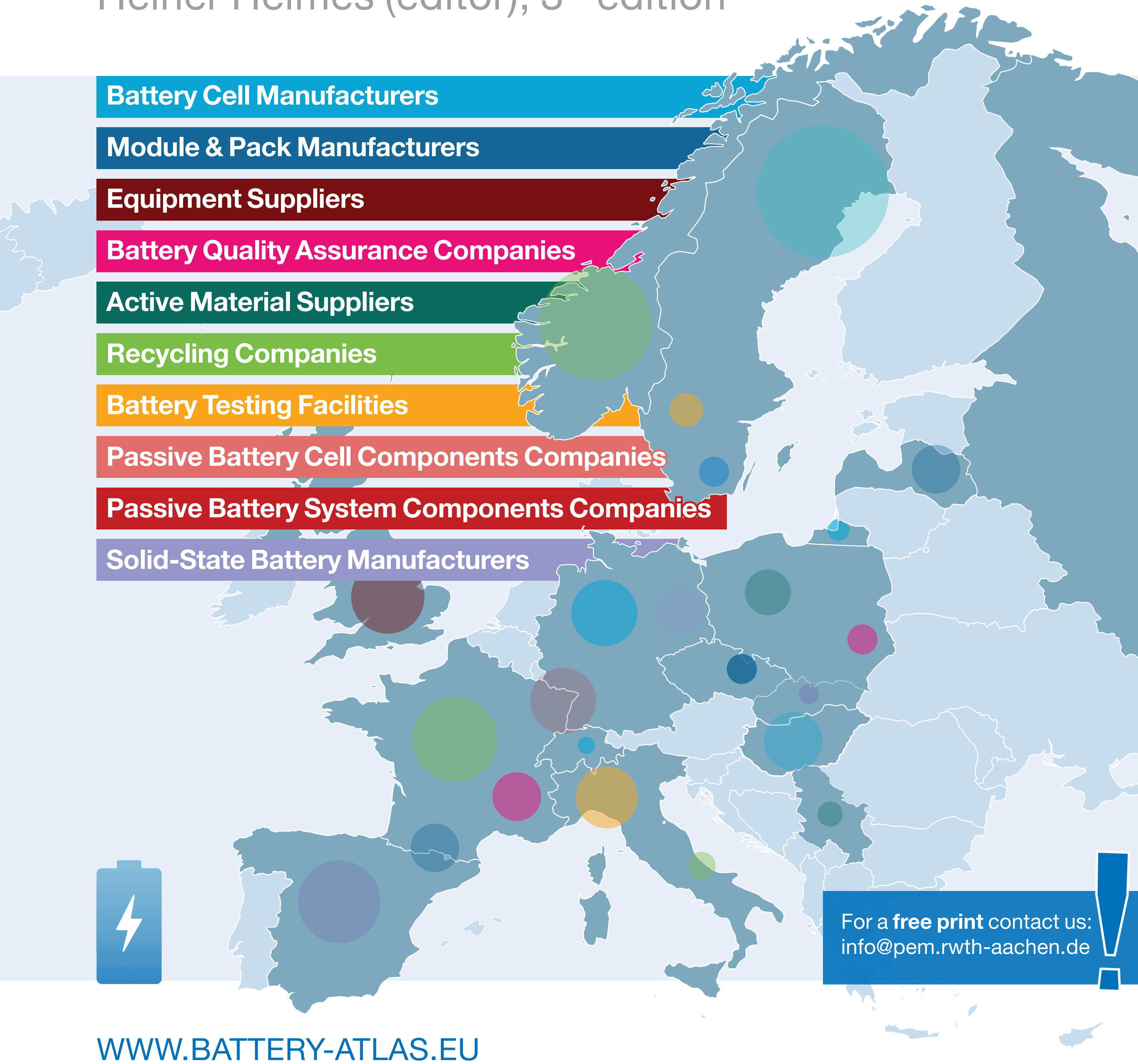
BATTERY ATLAS 2026

MAPPING THE EUROPEAN LITHIUM-ION BATTERY INDUSTRY

Heiner Heimes (editor), 3rd edition



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IMPORTANT NOTICE

Dear reader,

Although our Battery Atlas looks at the European battery market from many different angles and business areas, this document does not claim to be exhaustive. The third edition of the Battery Atlas thus once again reflects a snapshot in time. Nevertheless, all readers are invited to contribute to the topicality of this growing work. We will be happy to incorporate suggestions and additions submitted in writing into the next, updated edition.

Sincerely,
Your Battery Atlas Editorial Team

DEAR READERS,

The battery has become a key technology for our industrial future. It will determine whether value creation, employment, and technological sovereignty remain in Europe – or whether we enter into lasting dependencies. With the third edition of the Battery Atlas, we build on an established foundation and continue documentation that now allows developments, progress, and shifts within the battery ecosystem to be traced over several years.

From my daily work in research and industry, I know that the real challenge does not lie in inventing new battery concepts, but in the controlled, economical, and scalable production of battery cells. Producing a cell in the laboratory is relatively simple. Manufacturing it in large volumes with consistent quality, low scrap rates, and competitive costs, however, is a highly complex industrial process. This is precisely where competitiveness is decided.

Today, Asian manufacturers have a significant lead over the rest of the world, which is due less to individual technological breakthroughs than to decades of production experience. This experiential knowledge cannot be caught up in the short term. It arises from the continuous optimization of processes, materials, machines, and quality strategies on an industrial scale. Europe therefore faces the task of consistently and collectively progressing along this learning curve.

At the same time, battery cell production must not be viewed in isolation. Its success depends largely on a strong machinery and plant engineering sector, on material manufacturers, automation specialists, as well as logistics and quality systems. This is precisely where Europe's strengths lie. Over successive editions, the Battery Atlas has made visible how these competencies have evolved and increasingly interconnected. If they are systematically integrated with battery cell manufacturing, an industrial ecosystem emerges that creates value far beyond just the cell itself.

Meanwhile, another key pillar is recycling. Batteries are not only energy storage devices but also repositories of raw materials. Efficient recycling processes with high recovery rates are a prerequisite for economic resilience, ecological sustainability, and long-term security of supply. Here too, the Battery Atlas documents the growing importance of recycling technologies and companies as integral partners of the battery industry – technologically, economically, and strategically.

To successfully pursue this path, transitional solutions are also required. Production ramp-ups must be enabled even if they are not yet cost-competitive at the outset. What matters is the build-up of know-how, the stabilization of processes, and the accumulation of industrial experience. Only from this does long-term competitiveness emerge.

In this context, the Battery Atlas sees itself as a tool for orientation and collaboration. Across its editions, it highlights competencies, stakeholders, and interfaces along the entire value chain – from research and development through machinery and plant engineering to recycling and qualification. The goal is to facilitate collaboration, make gaps visible, and support the development of a strong, integrated battery industry.

If we view battery production as a collective industrial task and consistently pool our existing strengths, Europe still has the opportunity to play an active and influential role in this key area of technology.

Best regards,

Prof. Dr. Heiner Hans Heimes

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Are you interested in an exchange of ideas? Feel free to contact us!

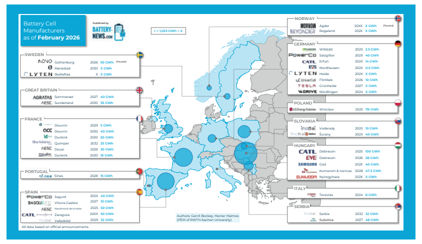
INTRODUCTION

The Battery Atlas 2026 offers a comprehensive and multifaceted overview of the European battery industry and its value chains. Using thematically structured maps, it visualizes the geographic distribution, specialization, and interconnections of key players shaping Europe's battery ecosystem. This approach provides a transparent view of complex industrial structures and enables clear comparisons across regions and value chain segments.

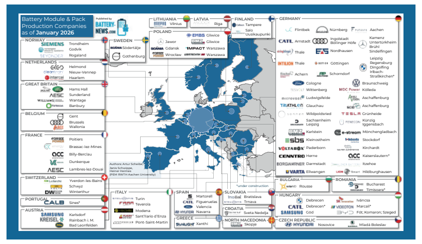
A key map on battery cell production highlights existing and planned manufacturing facilities, showing capacities and emerging hubs crucial for meeting growing demand. Additional maps cover battery cell components and active materials, illustrating supplier locations and their impact on performance, cost, and security of supply. A map on machine and plant manufacturers emphasizes the role of specialized equipment providers as the backbone of large-scale production. Technological progress is reflected in a map on solid-state battery activities, showing Europe's efforts to develop next-generation batteries with higher energy density, safety, and sustainability.

Sustainability is addressed through a battery recycling map, highlighting facilities involved in material recovery and the importance of circular economy approaches. Another map on quality assurance and testing facilities identifies institutions validating battery safety, reliability, and performance.

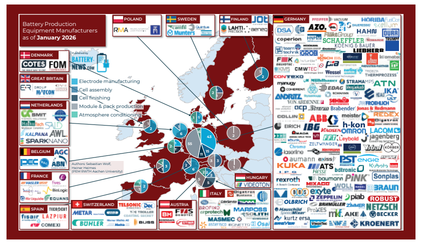
Battery Cell Manufacturers



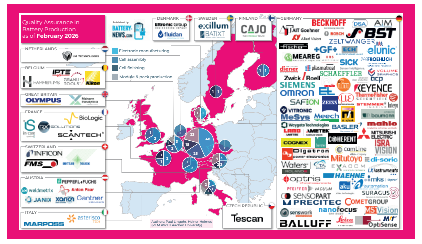
Module & Pack Manufacturers



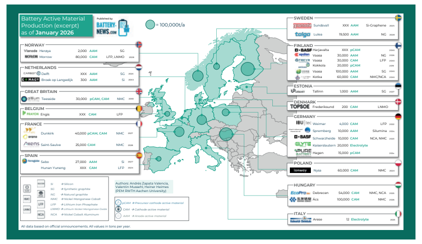
Equipment Suppliers



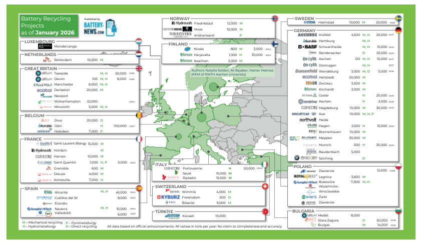
Battery Quality Assurance Companies



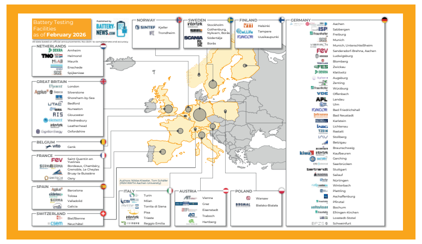
Active Material Suppliers



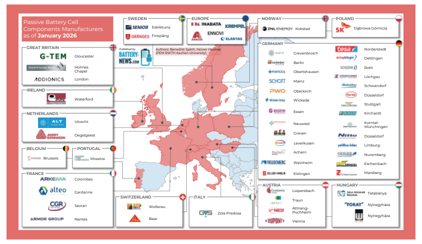
Recycling Companies



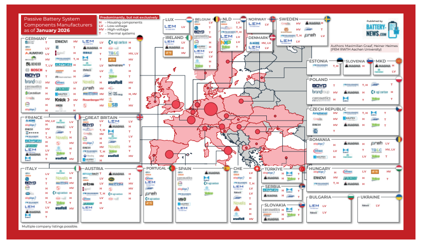
Battery Testing Facilities



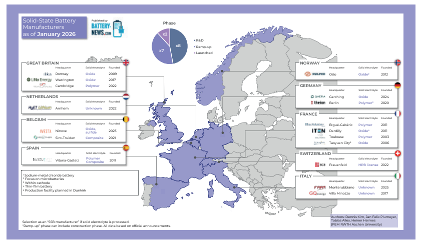
Passive Battery Cell Components Companies



Passive Battery System Components Comp.

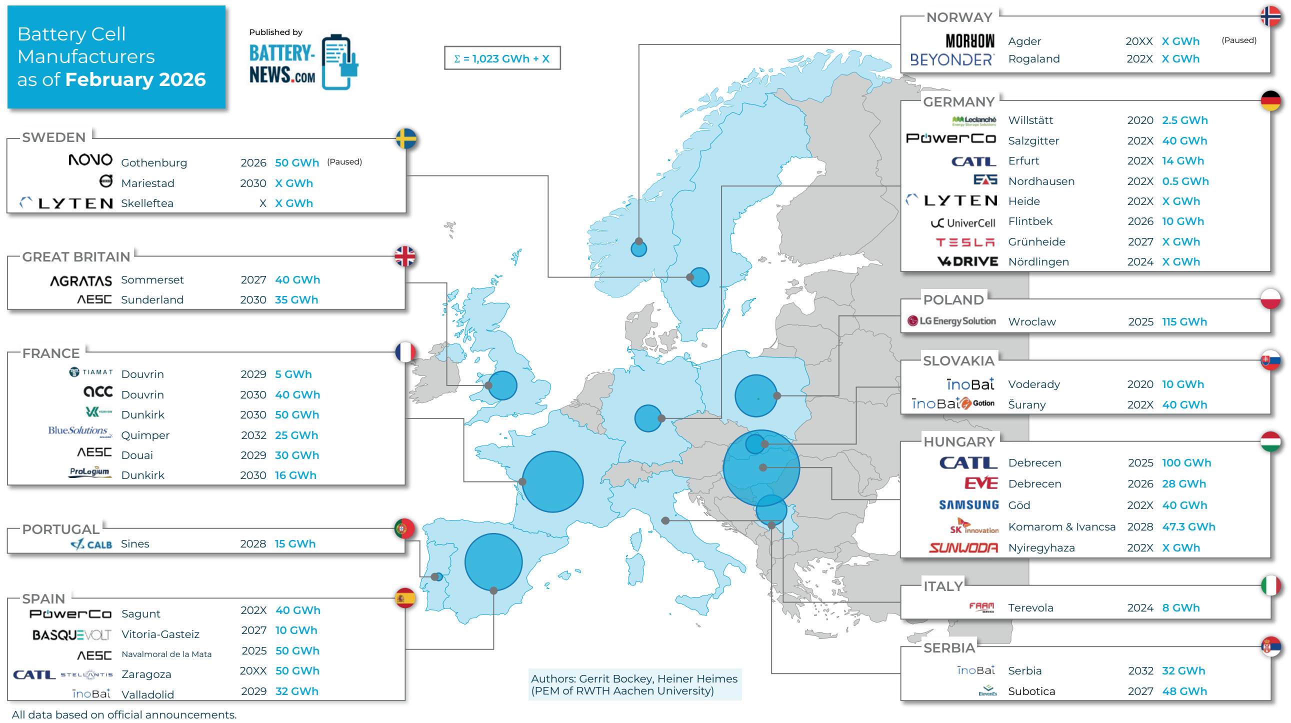


Solid-State Battery Manufacturers



Overall, the 2026 Battery Atlas provides an integrated perspective on Europe's battery landscape, combining production, supply, technology, and sustainability insights. It supports informed decision-making for industry, research, and policy stakeholders, offering a clear view of current capabilities and future development potential.

BATTERY CELL MANUFACTURERS



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

Europe's battery industry is transforming, but the path remains uncertain. Announced capacity has fallen from more than 2,000 gigawatt-hours in 2023 to about 1,190 gigawatt-hours by early 2025, reflecting the "Trough of Disillusionment." As viable projects emerge, Europe is moving toward the "Slope of Enlightenment," where realistic business models replace earlier speculative plans.

ANALYSIS

A clear sign of uncertainty is the widespread use of "202X" and "20XX" placeholders across Europe, showing how many projects lack concrete completion dates. These vague timelines stretch across the continent, indicating systemic challenges rather than isolated delays.

Europe's difficulties in conventional battery manufacturing became apparent as leading projects faced production delays, quality issues, and financial crises. The bankruptcy of a major European cell manufacturer in late 2024 highlighted the harsh reality of competing directly with established Asian players, who benefit from decades of experience, integrated supply chains, and lower costs.

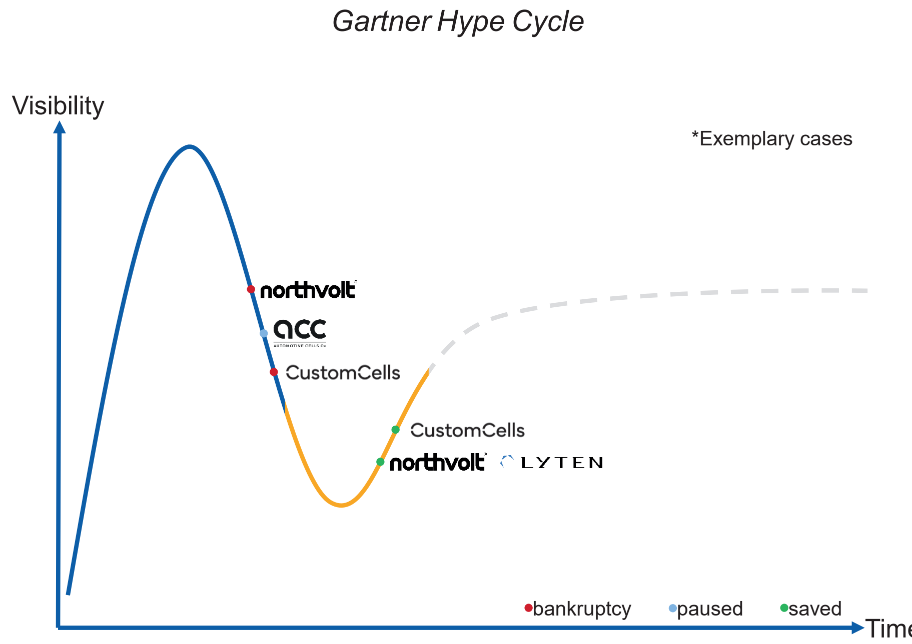
This setback raises a crucial question: Should Europe try to compete head-to-head in conventional lithium-ion battery mass production, or focus on areas of comparative advantage? The acquisition of failed European capacity by companies developing next-generation chemistries – such as lithium-sulfur – suggests a promising alternative. Rather than replicating Asian success, Europe could leapfrog into future battery technologies.

Next-generation chemistries – lithium-sulfur, solid-state, sodium-ion – offer advantages such as higher energy density, more abundant materials, improved safety, and lower environmental impact. Crucially, these technologies have not yet been industrialized at scale, meaning Asian manufacturers hold no decisive lead. By repurposing existing infrastructure – cleanrooms, logistics networks, testing facilities, and skilled workforces –, Europe could transform apparent failure into strategic opportunity.

The key challenge is whether production lines for conventional cells can adapt to fundamentally different chemistries. If so, European facilities could become testbeds for the batteries of the 2030s, establishing a new strategic direction focused on next-generation technologies.

Regional patterns vary. Areas with coordinated government support attract concrete investments, while market-driven regions show more "202X" placeholders. Hungary's rise to 215.3 gigawatt-hours, including 128 in Debrecen, illustrates how competitive conditions lure Asian manufacturers – yet also raises the risk that Europe becomes a production site for foreign technology.

Challenges remain, as Asian companies dominate much of planned expansion. Of the 1,190+ gigawatt-hours projected, roughly 673 are led by Asian manufacturers. The reduction from more than 2,000 gigawatt-hours reflects a market correction, leaving only projects with robust business cases.



OUTLOOK

Europe's battery future requires a realistic assessment. The industry is emerging from its "Trough of Disillusionment," having shed overambitious projects. This painful process may position survivors for productivity, potentially in different technological domains than originally planned.

Repurposing existing infrastructure tests Europe's adaptability. Can large investments be redirected toward next-generation chemistries where Europe might genuinely compete? Instead of expanding conventional lithium-ion capacity against Asian dominance, the focus could shift to flexible platforms for emerging technologies, turning late entry into a strategic advantage.

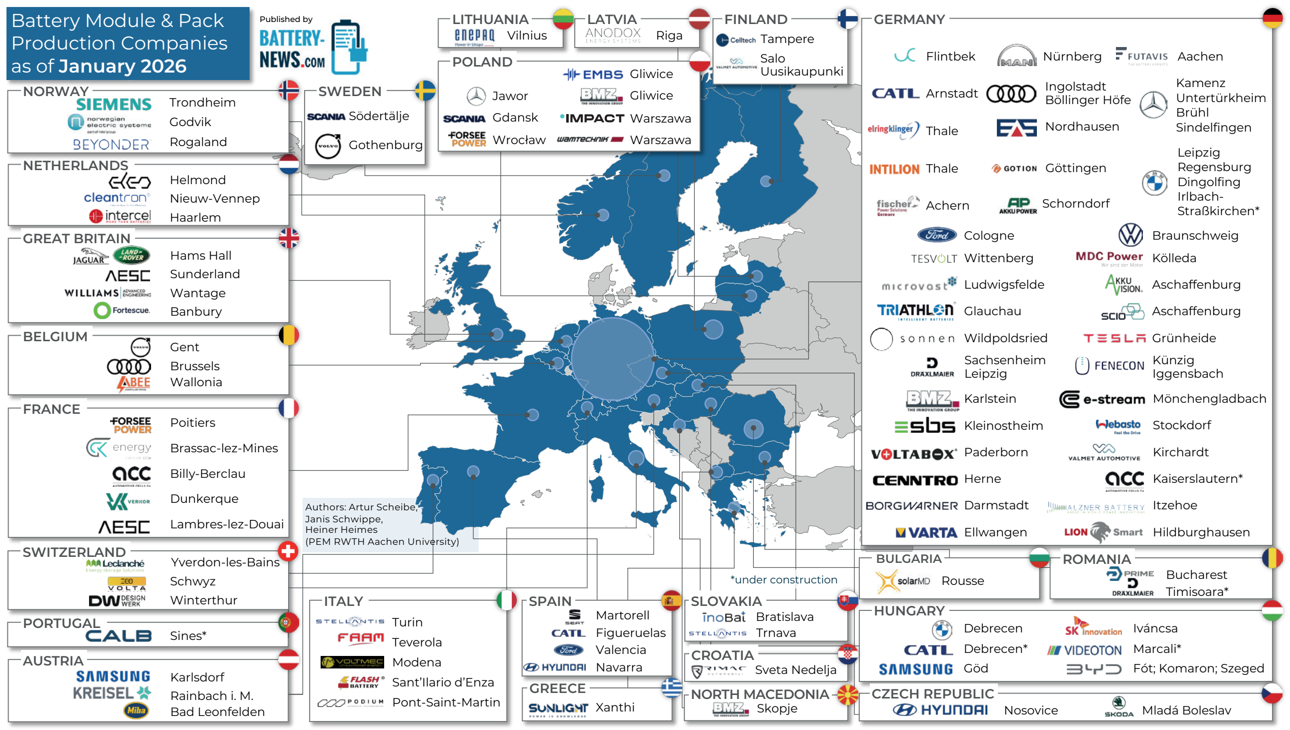
This raises key questions: Should public support continue backing conventional manufacturing or pivot toward next-generation technologies? Could new champions in alternative chemistries provide a more viable path to technological sovereignty? Transforming failed conventional capacity into platforms for advanced technologies could hold the answers.

The next two to three years are decisive. Projects currently operational or under construction – about 300 to 400 gigawatt-hours – define realistic near-term capacity in conventional technologies. The remaining 800+ gigawatt-hours depend on sustained political will and whether these "202X" projects pursue conventional or next-generation approaches.

The potential emergence of new champions focused on alternative chemistries is compelling. It will test whether Europe can leverage setbacks into strategic pivots, repurpose infrastructure, and exploit next-generation technologies to achieve a competitive edge. Success demands coordinated industrial policy, sustained investment, and strategic clarity about where Europe can genuinely compete. The race is not over, but bridging the gap may require embracing new technologies rather than catching up in existing ones.

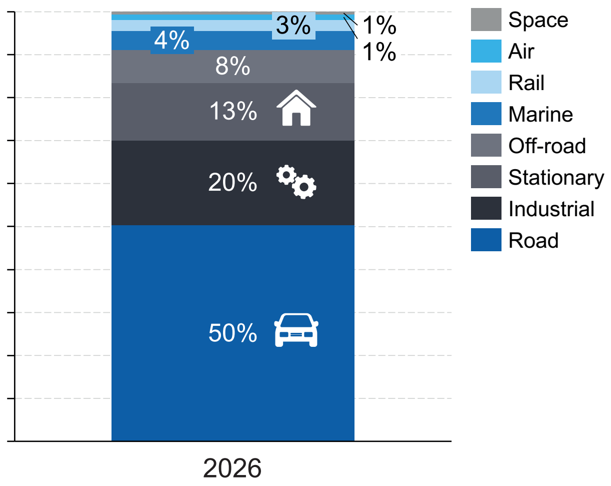
> If Europe can repurpose existing infrastructure – cleanrooms, logistics systems, testing facilities, skilled workforces – for alternative chemistries, it could transform apparent failure into strategic opportunity.

MODULE & PACK MANUFACTURERS

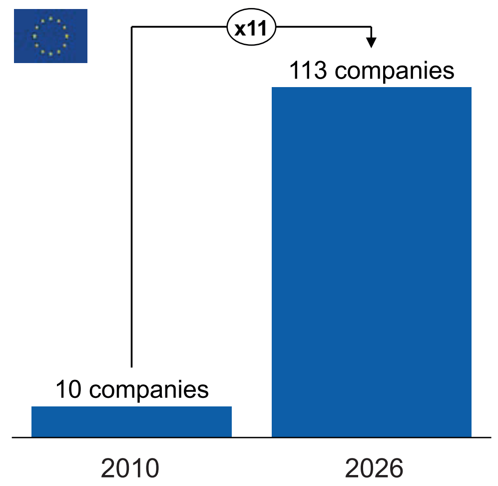


Source: www.battery-atlas.eu; abstract, no claim to completeness

Application segments served by European module & pack manufacturing companies



Growth in European module & pack manufacturing companies



INITIAL POSITION & MAP UPDATE

The updated map from January 2026 shows that Europe's manufacturing industry for battery modules and packs continues to expand, with almost 120 companies now identified. Germany remains the central production hub in terms of announced projects, followed by Poland and Hungary, while countries in Southern Europe and Scandinavia are gaining significance. At the same time, capacity is increasingly shifting toward Eastern Europe, particularly to the Czech Republic, Slovakia, and Romania. Also, Southern Europe is rising in relevance, as new projects in Portugal, Spain, and Italy expand Europe's battery production footprint. Energy costs seem to be increasingly shaping location decisions, with competitive or politically supported prices enhancing regional attractiveness. This trend is further accompanied by targeted corporate investments that accelerate regional development trajectories. Together, these dynamics are shaping the European production landscape with varying strategic priorities and levels of production maturity and capacity.

ANALYSIS

The map indicates that capacity growth and investments are concentrated in regions characterized by political stability and favorable subsidy frameworks. Central European corridors gain an advantage from established industrial clusters, research infrastructure, and targeted incentives. The overall growth in local production capacity is driven by rising EU-wide demand for electric vehicles and by strategic efforts to reduce Europe's long-standing dependence on Asian suppliers especially in downstream stages of the value chain. In contrast, developments in German-speaking countries and Northern Europe are more heterogeneous, with some sites expanding capacity, modernizing production processes, or building broader collaboration networks, while others are consolidating operations, repositioning within existing value chains, or delaying projects due to financing and market uncertainties.

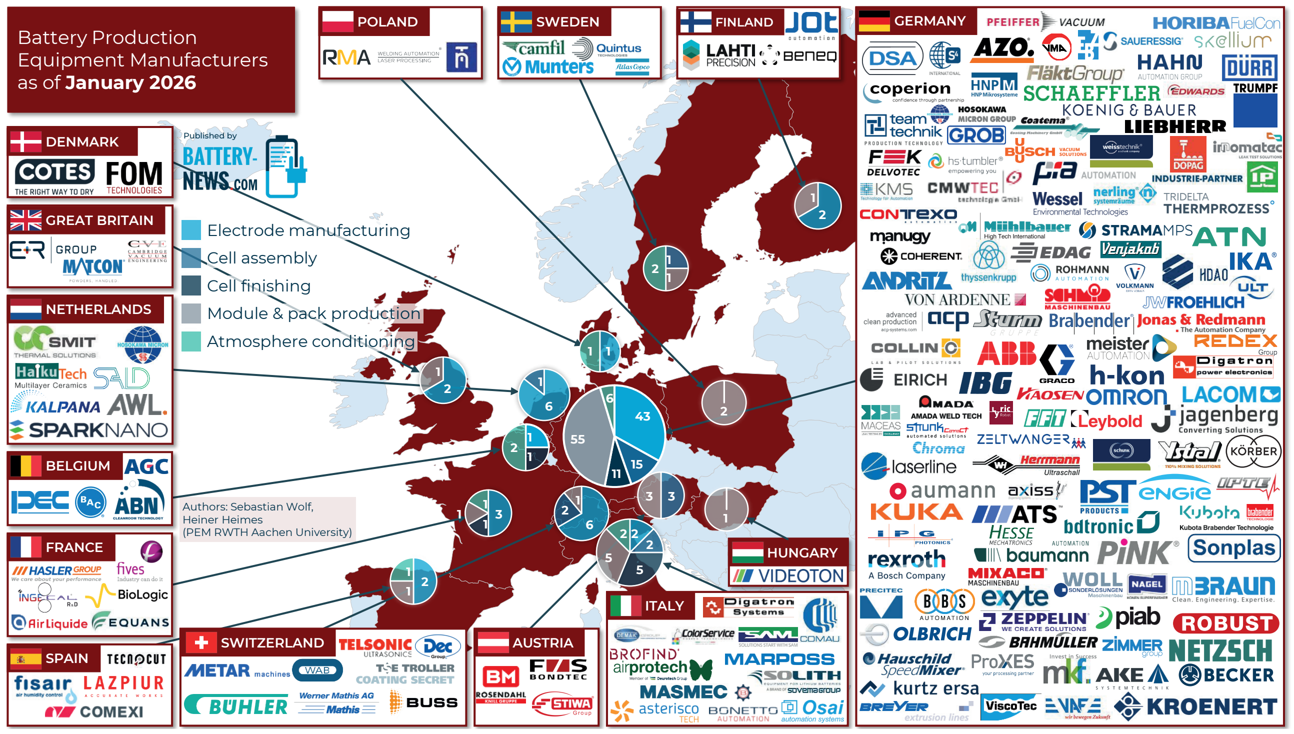
Overall, developments in the past 15 years indicate a fundamental transformation of the European module and pack manufacturing landscape. In 2010, production was concentrated in a few locations in Germany and France, whereas today it extends across nearly all European regions. Smaller countries are developing specialized competencies alongside the traditional Central European hubs, and the growing number of production sites reflects the increasing demand for energy storage across a wide range of electrified applications. Electrification in the automotive sector continues to rise for both passenger cars and commercial vehicles, while stationary energy storage systems are expanding rapidly, driven by the growth of renewable energy and the need for grid stability. Aerospace, rail, and maritime applications – while currently accounting for only minor shares – are gaining importance due to decarbonization targets and the drive to reduce life cycle emissions in all modes of transport. It remains to be seen to what extent the shift toward stronger local value creation will, in the long term, contribute to building a more resilient industrial base that secures supply, supports innovation, and fosters technological sovereignty.

OUTLOOK

Europe is expected to remain competitive in module and pack production, supported by a broad regional industrial base and specialized expertise. Production capacities are expanding across multiple regions, with Central Europe remaining a key hub while Southern and Eastern Europe are increasingly gaining importance thanks to targeted investments and favorable local conditions. While conventional battery modules are losing importance in the automotive sector due to vertical integration and highly integrated system architectures (such as cell-to-pack systems), they are becoming increasingly important in the areas of stationary storage, renewable energy integration, and emerging transportation applications such as in the aerospace, rail, and maritime sectors. Manufacturers appear to be responding by investing in flexible product platform architectures that support multiple cell formats and adaptable production systems. Looking ahead, political and regulatory frameworks – including carbon pricing, emissions regulations, and EU sustainability requirements –, together with energy costs, will continue to influence the investment climate, production strategies, and growth, as well as localization across Europe.

The European battery module and pack manufacturing industry is evolving towards a geographically diversified presence with multiple production sites, driven by demand for electrification, strategic investments, and the pursuit of a resilient supply chain.

EQUIPMENT SUPPLIERS



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

Since 2024, the European battery industry has experienced significant project delays and cancellations. In 2025, developments at several large-scale cell manufacturing projects had a particularly pronounced impact. Many of these projects were designed with a high proportion of European-sourced production equipment. Consequently, the suspension or discontinuation of such initiatives has had substantial repercussions for the European machinery and plant engineering sector, as major equipment orders were postponed or canceled at short notice.

This challenging market environment has led to increased economic pressure on equipment suppliers. In some cases, this has resulted in corporate restructurings, including insolvency proceedings and subsequent asset acquisitions. These developments indicate an ongoing phase of structural consolidation within the European battery equipment market.

Despite these challenges, substantial new battery production capacities continue to be planned and implemented in Europe. In December 2025, Tesla announced an expansion of cell production at its Grünheide site to up to eight gigawatt-hours annually from 2027.[1] At the same time, major European gigafactory projects are in the ramp-up phase of their first production lines as of February 2026, indicating continued medium-term demand for production and retrofit equipment.

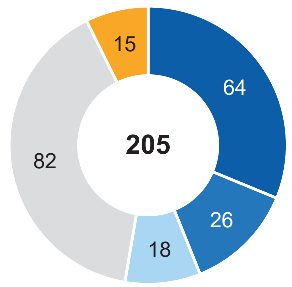
Beyond large-scale automotive applications, European machinery and plant engineering companies remain active in niche markets and highly specialized solutions.

New ventures and start-ups are emerging, including the Fraunhofer spin-off MANUGY (founded in 2024 in Cologne) and the PEM RWTH Aachen University spin-off Skellium, both focusing on innovative battery manufacturing processes.[2,3]

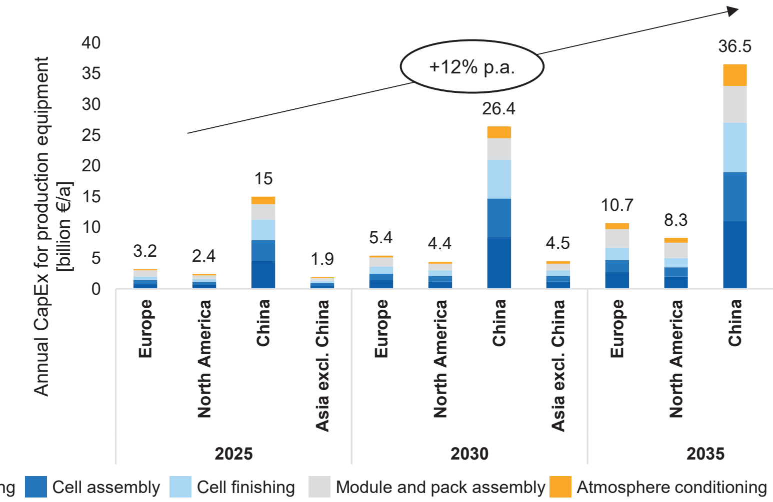
Process optimization remains a key innovation field, particularly in electrode drying, cell finishing, and clean and drying room technologies, due to their high energy demand and significant CapEx and OpEx shares.[4] Dry electrode processing is often discussed as a potentially disruptive approach with major cost-reduction potential, but scaling to high-volume production remains challenging.[5] In the short to medium term, innovative drying technologies such as laser drying appear particularly promising, offering significant CapEx and OpEx savings, retrofit compatibility, and real-time process control to improve overall process quality.[6]

1 https://www.reuters.com/business/autos-transportation/tesla-ramps-up-battery-cell-investments-german-gigafactory-2025-12-16/?utm
2 https://fraunhoferinvestmenthub.de/manugy/
3 https://skellium.eu/
4 https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2023/Fraunhofer-ISI_LIB-Roadmap-2023.pdf?utm
5 https://www.autoevolution.com/news/musk-admits-that-pursuing-the-dry-battery-electrode-process-in-4680-cells-was-a-

Number of European equipment suppliers along the battery production process chain



Market demand for production equipment for lithium-ion batteries



ANALYSIS

The initial greenfield phase of European gigafactory development is largely completed. During this phase, most engineering and equipment contracts were awarded to Asian turnkey suppliers, reflecting the limited competitiveness of European suppliers in fully integrated greenfield projects at that time.[7]

As the market moves from first capacity build-up toward scaling and optimization, the modernization of existing production facilities becomes a key driver. This brownfield phase focuses on retrofits, targeted technological upgrades, and performance optimization of installed equipment. Market analyses indicate that brownfield investments will account for a substantial share of future spending, with cumulative investments in battery production equipment upgrades expected to reach around 135 billion euros by 2035.[8] This shift creates a structurally different market environment in which modular solutions, process-specific innovations, and deep process expertise gain importance – areas where European equipment suppliers are comparatively well positioned.

At the same time, geopolitical developments are reshaping competition. Chinese export restrictions on advanced battery technologies and equipment increasingly extend from materials to core manufacturing processes. While this exposes Europe's dependency on Asian suppliers as a structural risk, it also creates a long-term opportunity for the European machinery and plant engineering industry to strengthen its technological sovereignty and market position.[9]

OUTLOOK

In the coming years, the focus will be on retrofitting existing production lines and reducing dependency on Asian equipment suppliers, despite typically higher CapEx for European solutions. At the same time, increasing geopolitical risks, including potential export restrictions on Chinese high-tech equipment, strengthen the case for a resilient European supply chain. Alongside automotive gigafactories, niche and new greenfield projects are gaining importance, particularly in defense and aerospace applications such as batteries for drones and specialized energy storage systems, where a reliable European value chain is critical for security and sovereignty. Strategically, European machinery and plant engineering companies must differentiate through process innovation.

System-level capabilities such as end-to-end traceability and inline, real-time measurement and control enable lower scrap rates, faster ramp-up, and reliable quality compliance, creating a key competitive advantage over hardware-focused suppliers.

European battery equipment suppliers' competitiveness will rely on process innovation, system integration, and real-time control to increase production yield.

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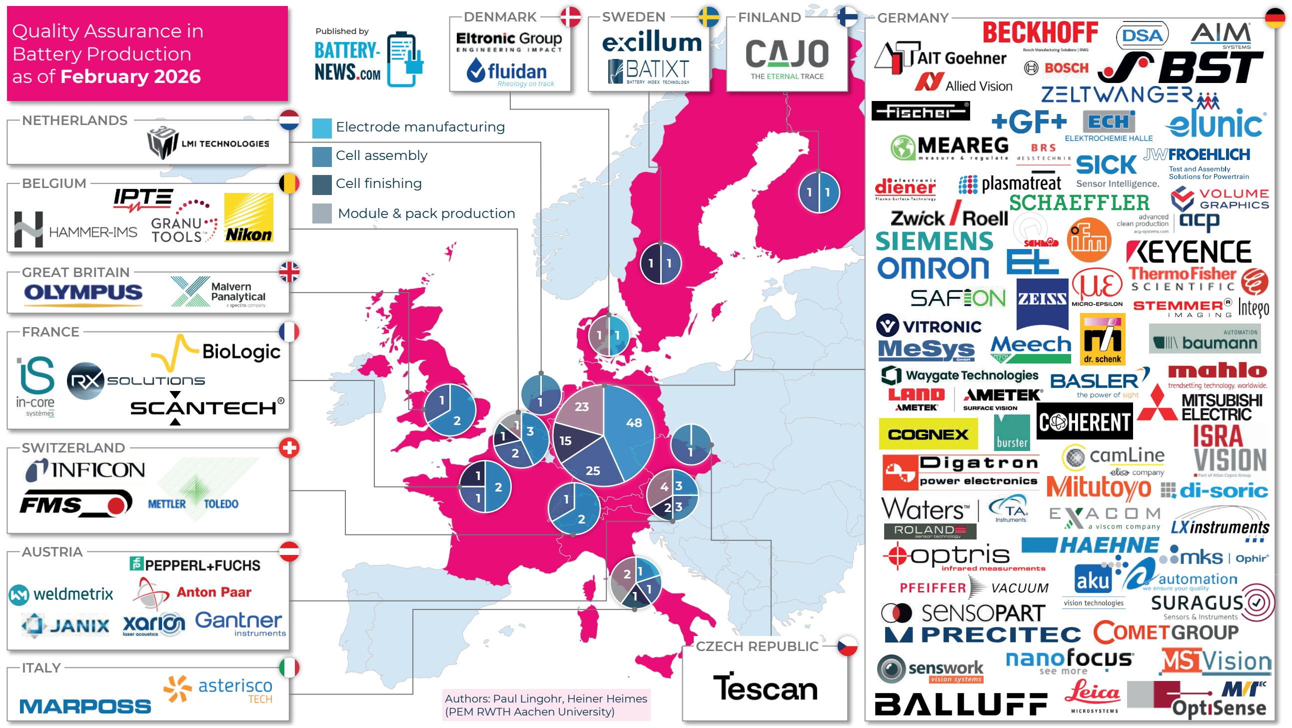
6 https://www.pem.rwth-aachen.de/global/show_document.asp?id=aaaaaaaabzkmfxo
7 https://www.zeit.de/2025/54/batteriefabrik-salzgitter-vw-elektroauto-batteriezellen-produktion-china/seite-2
8 https://www.porsche-consulting.com/international/en/publication/battery-manufacturing-2030-hype-hard-truths
9 https://www.iea.org/commentaries/with-new-export-controls-on-critical-minerals-supply-concentration-risks-become-reality?utm

BATTERY QUALITY ASSURANCE COMPANIES



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

Battery cell production involves numerous process steps, from dosing and mixing in electrode production to end-of-line inspection after pack assembly. Depending on the step and facility setup, processes are carried out as reel-to-reel or batch. Optimal process interaction is crucial for cell quality and safety, supported by quality assurance systems, sensors, cameras, AI, and equipment networking.

Public announcements project up to two terawatt-hours of capacity by 2030. Europe is currently in a market consolidation phase, highlighting the importance of production quality. Northvolt's scaling challenges illustrated the difficulty of maintaining quality. Beyond plant construction, actual output depends on quality assurance systems, which ensure throughput matches theoretical capacity.

For this purpose, different systems exist for the respective process steps to check individual factors. These tests can be performed inline or by offline measurements. Exemplary quality checks or systems to ensure quality in battery production are

- determining agglomerate size and viscosity after mixing,
- checking wet film thickness after coating,
- maintaining web tension in the drying process,
- checking porosity after calendering,
- determining wetting degree in electrolyte filling.

Early detection of defects or irregularities allows early identification of faults or even countermeasures. Depending on the cell shape and module as well as pack design, battery production comprises up to more than 15 manufacturing steps. In a very simplified view and in a fictitious scenario, quality assurance measures would reduce the scrap per process step by one percent, so output would be increased by up to 20 percent.

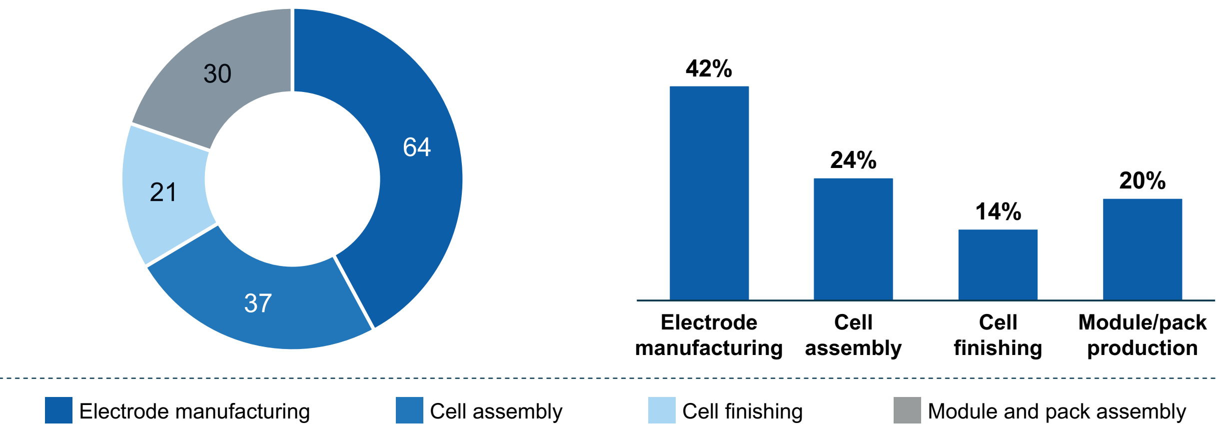
An additional driver for quality assurance is the "EU Battery Passport" which will be mandatory from February 2027 for electric vehicles and industrial batteries, requiring companies to capture and document specific production and life cycle data.

ANALYSIS

Research by the PEM Chair of RWTH Aachen University shows that roughly 42% of quality assurance (QA) equipment is used in electrode manufacturing, 24% in assembly, and 14% each in cell finalization and module/pack assembly. A similar pattern appears among European equipment manufacturers, particularly in electrode production. Limited sales scaling reduces the informative value of pie charts, but the distribution illustrates relationships between processes and equipment in an exemplary way.

Number of European quality equipment suppliers in battery production

Strongly generalized quality monitoring distribution, derived from PEM projects



AI-based applications are increasingly combined with measurement systems for predictive quality control and process optimization. These range from machine vision detecting electrode coating defects to algorithms identifying anomalies in X-ray images of finished cells. New models for root cause analysis and quality prediction allow manufacturers to correlate process parameters with outcomes and anticipate defects.

In module and pack production, fewer solution providers exist compared to plant engineering maps. Conventional pick-and-place processes have different QA needs than web-based ones, and many companies focus on automation. Distinguishing manufacturers by battery-specific QA applications remains challenging when they do not clearly advertise their capabilities.

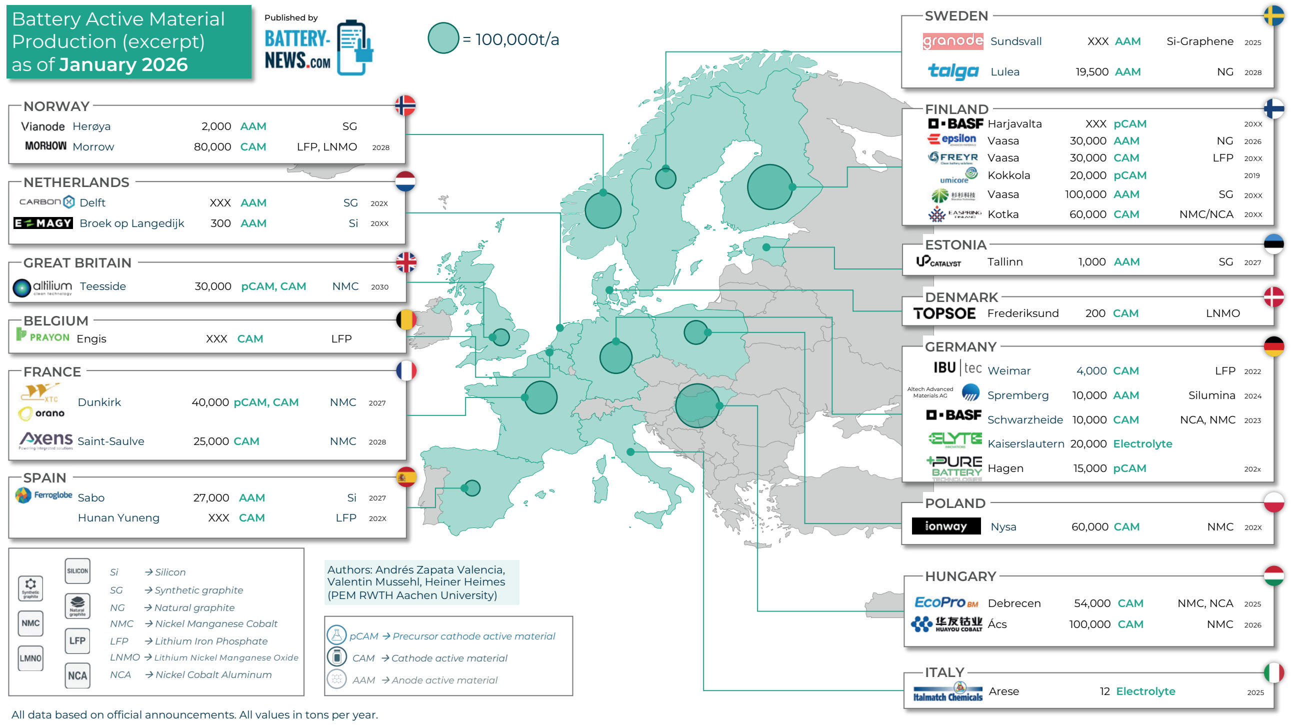
OUTLOOK

As competition in the battery industry intensifies, driven by cost pressure and increasing quality demands, quality assurance concepts are continuously evolving. One of the most important topics in this field is quality assurance using artificial intelligence and the application of digital twins. Companies are already equipping their production facilities with such data-based systems, which can reduce deployment times by up to 30 percent and achieve yield improvements of more than ten percent through early defect detection. All the exact interrelationships in the production of battery cells are not yet known. Interviews with leading industry experts support the statement that the expansion of knowledge and the analysis of the process as well as the associated interdependencies will lead to a reduction in necessary quality assurance equipment in the medium term.

Over the long haul, it is not yet clear what the minimum of measuring equipment will be and what it will look like. Whether this will be a surface inspection supported by exposure techniques, a porosity analysis of the entire web, or novel ultrasound-based inline inspection methods will only become clear as further production lines are set up. An increasing understanding of quality intricacies can be observed, with more and more tailored solutions being developed by quality inspection providers. However, it is already becoming obvious that companies want to know and track more about their product. The exact transfer of information about the product and thus the collected measurement values within production in the form of data are becoming increasingly valuable for the industry.

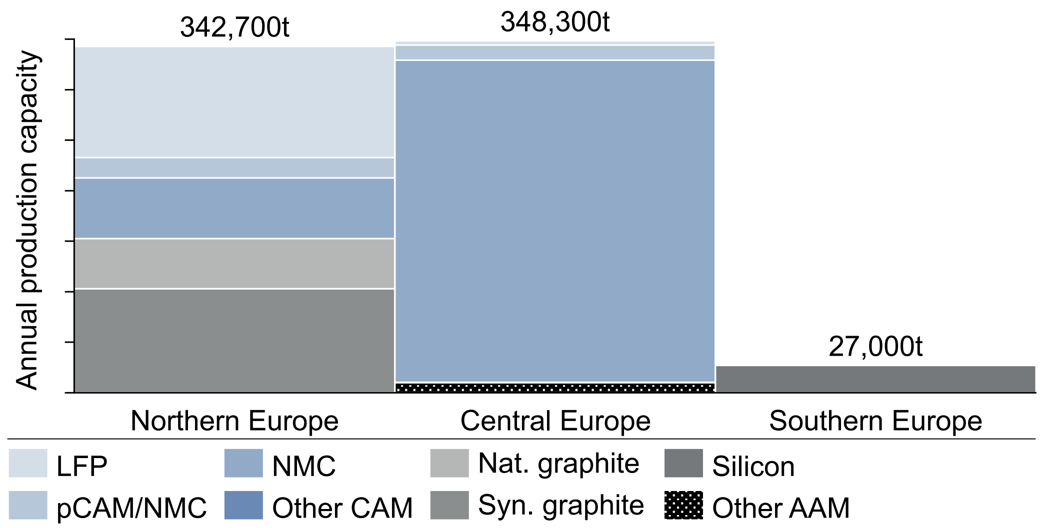
European quality assurance providers have learned from early gigafactory projects and developed tailored solutions for battery production. AI-powered applications are increasingly integrated to enhance defect detection and yield improvement.

ACTIVE MATERIAL SUPPLIERS



Source: www.battery-atlas.eu; abstract, no claim to completeness

Current material supply distribution for electrode material and region



INITIAL POSITION & MAP UPDATE

The updated map from January 2026 illustrates the dynamic expansion of Europe's battery active material production landscape, now encompassing more than 20 announced projects for cathode active material (CAM/pCAM) and anode active material (AAM). Germany leads in project density, particularly for high-energy lithium nickel cobalt aluminum oxide (NCA) and lithium nickel manganese cobalt oxide (NMC) cathodes, complemented by major initiatives in silicon-graphite anodes.
Meanwhile, France, the Netherlands, and Sweden are establishing themselves as key hubs for NMC production and natural graphite processing. These locations benefit from existing chemical infrastructure, accessible port logistics, and political support for strategic materials. Production capacity is simultaneously shifting eastward and northward, with Finland and Poland scaling up synthetic graphite and lithium iron phosphate (LFP) capabilities.
Smaller countries in Southern and Northern Europe are also gaining prominence: Norway is advancing silicon-based anode projects, while Sweden's research teams are developing graphene-enhanced materials offering higher conductivity and mechanical stability. This expands Europe's active material footprint both geographically and technologically.
Location decisions are closely tied to rising energy costs and EU sustainability mandates. Regions with high shares of renewable energy, stable infrastructure, and proximity to planned battery gigafactories are preferred. Strategic partnerships with Asian technology leaders, such as joint ventures or technology licenses, accelerate know-how transfer and commercialization of next-generation materials. The result is a heterogeneous yet innovation-driven ecosystem with varying technological maturities.

ANALYSIS

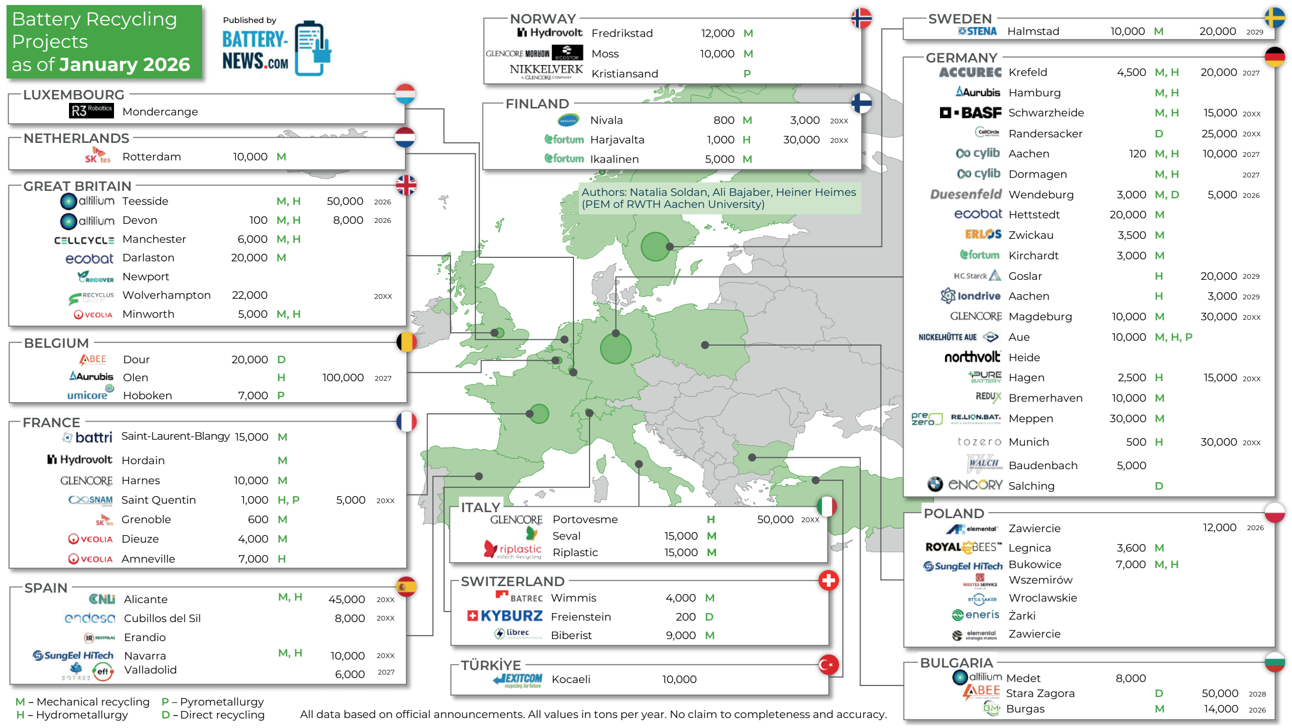
The geographical distribution of investments highlights that capacity expansions are concentrating in politically stable regions benefiting from European IPCEI ("Important Projects of Common European Interest") funding and national programs. Central and Western Europe leverage established chemical clusters, research networks, and streamlined permitting to realize projects swiftly.
Growth in local active material production is primarily driven by surging demand for battery cells in electric vehicles, stationary energy storage, and industrial applications. At the same time, the European Union aims to reduce dependence on Asian supply chains, particularly for cathode precursors and graphite.
Developments in Northern and Eastern Europe are more heterogeneous. Some sites are transitioning from pilot to commercial production, such as natural graphite processing in Luleå, Sweden. Others are shifting to alternative chemistries (e.g. LFP or LNMO) or testing silicon additives for higher energy densities. Challenges persist, especially in financing young companies and securing cost-effective raw materials amid volatile markets.
In retrospect, the evolution is remarkable: From a handful of pilot plants around 2015, an industrial production network at multi-gigawatt-hour scale has emerged within a decade, spanning nearly all EU member states. While major economies like Germany and France dominate, smaller countries are increasingly specializing in niches, such as ultra-pure synthetic graphite or particularly nickel-rich cathode materials. This differentiation mirrors the broad electrification trend across mobility, grid storage, and industrial processes.

OUTLOOK

In the coming years, Europe is poised to strengthen its competitiveness in battery active materials through diversification and technological specialization. The Central European region, with Germany, Poland, the Czech Republic and Austria as the core zone, remains the industrial backbone, while Northern and Southern Europe gain importance through specialized projects and new recycling capacities. A key element is the transition to closed-loop systems. Advances in hydrometallurgy and black mass recycling will enable recovery of significant quantities of cathode and anode raw materials by 2030. This reduces primary mineral imports and buffers cost risks from geopolitical fluctuations.
Regulatory measures like the EU Battery Regulation, the Carbon Border Adjustment Mechanism (CBAM), the digital battery passport, and critical raw materials strategies create incentives to deeply integrate recycling processes and secondary material sources into supply chains. Combined with falling energy costs in regions with high renewable shares, this fosters an increasingly circular, resilient, and technologically sovereign value chain for Europe's battery materials.

Europe's battery active material sector is morphing into a diversified, resilient network fueled by EV/ESS electrification, EU autonomy drives, and tech diversification in NMC, LFP, and silicon-graphite. !

RECYCLING COMPANIES



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

The continuous growth of the electric mobility industry has led to a significant increase in the consumption of battery raw materials, making the management of these resources essential. Since most of these materials are imported from outside Europe, promoting a circular economy is crucial to reducing dependence on external suppliers and strengthening the recycling infrastructure within Europe. The location of recycling plants is key, as transport makes up a large part of the recycling costs.

The European Union has introduced new regulations to improve battery recycling while promoting a circular economy. These regulations set specific targets including an overall recycling efficiency of 70% by 2030, along with material-specific recovery rates of 50% for lithium and 90%for cobalt, nickel, copper, and lead by 2027, increasing to 80% for lithium and 95% for the other metals by 2031. These targets present a major challenge for the recycling industry as current processes are primarily optimized for metals such as cobalt and nickel and are not yet designed for efficient lithium recovery. The regulation also sets minimum recycled content requirements for new batteries, which leads to manufacturers having to use a certain share of secondary materials. This promotes demand for recovered metals and strengthens the link between recyclers and battery producers.

Recycling facilities differ in how far they process battery materials – from basic pre-treatment to advanced material recovery. In a spoke-hub system spoke facilities handle the initial, mostly mechanical steps of discharging, disassembly, shredding, sorting, and separating battery components. They mainly produce intermediate materials like metals, plastics, and most importantly the battery active material mixture (BAMM), commonly referred to as "black mass." Its composition is not standardized and typically includes a mixture of anode and cathode materials, electrolyte residues, and other components. Hub facilities focus on the chemical processing of battery materials, carrying out steps such as leaching, purification, and precipitation to extract high-purity metals. These include lithium, nickel, cobalt, manganese, and graphite and are used for the production of new batteries.

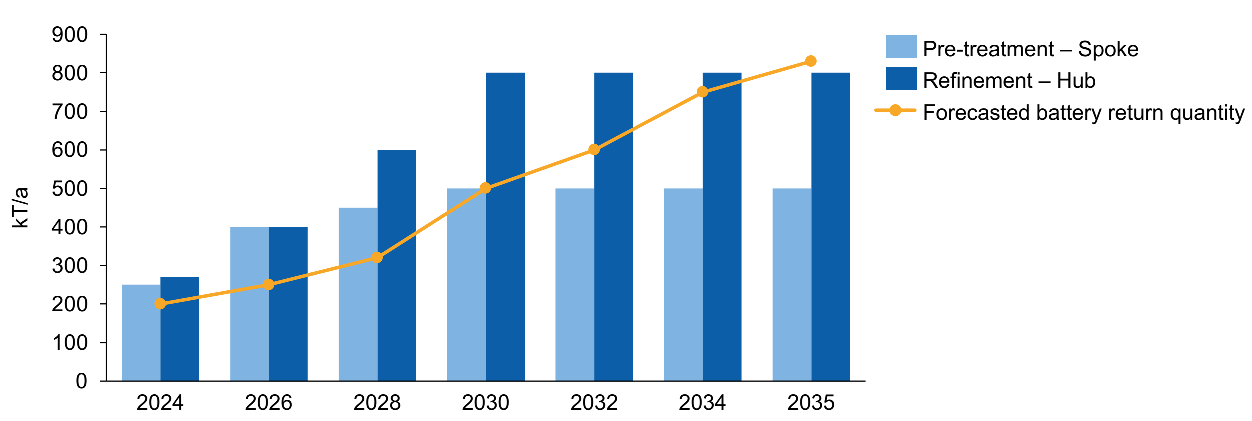
ANALYSIS

In the course of 2025, several major recycling projects in Europe have been scaled back or canceled, mainly due to a slowdown in the projected growth of the battery-cell manufacturing industry. Notable examples include Northvolt in Sweden, BASF in Spain, and Eramet in France. Together, these cancellations represent a combined planned capacity of roughly 225,000 tons per year, highlighting a significant reduction in expected recycling capacity.

Even with these setbacks, the amount of used batteries in Europe will continue to increase, reaching more than 800 kilotons per year by 2035. However, updated estimates from Fraunhofer ISI show that the expected return volumes for 2030 are now about 40 percent lower than previously assumed. This is once again due to the slowdown in the battery-cell manufacturing industry, which means fewer end-of-life batteries will be available for recycling in the near future.

At the same time, announced spoke and hub capacities continue to expand and remain well above anticipated material inflows. Spoke capacity is projected to reach about 420 kilotons per year by 2026 and 520 kilotons per year by 2030, while refinement capacity could climb to 820 kilotons per year within the same timeframe. This growth reflects Europe's strategic focus on securing access to critical raw materials. However, the mismatch between capacity growth and reduced end-of-life battery availability means many facilities may run below optimal capacity.

Recycling demand and forecasted capacities for lithium-ion battery recycling in Europe



OUTLOOK

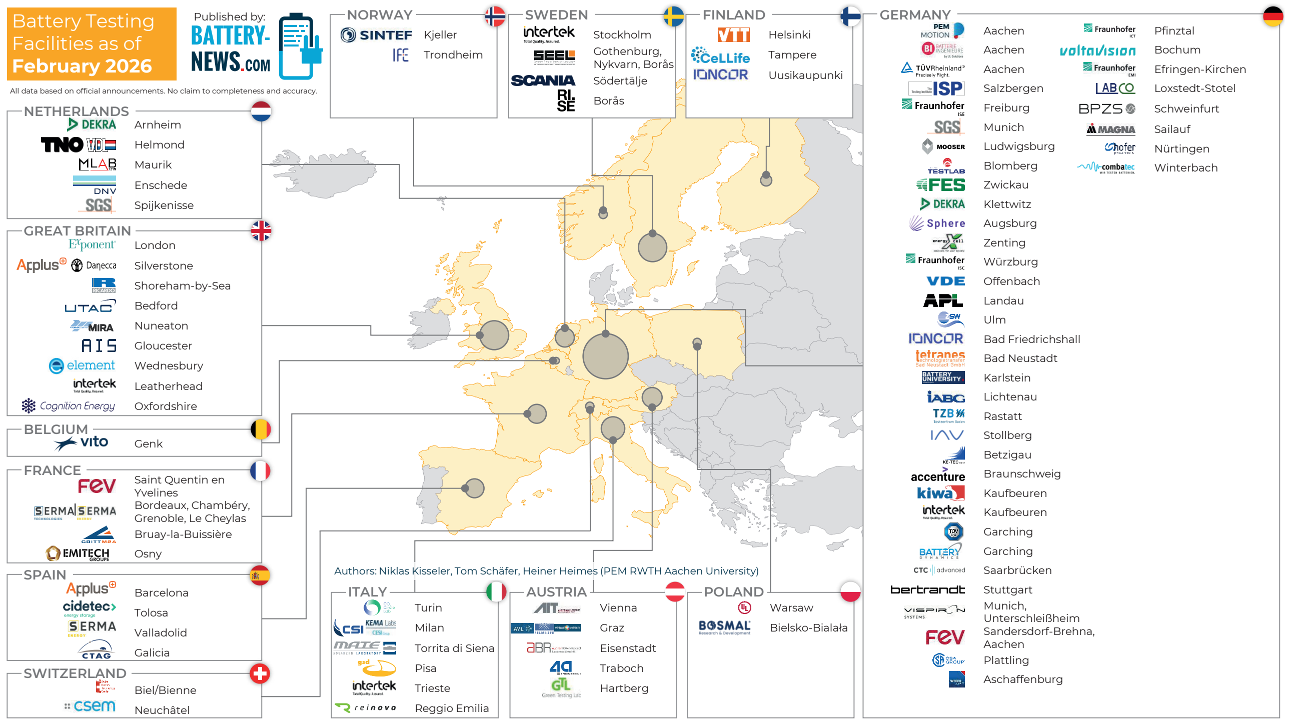
In the coming years, Europe's battery recycling industry will face a temporary imbalance, as recycling capacities will be growing quickly and the amount of available end-of-life batteries will be increasing slower than expected. This will cause many plants – especially new spoke and hub facilities – to operate below capacity and rely more on production scrap or imported black mass to stay profitable.

From 2030 onward, the situation is expected to improve. Large numbers of electric vehicles will begin reaching end of life, providing significantly higher material volumes allowing facilities to run more efficiently. Digital battery passports will also play an important role in this transition. They will provide detailed information on each battery, including chemistry, state-of-health, and guidance for safe disassembly. This will allow recyclers and other stakeholders to plan processes more accurately, reduce safety risks, and improve efficiency – especially during the years when material volumes are still limited.

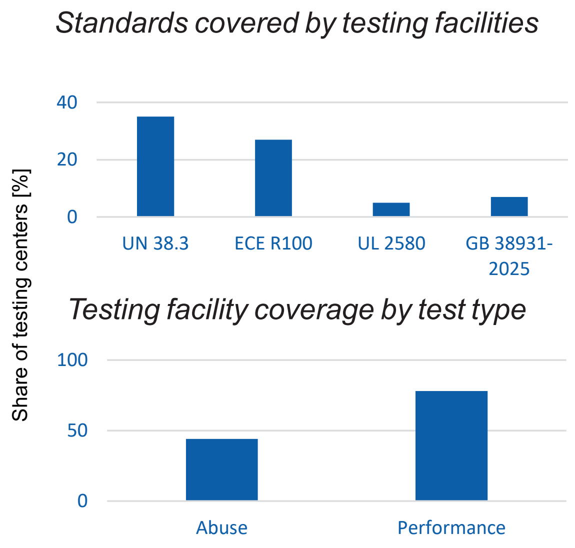
Overall, despite short-term challenges, the long-term outlook is positive: Higher battery return volumes and stricter EU regulations will make recycling a key part of Europe's circular economy.

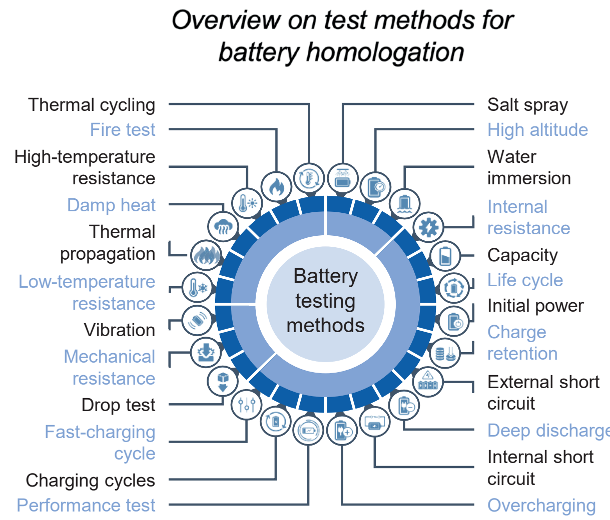
By 2030, Europe's recycling capacity will exceed battery returns – with an annual spoke capacity of 520 kilotons and an annual hub capacity of 820 kilotons –, while end-of-life volumes will be 40 percent lower than anticipated, but increasing battery inflows and stricter EU regulations are expected to balance the system over time.

BATTERY TESTING FACILITIES



Source: www.battery-atlas.eu; abstract, no claim to completeness





INITIAL POSITION & MAP UPDATE

Modern batteries undergo extensive testing to ensure safety and performance at cell, module, and system levels. High-demand applications and different markets require diverse procedures. Europe's testing landscape is expanding rapidly, now featuring over 90 facilities with extended portfolios to comply with updated standards. Updates and further developments of standards come in particular from the Chinese region. The updated 2025 GB 38031 standard adds procedures such as bottom impact and fast-charging cycle tests and strengthens existing requirements, including insulation resistance to enhance electrical robustness. GB 38031-2025 also replaces time-based safety arguments with a strict physical requirement: A single thermal event may occur, but must not lead to a fire or explosion of the entire battery system. Meeting this higher requirement represents a significant barrier to market entry, particularly for smaller companies with limited capacities. In addition to conventional chemistries and battery designs, Europe is preparing for structural batteries and sodium-based chemistries. While current standards apply broadly, China's GB/T 4465-2024 introduces tests specifically for sodium-ion stationary storage, addressing electrical performance and system reliability. Overall, the combination of expanding facilities, evolving standards, and emerging chemistries demonstrates Europe's commitment to battery safety and performance. Modern batteries are tested under rigorous conditions to ensure reliability across applications, from automotive to stationary storage, while adapting to new technologies. This integrated approach ensures that both conventional and next-generation batteries meet high safety, performance, and regulatory standards, preparing Europe for the challenges and innovations of future battery markets.

ANALYSIS

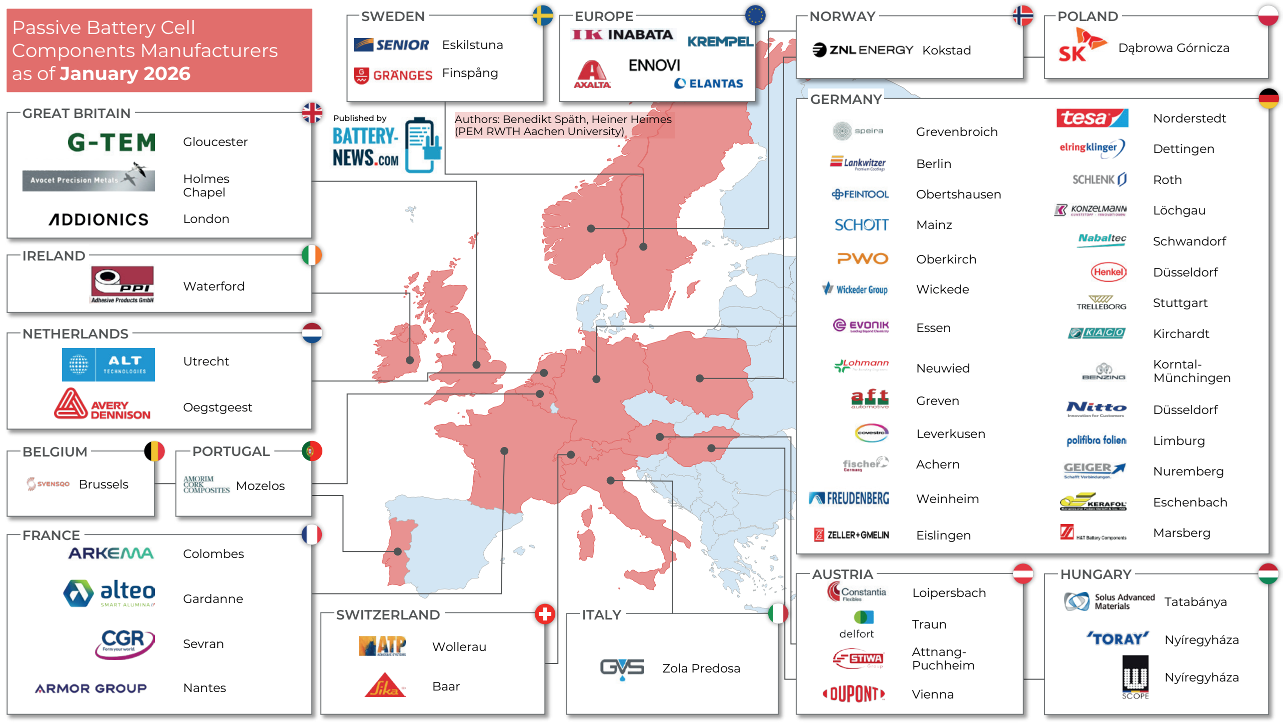
As in previous years, our map shows a steadily increasing number of service providers in the field of battery testing, reflecting the continuous growth of the market. Alongside the expansion in the diversity of testing procedures in Europe, this development has also led to intensified competition among testing laboratories. In recent years, automotive OEMs are also increasingly establishing and expanding their own battery testing infrastructure. Examples include the Scania plant in Södertälje (Sweden), the "Mercedes-Benz eCampus" in Stuttgart, and the BMW plant in Wackersdorf (both Germany). These developments highlight the necessity for external service providers to align their testing capacities in a complementary manner and emphasize their unique selling points. Evaluating the portfolios offered by the testing facilities included in the map shows that most service providers cover mechanical, electrical, and thermal testing methods. With the focus on electrical testing encompassing performance and aging evaluations in the past, a large proportion of battery testing facilities still prioritize performance testing, placing comparatively less emphasis on abuse testing. In addition, most centers offer testing services according to UN 38.3 and ECE R100, as both are required for the European market. However, only a small share conducts tests in accordance with the requirements of the Chinese GB 38031-2025 standard, which reveals a potential differentiation opportunity.

OUTLOOK

The increasing number of testing facilities in Europe demonstrates not only the general market demand for battery evaluation but also the growing establishment of the testing industry on the continent. However, this development is not yet complete as the battery testing landscape is projected to undergo continued expansion, primarily driven by increasingly stringent safety requirements, accelerated technological advancements, and rising demand for high-performance energy storage systems. The progressive tightening of international standards – as exemplified by the most recent regulatory updates in China – is also expected to affect testing protocols and, consequently, the testing infrastructure in Europe. Ultimately, this leads to three major objectives for the European battery testing industry: to expand testing capacities and to broaden the portfolios of existing facilities while differentiating through the development of niche expertise in strategic areas. While automotive OEMs continue to establish their own testing infrastructure and, at the same time, face increasing competition from other testing service providers, it is becoming even more important to specialize and build expertise in battery testing for other high-demanding, innovative applications – for example, stationary storage, industrial applications, or emerging technologies such as all-solid-state batteries. Another distinguishing feature lies in the development of innovative testing methods to reduce testing times and thus lower costs.

Europe's ongoing intensive development activities in battery systems are driving a sustained demand for external testing services. This trend is expected to continue, requiring larger testing capacities, broader portfolios, and increased specialization in testing procedures and technologies – also for non-European markets.

PASSIVE BATTERY CELL COMPONENTS COMPANIES



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

Battery cell components are classified as active, which store or transport lithium ions, and passive, which serve structural, protective, or functional roles. In the automotive sector, cell formats differ mainly in geometry and passive components. Cylindrical cells, common in electronics, offer high safety, advanced industrialization, and low costs, but their nickel-plated steel housing adds weight and limits packaging density. Prismatic cells use aluminum housings, allowing higher energy density and flexible dimensions but with lower industrialization. Pouch cells employ lightweight aluminum composite foils, enabling high energy density but lower structural stability and more complex integration.

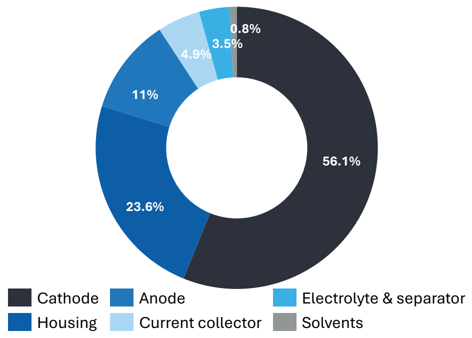
Prismatic and cylindrical housings include the casing, vents, terminals, and current interrupt devices, while pouch cells consist only of foil and tabs. Current collectors and separators are shared across formats, as are tapes, coatings, and insulators. Adhesive tapes hold electrodes and provide insulation in pouch cells; cylindrical cells use insulation rings and sleeves, prismatic cells use insulator bags and tapes. Gaskets seal cylindrical lid-to-can and prismatic terminal-to-busbar interfaces, whereas pouch cells are welded without gaskets.

ANALYSIS

The global market for lithium-ion battery cell components – including cathodes, anodes, separators, electrolytes, and packaging – is among the fastest-growing in the battery value chain and is expected to exceed 235 billion US dollars by 2030. Core materials dominate costs, while passive components like current collectors, separators, electrolytes, and housings account for about a quarter of manufacturing costs, depending on chemistry and format.

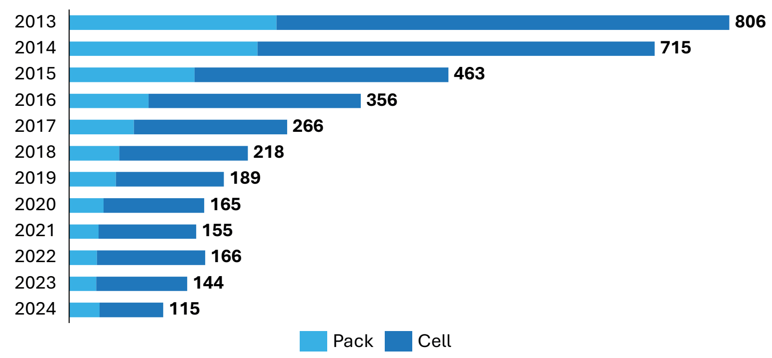
Production remains highly concentrated in Asia: China, Japan, and South Korea supply roughly 95 percent of cathode and anode materials and 90 to 95 percent of separators and electrolytes. Europe and North America together hold only a low single-digit share and are heavily import-dependent. In Europe, battery cell production has ramped up more slowly and with greater volatility than expected. Existing plants provide only a few hundred gigawatt-hours. While announced projects suggest over two terawatt-hours by 2030, more than 700 gigawatt-hours have already been delayed or canceled, with only about three quarters likely to be realized. This uncertainty affects passive component suppliers: Several early European players have cut investments, exited the market, or restructured, while some projects

Cost breakdown of a round cell



Source: Aachener Beiträge des ISEA Vol. 183

Volume-weighted average lithium-ion battery pack and cell price split in $/kWh



Source: BloombergNEF

were taken over by Asian incumbents. European demand remains below projections, creating a "valley of tears" from 2024 to 2028 with low utilization, price pressure, and high capital intensity.

Europe's strengths lie in aluminum and copper processing, foil production, and specialty polymers, particularly in Germany, followed by France, the Nordics, and the UK. However, major gaps persist, notably in large-scale production of prismatic cell cans and lids, advanced separator films, high-purity electrolytes, and integrated packaging solutions for next-generation cell formats.

For the upstream supply chain of passive components, several key materials are required:

- **Cell housing components:** aluminum alloys, copper alloys, and nickel-plated steel
- **Foils and separators:** aluminum alloys, copper alloys, polypropylene (PP), polyethylene (PE), polyethylenterephthalat (PET), and ceramics
- **Tapes, coatings, and insulators:** polypropylene (PP), polyethylene (PE), polyethylenterephthalat (PET), and ceramics
- **Gaskets and sealings:** electrolyte resistant rubber

OUTLOOK

Recent cost analyses show that automotive lithium-ion battery cells cost around 80 to 100 euros per kilowatt-hour for NMC and about 60 euros per kilowatt-hour for LFP at cell level. Passive components such as current collectors, separators, electrolytes, and housings account for roughly 20 to 30 percent of total cell manufacturing costs. As European cell production scales to several hundred gigawatt-hours annually, this represents a substantial market opportunity for local passive component suppliers.

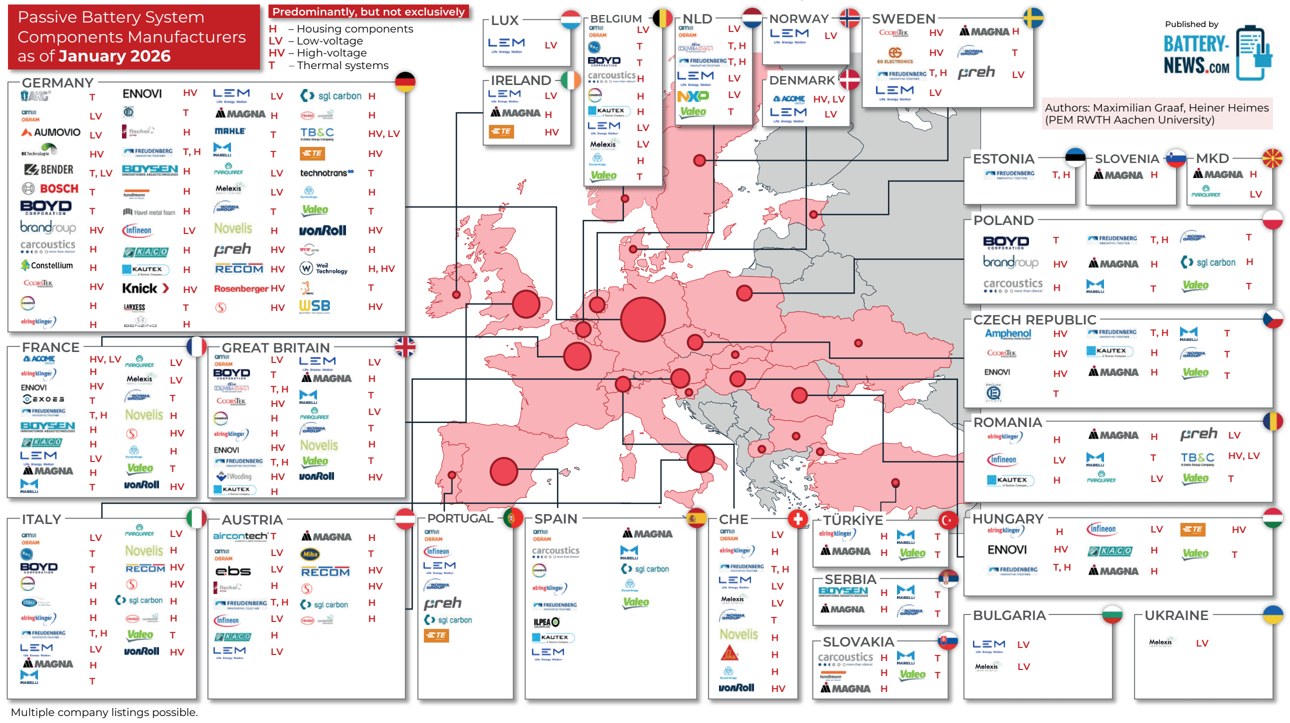
Despite this potential, Europe remains highly dependent on Asian imports for many passive materials. To benefit from announced cell capacities, regional production of separators, electrolytes, current collectors, and housings must expand quickly and align with European technology road maps. In the short term, however, the ecosystem faces consolidation driven by weaker EV demand, delayed or canceled gigafactory projects, and restructuring or market exits, resulting in canceled orders and excess capacity.

At the same time, increasing product variety from new cell formats, chemistries, and customized designs raises complexity for suppliers in tooling, qualification, and capital investment. These challenges can be mitigated through early, long-term collaboration between cell manufacturers and component suppliers, enabling joint development, regulatory compliance, and synchronized production ramp-up.

Commitments of European cell manufacturers to European passive cell component suppliers in early development phases could enable a parallel scaling of the manufacturing capabilities. This would also enable a European supply chain growth and competitiveness with larger and more integrated players from Asia.

> European cell demand remains below expectations, creating a 2024-to-2028 "valley of tears" with low utilization, price pressure, and high capital intensity.

PASSIVE BATTERY SYSTEM COMPONENTS COMPANIES



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

In lithium-ion battery pack specifications, components are divided into active and passive elements. Active components directly store energy and enable ion transport, primarily the battery cells, including electrodes, separators, and electrolytes. Passive components include all other parts required to house, connect, operate, and protect the energy storage system. These passive elements can be grouped into four categories: battery housing, high-voltage components, low-voltage components, and thermal management components.

The battery housing is the physical enclosure that contains and protects all internal components. It provides structural integrity and shields the battery from mechanical shocks, vibrations, water intrusion, and environmental exposure. In addition, the housing must meet strict crash safety requirements to ensure battery protection in the event of a collision.

High-voltage components manage the pack's electrical power flow. They include busbars, high-voltage cables, and connectors, which together form the high-voltage distribution unit. This unit transfers power from the cell array to the vehicle's inverter and motor and must enable rapid disconnection in emergency situations to ensure safety.

Low-voltage components comprise the battery's electronic control and monitoring systems. Central to this is the battery management system (BMS), which monitors cell voltages and temperatures, manages cell balancing, and communicates with higher-level vehicle control units.

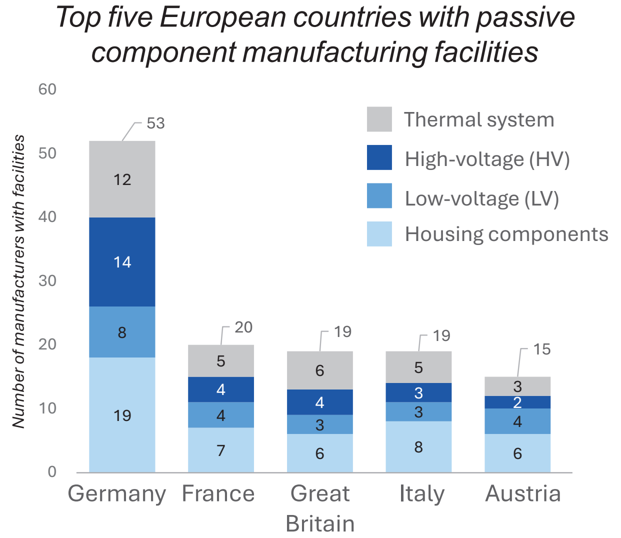
Thermal management components regulate battery temperature to ensure optimal performance and lifetime. These include cooling plates or jackets, coolant channels, pumps, and valves, enabling both cooling during operation and heating under cold conditions.

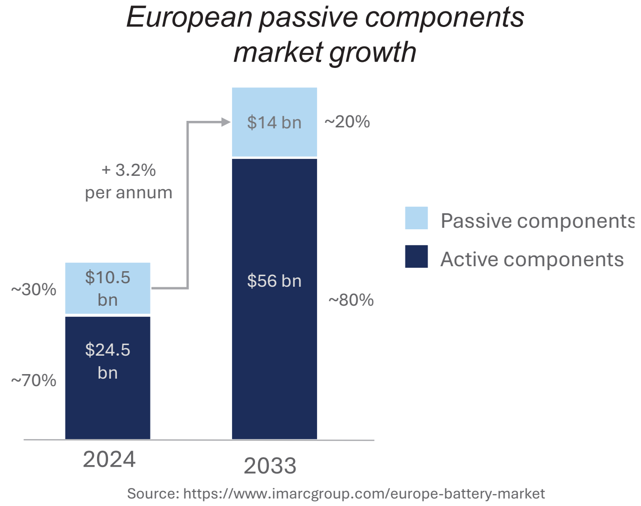
ANALYSIS

The material cost of a battery system is mainly dominated by the cells, but the passive components contribute a significant share as well. On average, roughly 70% of a battery pack's cost is linked to the battery cells, while about 30% are made up by the passive pack integration components. Over the years, battery pack prices have fallen significantly from 165 US dollars per kilowatt-hour in 2020 to 115 US dollars per kilowatt-hour in 2024 worldwide. Cell prices and passive-component costs have fallen in parallel, indicating that providers are both improving production efficiency and squeezing margins.[1]

1 Bloomberg: https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/

2 IEA: https://www.iea.org/reports/global-ev-outlook-2025/electric-vehicle-batteries?





In a European comparison, Germany hosts by far the largest number of passive-component manufacturers with own production facilities, followed by France, Italy, the United Kingdom, and Austria. Across these five countries, battery housings represent the dominant share of passive-component manufacturing output. Notably, many larger passive-component manufacturers have established facilities in Eastern Europe, presumably driven by cost considerations.

Battery demand across the energy sector, including electric vehicle (EV) batteries and stationary storage, reached a historic milestone of one terawatt-hour in 2024. In fact, a single average week of demand in 2024 surpassed the total annual demand from just a decade earlier. Electric passenger cars remain the dominant driver of EV battery consumption, accounting for more than 85 percent of the total. Compared to 2023, electric trucks showed the strongest growth, expanding by more than 75 percent in 2024 and reaching nearly three percent of global EV battery demand.[2]

Potential global battery manufacturing capacity grew almost 30 percent in 2024 to reach more than three terawatt-hours. About 85 percent of global battery manufacturing capacity is in China, showing little change from 2023. Manufacturing capacity in the United States grew by almost 50 percent and thus surpassed the European Union, which increased by ten percent.[2] Given China's dominant position in global cell and pack manufacturing, it is reasonable to assume that the market for passive battery pack components is likewise significantly larger in China than in Europe.

OUTLOOK

Innovative battery system architectures (such as cell-to-pack) which eliminate intermediate battery modules by integrating cells directly into the pack, substantially reduce the quantity and therefore the cost of passive pack components while simultaneously increasing overall energy density.[3] Despite these reductions at pack level, absolute demand for passive components in Europe is expected to keep rising as the battery system market grows. While China could account for about 45% of total lithium-ion demand in 2025 and around 40% in 2030, with most battery chain segments already highly mature, future growth is projected to be strongest in the European Union and the United States.[4]

The European battery market for all chemistries and applications in 2024 is valued at around 35 billion US dollars and is projected to grow to roughly 70 billion dollars by 2033, corresponding to an annual growth rate of more than 7%.[5] Assuming that passive elements will decline from today's roughly 30% cost share to about 20% in future high-integration designs, this corresponds to a passive-component market of about 14 billion US dollars in 2030, compared to an estimated 10.5 billion dollars in 2024. It highlights the continued demand for housing components, electronic subsystems, and thermal management hardware across Europe's battery industry.

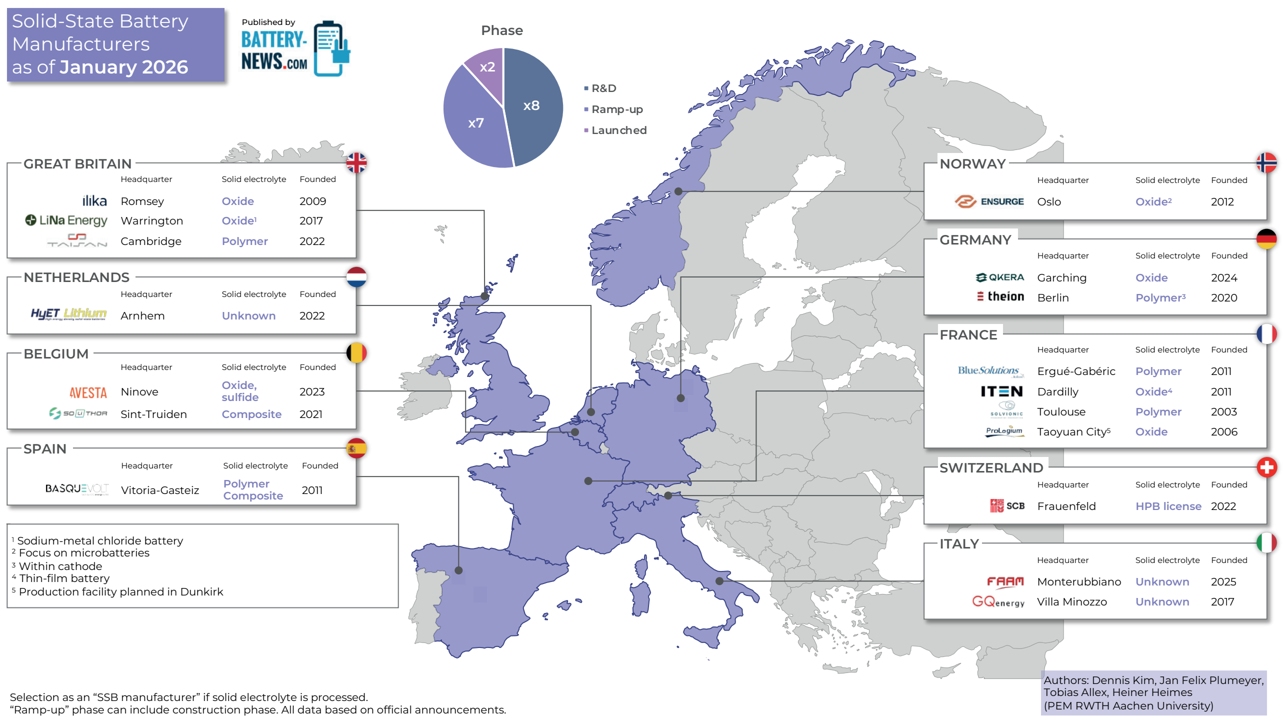
Passive components remain a key cost and value driver in battery systems. Despite rising integration and cost pressure, demand for housings, electronics, and thermal systems in Europe continues to grow.

3 PEM/Roland Berger: PEM of RWTH Aachen University & Roland Berger GmbH. (2025). Battery Monitor: 4th edition. RWTH Aachen University / Roland Berger. ISBN 978-3-947920-65-5

4 McKinsey: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular?

5 IMARC Group: https://www.imarcgroup.com/europe-battery-market

SOLID-STATE BATTERY MANUFACTURERS



Source: www.battery-atlas.eu; abstract, no claim to completeness

INITIAL POSITION & MAP UPDATE

Solid-state batteries (SSBs) are widely regarded as the most promising development in next-generation battery technology, offering the potential to unlock entirely new performance characteristics. The transition from conventional lithium-ion batteries (LIBs) to SSBs carries profound implications for both production processes and factory layouts, which vary significantly depending on the specific SSB technology employed.

In Europe, the landscape is characterized by numerous strategic announcements from established cell manufacturers and agile start-ups, all aiming to secure technological sovereignty. The approaches are clearly differentiated: Some players are pursuing the establishment of comprehensive pilot and series production lines for full cell systems, while others focus on specialized components or specific value-chain steps, such as innovative anode concepts or the complex processing of solid electrolytes.

The required production of the solid electrolyte as the separator represents the most radical change in the production chain. Traditional liquid electrolytes and microporous separators are replaced by ultra-thin ceramic, polymer or sulfide layers that must be manufactured with extreme precision and reliably integrated with the electrodes. This shift introduces significant engineering hurdles, requiring specialized sintering and advanced coating methods, for example. However, these challenges also present substantial opportunities. Emerging trends like thin film deposition, isostatic pressing and solvent-free dry coating can significantly streamline industrialization by offering more efficient and environmentally friendly processing.

The industrial handling of solid electrolytes is the critical bottleneck in the new production chain. Integrating these materials requires new assembly techniques to ensure homogeneous layers and stable, low-resistance interfaces. While sensitivity to environmental factors like humidity increases process complexity, the solid-state approach also offers massive potential for efficiency. It eliminates the need for electrolyte filling and potentially shortens the formation stage. Ultimately, Europe's competitiveness will depend on mastering these manufacturing processes and fostering collaboration across the entire value chain – from equipment suppliers to OEMs – to ensure high-performance, reliable and globally leading battery systems.

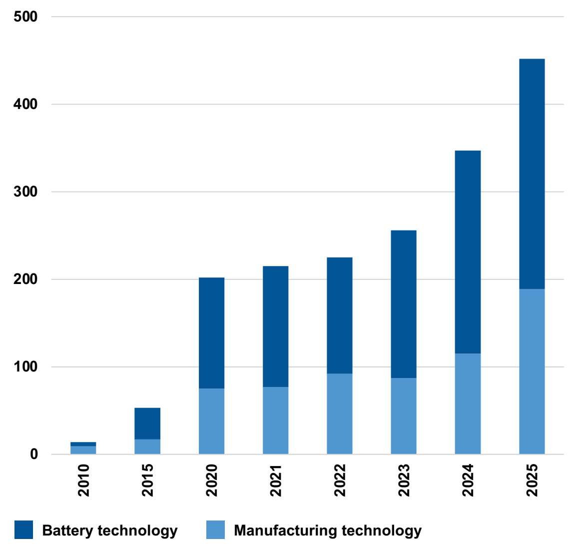
ANALYSIS

Solid-state battery (SSB) technology is currently transitioning from basic research to industrial maturity. While polymer, oxide, and sulfide systems dominate the market, the European provider landscape remains highly heterogeneous. Blue Solutions is currently one of the very few commercially established suppliers for vehicles while companies like ITEN focus on thin-film batteries. Other players often focus on specific value chain components or licensing.

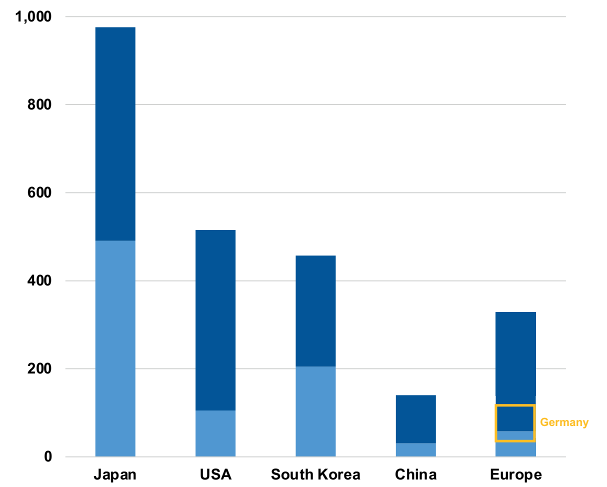
Globally, Japan leads the patent landscape with a balanced ratio of technology and production-related patents. However, Europe maintains a strong competitive position, standing on par with other major regions like the US and South Korea. Within Europe, Germany holds a particularly significant role. Reflecting the growing importance of the field, both the number of patent filings and scientific publications have been increasing steadily year after year since 2000, making clear the technological and strategic relevance of solid-state batteries.

The underrepresentation of research into manufacturing issues to date represents a key shortcoming in the current landscape. When it comes to transferring technology from the laboratory to industrial scale, start-ups play an additional key role in closing this gap, although experience often needs to be expanded and investments made first. Established production lines for conventional lithium-ion batteries are only transferable to a limited extent due to the specific requirements for handling solid-state electrolytes and are also often oversized or too inflexible in view of expected market developments.

SSB-related patents over time



SSB patents granted by WIPO[1] PATENTSCOPE



[1]World Intellectual Property Organization (Screening for Applicant Address Country and Publication Date)
Query Man. Techn.: EN_ALL:(H01M10/0562 OR H01M10/0565) AND (H01M10/058) AND ("solid state")
Query Batt. Techn.: EN_ALL:(H01M10/0562 OR H01M10/0565) AND NOT (H01M10/058) AND ("solid state")

OUTLOOK

The current momentum offers Europe a unique opportunity to shape next-generation battery technology. To realize this, the value chain must be integrated through close networking of all players, building on existing overlaps in lithium-ion know-how. Instead of remaining dependent on external markets, Europe can leverage this technological shift to establish its own resilient value chains. The core strength lies in cross-sector collaboration between research, engineering and manufacturing. This synergy enables the rapid translation of innovation into scalable products and protected intellectual property. Beyond strengthening the materials base – particularly composite cathodes, solid-state electrolytes, and high-energy anodes –, manufacturing research is the decisive factor for efficient industrial scaling. Instead of focusing on the existing risks, the considerable opportunities offered by this early phase of technological change should be exploited. Right now, there is an opportunity for positioning as an international pioneer. Through targeted investments and further development of key production processes, players across the value chain can set important standards for solid-state battery technology and establish Europe as a leader for sustainable high-performance technologies in the long term.

European SSB production is still in its early stages; only a few manufacturers are commercial, and rapid scale-up is needed to remain globally competitive.

IMPRINT

PEM | RWTH AACHEN UNIVERSITY

The Chair of Production Engineering of E-Mobility Components (PEM) of RWTH Aachen University was founded in 2014. In numerous thematically organized research groups, the PEM team is dedicated to all aspects of the development, production, and recycling of battery systems, electric motors, fuel cell technologies, and their respective components as well as their integration, especially in heavy-duty commercial vehicles.

At the time of publication of the 2026 Battery Atlas, a total of 70 researchers, 30 non-scientific employees and 88 student assistants are employed at the PEM Circularity Innovation Cluster (CIC) in the German-Dutch Avantis business park and at the PEM Battery Innovation Cluster (BIC) on RWTH Aachen Campus. The PEM team is active in teaching as well as in nationally and internationally funded research projects, also collaborating with renowned industrial partners. The focus is always on sustainability and cost reduction – with the aim of a seamless “Innovation Chain” from basic research to large-scale production in the immediate vicinity.

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