, and dendrite formation. This limits fast charging, can lead to an even poorer interface between the electrolyte and the electrodes, and increases the need for more robust and rigid electrolytes, respectively. [2], [6].

Table 1: Typical values for key parameters in liquid-state batteries and SSBs [2], [7]–[9]

PROPERTIES / TYPE OF ELECTROLYTE	IONIC CONDCUTIVITY (S/CM AT ROOM TEMP.)	ELECTROCHEMICAL STABILITY WINDOW (V)	ENERGY DENSITY (WH/KG)	POWER DENSITY (WH/L)	SAFETY
Liquid state (LIB)	10^{-4}-10^{-2}	5,0	270	500-700	Low
Solid-state	10^{-9}-10^{-3}	1,7-4,2	450	750-1000	High

COMPARISON OF SOLID-STATE ELECTROLYTES

Polymer solid-state electrolytes (SEs), with polyethylene oxide being the most common, are the only solid electrolytes currently utilised on a large scale. This is due to their **highly feasible processing route** and compatibility with lithium salt, which is important for the ionic conductivity of lithium [1], as well as their exhibition of **high mechanical flexibility** which can promote a long cycle life [9]. They can have matrices of different polymers with additives to give the wanted properties.

The downsides of these electrolytes are their **high operating temperatures** (50-80 °C) and **limited ionic conductivity,** which restrict their applications. At altered temperatures, it is possible to obtain an enhanced ionic conductivity [9], but it would require temperature management in the battery pack, which would lower the volumetric energy density and increase energy consumption. These electrolytes also raise an issue with the **chemical compatibility with energy-dense positive electrodes** [1] as most polymer SE have a low electrochemical stability window (ESW) of below 4 V, which is a measure of the voltage range where the electrolyte will not degrade and remain stable [9]. Some polymer electrolytes can resist dendrite formation, but as these SEs are less robust, this is still an issue.

Sulphide SEs, on the other hand, offer **increased ionic conductivity** together with material softness that gives **good electrode contact**. Even during volume changes this contact remains high, ensuring **high resistance to dendrite formation** as a result. As for polymer SEs, it is possible to obtain different compositions, and when it comes to ionic conductivity, there are several options, like the thio-LISICONs (Lithium SuperIonic CONductor), that have excellent conductive properties at room temperature **[10]**, which can compete with the values found in conventional liquid electrolytes. When sulphides are in contact with humid air, they form the **toxic gas H_2S**, which restricts their use. This reaction also leads to the **degradation of the electrolyte**, which shortens the lifetime of the battery. Compared to polymer SEs, they offer a narrow ESW **[11]** of about 1,7-2,3 V **[9]**, and therefore poor high-potential compatibility and are **not suitable to use with high-potential lithium anodes**.

Oxide SEs offer **excellent mechanical stability**, and a **wide ESW**, making dendrite formation harder, as well as giving a more durable battery pack. The wide ESW opens the possibility to utilise lithium anodes **[9]**, and high-potential cathodes which is favourable as new cathode technology is constantly under development. However, oxide SEs have disadvantages such as **chemical incompatibility**, **low ionic conductivity**, and a **poor electrode interface** and **brittleness**, leading to lower cycling stability. The incompatibility with certain electrode materials makes it necessary to use a separate interfacial layer between the electrolyte and electrodes **[1]**, **[9]**. Another issue is the general **low ionic conductivity** they present due to the influence of crystal structure, high production temperature, and grain boundaries **[12]**. In recent years, the emphasis on two types, LLZO and LLTO, has increased, as these types offer a much higher ionic conductivity, but they use rare elements like Ge **[1]** which makes them less favourable. Moreover, the oxides are produced through a costly processing step called sintering, to obtain dense layers with lower grain boundary resistance.

Figure 2 shows the comparison of the important parameters discussed in this part between the three different electrolytes.

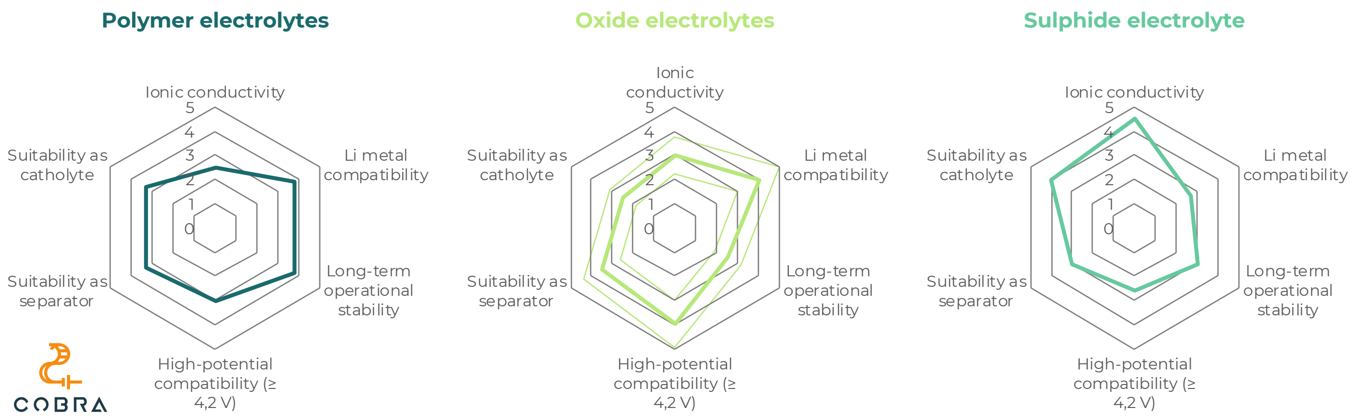

Figure 2: Comparison of solid-state electrolyte types (based on [9])

PRODUCTION OF ELECTROLYTES

SOLID ELECTROLYTES PRODUCTION APPROACHES

Polymer SE is the only SE being produced on a large scale, while the other two are only being produced on a laboratory scale. Solid electrolytes can be produced following three different approaches: **wet processing**, **solvent-free concepts**, and **powder-based processing**.

Wet processing is a method in which the raw material particles, binders, additives, and a solvent are mixed into a **slurry** [13], for then either to be deposited directly onto the cathode or into an inert mould. The binder is added to ensure that the particles react with each other in a favourable way, as both too much or too little can affect the ionic conductivity and stability. Following the deposition of the slurry, the **solvent is evaporated**. The final thickness of the electrolyte is influenced by the substrate used during the deposition process and typically ranges between 5 to 30 microns. It is advantageous to achieve a thinner electrolyte thickness, similar to the state-of-the-art Li-ion batteries, where the separator thickness is less than 30 microns. [14]. The last step of wet processing is **compacting** to obtain good battery properties, which can be done by pressure, or by sintering for oxides.

Another approach is **solvent-free processing**, where the baseline is to not use any solvent. This is mainly used for polymers, but some of the techniques can also be used for inorganic solids. Among these techniques are **solvent-free dissolution** where the salt is directly dissolved in molten polymer to then be annealed for 24 hours, **hot pressing** of the polymer and the salt onto a substrate, and **dry extrusion** where the salt and polymer are blended in an extruder to process a laminate. The last technique can, in theory, be used for inorganic solids as well but is still under development [9].

Powder-based processing is the last approach, which is mainly used for the oxides to avoid high-temperature sintering. The electrolyte powder is deposited onto the cathode in an evacuated deposition chamber where it is transported by an aerosol. For even denser layers, an **annealing** step at 600 degrees C is added subsequently. Although sintering is avoided, thin, dense layers can be made.

Table 2: Comparison of approaches for solid-state electrolyte production

COBRA	ADVANTAGES	DISADVANTAGES
WET PROCESSING	Controlled thicknesses. Can be derived from existing LIB infrastructure.	Sintering needed for oxides. Harder with controlled thicknesses on mass-scale.
SOLVENT-FREE	Elimination of solvent costs and disposal. No traces of solvents which decreases IC of electrolyte [15].	Time inefficiency in solvent-free dissolution due to annealing step. Limited to mainly polymer SE [15].
POWDER-BASED	Strong adhesion and dense layers are obtained due to pressure differences. Sintering avoided.	The process is still under development as it for now is not scalable [9].

CHALLENGES AND INNOVATIONS IN THE PRODUCTION OF BATTERY ELECTROLYTES

CONVERSATION WITH SÉBASTIEN FANTINI
HEAD OF RESEARCH AND INNOVATION AT SOLVIONIC

What have you achieved so far in the COBRA project?

In the COBRA project, Solvionic has mainly focused on tackling safety concerns posed by both LiPF6 salt and carbonate solvents in liquid electrolytes by developing polymer electrolytes based on ionic liquids with high conductivity and oxidation stability. Thanks to the collaboration with COBRA colleagues, we have learnt how to apply specific conditions to test our electrolytes and optimise their performance with electrodes provided by other partners.

How difficult it is to switch from liquid to solid electrolyte production?

We already started including polymerised ionic liquid (IL) in the electrolyte used in COBRA cells which is a step towards solid-state. Using ionic liquids makes the transition to SSBs smoother for us than for companies which produce electrolytes from lithium carbonate. Of course, there are some changes in manufacturing liquid and solid electrolytes, e.g. the solid ones need to be processed as a polymer film. We have managed to demonstrate production on the lab scale, and now we are trying to scale it up to the pilot level.

Which factors influence the developments in solid-state batteries?

The developments in electrolytes are strongly influenced by the progress in the electrode active materials. It is important to adapt to this next generation of materials, such as Si-C anodes and LMNO cathodes used in the COBRA project. Safety concerns are another important factor boosting developments of SSBs: solid-state electrolytes based on ionic liquids are non-flammable. The ever-lasting search for higher volumetric and gravimetric energy density also plays a significant role – solid electrolyte is compatible with lithium metal anode which would significantly improve these properties.

What are your key development plans for the upcoming years?

We plan to industrialise our continuous flow technology to maintain low consumption, reduce process waste, and achieve a high yield of IL production. Such challenges were already demonstrated in our current operating liquid electrolyte pilot plant (20 t/y capacity). By 2025, our capacity should grow up to 300t/year/production line and by 2030, we aim to replicate the production in other factories in Europe, close to our customers' production sites. The development of SEs will also remain one of the key points of our R&D strategy. We are involved in several national and EU projects in this area, such as France 2030 ESPILON and H2020 project SOLiDIFY on upscaling of materials, processes, and architectures for SSBs. From such projects, we will upgrade our know-how to optimise interphases between electrodes and electrolytes which is an important issue in SSBs.

SOLVIONIC

The reliance on batteries and supercapacitors intensifies and consumers' expectations push towards decreasing cost and increasing performance. However, such improvements often come with a compromise in safety. Solvionic's technology and expertise in ionic liquid electrolytes address not only the cost challenges but also the access to high voltage systems and enhanced safety with non-flammable electrolytes. The reduction of environmental impact is also currently industrialising its production process through continuous flow chemistry.

R&D CHALLENGES FOR SOLID ELECTROLYTE PRODUCTION

The **solid-solid interface** between the electrolyte and the electrode is a problem that prevents the full utilisation of the electrode's active material. Sulphides and polymers are softer than oxides giving a better interface, but are still not comparable to that of conventional LIBs. One way to solve this is to enhance the interface quality on the nanoscale level by **implementing nanostructures** that will increase the performance by overcoming diffusion problems and assuring good particle-to-particle contact between the electrolyte and the electrode [16].

Another issue is the **dendrite formation** penetrating the electrolyte, leading to a **short-circuit**. Practically, solid-state batteries should be able to counteract the formation by promoting higher mechanical resistance than liquid electrolytes, but it has been seen that it is still an issue in these batteries. One cause of this is the existence of voids, porosities, or other defects in the interface between the electrode and the electrolyte [17]. This defect can be improved by nanostructures in the solid materials at the interface as mentioned above. Another way to solve this is to **avoid the use of lithium anodes**, and rather use silicon anodes, though this will lead to decreased energy density [9].

The production of electrolyte films tends to give **porosities and non-uniformity**, as thin microscale films resembling the polymer separator in conventional LIB are wanted. Such defects make the electrolyte more prone to dendrite formation and, in general, lower mechanical stability. A strategy to eliminate the void space is to **use filling materials** of a lithium-ion conducting material [16].

Using solvent-based production methods leads to unnecessary **harmful disposals**. In the long-term, using **solvent-free** or **green solvent-based** processes is the way to solve this. There are several dry process options today, but they are not as scalable as wet processing. In addition, new technological infrastructure will need to be raised, which demands investments.

The sintering step in oxide production is **energy-, time-, and cost-demanding** which makes the oxide electrolyte less favourable, despite its good properties. Today, aerosol deposition allows oxide production without the sintering step, but the technology is still immature and under development, and has a low throughput which makes it only suitable on a laboratory scale. It is desired to also find suitable production routes or modifications that can decrease the sintering temperature. One way to do this is to use sintering agents like Al2O3 and Li_3BO_3 **to reduce the sintering temperature** [9].

In conventional liquid electrolyte batteries, the electrolytes are typically **not recycled,** but rather just washed away due to costs and already existing end-of-life handling of LIBs. As solid-state batteries still are in the early stages, it is possible to **implement recycling considerations in cell designs** and manufacturing [1], [18]. A proposed recycling route is recycling the entire battery directly without separating the different components by cell stack dissolution, phase separation, solution evaporation and solute recovery, then thermal annealing of the solid-state electrolyte and re-lithiation of the cathode [18].

ELECTROLYTES MARKET ANALYSIS

SUITABILITY FOR APPLICATIONS

Currently, conventional liquid electrolytes and polymer solid electrolytes are the only ones used on a larger scale. **Polymer** SSBs are already used in buses and industrial applications like automated guided vehicles (AGVs). According to Fraunhofer's roadmap on solid-state batteries [9], it is expected that these can also be used in stationary storage from 2025 and in lower-end passenger cars and trucks from 2030. It is forecasted that both oxide SSB and sulphide SSB will also enter the market in the medium term. The **oxide** SSBs with their expected high stability can be used first in industrial heavy-duty and harsh environment equipment (e.g. military), while **sulphide** SEs in autonomous aircraft due to their foreseen excellent energy density. By 2030, sulphides and oxides are also expected to be first utilised in passenger cars and after 2035, even in passenger aviation and trucks. Microelectronics such as flexible and implantable medical devices will adopt solid-state **thin-film** batteries (SSTFBs) which are a separate category from the bulk form SSBs this report is focused on.

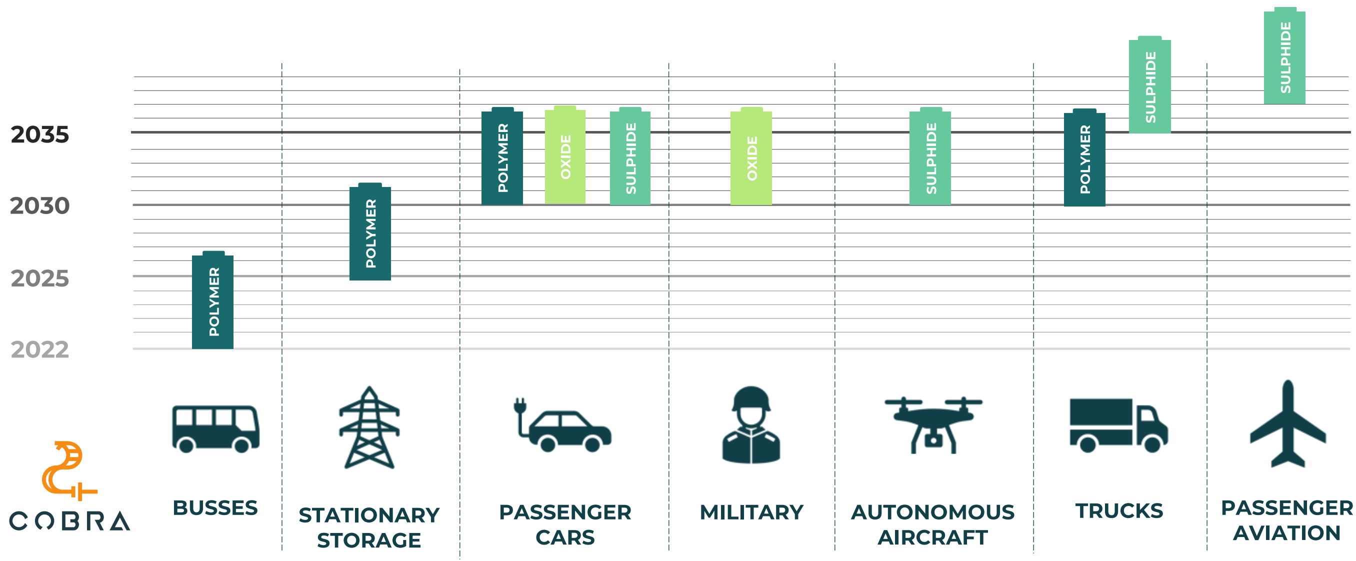

Figure 3: Expected readiness of SSB types for applications (based on [9])

There are still various challenges to overcome by all three SSB types to enter the market in more applications. **Polymer solid electrolytes currently require constant heating** of the battery because of the narrow operating temperature: 50-80 °C. So far, polymer SSB has only been demonstrated with an LFP cathode, which limits its energy density. **Significant stability improvements would be needed** to combine the polymer solid electrolyte with high-potential cathodes like NMC or NCA. Another challenge is the fast-charging capability, where **oxide and sulphide electrolytes, in general, outperform polymers because of larger operating temperatures**, but their ionic conductivities have to be optimised. In terms of safety, while SSBs are in general considered safer, the Li metal anode utilised in many SSB concepts poses a potential safety risk due to its high chemical reactivity which is another R&D area to address before high-performance SSBs enter the market.

ECONOMIC ASPECTS OF ELECTROLYTES PRODUCTION

Only meeting the functional requirements outlined in the previous chapter is not enough to ensure the success of solid-state electrolytes on the mass market – SSBs will also have to be cost-competitive. To put things in perspective, currently, the cost of electrolytes is roughly 6-10% of the total liquid Li-ion EV battery cost. In 2022, the average cell cost was $120/kWh [19], which means that the average cost of electrolytes was approximately $7-12/kWh. The cost of liquid electrolytes mostly depends on the cost of materials used in the production process: lithium salts (which make up 50% of the electrolyte's cost), additives, and organic solvents. The prices of lithium salts (in 98% of cases LiPF6) are changing very fast due to the volatility of raw material prices: **in the last 2 years lithium carbonate price spiked by 500% and only now it's returning to the 2021 levels** (Figure 4). Recently, the electrolyte industry introduced a significant process innovation which helped to increase the yield and keep the costs low despite the raw materials surge: shortening the process by using a stable battery electrolyte solvent like diethyl carbonate (DEC) to make LiPF6 in solution [20]. In 2020, 255,000 tonnes of liquid electrolytes were produced and the market size was $2.3 bn [21]. The electrolyte market is expected to closely follow the dynamic development of the Li-ion battery market.

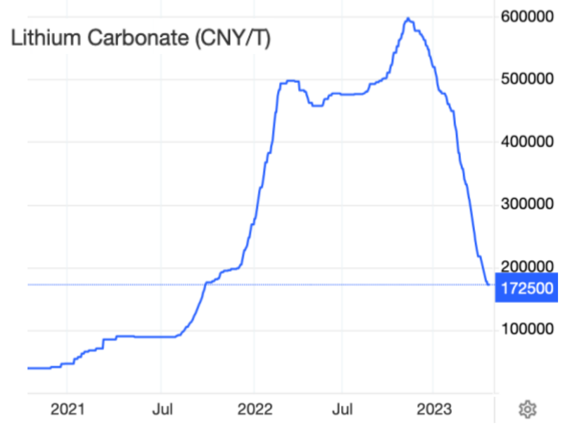

Figure 4: Price development of lithium carbonate [22]

The cost developments and market sizes of SSBs are highly speculative, since most solid-state concepts have not been introduced to the market. Nevertheless, some assumptions can be made by looking into differences between materials and processing steps. Polymer-based SEs have similar materials and processes to liquid electrolytes, so production costs can be assumed to be similar. **The material footprint of sulphide and oxide SSBs can be even twice lower** than for cells with liquid electrolytes [23] which can give a cost advantage over SotA batteries, depending on the metals used: their prices range from very high (>100EUR/kg for germanium) to economically feasible (<5EUR/kg for titanium, lanthanum, and zirconium). Similar to liquid electrolyte batteries, SSBs are expected to have a strong dependency on the price of lithium. Several processing steps, such as formation and ageing time, can be reduced, while others, such as sintering in oxide SEs, must be added. As a new infrastructure and supply chain will have to be established for inorganic SE production, cost parity is not expected to be achieved until 5-10 years after commercialisation [24]. Considering these factors, SSBs are expected to cover no more than 2% of the demand for Li-ion batteries until 2035 (Figure 5).

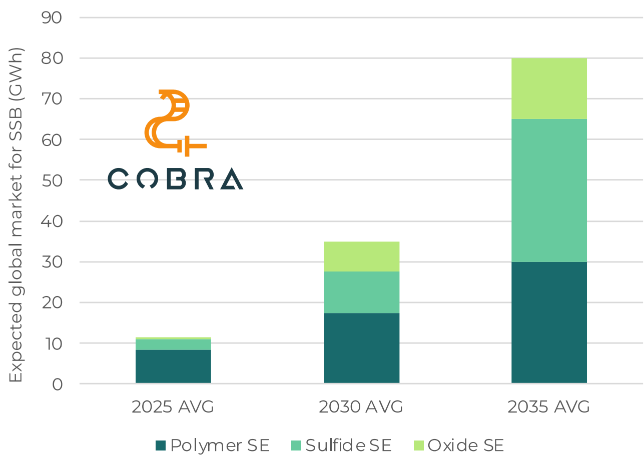

Figure 5: Expected global market for solid-state batteries (based on [9])

KEY STAKEHOLDERS IN THE ELECTROLYTES MARKET

The global electrolytes market is dominated by three countries: China, South Korea, and Japan. Recently, Asian companies have invested in several major manufacturing facilities in Europe: e.g., a 100 kt plant of Tinci in the Czech Republic and a 40 kt Shenzhen Capchem plant in Poland. Most producers use lithium hexafluorophosphate ($LiPF_6$) as a conducting salt in their electrolytes.

Although European and American companies currently have no significant electrolyte production capacities, this may change with the exponential growth in the demand for Li-ion batteries and the **industrialisation of solid-state electrolytes, which may give Western entrants a chance to catch up with established Asian manufacturers**.

In the US, companies like Quantum Scape, Solid Power, Factorial, and SES have secured over $100M investments and partnerships with major EV OEMs [25]. In France, Blue Solutions – Bollore has equipped Mercedes buses with polymer solid-state cells [26] and plans further deployments of SSBs in city buses. Solvionic, also based in France, is on the way to deploying its first mass production plant of electrolytes based on ionic liquids and Li-FSI salt, with a capacity of 300 tonnes expected by 2025. In Poland, The Batteries is developing a low-cost thin-film solid-state technology for IOT applications [27].

Table 3: Key global players in the electrolytes market [23], [28], [29]

LIQUID ELECTROLYTE PRODUCERS		SSB DEVELOPMENTS	
TINCI 天赐 CHINA	BYD CHINA	SVOLT CHINA	GanfengLithium CHINA
新宙邦 CAPCHEM CHINA	enchem SOUTH KOREA	WELION CHINA	ProLogium TAIWAN
GTHR GUOTAI-HUARONG CHINA	CENTRAL GLASS JAPAN	SES USA	Factorial USA
MUIS MU Ionic Solutions JAPAN	soulbrain SOUTH KOREA	QuantumScape USA	ionic MATERIALS USA
杉杉科技 Shanshan Technology CHINA	MITSUBISHI CHEMICAL GROUP JAPAN	Solid Power USA	BlueSolutions BOLLORÉ FRANCE
天津金牛 TIANJIN JINNIU CHINA	Smooth Way CHINA	THE BATTERIES POLAND* (thin-film SSBs)	solvionic FRANCE

TECHNICAL DEVELOPMENTS

ENHANCED ATMOSPHERIC STABILITY OF LLZO

One of the most common oxide solid electrolytes is the LLZO ($Li_7La_3Zr_2O_{12}$), due to its excellent ionic conductivity. Despite this important property, the electrolyte raises a significant issue, as when exposed to moisture and carbon dioxide in atmospheric air, lithium carbonate forms at the surface and penetrates the grain boundaries, leading to a decrease in ionic conductivity. Researchers have found a way to **increase atmospheric stability by doping gallium and tantalum** which can promote a higher level of ionic conductivity of LLZO in ambient air, by the formation of $LiGaO_2$ that will suppress the surface adsorption of moisture and carbon dioxide, thus inhibiting lithium carbonate formation.

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MACHINE LEARNING (ML) FOR SSE PREDICTIONS

The use of AI has already been utilised to discover new promising compounds for conventional LIBs due to good access to open-source data, and now the next step is to use ML to develop an ionic conductivity (IC) model to predict suitable SSEs for enhanced performance of solid-state batteries. In this work, an initial dataset of 4826 data points of IC with related temperatures of various SSEs was extracted from accessible journals. Then, three different algorithms were used on these data points to achieve the results. It was proven that the results were of high accuracy as the SSE compounds obtained had a wide electrochemical stability window and high ionic conductivity. From this, **it was predicted that $LiYS_2$ is a promising SSE** with high ionic productivity.

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CHLORINATION OF ELECTROLYTE/CATHODE INTERFACE

Lithium argyrodite, a sulphide-type solid electrolyte, offers high ionic conductivity as well as good processability, but also an issue related to degradation in the interphase with the cathode. Researchers have studied Li_6PS_5Cl and $Li_{5,5}PS_{4,5}Cl_{1,5}$ to investigate how halogenation affects the chemical degradation rate. The results showed that the halide content affects the amount of introduced Li^+ vacancies and Cl^-/S^{2-} site disorders, and an increased chloride content gives higher electrochemical decomposition at low voltages compared to lower chloride compositions. At higher voltages, $Li_{5,5}PS_{4,5}Cl_{1,5}$ gives reduced levels of solid oxygenated degradation products, and thus **lower interfacial resistance**, compared with Li_6PS_5Cl. This gives an overall higher cell performance for higher chloride compositions.

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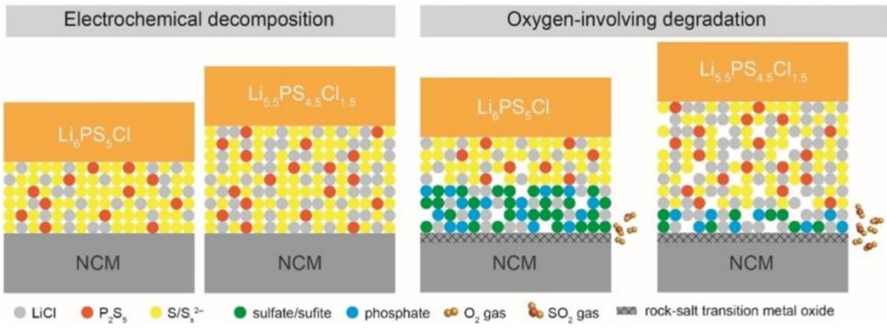

MARKET DEVELOPMENTS

HYUNDAI WITH NEW SSE PATENT

Hyundai is focused on solid-state batteries and has recently patented a crystalline SSE composed of lithium, sulphur, phosphorous, nitrogen and a halogen. They have proven its discharge capacity to be 117-118 mAh/g during a ten-hour discharge test. This is **below the values of already existing mass-market cells** such as LFP and NMC, but as of now, it is just a proof of concept which shows promising possibilities for the use of SSEs in EVs.

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THE FIRST 24-LAYER SSB PROTOTYPE SHIPPED FOR TESTING

QuantumScape is a company working on the commercialisation of solid-state batteries for EVs, where they focus their work on developing a **ceramic electrolyte with higher ionic conductivity than other solid-state electrolytes**, as well as a novel manufacturing process that will allow mass production at lower costs. They have recently shipped their first 24-layer prototype battery to automotive OEMs for testing. The OEMs will run tests at their facilities and give feedback to QuantumScape for further developments to enhance higher quality and better performances in the coming years and towards commercialisation.

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DEVELOPING A RECYCLING PLATFORM IN EUROPE

The Polish company **Elemental Strategic Metals** and Taiwanese **ProLogium Technology** have signed a formal agreement to look at collaboration opportunities to build a solid-state battery recycling platform in Europe. The plan is for ProLogium Technology to send their batteries to Elemental Strategic Metals and develop suitable recycling technology for the solid-state batteries, strengthening the European EV battery industrial chain ecosystem and reducing emissions and the overall life cycle carbon footprint connected to the batteries.

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NAVIGATING THE SSB HYPE: AN INDUSTRY-DRIVEN ASSESSMENT

In a recently published white paper by Sphere Energy, several popular opinions on solid-state developments are validated, based on discussions with industrial experts. According to the authors, many SSB concepts may become commercialised before 2030, but they can become cheaper than liquid electrolyte batteries only 10-15 years from now. **The statement about SSBs being easier to recycle is considered false** and based on speculation since no real test for recycling large-format SSBs has been performed. The paper also analyses the stage of development by key global industrial players, assigning TRL levels.

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POLICY DEVELOPMENTS

THE CRITICAL RAW MATERIALS ACT TO ENSURE A SECURE AND SUSTAINABLE SUPPLY CHAIN

Critical raw materials are of high significance in various strategic sectors, including the renewable energy sector, and ensuring a secure and sustainable supply chain is important. The new Critical Raw Materials Act focuses on the strengths and opportunities of the Single Market and the external partnerships of the EU. It will also make it more feasible for the EU to monitor and reduce the risks of supply chain disruptions. Ursula von der Leyen stated that **the act will improve the life cycle of critical raw materials** and lead to stronger cooperation with reliable partners globally. The Act includes a list of strategic raw materials which are crucial for green technology and additional regulations with benchmarks for domestic capacities and to diversify the EU supply.

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EU 2035 PETROLEUM AND DIESEL CAR BAN

The European Parliament voted in February for a new law to ban the sale of diesel and petroleum cars from 2035. The next step is to take it to the European Council to vote again to make it official. Some countries, with Germany in the lead, formed an opposition to the proposal as they want cars running on **e-fuels to be excluded from the ban**. On the 25th of March, the European Commission and Germany announced a deal allowing the exclusion of cars running on e-fuels from the new law that is yet to be made official.

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CARA BATTERY HEALTH CHECK SCHEME TO ENSURE RELIABLE BATTERY HEALTH FOR REMARKETING

The CARA Battery Health workgroup has together with industrial stakeholders established a **certification process** including standards to make remarketing of residual EV batteries more reliable. The aim is to set the standards for the state of health (SOH) measurements for the remarketing industry in Europe and make the test results clear and comprehensive to foster the acceptance of used EVs, which today is highly influenced by trust between private individuals. The plan is to move in a two-phase approach. The first phase will focus on the certification of basic solutions that read out the battery SOH from the Battery Management System, which will not be an OEM-independent measurement. The next step is a continuation of certification scheme development for an OEM independent test.

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