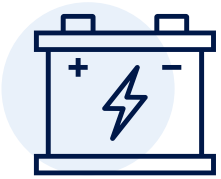
COMPETITION IS GOOD FOR BUSINESS: EUROPE AND NORTH AMERICA STIMULATE SCALE-UP OF BATTERY INDUSTRY



Both electric vehicle as well as battery sales continue to grow in 2023 in the double-digit percentage range, and especially Europe and the US show high increases of fully battery-electric vehicle (BEV) sales in year-over-year comparisons. However, expectations for future developments are currently muted as decreasing demand is predicted in some cases. As a result, medium-term expansion targets are corrected downwards or delayed. In the USA, the Inflation Reduction Act was and is a driver for ambitious expansion targets. This act of legislation came into effect in the middle of 2022 and was followed by private investments of more than 110 billion USD, especially into the creation of a local battery value chain. European companies are seizing the opportunity to build production sites in North America as well. Though, these market actors still aspire to uphold their expansion plans in Europe so that local value chains develop in both Europe as well as North America. Part of these value chains are the production of battery cell casings and aluminium as well as copper foils. This market update shows where the producers of these components are located in Europe and what expansions plans are currently known.

2023 is still going strong, but future growth could experience slowdown

The worldwide sales of BEVs increased in the double-digit percentage range over the course of 2023. Until October, the sales of BEVs in **Germany** rose by 42% compared to 2022 values, and total new registrations could surpass 500,000 vehicles. August proved the strongest month of the year with more than 85,000 new registrations. Causal to this remarkable development is the phase-out of the environmental benefit for enterprises towards the end of August. In contrast, the sales of plug-in hybrid electric vehicles (PHEV) declined by 44% year-over-year until October, since benefits for PHEV in Germany were already phased out by the end of 2022.

In the **European Union**, BEV new registrations until August increased by 56% compared to the previous year and a rise by up to 1.4 million BEVs is expected until the end of 2023. PHEV sales remained nearly constant in comparison to 2022 numbers and could amount to 800,000 new registrations within the EU until the end of the year.

In the **USA**, BEV sales saw an increase of almost 56% year-over-year, hence the threshold of 1 million sold BEVs is in range for the first time. Likewise, the PHEV market increased significantly by 58% compared to 2022. In contrast to Germany, PHEVs continue to be supported with up to 7,500 USD in order to accelerate the shift to electromobility in the USA. However, other than in Germany the share of electric vehicles within the entire car market remained in the single-digit percentage range throughout 2022.

China remains the dominating market for electric vehicles. BEV sales were boosted by 26% year-over-year until October 2023. Until the end of the year, more than 5 million BEVs may be sold in China. In particular, the PHEV market experienced significant growth, with sales increasing by 82% compared to 2022.

Despite the strong growth worldwide car manufacturers are able to keep pace with demand. In parts, production even had to be throttled due to overproduction. For example, Volkswagen paused the production of the ID.3 in Zwickau due to low demand. Rising inventories as a result of overproduction were also reported in North America. Tesla, General Motors, and Ford expect lower demand due to a challenging market and are slowing down their expansion plans. On the one hand, the declining demand is attributed to high interest rates. On the other hand, consumers remain concerned regarding cost, safety, and range.

A first step to counteract the waning interest in Europe could be the Citroën ë-C3. This car is supposed to be produced in Slovakia and feature a range of 320 km at a price of under 25,000 EUR. The model is slated to be available during the first half of 2024. Other manufacturers such as Volkswagen, Tesla and Renault are also working on the introduction of more affordable electric cars. These are expected to be available from 2025.

Concurrent with rising sales and registrations, battery demand increases in 2023 as well. According to SNE Research, the energy capacity installed in electric vehicles worldwide in 2023 until September equalled almost

485 GWh, amounting to a 42% increase year-over-year. Of these 485 GWh, approximately 260 GWh account for China alone, yielding an increase of 33% over 2022. These data include BEV, PHEV as well as hybrid vehicles without an external charging port. By the end of the year, the energy content could rise to around 650 GWh, which, according to figures from the Federal Statistical Office, is roughly equivalent to the annual electricity requirements of 200,000 households.

The waning demand for electric vehicles should entail a slower growth of the battery sector. Several cell manufacturers have reacted accordingly and are throttling production or even delaying the build-up or scale-up of production sites. Upstream value stages, such as cathode active material, are impacted as well and expansion targets are adjusted to current market developments.

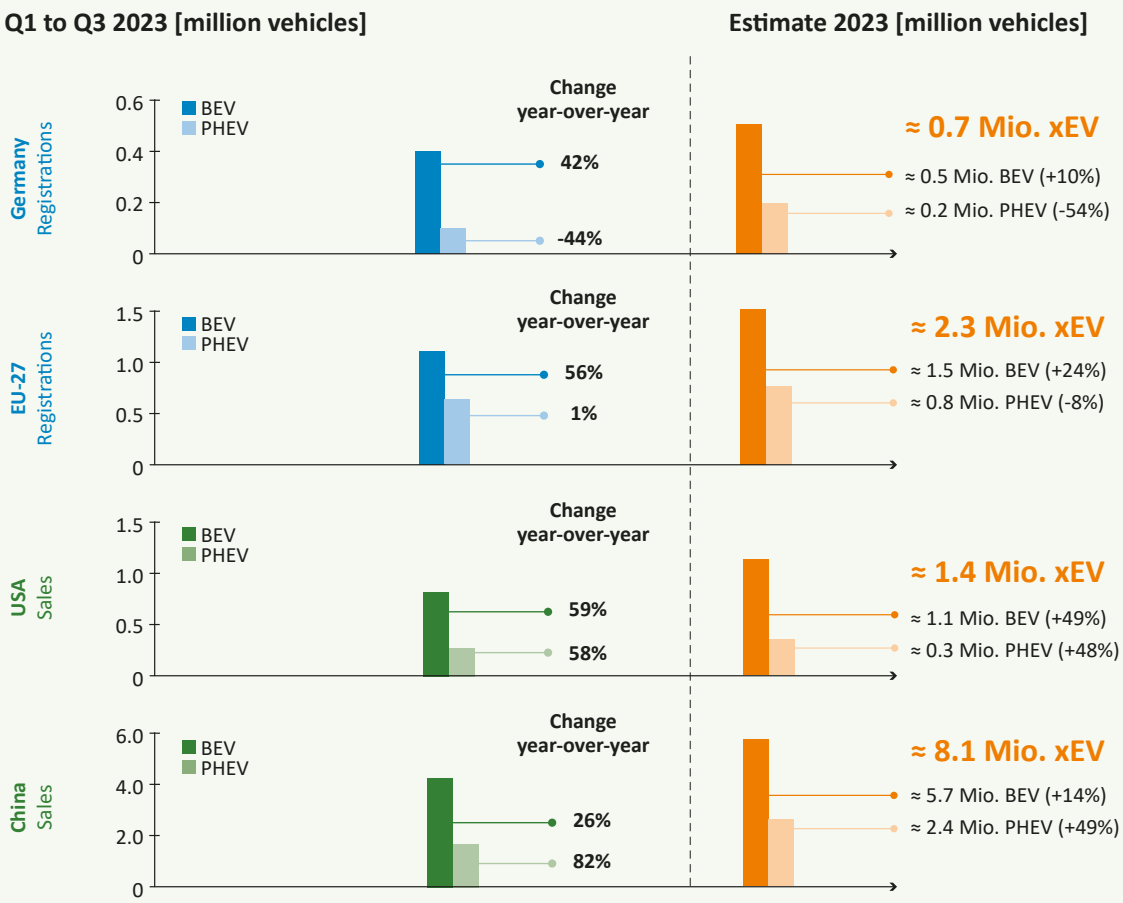
However, the muted growth offers the opportunity for industry to develop projects more diligently and under less pressure.

The Inflation Reduction Act driving the North American battery industry

With the Inflation Reduction Act (IRA), a piece of legislation came into effect about a year ago that aims at advancing renewable energies and especially at stimulating the expansion of the battery and BEV value chain in the USA/ North America.

The expansion of the battery value chain is supported by two means. One the one hand, projects can benefit from the so-called Advanced Energy Project Investment Tax Credit (short: Investment Credit), granting a tax

Figure 1: Registration/sales figures for battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) in Germany, the European Union, the USA and China.



The estimate is based on a linear increase in new registrations/sales. In some regions, November/December are particularly strong sales months, so the actual figures may be slightly higher.

Source: Kraftfahrt Bundesamt, European Alternative Fuels Observatory, Argonne National Laboratory, China Association of Automobile Manufacturers, own depiction.

credit for project investments of up to 30% of the capital expenditure. Alternatively, cell and module producers in the USA can obtain an Advanced Manufacturing Production Tax Credit (short: Production Credit) on production costs.

While the Investment Credit is limited to 10 billion USD, the Production Credit has no upper limit. The latter supports the production of battery cells with 35 USD/kWh and the assembly of modules with 10 USD/kWh. The credits can be claimed in their entirety until 2029, after which they decrease by 25% annually, and ultimately run out in 2033.

As of now, the IRA has stimulated investments of more than 110 billion USD, 70 billion of which are accounted for by the electric vehicle/battery value chain. However, these investments cause follow-up costs. According to estimates, due to the Production Credit alone, the USA could be foregoing tax income of around 150 billion USD until 2032. In the original calculation by the Congressional Budget Office (CBO), 30.6 billion USD were estimated for Production Credit between 2022 and 2031.

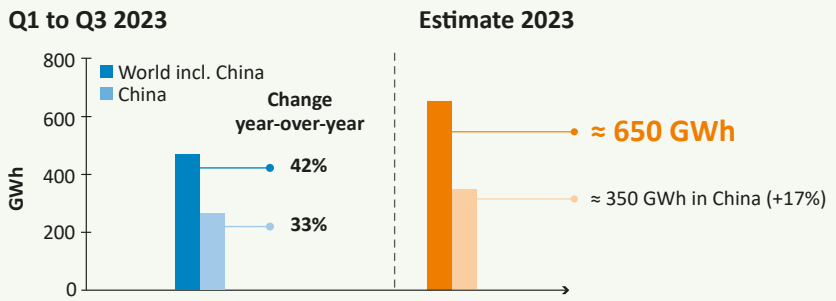
Not just due to this cost explosion the IRA is facing opposition from Republicans, and several attempts have been made to roll it back at least in part. However, lacking the necessary majorities, these attempts are not promising, but these majorities could change in the course of the upcoming elections in 2024. Since large investments are also made and new jobs are created in states under Republican leadership, bipartisan support for the continuation of the IRA may form as well. Due to the scope and the long-term nature of the planned private investments it is generally unlikely that the IRA will be retracted in its entirety.

The IRA as well as additional funding instruments such as the Bipartisan Infrastructure Law help to develop the local battery value chain in North America, thus – as in Europe – battery cell production capacities of more than 1,000 GWh/a have been announced. Next to the Production Credit and the Investment Credit, the expansion of the local supply chain is particularly supported by the fact that electric vehicles can only benefit from the 7,500 USD discount if they adhere to certain standards regarding the sources of components. According to these standards, at least 50% of the minerals regarded as critical must originate from the USA or a country with a free trade agreement from 2024 onwards. Furthermore, 60% of the battery components must be furnished in North America. The conditions for critical minerals rise to 80% until 2027, and for battery components to 100% until 2029.

As a result of these standards, only a part of the available inventory in the USA are eligible for the 7,500 USD discount. Though, the automobile industry aspires to qualify as many units for the discount as possible since it can be a deciding factor. The tightened regulation regarding fleet consumption is putting additional pressure on the automobile industry. Consequently, there is a high demand for battery components made in North America, giving rise to an additional incentive next to Investment Credit and Production Credit, to develop the production of battery components in North America.

Among others, European cell manufacturers are attracted to North America by these incentives. For example, Freyr announced a battery cell production in the USA. Northvolt and PowerCo are building plants in North America as well. However, Northvolt and PowerCo are still committed to Europe. PowerCo is simultaneously building two plants in Germany and in Spain. Northvolt is already running one cell production facility in Sweden with Ett and, together

Figure 2: Energy content of batteries installed in vehicles registered worldwide.



The estimate is based on a linear increase in new registrations/sales. In some regions, November/December are particularly strong sales months, so the actual figures could be slightly higher.

Source: SNE Research, own depiction

Inflation Reduction Act (IRA)

Incentives for production sites

Advanced Energy Project Investment Tax Credit
- Up to 30% tax credit on capital investment
- Capped at 10 billion USD

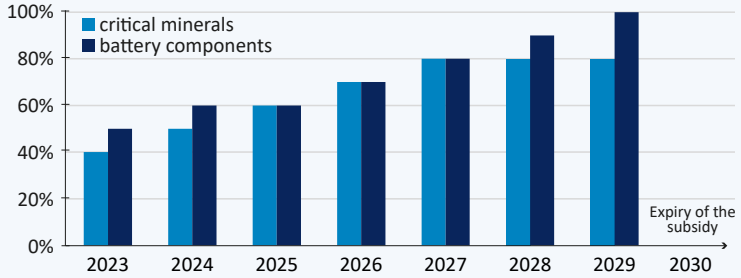
Advanced Manufacturing Production Tax Credit
- 35 USD/kWh for cells
- 10 USD/kWh for modules
- 10% credit for production costs of raw materials and active materials

Incentives xEV

Up to 7,500 USD tax credit on the purchase of electric cars
- Up to 3,750 if **a certain percentage of critical minerals** were produced or recycled in the U.S. or in countries with free trade agreements / critical minerals agreements (see time scale)
- Up to 3,750 USD if **a certain percentage of the battery components** were produced in North America (Canada, USA and Mexico) (see time scale).

Time scale

Proportion of critical minerals and battery components required to qualify for full subsidy.



To qualify for the tax credit, no battery components may be sourced from foreign entities of concern (FEOC) from 2024 and no critical materials from 2025.

Excursus critical minerals

Free trade partners of the USA and countries with agreements on critical minerals.

With regard to the production of lithium-ion batteries, the category of critical minerals includes not only raw materials but also processed materials. Materials are assigned to the „critical minerals“ category until no further chemical, physical or thermal processes are required for the production of battery components. This means, for example, that cathode and anode active materials, metal foils, electrolyte salts or additives also belong to the critical minerals category.

It should be noted that this definition is a preliminary proposal that can still be adapted.

with Volvo, is building another cell production plant near Gothenburg (Sweden). Moreover, a cell production plant in Germany is planned. So far, Freyr has advanced its activities in Norway as well. However, in its third quarterly report 2023 the company announced that it will reduce spending on its cell production in Norway in 2024 as the regulatory framework in Europe is not competitive.

To counteract the shifted investment focus and strengthen Europe's position in global competition, the EU has created an opportunity to fund strategic battery projects in particular within the Temporary Crisis and Transition Framework (TCTF). By means of the TCTF, member states can support battery projects with up to 350 million EUR. Funding can be granted under TCTF conditions until 31st of December 2025, with a distribution of funds being possible until 2031. For example, IONWAY's cathode active material production in Nysa, Poland is supported with 350 million EUR. The announced Northvolt facility in Germany could also be funded within the TCTF.

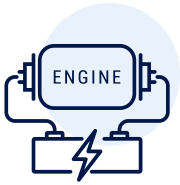
Thus, local supply chains are established in both North America and Europe. Under current market conditions and the slower growth predicted by some car manufacturers, the announced production capacities appear sufficient to meet the demands. Accordingly, some manufacturers are planning a little more time for further investment decisions. For example, Volkswagen announced that, due to current circumstances, there is no need to settle on a third production site in Europe at the moment.

The European supply chain is growing: production of cell cases and current collectors

To strengthen the resilience of the entire battery cell supply chain in Europe, companies are also driving the expansion of battery cell component production. Besides electrode active materials, separator, and electrolyte – which were analysed in detail in the last market analysis update – these include cell casings and current collectors, usually in the form of metal foils. Figure 3 shows active and planned production facilities for copper foil, aluminium foil, and battery casings destined for the European battery cell industry.

Metal foils made of copper and aluminium directly contact the electrode active materials and provide the necessary current flow. Commonly, aluminium is used on the cathode side while copper is used on the anode side. Both copper and aluminium combine with other elements to form alloys, which vary in their properties and are hence suited to different manufacturing processes of the foils. This fact is decisive since the employed method strongly determines the properties of the resulting material, such as surface roughness and homogeneity. These properties are fundamental to how stable the adhesion of the electrode materials is to the current collector. The better the adhesion is, the lower the contact resistance and the more durable the cell.

By use of less current collector foil the mass of the entire cell can be reduced, and material saved. Therefore, foils are being produced as thin as possible without compromising functionality. In an alternative approach, metalized framework structures are used to simultaneously reduce material intensity and increase the size of the interface between active material and current collector.



Copper foils for battery cell production are produced via electrolytic deposition or repeated rolling and annealing processes. Electrolytic foils display high conductivity, even thickness, as well as high stretchability and tensile strength. On the other hand, rolled annealed foils exhibit higher mechanical flexibility. In contrast to electrolytic copper foils, which consist of pure copper, rolled annealed foils can be composed of alloys (e. g. with nickel or silver), thus mechanical strength and conductivity can be tailored to specific requirements. Electrolytic foils have typical thicknesses of 4.5–10 µm while the thicknesses of rolled annealed foils range between 6 and 100 µm. A recent study has shown that lithium-ion battery manufacturers have been using copper foils with thicknesses between 8 and 10 µm in the last few years.

In Europe, copper foils are produced by Avocet Precision Metals in Great Britain, by Schlenk in Germany, which specialises in rolled annealed foils, and the South Korean company Solus Advanced Materials. Volta Energy Solutions (formerly Doosan Energy Solution) – a daughter company of Solus Advanced Materials – has been producing 50,000 t/a copper foils in Tatabánya (Hungary) in 2020. In 2022, the company received support by the EU for an expansion by a second plant with a total investment of 206 million EUR. Solus Advanced Materials have announced the production target of 100,000 t/a battery foils. Other than the location in Hungary, Circuit Foil, another daughter company of Solus Advanced Materials, produces battery foils in Wiltz, Luxembourg.

In Stalowa Wola in Southern Poland, SK Nexilis is targeting mid 2024 to start production of 50,000 t/a copper foil.

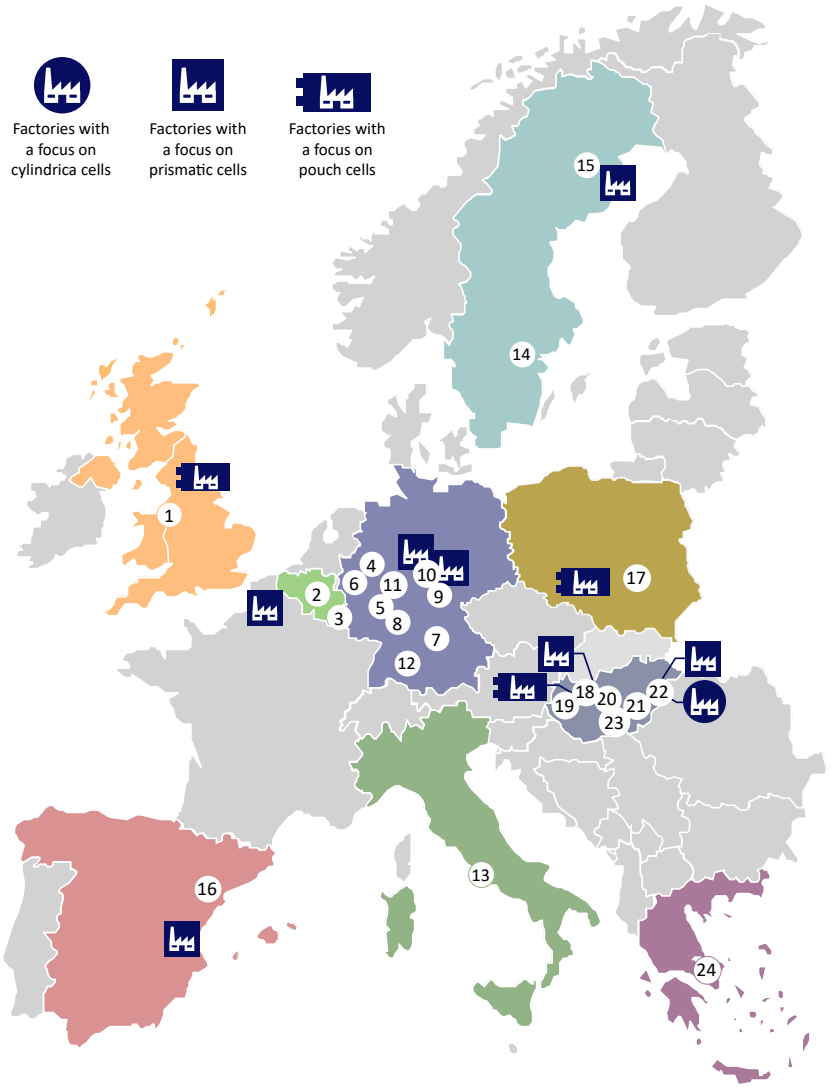
Figure 3: Selected active and announced battery cell production sites in close proximity to current collector and casing production.

			Foils		Casing material		
			Copper	Aluminum	Cylindrica cell	Prismatic cell	Pouch cell
Great Britain							
1	APM	i. o.	■	■			▭
Belgium							
2	诺德股份 NUODE	n. s.	■				
Luxembourg							
3	CIRCUIT FOIL	i. o.	■				
Germany							
4	Wickeder Group	i. o.	■	■			
5	polifibra	i. o.		■			▭
6	speira	i. o.		■	▯	▭	
7	SCHLENK	i. o.	■				
8	FEINTOOL	i. o.			▯	▭	
9	EUBACO	i. o.			▯	▭	
10	KDL科达利	i. o.			▯	▭	
11	H&T Battery Components	i. o.			▯	▭	
12	elringklinger	i. o.			▯	▭	

Factories with a focus on cylindrica cells

Factories with a focus on prismatic cells

Factories with a focus on pouch cells



			Foils		Casing material		
			Copper	Aluminum	Cylindrica cell	Prismatic cell	Pouch cell
Italy							
13	SLIM ALUMINIUM	2024		■			
Sweden							
14	GRÄNGES	i. o.		■			
15	KDL科达利	i. o.				▭	
Spain							
16	LOTTE ENERGY MATERIALS	2024/ 2025	■				
Poland							
17	SK nexilis	2025	■				
Hungary							
18	LOTTE ALUMINIUM	i. o.		■			
19	Solus Advanced Materials	i. o.	■				
20	KDL科达利	i. o.			▯	▭	
21	SANGSINEDP	i. o.				▭	
22	震裕科技 ZHENYU TECHNOLOGY	2027			▯	▭	
23	SHINHEUNG SEC	i. o.				▭	
Greece							
24	SYMETAL	i. o.		■			▭

Start of operations (i. o. = in operation; n. s. = not specified)

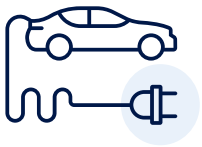
These maps do not claim to be exhaustive.

Source: Company announcements, own depiction

To that end, SK Nexilis have invested 693 million EUR and announced an expansion to 150,000 t/a at a later time. South Korean Lotte Energy Materials have announced the goal to produce 30,000 t/a copper foils near the PowerCo plant in Tarragona, Spain from 2025. An expansion to 100,000 t/a in the following years is envisaged. Furthermore, Nuode New Materials is planning the construction of a plant with a capacity of 30,000 t/a copper foils in Wallonia, Belgium, for an investment of 500 million EUR.

Copper foils are also being employed as battery connectors (so-called tabs), which are welded together with the current collectors. These are produced in Europe by Wickeder, Schlenk and Avocet Precision Metals, among others.

Aluminium foils are normally made from highly pure alloys of types 1XXX or 8XXX. Tailored aluminium foils contribute to good thermomanagement by merit of good thermal conductivity and even temperature distribution, which allows for faster charging of cells. Common thicknesses of cathode foils are 10-20 µm, and studies of recent cells have shown that preferred thickness lies between 12 and 15 µm.



Currently, aluminium foils are made in Europe by Swedish company Gränges, by Speira in Germany, by Avocet Precision Metals in Great Britain, by Symetal in Greece, and by Lotte Aluminium in Hungary. Lotte Aluminium invested 84 million EUR into a facility in Tatabánya, with an annual production capacity of 180,000 t/a. Further 80 million EUR are slated to follow in order to double the capacity. Chinese Company Dingsheng has acquired Italian aluminium producer Slim Aluminium to expand the production of cathode foils in Europe. In addition to the plant in Cisterna di Latina in Italy, another aluminium production site in Germany, Slim Merseburg GmbH, belongs to the company. Both facilities have a combined production capacity of 135,000 t/a aluminium material and were taken over by Dingsheng für 56 million EUR. It is expected that first deliveries to the European cell production facilities of CATL will take place in 2024.

Cell casings of batteries are used in three typical shapes: prismatic, cylindrical, and pouch cells. The standard formats of cylindrical cells are 18650 and 21700, where the first two digits describe the diameter and the next two digits indicate the height of the cylinder in millimetres. Larger cells of 46800 and 46950 formats enable a more advantageous ratio of active to inactive material in order to deliver higher energy density at a system level. Cylindrical cell casings are mainly made of steel, but a new trend is focusing on aluminium casings since these are lighter and offer better heat conductivity. In contrast to steel casings, which are closed under pressure, aluminium casings can be closed via laser welding.

Prismatic cell casings appear on the market in various sizes and aspect ratios, and current developments move towards higher aspect ratios. The height of the casing depends on its intended use and increases with the size of the available construction space within the vehicle (e.g., in buses and heavy-duty vehicles).

Pouch cells, also known as “casing foil” or “coffee bag”, are made of an aluminium-plastic-composite foil that forms the outer hull of a battery cell. In Europe, there are only few manufacturing capacities of pouch cell foils, which can be found in the portfolios of Polifibra Folien, Symetal and Avocet Precision Metals, among others.

The production of cell casings in Europe is strongly centralized in Germany and Hungary. In Germany, casings for prismatic as well as cylindrical cells are produced by Eubaco (in Georgenthal), Feintool (in Weinheim), H&T Battery Components (in Marsberg), Elring Klinger (in Dettingen), Kedali Germany GmbH (in Arnstadt) and Speira (in Grevenbroich). Kedali Germany GmbH announced to deliver to CATL’s nearby plant in Erfurt in a strategic partnership.

Hungary is currently developing into an investment hotspot for the production of battery components by actors from Asia looking for spatial proximity to the battery cell production plants in East Europe. For example, South Korean manufacturer Sangsin EDP (in Jászberény) and Shinheung SEC EU Kft. (in Monor) are producing prismatic cell casings to deliver to Samsung SDI in Göd. Both companies have announced investments for the expansion of their production capacities. The Chinese branch Kedali Hungary Kft. of the Kedali Group is producing cell casings in Gödöllő. Kedali invested 40 million EUR in a new plant in Gödöllő which has been producing casings since the end of 2021 and is expected to reach its second build-out stage in 2024.

According to press releases, the battery casing market is expanding further. Ningbo Zhenyu Technology is investing 58.7 million EUR in a new production site in Debrecen (Hungary), which is planned to come online at the end of 2027. Furthermore, Kedali is planning to produce prismatic cell cases in Sweden in collaboration with Northvolt.

An ecosystem of cell manufacturers and component producers is currently forming in Europe, with two geographical focal points in Southwest Germany and Hungary. Until now, European car manufacturers mainly used pouch cells in their models, but currently prismatic and cylindrical cells are on the rise again. Large producers like Samsung SDI are not committed to a single cell type, using various shapes and formats instead.

In Eastern Europe – mainly in Hungary and Poland – predominantly prismatic and pouch cells are manufactured, but the production of cylindrical cells is under development as well. The largest actors in this field are EVE Energy and Samsung, who will deliver to the BMW facility in Debrecen. The Polish LG Energy Solution plant is currently the largest European production site of pouch cells and caters to several car manufacturers in Europe. The demand in metal foils and cell casings of these production sites can be supported by the nearby factories in Hungary.

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