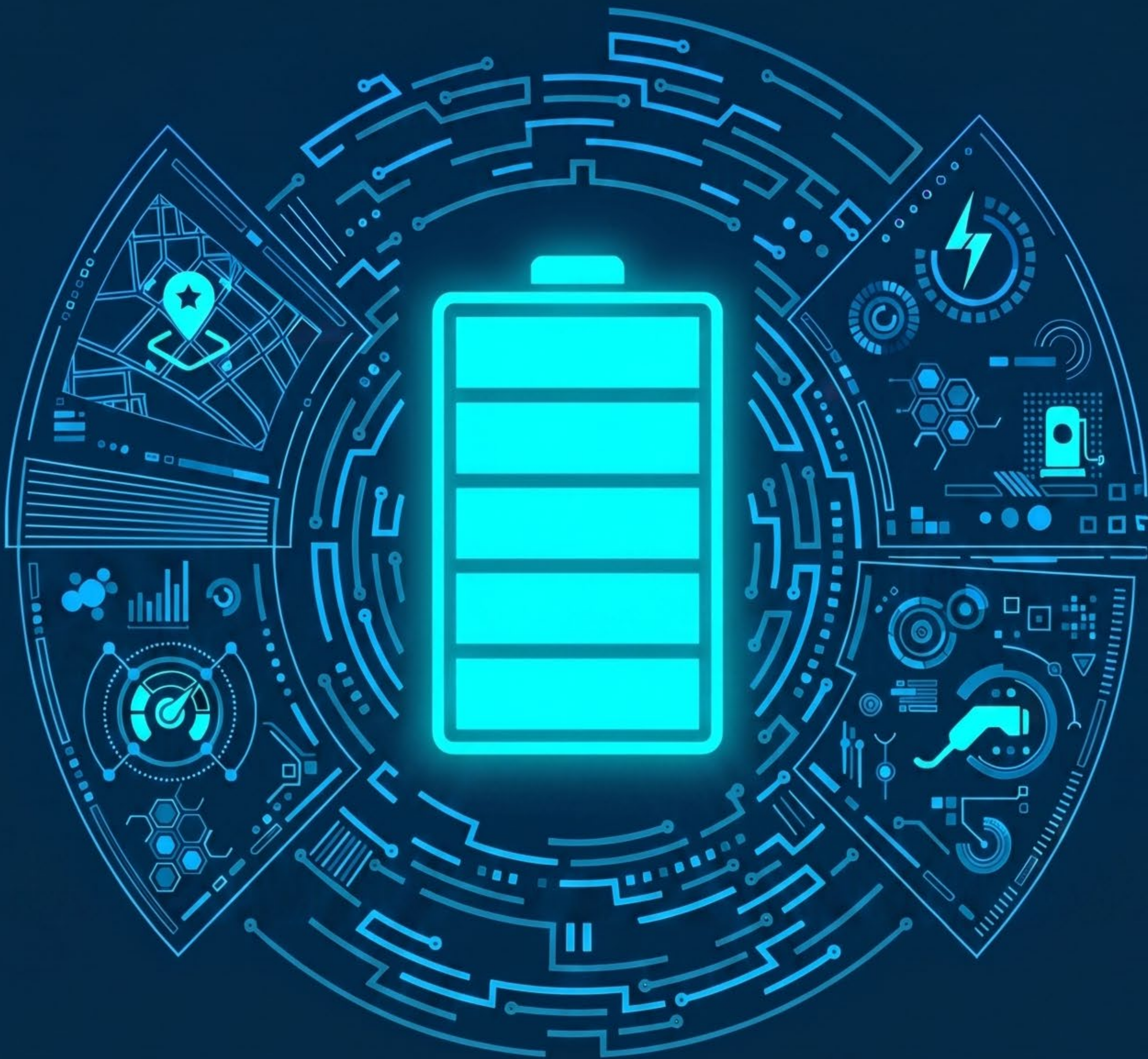
BATTERY R&I BLUEPRINT

Batteries for a sovereign and competitive Europe



bepassociation.eu/blueprint

BEPA
Batteries European Partnership Association

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FOREWORD

The battery industry in Europe is not new. My company, Saft, has been producing batteries in France for over a hundred years. What has changed over the past two decades is the pace at which the battery market has grown, as batteries have become central to powering new technologies from personal electronics to electric vehicles.

Batteries are now the backbone of electrification, a far broader effort than automotive alone. It spans all road transport, including trucks and buses, as well as off-road vehicles. It extends to other transport modes, waterborne and aviation in particular. And it reaches well beyond transport into the power sector, robotics, satellites, space and defence.

Europe's competitiveness and security depend on our ability to develop and deliver the battery technologies that will enable these industries. The automotive sector needs them to build the cars the market demands. The European aviation industry needs them to retain its global leadership. And they are what will allow us to keep control of our electricity system, mastering the technologies that secure supply and ensure the operation, safety and cybersecurity of our grids. If we succeed in developing and providing these technologies, Europe can support these industries and generate lasting prosperity. If we fail, our only option is to buy batteries from Asia, exchanging our dependency on fossil fuels for a dependency on batteries.

Competitiveness in battery R&I requires us to avoid fragmentation and to stay focused on impact. Research and innovation must serve a clear goal: uptake by industry and the delivery of technologies to market. We cannot afford duplicated effort, with different teams working on the same problems in isolation, nor a lack of coordination and cooperation between them. If there is one place in Europe where stakeholders from research, established industry, start-ups, and the political and financial sectors come together to define the impact we want, set priorities and chart the path toward them, it is in a European Partnership on batteries.

As Chairman of BEPA and Co-Chair of the BATT4EU Partnership, I am proud of how the battery R&I community has united since the Batteries Partnership was launched in 2021, because only through unity can Europe compete on a global scale. This Battery R&I Blueprint sets out how we can leverage that collective strength to build a competitive Europe.

Michael Lippert

Chairman of BEPA

EXECUTIVE SUMMARY

Batteries have become one of Europe's most strategic technology priorities. Energy security and cost competitiveness have overtaken climate objectives as the primary drivers of clean technology investment globally, and batteries sit at the intersection of all three. They reduce dependence on fossil fuel imports, anchor value creation across mobility, energy, defence, electronics and data infrastructure, and enable the electrified, digitalised economy Europe is building. Their reach is broad and still widening, extending across transport, stationary storage, industrial and specialty markets, several of which offer Europe genuine opportunities to build competitive and export-oriented positions. Even the volume-driven applications have not yet matured: global battery demand is forecast to grow seven-fold by 2040, with 1 TWh per year needed for electric vehicle sales alone and stationary storage reaching a potential 3 to 6 TWh in Europe under a decarbonised grid.

Yet Europe is not in a winning position. Its strengths are real: a world-class research base, deep materials and chemicals expertise, and strong positions across much of the value chain. But they are not yet converting into industrial leadership. Dependence on non-European supply runs deep, cost gaps against Asian producers persist, and announced capacity across the value chain is being cancelled or postponed. The sector is also volatile by nature, as markets, technologies and geopolitics can all shift the rules quickly, which makes getting the response right all the more decisive.

Research and innovation is the thread running through every dimension of this challenge. It closes the cost and efficiency gaps, builds European leadership in next-generation chemistries, turns regulatory requirements into competitive advantages, and activates the assets Europe already has across materials, manufacturing, integration and recycling. Above all, it is what makes the sector investable, by reducing the technology, value-chain and end-use risks that no individual company can absorb alone.

But for R&I to do this, it needs a home. What the sector requires is a dedicated Batteries Partnership under the next MFF, building on the proven track record of BATT4EU under Horizon Europe. It is the only instrument designed to address all three structural risks at once, because it is the only one that spans the full value chain, the full portfolio of chemistries, and all strategic applications simultaneously.

INNOVATION

R&I as enabler of Europe's competitiveness

COORDINATION

Aligning efforts. Accelerating innovation.

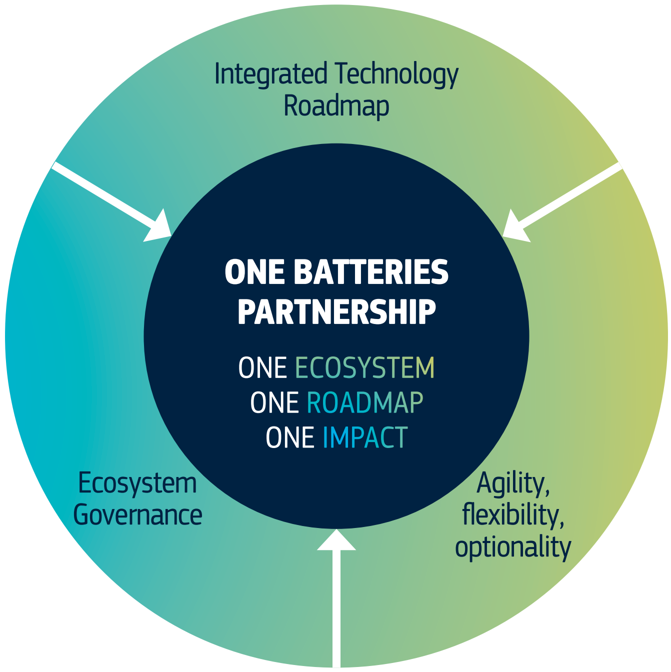
TECHNOLOGY PORTFOLIO

Diverse solutions, one roadmap, greater impact

PARTNERSHIP CONTINUATION

Building on success. Driving the future together.

That breadth is not a coordination burden to be trimmed away but the source of Europe's resilience: a double-diversity, portfolio-based approach that hedges technology bets, lets manufacturing knowledge transfer across applications, and avoids lock-in when no single pathway has yet proven itself. Unfragmented and all under one roof, the Partnership provides the integrated technology roadmap and ecosystem governance the sector needs, together with the agility, flexibility and optionality to navigate a fast-moving market. Fragmenting this effort, narrowing its scope, or leaving coordination to ad hoc national programmes would forfeit exactly the advantage Europe is best placed to build.



That ask is no longer BEPA's alone. Through the SET Plan's battery working group, seventeen Member States have adopted a Thematic Vision whose first recommendation is to maintain a dedicated battery partnership beyond the current Framework Programme. Just as Europe is committing to a "Made in/with Europe" industrial agenda, that agenda can only deliver if it rests on an equally strong "Innovated in/with Europe" pillar.

“BATTERIES AT THE HEART OF OUR INDEPENDENCE”

Ursula von der Leyen

President of the European Commission

State of the Union 2025

Europe’s battery ecosystem is powering the transition towards strategic autonomy, industrial competitiveness and climate neutrality.

AN R&I BLUEPRINT FOR A COMPETITIVE EUROPEAN BATTERY VALUE CHAIN

THE STAKES: BATTERIES AT THE HEART OF EUROPE

Batteries go to the heart of our independence.

With this sentence, Ursula von der Leyen underlined in the State of the Union how essential batteries are for Europe[1]. Batteries are a crucial technology for European competitiveness, and for European security and sovereignty. Batteries are also the technology to beat for zero-emission mobility and are key to maximise the use of renewable energy in our electricity system.

FROM CLIMATE TOOL TO STRATEGIC ASSET

For years, the case for batteries rested heavily on net-zero transition: batteries enable electric vehicles, store renewable energy, and reduce dependence on fossil fuels. That case remains valid. But it is no longer sufficient, nor is it the primary driver of investment decisions. The International Energy Agency's (IEA) Energy Technology Perspectives 2026 confirms that governments and investors worldwide have reordered their priorities: energy security and cost reduction now rank ahead of climate objectives as the main forces driving clean technology deployment and manufacturing policy.

Batteries sit at the intersection of all three dimensions. They are a sovereignty tool: domestic battery production reduces dependence on fossil fuel imports and on foreign-controlled supply. The IEA estimates that a single month's disruption to Chinese battery supply chain exports would result in approximately USD 17 billion in lost output from electric vehicle factories globally, with EU facilities bearing the largest share. That is not a climate risk: it is an economic security risk. Batteries are also a competitiveness asset: they anchor value creation across mobility, energy, defence, electronics and the digital economy. And they are the enabling technology of an electrified, digitalised economy that Europe is committed to building.

A TECHNOLOGY FOR EVERY STRATEGIC PRIORITY

The breadth of battery applications maps directly onto Europe's strategic agenda. Grid-scale stationary storage is essential for energy system resilience and for integrating the renewable generation that underpins both decarbonisation and energy independence. Electric mobility across road, rail, aviation and maritime reduces fossil fuel consumption and opens export markets for European industry. Defence and security applications (autonomous drones, soldier-carried systems, forward-operating-base energy, naval and aerospace platforms) make batteries a military technology, recognised as such since the battlefields of Ukraine demonstrated the operational importance of reliable, portable electrical power. Robotics, electronics, medical devices and data centres further extend battery demand into segments where European industry remains globally competitive and where innovation leadership can still be claimed.

The shift from climate instrument to strategic asset does not diminish the importance of sustainability. It reinforces it: a battery sector that is genuinely cleaner and more circular than its competitors turns regulatory compliance into a commercial advantage in markets that increasingly require it.

BATTERIES AS THE ANSWER, NOT JUST THE CHALLENGE

For energy security, batteries are the enabling technology for a grid that can function without constant fossil fuel input. Large-scale stationary storage absorbs renewable generation when supply exceeds demand and releases it when it does not, reducing both dependency on gas peaker plants and exposure to price volatility in fossil fuel markets. Grid-scale battery storage is the infrastructure that makes energy independence operationally achievable, not just a political commitment. The scale of this opportunity is striking. According to CRU[3], if Europe achieves a fully decarbonised energy mix, between 3 and 6 TWh of stationary battery capacity would need to be installed. Stationary storage is not the secondary market to EV transport; over the long term it is likely to be the larger one. Global battery demand for stationary energy storage already grew 65% year-on-year in 2024, far outpacing EV battery demand growth of 22% in the same period. Manufacturers are already responding: multiple battery producers have begun converting EV battery lines to produce energy storage cells[4], illustrating both the scale of stationary storage demand and the value to industry of not being locked into a single application.

This ambition is now embedded in the EU policy. The European Commission's 2026 Electrification Action Plan[5] sets a target of 200 GW of storage capacity by 2030, rising to 500 GW by 2040, from around 55 GW in 2026, and the accompanying Tripartite Agreement on Energy Storage[6] brings Member States, developers, manufacturers, industrial consumers and financial institutions together behind an initial 30 to 35 GW of stationary storage pledged for 2026 to 2028.

For industrial competitiveness, batteries underpin the electrification of transport, a sector that accounts for a substantial share of European industrial employment and export revenue. The transition to electric mobility is not a threat to European industry if Europe controls the battery technology at its core. It is an industrial opportunity. The EV battery value chain, from materials to cells to systems to recycling, is itself a major new industry, projected to represent a global value pool of approximately EUR 450 billion by 2030[7].

For defence and security, batteries are already a frontline technology. The war in Ukraine has made visible what military planners already understood: portable, reliable electrical power is as strategically important as fuel supply lines. Autonomous drones, soldier-carried electronics, forward operating bases powered by solar-plus-storage, naval and aerospace platforms, all depend on batteries that deliver the right performance in demanding conditions. This is now a stated EU priority: the 2025 White Paper for European Defence – Readiness 2030[8] names drones and counter-drone systems, electronic warfare, and critical-infrastructure protection among its seven priority capability areas, each of them battery-dependent, and the accompanying Readiness 2030[9] package mobilises up to €800 billion in defence investment, including a €150 billion SAFE loan instrument[10] targeting exactly these capabilities. A Europe that cannot manufacture advanced batteries domestically cannot be fully sovereign in its defence capabilities, nor spend that investment on European-made systems.

[1] 2025 State of the Union Address

[2] Energy Technology Perspectives 2026

[3] Battery Technology and Cost Model

[4] Why General Motors is making a 'risky' bet

[5] Electrification Action Plan

[6] EU tripartite agreement signed to boost energy storage

[7] Battery 2030: Resilient, Sustainable and Circular

[8] European Defence Readiness 2030

[9] Readiness Roadmap 2030

[10] SAFE — Security Action for Europe

For climate and sustainability, batteries remain indispensable: for zero-emission mobility, for renewable energy integration, and for the electrification of industrial processes. But the argument is stronger when it is not made in isolation: batteries serve climate goals while simultaneously serving energy security, industrial competitiveness and defence. That convergence is what makes them a true strategic priority, and Europe is now moving to capture the value it creates at home. The Industrial Accelerator Act[11] establishes "Made in EU" lead markets for batteries as part of an ambition to raise manufacturing back to 20% of EU GDP by 2035. But such demand-side pull only delivers if Europe has first innovated the technology worth manufacturing, and it is that innovation pillar, alongside the public investment and coordination it requires, that this Blueprint calls for.

[11] Industrial Accelerator Act

BATTERIES: A STRATEGIC PRIORITY FOR EUROPE

ENERGY SECURITY

Enabling a grid independent from fossil fuels.

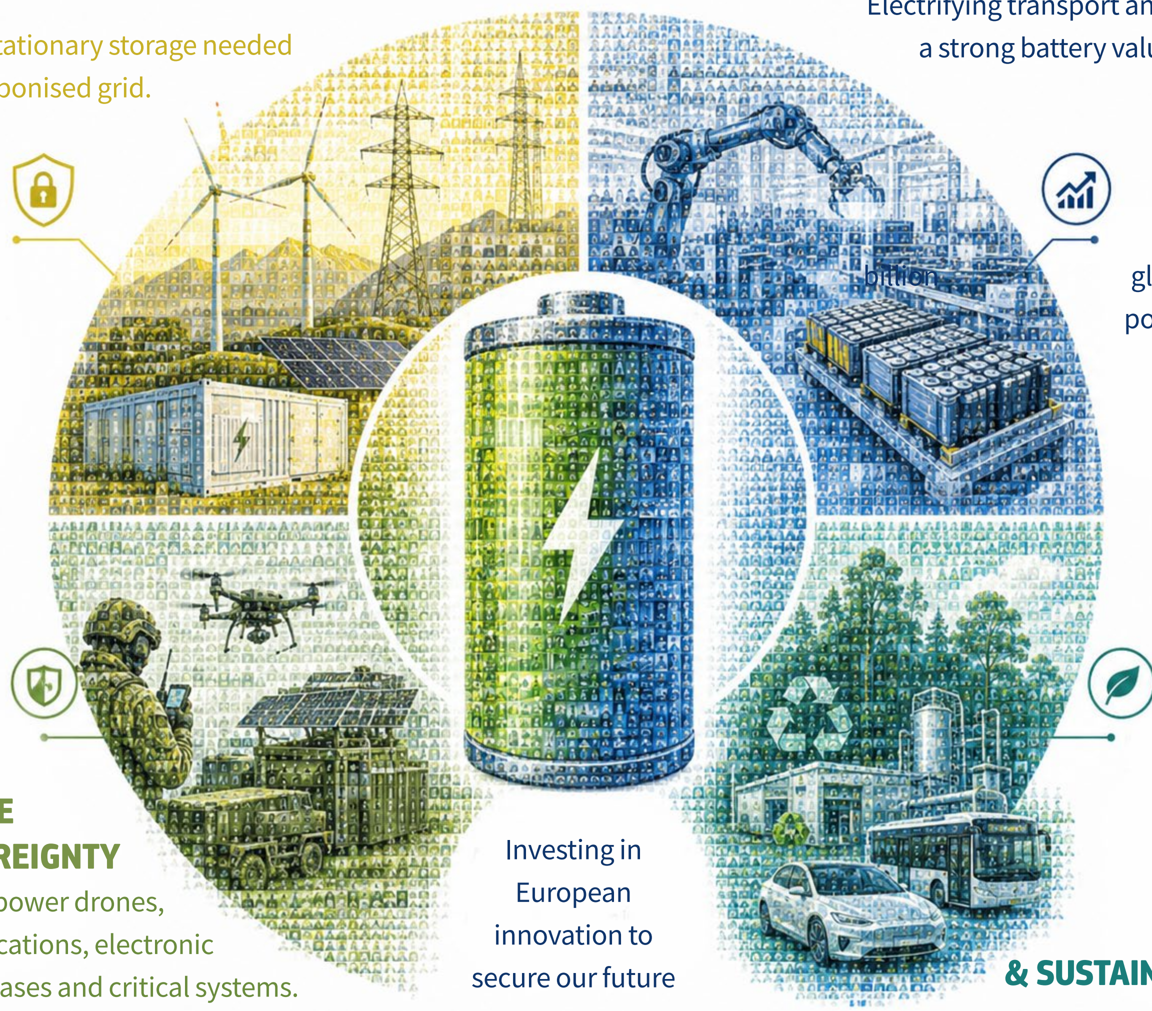
3-6 TWh stationary storage needed in a decarbonised grid.

INDUSTRIAL COMPETITIVENESS

Electrifying transport and building a strong battery value chain in Europe.

€450 BILLION

global value pool by 2030



DEFENCE & SOVEREIGNTY

Batteries power drones, communications, electronic warfare, bases and critical systems.

A strategic capability for a sovereign Europe.

Investing in European innovation to secure our future

CLIMATE & SUSTAINABILITY

For zero-emission mobility, renewable integration and industrial electrification. A key enabler of Europe's climate neutrality.

THE BATTERY SECTOR IN EUROPE: WHAT YOU NEED TO KNOW

AN ECOSYSTEM BUILT ON DOUBLE DIVERSITY

Battery R&I did not begin with passenger cars, and the integrated battery ecosystem that exists today reflects that history. Lithium-ion technology was commercialised first in portable electronics, then in power tools, medical devices and defence applications, accumulating manufacturing knowledge, supply chain depth and materials expertise across many years before automotive manufacturers adopted it at scale. Electric vehicles benefited enormously from that accumulated ecosystem. The lesson is simply that a broad, integrated approach to battery R&I across multiple cell technologies — battery "chemistries" as the industry calls them —and applications is what produces technological progress at pace, including for EVs. Narrowing the development agenda to serve a single application, however important, weakens the ecosystem that makes every application possible.

Today, the world's leading battery cell producers serve a wide matrix of applications in parallel. CATL, BYD, LG Energy Solution, Samsung SDI, Panasonic and others are active across electric vehicles, stationary energy storage, consumer electronics, construction and mining, marine vessels, robotics and defence. They do this because different applications provide different market signals, de-risk different chemistries at different speeds, and allow manufacturing knowledge to transfer across segments.

This double diversity—covering multiple chemistries and multiple applications—is not a coordination problem to be managed. It is Europe's key to success in the battery space. A portfolio approach covering the full matrix gives the industry, and its R&I partners, the resilience to navigate shifts in any single market, the agility to respond to new opportunities, and the optionality to hedge when no single technology pathway has yet proven itself at scale.

Rank	Company	HQ	2025 EV Share	Electric Vehicle	Stationary Storage	Consumer Electronics	Aviation & Aerospace	Maritime
1	CATL	China	39.2%	✓	✓	✓	✓	✓
2	BYD	China	16.4%	✓	✓	✓	✓	✓
3	LG Energy Solution	South Korea	9.2%	✓	✓	✓	✓	✓
4	CALB	China	5.3%	✓	✓		✓	
5	Gotion High-Tech	China	4.5%	✓	✓	✓		✓
6	SK On	South Korea	3.7%	✓	✓			
7	Panasonic	Japan	3.7%	✓	✓	✓	✓	
8	EVE Energy	China	2.6%	✓	✓	✓		✓
9	Samsung SDI	South Korea	2.4%	✓	✓	✓		✓

Market share figures refer to global EV battery installations in 2025 (SNE Research). Target applications reflect each company's publicly disclosed business segments and product portfolios.

DIFFERENT MARKETS, DIFFERENT REQUIREMENTS, DIFFERENT GROWTH PATHS

Each application segment has distinct technical requirements and follows a different growth trajectory. These different requirements favour different chemistries, create different timelines for investment returns, and respond differently to policy changes.

Road transport demands moderate to high energy density, long cycle life, fast charging and cost reduction as the primary design objectives. Stationary energy storage prioritises cycle life, safety and cost of ownership over weight; LFP chemistry dominates here, accounting for nearly 90% of all stationary energy storage installations globally in 2024[12]. Aviation demands the highest possible gravimetric energy density and safety performance, making it a natural development ground for technologies like solid-state and lithium-sulphur batteries. Defence and security applications require extreme reliability under harsh conditions. Medical devices need ultra-long lifetimes in compact, safe form factors. Robotics and industrial automation balance power density with durability. This market diversity is also a commercial buffer: when EV sales softened in 2024 and 2025 following policy rollbacks in the United States, producers with exposure to stationary storage could partially compensate, while those locked into EV batteries faced more acute pressure. The ability to serve multiple markets from the same manufacturing and R&I base is not just a strategic asset; it is a commercial resilience mechanism.

[12] Global Energy Review 2026

	Road Mobility (Mass Market)	Road Mobility (Premium Market)	Off-Road & Heavy-Duty	Light Mobility	Maritime & Rail	Aviation & Aerospace	Stationary Storage	Robotics & Electronics	Defence
LF(M)P	●●●	●	●●●	●●●	●●	/	●●●	●●	●
Na-ion	●●	/	●●	●●●	●	/	●●●	●●	●●
Semi-Solid & All Solid-State	●	●●●	●●	●	●	●●●	●	●●	●●●
HLM/LMR	●●●	●	●●	/	●●	●	●●	●●	/
Hi-Ni NMC	●●	●●●	●	/	●●	●●●	●	●●	●
Mid-Ni HV NMC	●●●	●●	●	/	●●	●●	●	●●	●
Li-S	/	●	/	●	●	●●●	●●	●●	●●●
Redox-Flow	/	/	/	/	●●	/	●●●	/	●●
Metal-Air	/	●	●	/	●●	●●	●●●	●	●●

●●● Primary / Dominant use ●● Significant / emerging use ● Niche / potential use / Not applicable

Scores reflect current trajectory and near-term innovation relevance, not current market share.

Startups and early-stage companies navigate this landscape strategically. A chemistry or process that is too immature for automotive validation can be proven in a niche application with higher tolerance for cost and lower volume requirements. This validates the technology, builds manufacturing experience, attracts investors, and creates the evidence base needed to later access automotive or stationary markets. This de-risking pathway is not a detour: it is the established route by which new battery technologies reach scale. European startups working in solid-state batteries (companies like Blue Solutions, Ilika, LionVolt, Basquevolt and SOLiTHOR), as one of many examples across value chain and technologies, follow the same logic: they target aviation, medical devices, aerospace and defence alongside automotive, using niche applications to validate technologies and build investor confidence before moving toward giga-scale.

European SSB Startups		Electric Vehicle	Energy Storage	Aviation & Drones	Consumer Electronics	Medical & healthcare	Maritime
Basquevolt	*Spain*	✓	✓	✓			
Blue Solutions	*France*	✓		✓	✓		
Solithor	*Belgium*	✓		✓	✓		✓
Lina Energy	*UK*		✓				
Ilika	*UK*	✓				✓	
LionVolt	*Netherlands*	✓		✓			

Target applications are indicated as publicly communicated by each company through official channels and product disclosures. Scope may evolve as technologies mature.

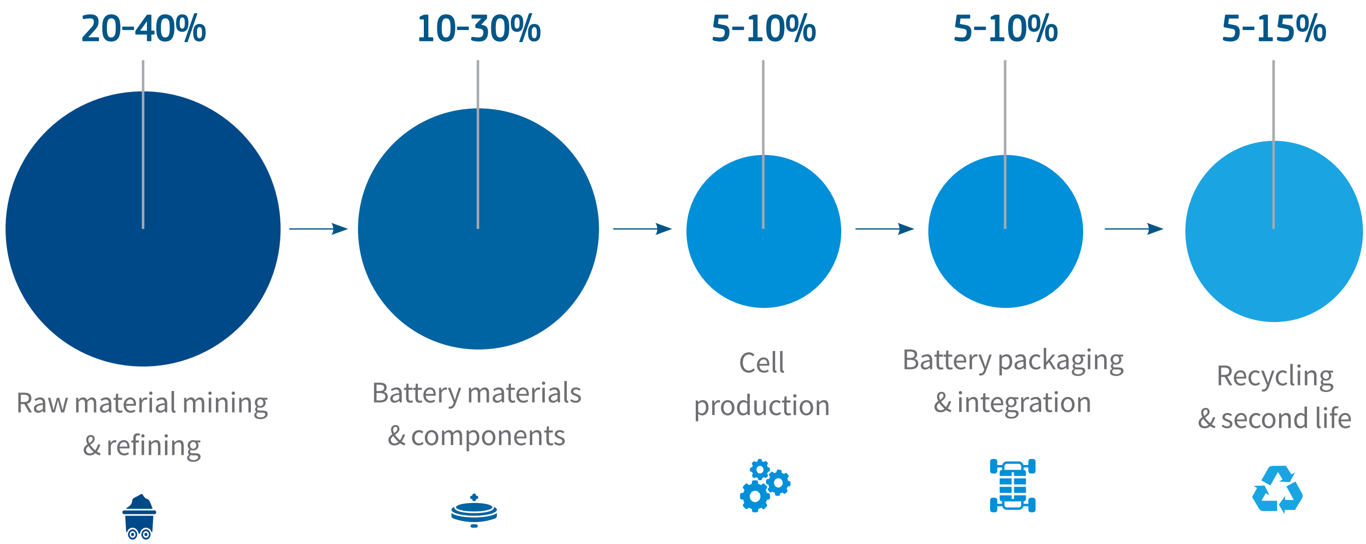
THE BATTERY VALUE CHAIN: WHERE VALUE IS CREATED

Batteries are integrated value chains, not single products. From refining and recycling of critical raw materials, through advanced materials production, cell and pack manufacturing, and integration into end-use applications, value is created at every step, and the steps are interdependent. A weakness in any segment exposes the whole chain. Global battery demand reached 1,545 GWh in 2024, growing 29% year-on-year, with EV batteries accounting for around 1,050 GWh and stationary storage for 370 GWh, according to the Joint Research Centre[13]. Looking ahead, global EV battery demand is forecast to reach approximately 2.5 TWh by 2030, the global BESS market is projected at 0.5 to 0.8 TWh, and overall battery demand is projected to grow seven-fold by 2040[14].

That value is not evenly distributed. Cell manufacturing for EVs is, by design, a high-volume, capital-intensive, low-margin business: JRC analysis confirms that battery pack prices in the EU remain around 48% higher than in China, where cell prices fell to as low as 50 to 55 EUR per kWh in 2024. Of the roughly EUR 450 billion global EV battery value pool projected for 2030, raw and advanced materials account for around half, cells for around 30%, and packaging and integration for the remainder[15]. Margins follow the same gradient: 20 to 50% EBITDA upstream, compressed to 5 to 10% at the cell level.

This is where Europe's position is strongest.Its established chemicals and materials industry, including major players in specialty chemicals, electrolyte and active materials, binders and coatings, provides a natural foundation for competitive upstream materials capacity, backed by real research depth and industrial experience. The Draghi report on European competitiveness identified advanced materials and clean technology value chains as areas where Europe must move from research strength to industrial leadership, and batteries are among the clearest cases where that transition is both possible and urgent[16]. Protecting and developing those upstream positions is as important as building cell manufacturing capacity, and activating the connections between Europe's existing industrial base is precisely what a well-designed R&I strategy can do.

EBITDA margin by EV battery value chain stage



Source: McKinsey Battery insights. Projected margins 2025-2030.

Europe's current situation is mixed. EU battery demand for electric vehicles reached 107 GWh in 2024 and is expected to grow to 320 GWh per year by 2030, according to JRC[17]. But Europe's domestic cell supply capacity stood at approximately 75 GWh in 2025, against China's 1,850 GWh, according to Benchmark Mineral Intelligence[18]. The growth of European cell production is largely reliant on non-European producers: Korean and Chinese-owned gigafactories account for the majority of European cell supply, and European-owned capacity remains a fraction of total installed capacity. Over half the electric vehicles produced in Europe in 2024 used batteries manufactured in China or other Asian countries. There has been real progress: ACC, Verkor and PowerCo have all started production, but Northvolt's bankruptcy and the rollback of over 700 GWh of announced capacity since 2024 show how fragile progress is without sustained support.

13 CETO: Battery Technology in the EU

14 Battery & Gigafactory (BMI)

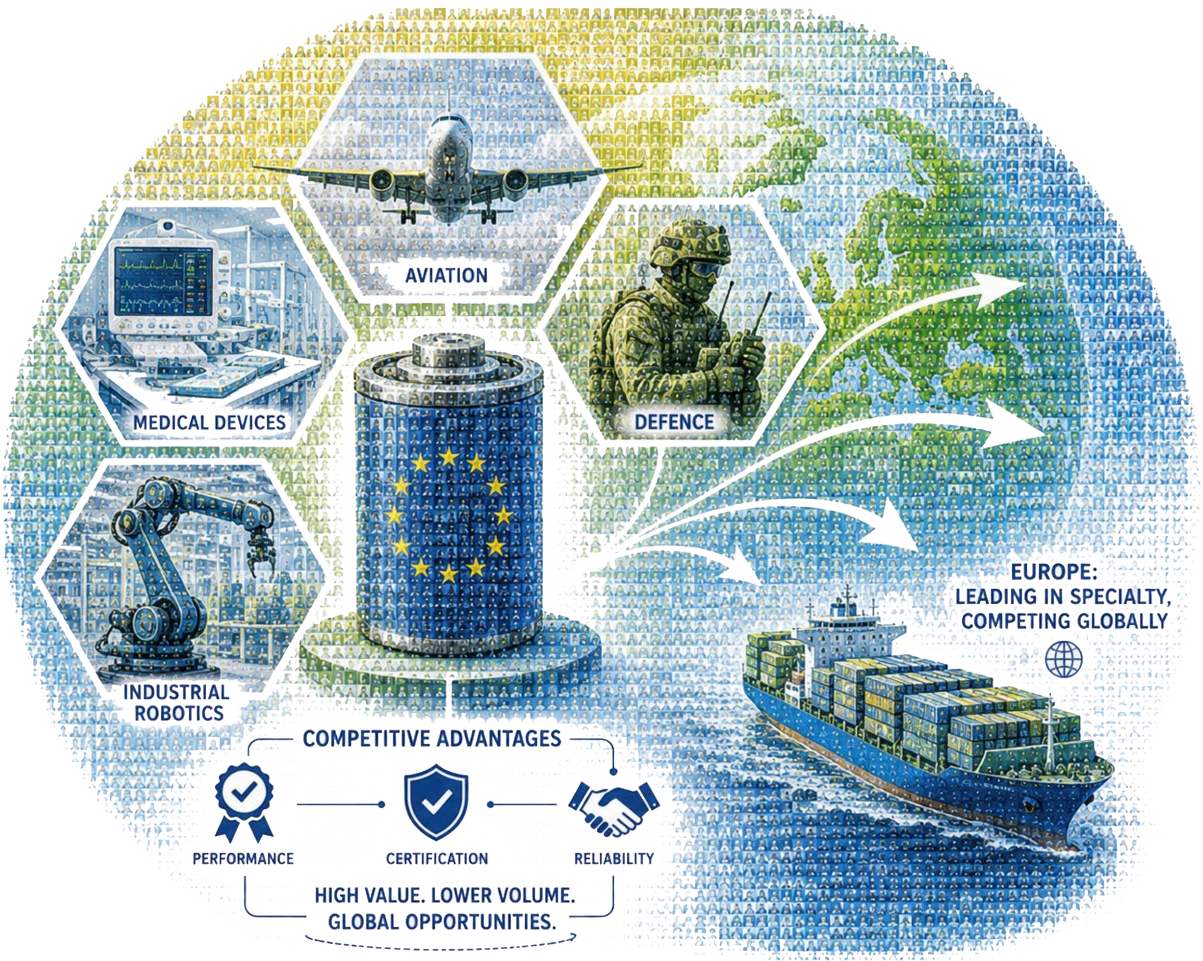
15 The Next Evolution of LFP Batteries

16 The Draghi Report on EU Competitiveness

17 CETO: Battery Technology in the EU

18 Battery & Gigafactory (BMI)

Beyond closing the domestic competitiveness gap, Europe has an opportunity to build genuinely export-oriented positions in niche and specialty battery segments: chemistries and form factors optimised for aviation, defence, medical devices, industrial robotics and other high-performance, lower-volume applications, where competition is based on performance, certification and reliability rather than cost per kWh alone. These are precisely the segments where European manufacturing costs are least disadvantaged relative to Asian commodity cell production, and where European materials science and engineering depth translate most directly into commercial advantage. Rather than treating non-EV applications solely as a domestic de-risking pathway toward eventual EV-scale production, Europe should also consider them as standalone export opportunities: a battery industry that leads on specialty as well as volume.



THE CHALLENGE: WHAT STANDS IN EUROPE'S WAY

Four Challenges Facing the European Battery Value Chain

Europe can become a globally competitive battery player and deliver on its objective of creating an economically secure, sovereign and climate-neutral continent. This will require serious action. As outlined in *A Battery Deal for Europe*[19]. , Europe needs to overcome four fundamental challenges, challenges regarding scope, scale, speed, and sustainability. These challenges are interlinked and the lines between them are sometimes blurred, but moving forward to tackle these challenges head-on will be decisive if Europe wants to keep its battery future in its own hands. What unites these challenges is that continued innovation plays a central role in addressing them all.

For the comprehensive list of industry challenges and the proposed R&I actions, see annex B.

SCOPE: MANAGING THE DOUBLE DIVERSITY

The scope challenge is about breadth. Batteries must serve a growing matrix of applications, each requiring different performance profiles, and must do so using an expanding range of chemistries, form factors and integration architectures. Europe's current weakness is insufficient diversification across both dimensions: too concentrated on a small number of chemistries, and too dependent on automotive as its commercial anchor.

No single chemistry serves all applications equally well. LFP and LMFP offer cost and safety advantages for road transport and stationary storage. NMC and NCA provide higher energy density for premium mobility. Sodium-ion offers a path to lower-cost, cobalt-free batteries for cost-sensitive markets. Solid-state batteries promise step-change improvements in energy density and safety, with particular relevance to aviation, defence and premium EVs. Lithium-sulphur targets extreme gravimetric performance for aerospace and defence. Redox-flow batteries suit large-scale stationary applications where weight is not a constraint. While some fundamental aspects are shared, each chemistry requires different materials expertise, different manufacturing processes, and different validation pathways.

Managing this complexity across the full value chain requires a portfolio approach with long time horizons. The capital intensity of battery production means that technology choices, once made, are hard to reverse. A portfolio approach hedges those choices: capabilities built for one chemistry or application create optionality for others, reducing the risk of being locked into a pathway that the market or technology landscape later makes obsolete.

[19] A Battery Deal For Europe

Examples of European R&I actions needed to tackle the Scope challenges

- Create low-threshold funding opportunities to investigate new chemistries
- Bring promising, industry-validated battery technologies up the Technology Readiness Level (TRL) scale to serve an increasingly diverse set of applications
- Improve the flexibility of battery manufacturing and recycling, to reduce the risk of stranded assets
- Derisk innovative technologies by promoting adoption in niche/defence markets

SCALE: THE ECONOMICS OF GIGAFACTORY PRODUCTION

The scale challenge is about production economics. European producers face three compounding pressures. First, the upfront capital cost of building and equipping gigafactory-scale production is enormous. Second, operating costs (energy, labour, logistics) in Europe are higher than in competing regions. Third, and most decisively, yields in the early years of production are low. Manufacturing lines take time to master. Scrap rates are high during ramp-up, and the cost of defective output is carried at a time when revenues are still limited.

The IEA's Energy Technology Perspectives 2026 quantifies this precisely: manufacturing efficiency (production yield and line uptime) accounts for over 40% of the production cost gap between Chinese and European battery producers, outweighing differences in labour costs, energy prices or components. This is a critical finding. The gap is not primarily structural or geographic. It is operational, built through years of accumulated manufacturing experience. It is therefore addressable, but only with sustained, output-based public support through the ramp-up phase, when scrap rates are highest and margins are thinnest.

The scale challenge has a second dimension: the value chain must scale in parallel. Manufacturing battery cells at giga scale using foreign materials and foreign machinery simply shifts the dependency. European upstream capacity in materials processing, refining and production equipment must grow alongside cell manufacturing, or Europe's gigafactories will remain exposed to the supply chain vulnerabilities already documented.

Examples of European R&I actions needed to tackle the Scale challenges

- Lower CAPEX throughout the value chain to reduce investment/technology risk
- Develop modular processes/systems to start fast and scale even faster
- Improve production routes towards less energy intensive processes
- Improve manufacturing expertise and develop turnkey solutions based on European machinery to reduce the length of the costly ramping-up phase
- Invest in the upstream of the value chain to ensure that supply will scale with gigafactory demand

SPEED: CLOSING THE TIME-TO-MARKET GAP

The speed challenge is about the time it takes to move from research to commercial deployment, and Europe is slower than its main competitors at every stage. Three delays compound each other: Discovery and process optimisation take longer because AI, advanced modelling and digital twins are not yet embedded as standard practice in European battery R&I workflows. Technology validation takes longer because the chain of approvals, from materials supplier to cell-maker to system integrator or OEM, is long, poorly standardised and capital-intensive for early-stage companies. Permitting takes longer because new production facilities must demonstrate regulatory compliances through processes that are not designed for speed. Together, a technology that could reach market in five years in Asia may take eight to ten in Europe, eroding the first-mover advantage that R&I investment is supposed to deliver.

Examples of European R&I actions needed to tackle the Speed challenges

- Digitalisation of battery discovery and development
- Advanced digital twins for battery manufacturing to test new production methods faster
- Faster validation loops to introduce new battery technologies
- Reduction of emissions to speed-up permitting for new plants

SUSTAINABILITY: TURNING COMPLIANCE INTO COMPETITIVE ADVANTAGE

The sustainability challenge is about more than environmental obligation. Europe has set binding requirements through the Battery Regulation: recycled content targets, carbon footprint disclosure, end-of-life recovery rates and digital product passports[20]. These rules can be turned from cost into advantage: a European battery industry that is genuinely cleaner and more circular than its competitors earn premium market access in regions where sustainability increasingly drives procurement decisions and supply chain due diligence.

Three R&I priorities are central. First, supply chain resilience through recycling: domestic processing of end-of-life batteries reduces dependence on primary material imports and on China's dominance of refining. Economically viable recycling routes, including for materials with low intrinsic market value, require continued innovation in pyrometallurgy and hydrometallurgy, direct recycling and automated disassembly. Second, battery longevity: the largest reduction in lifetime environmental footprint comes from extending useful life. AI-driven usage analysis, improved cell chemistries and design-for-repairability all contribute. Third, safe and sustainable design at functional and system level: risk- and performance-based management of substances of concern used in battery components, including substitution where it demonstrably reduces overall risk and environmental impact, supported by bio-based or synthetic alternatives validated with realistic re-qualification timelines, helps reduce both regulatory uncertainty while ensuring that essential safety and longevity functions are maintained.

Examples of European R&I actions needed to tackle the Sustainability challenges

- Increase battery longevity by better understanding of battery usage
- Better designs to extend lifetime and enable repairability
- High-purity recycling processes of battery materials
- Cost-efficient recycling options for low-value materials like LFP and sodium-ion
- Bio-based solutions for battery materials based on carbon or silicon

[20] Regulation on Batteries and Waste Batteries

THE CASE FOR ACTION: WHY PUBLIC R&I SUPPORT

Research & Innovation: Where Solutions Begin

To solve the four challenges and make the European battery industry competitive, R&I will be a key enabler. However, any R&I action taken will need to address short-term and long-term priorities. On the one hand, Europe needs a sprint to close the gap in terms of producing the current generation technologies. On the other hand, Europe needs a marathon to lead on the development of next-generation Intellectual Property (IP). Europe cannot have one without the other.

NO SPRINT WITHOUT A MARATHON

Europe needs to catch up on the current generation of battery tech with other regions. Not addressing this gap is dangerous, not only because Europe will miss out the value of the battery market, but also that of the many industries to be built around batteries. A concrete illustration of this urgency, identified by the EU's Automotive Action Plan[21], is the European EV market, estimated to be EUR 2.4 trillion by 2050[22]. If car companies from other countries have the edge over European rivals in battery manufacturing, European OEMs will come under pressure from vertically integrated competitors. This puts in danger the 13 million direct and indirect jobs in the automotive industry[23]. In addition, Europe will fall into a new dependency, where dependency on foreign fossil fuels is replaced by reliance on foreign storage systems.

However, a singular focus on ramping up production of current technology will not lead to a sustainable level of competitiveness, and simultaneous investment in R&I is a complementary must. CATL, China's largest battery producer—currently the global leader across the value chain—spends more on R&I each year than all European public funding combined[24]. This gap underscores the difficulty of ever fully catching up. Europe cannot close this gap by importing someone else's technology. Building European-owned IP is what turns production capacity into genuine independence — and that requires urgent investment in innovation capacity and research infrastructures.

NO MARATHON WITHOUT A SPRINT

The other scenario, which focuses only on next-generation technologies, and which is often referred to as 'leapfrogging', is not feasible either. To put the novel IP to use and create a sovereign value chain in Europe, one still needs to have built up European manufacturing capability to turn Designed-In-Europe batteries into

[21] Action Plan on the Future of the Automotive Sector

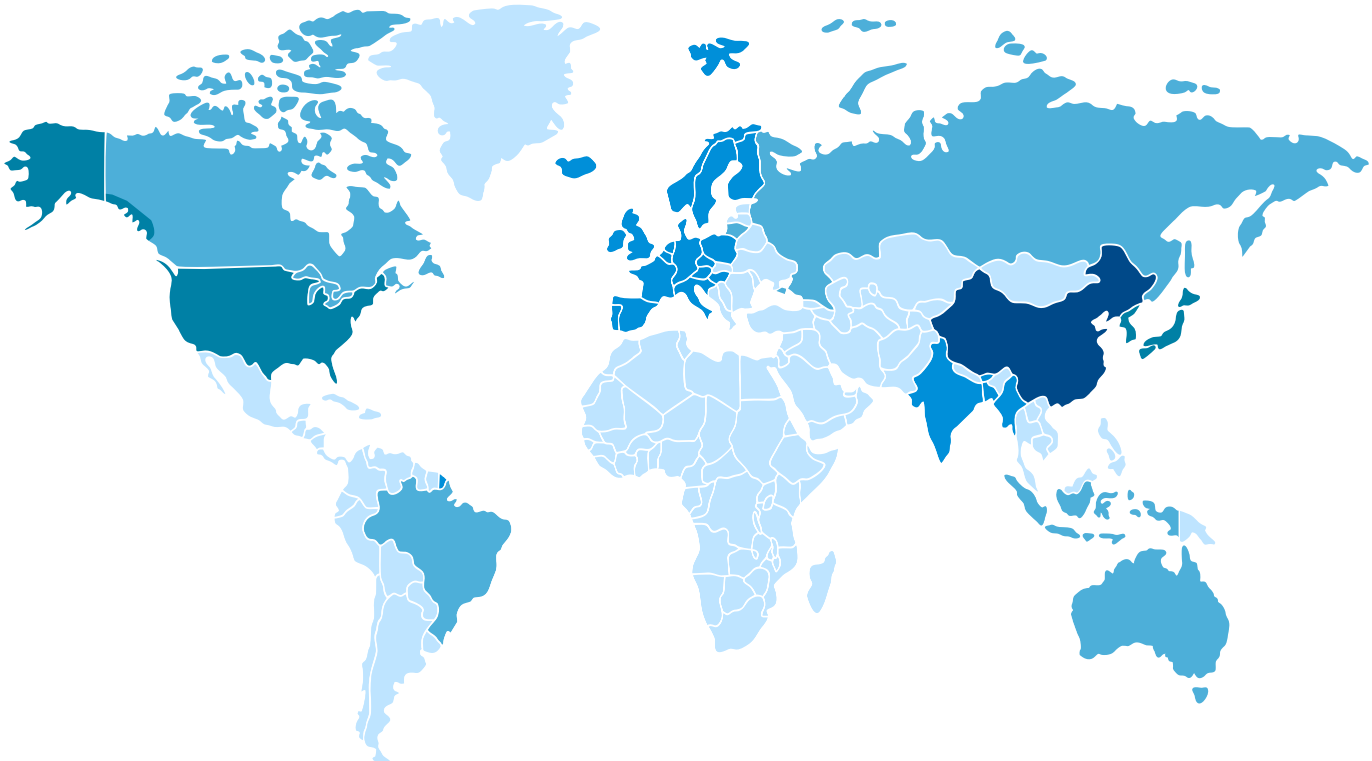
[22] The Future of European Electric Vehicles

[23] Launch of Strategic Dialogue on Automotive Industry

[24] CATL 2025 Annual Report

Made-In-Europe batteries. When looking at the number of patents on battery technology worldwide, it is striking that the regional distribution of the number of patents is highly correlated with the manufacturing capabilities in that region, and many patents are in the hands of the world's top battery manufacturers. Having an established manufacturing base allows for rapid testing of innovations and improvements.

Global Battery Landscape 2025



New battery patent families published in 2025
Source : KnowMade

- 12,000 - 100,000
- 3,000 - 12,000
- 200 - 3,000
- 11 - 200
- < 100
- No significant activity

To fully unlock the potential of Europe's battery R&I ecosystem, Europe must ensure that the right innovation-supporting instruments are in place. For Europe to compete with Asia in such a tough global arena, it is not about innovating less, but innovating more, innovating better, and innovating faster or Europe will be out innovated, and the gap widens even further in the upcoming years. The main challenge is that the European battery value chain needs to run both an innovation sprint for today's challenges and an innovation marathon to build and maintain Europe's competitiveness over a longer period.

WHY INDUSTRY NEEDS PUBLIC SUPPORT FOR R&I

The battery sector faces a level of investment risk that private actors cannot bear alone. Three structural risks define the sector, and they are mutually reinforcing.

Value chain risk arises from interdependence across a long and capital-intensive production chain. An investment in cell manufacturing depends on upstream materials supply being secure, on machinery being available, on downstream demand being committed. No single European actor controls the whole chain, and the failure of any link threatens the returns of all the others. China controls over 90% of refining capacity for many critical battery materials. European machinery makers produce competitive equipment but struggle to find European customers to anchor production. A dependence on imported materials and equipment creates exposure to export restrictions and geopolitical shocks, risks that have already materialised and that only coordinated action can address.

Technology risk is the inherent uncertainty of innovation: a technology pathway that looks promising today may lose out to a competitor, may fail to scale, or may be overtaken by events. Mass battery production has a 20-year head start in Asia. Technologies that are standard practice there need to be developed and validated independently in Europe, at significant cost and with uncertain outcomes. This risk is classically what public R&D funding was designed to address, but in batteries, the scale and speed of required investment exceed what national programmes or bilateral industry partnerships can provide.

End-use risk is the risk that downstream customers switch to a different technology, a different supplier, or scale back their electrification plans altogether. European OEMs and energy companies in grid have limited vertical integration in batteries compared to their Asian counterparts: no European company owns both materials production and cell production at scale. This means battery developers in Europe are exposed to offtake uncertainty that reduces the business case for long-term investment. When the economics of commitment are unattractive, private actors rationally remain on the sidelines.

Public support for R&I is the mechanism for accelerating technology development and reducing risk across all three dimensions simultaneously. It reduces the cost of technology validation, making it easier for private actors to commit. It creates shared infrastructure and knowledge that no single company would fund alone. It aligns the ecosystem around shared roadmaps, making interdependent investments less exposed to coordination failure. And it provides the sustained, multi-year horizon that battery R&I requires, in contrast to the short-cycle, project-by-project interventions that characterise fragmented national programmes or ad-hoc calls.

THE PROPOSAL: A DEDICATED BATTERY PARTNERSHIP

Flexibility, Agility and Optionality Under One Roof

Europe has a broad toolbox of instruments to support different parts of the battery value chain — from frontier science to breakthrough technologies, shared infrastructure and industrial deployment. To meet Europe's strategic objectives, all of these instruments must be used to their fullest.

Within this toolbox, a dedicated Battery Partnership plays a unique and complementary role. It is the only instrument designed to bring together the full value chain — advanced materials, cell manufacturing, integration, recycling and circularity — under a single, coherent framework. It provides a stable platform to move technologies up the TRL ladder, build long term capabilities, and anchor critical knowledge and skills in Europe.

WHY A BATTERY PARTNERSHIP IS ESSENTIAL WITHIN EUROPE'S BROADER TOOLBOX

The battery sector is dynamic and complex. Market signals shift, technologies mature at different speeds and geopolitical conditions can rapidly reshape supply chains. In such an environment Europe needs an R&I instrument with three characteristics: the agility to act proactively when opportunities emerge; the flexibility to react when conditions change; and the optionality to hedge across chemistries and applications when no single pathway has yet proven itself. This combination (agility, flexibility, optionality) is what delivers the best balance between risk and return on public investment.

Other instruments play important roles, but can not fully replace this function: The European Research Council (ERC) funds excellent frontier science but does not necessarily coordinate across the value chain or connect research to industrial deployment. The European Innovation Council (EIC) supports individual companies and breakthrough technologies but cannot create the ecosystem alignment needed to address value chain risk. Pillar 4 builds shared infrastructure but does not govern the R&I agenda that determines what that infrastructure must serve. Application-specific partnerships, including those focused on mobility, play a vital role for their sectors, but naturally concentrate on end-use integration and cannot cover the full diversity of chemistries, TRLs and applications that underpin Europe's battery strength.

A dedicated battery partnership complements these instruments by providing integrated ecosystem governance and a coherent technology roadmap that spans the entire value chain and all applications.

Europe has already demonstrated the effectiveness of this approach.. BATT4EU and the two battery IPCEIs[25] (Important Project of Common European Interest) were developed in parallel, each covering the full value chain and enabling innovation across multiple chemistries and applications. This broad, portfolio based model strengthened Europe's resilience, accelerated industrial deployment, and ensured that innovation served both automotive and non automotive markets.

A future R&I framework that narrows scope or limits the diversity of applications would risk weakening this progress. Europe needs an instrument that continues to reflect the full breadth of the battery ecosystem — mobility, stationary storage, industrial applications, specialty markets and recycling — and that provides a single, coherent roadmap for innovation.

A dedicated Battery Partnership is therefore not an alternative to other instruments, but a necessary complement that ensures Europe's battery R&I remains coordinated, inclusive and strategically aligned.

IMMUNE TO THE THREE RISKS

A dedicated Batteries Partnership directly addresses each structural risk.

It reduces value chain risk through value chain alignment: bringing the full range of actors, from mining to recycling, into shared governance, so that upstream investments receive demand signals from downstream, and downstream commitments are anchored by upstream supply assurance. A single overarching R&I strategy, spanning EU and national programmes, ensures every actor is working toward the same technology and capability goals, reducing the risk of investment in capabilities that prove strategically peripheral.

It reduces technology risk through public-private risk-sharing: providing consistent public financial support to move technologies through the valley of death (between TRL 4 and TRL 8), where private investment is insufficient. A shared roadmap, across technologies and applications, allows the partnership to identify the most critical technology gaps, avoid duplication between national and EU programmes, and ensure that advances at low TRL are picked up and developed rather than left stranded. An internal dedicated governance element monitors adjacent enabling technologies (AI, advanced materials, precision manufacturing) to ensure the partnership's roadmap captures disruptions before they arrive.

It reduces end-use risk through multi-application governance: another internal dedicated governance element creates a standing forum in which battery technology developers engage with the full range of end-users: automotive, stationary storage, heavy transport, defence, aviation and maritime. When commitments are made within a structured partnership, they carry institutional weight that purely bilateral negotiations do not. And because the technology portfolio is calibrated across applications, the risk of any single end-market switching is distributed across the whole.

[25] IPCEI Batteries

WHAT THE PARTNERSHIP SHOULD LOOK LIKE

The Batteries Partnership under the next Multi-annual Financial Framework (MFF), building on BATT4EU under Horizon Europe, covers the full battery value chain. It operates through three project tracks that span the full TRL range, supported by a governance structure designed to be as light as possible while ensuring alignment, accountability and articulation with the wider ecosystem.

SCOPE: FULL VALUE CHAIN, FULL CHEMISTRY PORTFOLIO, ALL APPLICATIONS

The battery value chain defines the partnership's scope. No segment is excluded. Upstream investment in materials is as important as cell manufacturing investment; recycling and circularity are as important as initial production. The partnership's integrated technology roadmap spans this entire chain and ensures that investments at each level are coherent with investments at every other level.

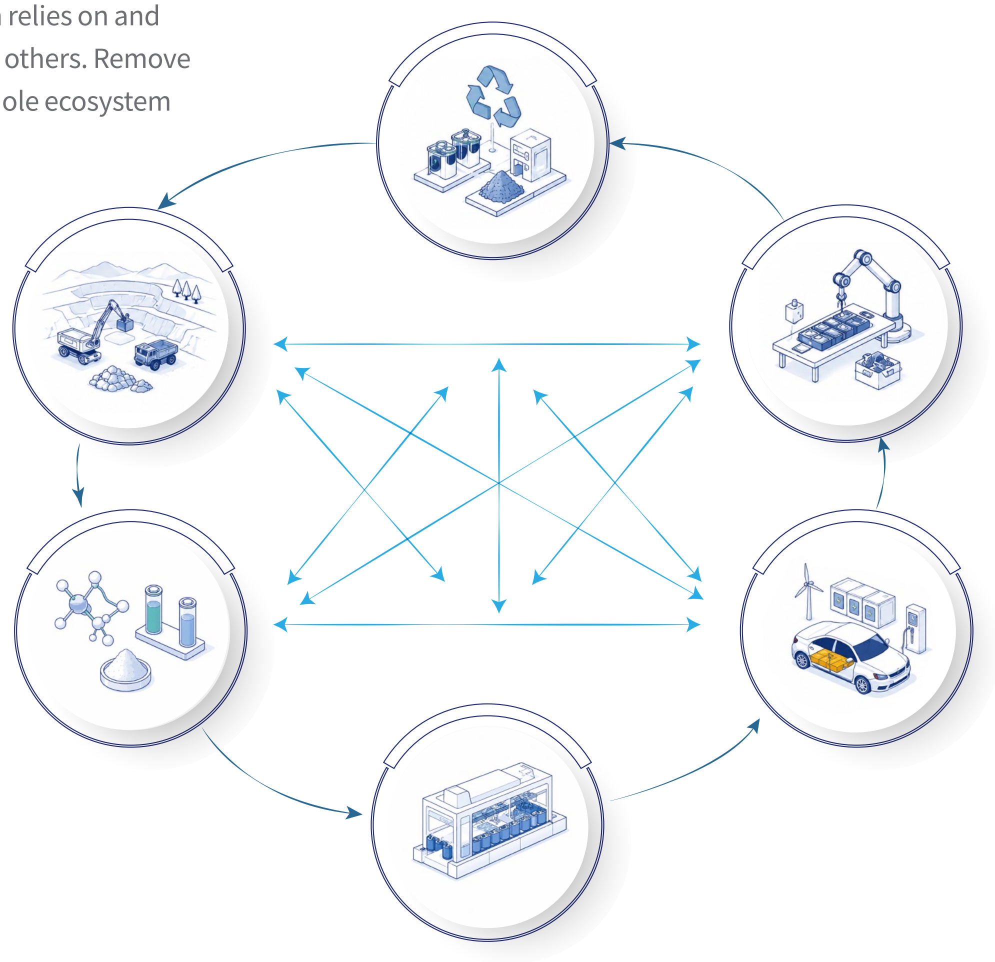
On chemistries, the partnership supports a deliberate portfolio: current-generation variants (Lithium-ion batteries) alongside next-generation chemistries (e.g., sodium-ion, solid-state in all electrolyte families, lithium-sulphur, redox-flow, metal-air). The portfolio approach is not about funding everything equally: it is about maintaining optionality across the chemistries that different applications and different market conditions will require, and building the manufacturing capability that allows European-developed IP to become European-manufactured products.

THE EUROPEAN BATTERY VALUE CHAIN

A complete competitive and circular ecosystem powering Europe's clean transition and industrial leadership.

AN INTERDEPENDENT ECOSYSTEM

Each dimension relies on and strengthens the others. Remove one, and the whole ecosystem loses balance.



01 Raw materials

02 Advanced materials & chemistries

03 Battery cell manufacturing

04 Battery pack & applications

05 Dismantling

06 Recycling

On applications, the partnership covers the full spectrum: road mobility (passenger and commercial), aviation, waterborne and rail, stationary energy storage, defence and security, robotics, electronics and medical.

VALUE CHAIN FLOW

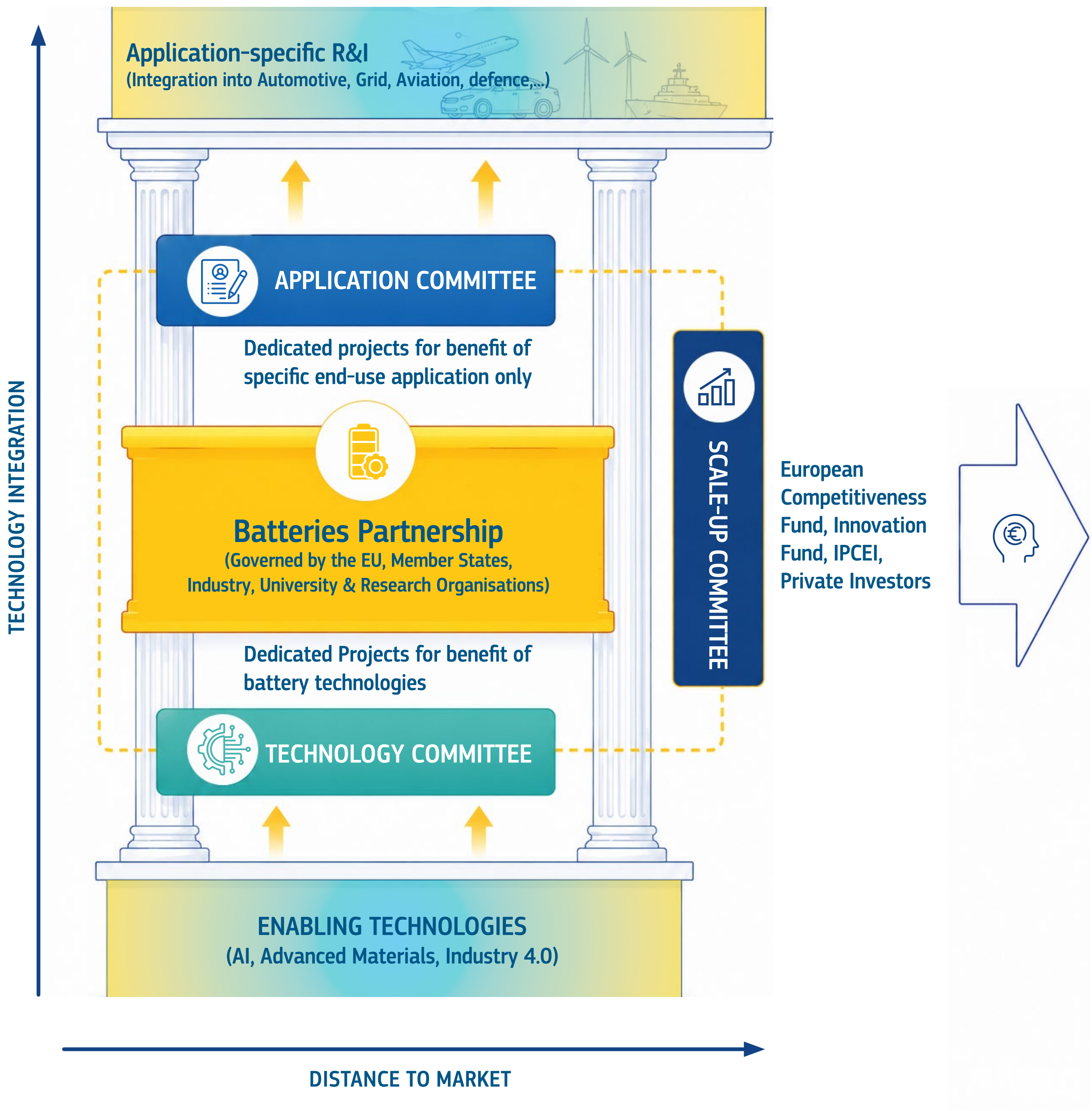
The main circular flow of the battery lifecycle.

INTERDEPENDENT LINKS

Cross-connections that strengthen the resilience of the entire ecosystem.

GOVERNANCE: AS LIGHT AS POSSIBLE, AS STRONG AS NECESSARY

In order to deliver the promises of the Partnership, a strong governance system needs to be put in place. The governance should consist primarily of an internal Partnership Board and three Committees that ensure alignment of the Partnership with the wider ecosystem: the Technology Committee, the Application Committee and the Scale-Up Committee.



Governance link
Coordination and oversight across the partnership

Strategic flow
Alignment and support enabling progress

Partnership Board

The core of the Partnership will be managed by a strong Partnership Board, consisting of representatives from the European Commission, the Member States and active members of the battery value chain, including but not limited to large industry players, SMEs, Universities and Research and Technology Organisations (RTOs).

The key here is to have an inclusive representation all under one roof. Public and private stakeholders, stakeholders involved with different parts of the value chain and stakeholders working along different TRL-levels. The Partnership Board will steer the development of the Strategic Research, Innovation and Deployment Agenda (SRIDA) and other strategic documents. It will also oversee budget allocation and be outwardly accountable based on clear Key Performance Indicators (KPIs).

Technology Committee

A great challenge across the next Framework Programme (FP10) will be to maintain a coherent Research, Innovation and Deployment (R&I&D) strategy while, thanks to rapid advances in AI and robotics, the technologies surrounding battery development progress faster than any single roadmap can anticipate. The Technology Committee will engage adjacent enabling technologies to coordinate and accelerate battery development across TRLs. The Technology Committee, comprised of a delegation of the Partnership Board and experts from key enabling technology sectors and partnerships such as AI, robotics, advanced materials and process technology, will decide which technological breakthroughs offer unique possibilities for the battery sector and which need to be applied within the Batteries Partnership, or as joint research topics.

Application Committee

As the battery serves many sectors and will serve more in the future, close collaboration with the various end-users is needed. The role of the Application Committee is to discuss with representatives of the different end-use sectors the state of different battery technologies and which can cater to their applications. This enables the battery partnership to streamline its agenda and deliver value to the application-specific (integration-driven) partnerships.

Scale-Up Committee

One of the key expected outcomes for FP10 is to make the transition to upscaling the results easier for the participants. Close coordination with upscaling and deployment funds like the European Competitiveness Fund and the Innovation Fund are necessary. BATT4EU has enjoyed good collaboration with the Innovation Fund under the current MFF, trying to bring in stakeholders from Horizon Europe to the Innovation Fund[26]. This approach needs to be structurally applied to all possible upscaling tools in the next MFF.

Together, these three “interface platforms” ensure that the R&I&D agenda of the Batteries Partnership stays up to date, useful for end-users and that results will be ready to be scaled up by other financial instruments.

[26] BEPA Event: Innovation Fund and Battery Calls

A TARGETED PROJECT SET-UP DEPENDING ON TRL

While the BATT4EU projects have yielded great results, this does not mean that the funded projects could not be improved. While a clear and common rulebook brings benefits, projects will need to be tailored to the technology readiness level that projects aim to achieve.

Sandbox track: smaller projects – faster results (proposed share of partnership budget: 20%)

One of the downsides of the current set-up of Horizon Europe is the long 'time-to-money' for participants and the long 'time-to-result' for the taxpayer. This time to get results can partly be reduced by faster evaluation and more frequent work programme windows, but another solution is to allow for sandbox calls which would allow for smaller projects (budget, number of participants) with shorter timespans than usual. Small projects can provide quick wins in terms of reducing technology risk. A few partners can assess the viability of a certain technology in under a year, without having to involve ten partners and three years of execution. These sandboxes need not to be limited to low-TRL research, as they can also target projects that seek to test whether a solution demonstrated at lab level can be implemented in an industrial-scale environment.

Validation track: building the value chain (proposed share of partnership budget: 60%)

The collaborative projects under Horizon Europe are great to reduce value chain and end-use risk and should also be continued under the new European Partnership. The validation track brings together many stakeholders of the value chain together in a collaborative to see whether the proposed solutions are feasible to implement along the value chain. These projects raise the general level of competence in the European battery sector. However, these projects would benefit from more flexible rules to scale-up their research results. It should be more feasible for 2 to 3 project participants to scale up their research results together, for example by applying for an EIC grant or launching a startup. This way, validation track projects become a launch platform for future success.

Pre-deployment track: scaling-up starts here (proposed share of partnership budget: 20%)

Scaling-up battery technology requires big investments. These investments were not always feasible under the rules of Horizon 2020 and the current incarnation of Horizon Europe. The pre-deployment track would allow for bigger projects in terms of overall funding and particularly for increased capital expenditure. Under the last Work Programme of Horizon Europe ('26-'27), some BATT4EU calls already moved in this direction, for example call HORIZON-CL5-2026-10-D2-03, a call targeting 3 projects of around 100 million Euros. Pre-deployment projects are key for scaling up and will ensure a pipeline of good projects which can apply for the European Competitiveness Fund or the Innovation Fund.

CONNECTING EUROPEAN AND NATIONAL RESEARCH

A key strength of the Batteries Partnership under FP10 will be its tripartite nature (Commission, Member States and industry) all under one roof. This structure was recommended by the European Court of Auditors' 2023 special report on EU battery industrial policy[27], which noted that until 2017 there was no EU-wide technology roadmap to guide coordinated investment, and called for stronger coordination between EU and national funding.

Under BATT4EU, national relationships have been built at two levels: directly with government representatives through the National and Regional Coordination Group (NRGC), and through national battery associations and clusters that participate as BEPA members.

Mapping Where Member States Actually Stand

In preparation for this Blueprint, BEPA has conducted interviews with national stakeholders to assess R&I priorities by country.

BEPA carried out a structured consultation with national battery clusters and key industrial players across 13 European countries, asking where future public and private R&I effort should be concentrated across the battery value chain. The results reveal both the depth of national engagement and the scale of the coordination challenge, evident by the diversity of countries' priorities in terms of different technologies and segments of the battery value chain. These results are indicative only and do not represent the official position of the national battery associations.

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[27] EU Industrial Policy on Batteries

L : Low

M : Medium

H : High

VH : Very High

	Value chain activities	NORWAY	SWEDEN	DENMARK	SPAIN	ITALY	PORTUGAL	FRANCE	HUNGARY	NETHERLANDS	GERMANY	BELGIUM	FIN-LAND	CZECH REPUB-LIC
ADVANCED MATERIALS / BATTERY CHEMISTRIES	Cathode active materials for Li-ion batteries - LFP/LMFP	H	H	M	H	VH	H	H	H	M	H	H	VH	H
	Cathode active materials for Li-ion batteries - NMC/NCA	H	M	L	M	H	H	M	M	M	M	M	H	H
	Cathode active materials for Na-ion batteries	M	H	VH	M	VH	VH	M	M	M	M	M	M	H
	Anode active materials based on graphite, carbons, ...	VH	VH	M	L	H	H	L	L	M	L	L	H	H
	Anode active materials based on silicon	VH	VH	H	H	VH	H	H	H	VH	H	H	H	H
	Electrolytes &/or catholytes for Li-based SSB	L	H	M	VH	VH	VH	VH	VH	VH	VH	VH	M	M
	Electrolytes &/or catholytes for Na-based SSB	L	M	VH	M	M	VH	M	M	VH	M	M	M	M
	Anode active materials based on Li-metal or Na-metal	M	H	VH	H	H	H	H	H	VH	H	H	M	L
	New battery materials for emerging battery chemistries	M	H	VH	M	VH	H	M	M	VH	M	M	H	M
	Binders, separators, copper, aluminium components, additives, other chemicals (solvents)	M	VH	H	VH	VH	H	VH	VH	M	VH	VH	M	M
BATTERY CELLS	Battery cells for road-transport	M	VH	L	VH	H	H	VH	VH	VH	VH	VH	H	H
	Battery cells for non-road-transport (aviation, drones, rail, maritime)	H	VH	H	H	H	H	H	H	VH	H	H	VH	H
	Battery cells for stationary energy storage (utilities, home storage)	H	H	VH	M	VH	H	M	M	VH	M	M	H	H
	Battery cells for other applications (defense, robotics, electronics)	VH	H	M	H	H	H	H	H	VH	H	H	VH	H
BATTERY PACKS / SYSTEMS	Battery packs/systems for road-transport	L	VH	VH	VH	VH	H	VH	VH	VH	VH	VH	H	VH
	Battery packs/systems for non-road-transport (aviation, drones, rail, maritime)	VH	VH	VH	VH	H	H	VH	VH	VH	VH	VH	VH	VH
	Battery packs/systems for stationary energy storage (utilities, home storage)	M	VH	H	H	VH	VH	H	H	VH	H	H	H	H
	Battery packs/systems for other applications (defense, robotics, electronics)	H	VH	VH	H	VH	H	H	H	VH	H	H	H	H
EQUIPMENT & SOFTWARE	Equipment for battery manufacturing & battery testing	M	M	VH	VH	VH	H	VH	VH	VH	VH	VH	VH	L
	Software for battery value chain (digital tools, AI, ...)	M	VH	VH	VH	VH	H	VH	VH	H	VH	VH	VH	L
CIRCULARITY	Processing of battery waste	VH	VH	H	H	VH	VH	H	H	H	H	H	VH	VH
	Refining of primary &/or secondary raw materials	H	VH	M	M	H	VH	M	M	H	M	M	VH	H

From National Survey to the EU's Official Roadmap: The SET Plan

In 2026 the European Commission re-established the Strategic Energy Technology (SET) Plan as the EU's primary platform for aligning public and private R&I priorities for strategic energy technologies, organised through 15 Implementation Working Groups (IWGs) covering technologies from batteries to hydrogen to wind energy. Batteries IWG, led by France and Italy, includes 17 Member States and associated countries (Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain and Sweden). IWG7 has been mandated to develop the Strategic Research and Innovation Agenda (SRIA) for batteries: the document that will define Europe's common R&I priorities for the sector. The SRIA is due in Q4 2026, feeding into the Implementation and Investment Commitments (Q1 2027), which together with the Thematic Vision and SRIA constitute the Common Implementation and Investment Plan (CIIP), the instrument that translates agreed priorities into concrete national and EU funding commitments.

BEPA is leading this work as content coordinator of Batteries IWG7. This is a direct validation of the Blueprint's central argument. The organisation BEPA has built to represent the full battery value chain and co-run BATT4EU is now the body the European Commission has entrusted with supporting Member States behind a single battery technology roadmap. The fragmentation this Blueprint warns against, national priorities pulling in different directions, is precisely the problem the SET Plan SRIA is designed to solve at the level of strategy, and that the Batteries Partnership is designed to solve at the level of implementation and funding. The two are two sides of the same coin: one sets the common direction, the other provides the integrated instrument to deliver it.

This alignment is not only structural, it is now on the record. In June 2026, IWG7 adopted its Thematic Vision on Battery Technology[28], the first pillar of the CIIP and the document that frames the SRIA to follow. Its conclusions map closely onto the case this Blueprint makes: the need for a resilient, circular and sovereign value chain across all applications and chemistries, coordinated action to close the cost gap and secure raw materials, and sustained public R&I support at every maturity level.

Most directly, the Thematic Vision's first recommendation to the SET Plan Steering Group and Member States is to maintain a dedicated public-private battery partnership beyond the current Framework Programme, to ensure continuity of the collaborative R&I ecosystem built through BATT4EU and to provide a stable framework for delivering the 2026 SRIA and future priorities. In other words, the renewal of the Batteries Partnership is not only an industry ask: it is a position the Member States have themselves endorsed, through the European Commission's strategic planning process.

In the new Partnership, Member States will hold seats in the extended Partnership Board, building on this same logic, with structured mechanisms to align national programmes and the priorities identified through the SET Plan SRIA.

[28] Thematic Vision — Batteries

HOW THE PARTNERSHIP WORKS WITH THE EUROPEAN INNOVATION COUNCIL

Another key interface, which is not directly covered by the different committees mentioned above, is the relationship with the European Innovation Council (EIC). Next to the BATT4EU Partnership, the EIC has delivered on excellent projects on batteries under the current Framework Programme. Like BATT4EU, the European Innovation Council is covering a wide range of TRLs, under its three schemes of Pathfinder, Transition, and Accelerator[29].

There are some key differences which make that these two funding instruments reinforce each other.

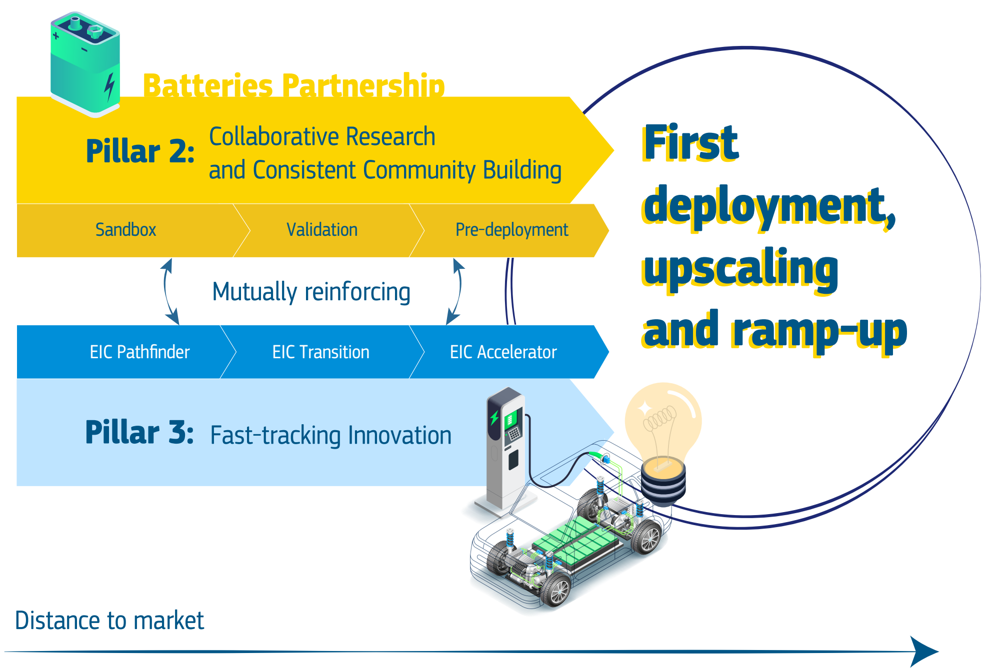
BATT4EU Partnership	European Innovation Council
Structural support	Periodic calls
Whole value chain	Narrow topics
Based on pre-agreed SRIA	Ad hoc interventions
Collaborative research	Boost for one or few stakeholders
Community building	Targeted exchange

Comparison between Horizon Europe BATT4EU Partnership and the European Innovation Council.

[29] EIC Funding Opportunities

[30] Battery Startups & Investors Forum

The community-building efforts of the BATT4EU Partnership ensure that there is a broad pool of high-quality applicants who could apply for the EIC grants. Graduates from the EIC Pathfinder calls can validate their results with industry stakeholders in the collaborative Horizon Europe calls, while results from the Horizon Europe projects can be boosted through the EIC Accelerator. Collaboration and alignment between the EIC and BATT4EU have been excellent under the current Horizon Europe programme, culminating in the joint event for Battery investors and startups in May 2026[30].



MOBILISING DEPLOYMENT FUNDS

The European Competitiveness Fund and the Innovation Fund take developments across battery value chain to industrial deployment. Their full potential is realised when they receive a steady pipeline of de-risked, ready-for-deployment projects, which is exactly what a well-functioning Batteries Partnership produces. The following are the battery industrial (first) deployment considerations where ECF and IF intervention would have the greatest strategic leverage by supporting scale-up and/or ramp-up (i.e., both CAPEX and OPEX). This is not a closed or exhaustive list.

- **Supporting the production volume of existing gigafactories** (current battery generation technologies)

> Output-based support during the ramp-up phase, rather than fragmented project-by-project grants, is the model that works, as demonstrated by comparable programmes elsewhere.

- **First-of-kind gigafactory for next-generation chemistries**

> Particularly solid-state batteries, Sodium-ion batteries and European-IP LFP and LMFP, where capital intensity and ramp-up risk exceed what private markets will absorb.

- **Industrial-scale battery recycling and refining facilities, particularly for black mass processing and critical material refinery and recovery.**

> These require large upfront capital but deliver strategic supply chain sovereignty that market signals alone will not incentivise sufficiently.

- **European battery equipment and machinery manufacturers scaling to serve gigafactory customers.**

> Reducing reliance on Asian production line equipment anchors process know-how in Europe and reduces a dependency that persists even when cells are manufactured domestically.

- **Large-scale stationary battery energy storage systems for grid stability, renewable integration and energy security**

> Where long project lead times and regulatory complexity deter private investment at the scale and speed needed.

- **Advanced materials production at industrial scale** (cathode and anode active materials, electrolytes, separators),

> where European players have R&I-backed IP but lack the capital to move from pilot to commercial volumes. The upstream value pool (roughly half the global battery value chain by 2030) makes strategic intervention economically justified.

- **Battery solutions for defence, dual-use and strategic mobility** (drones, forward operating base energy, naval and aerospace systems)

> Where European security and strategic autonomy objectives create a public interest that commercial markets alone will not adequately serve.

In all these areas, the partnership and the deployment funds are sequential, not competing. The partnership de-risks the technology and builds the industrial community. The deployment funds provide the capital to scale. The Scale-Up committee could make this handoff systematic and fast. Getting this right is Europe's most important near-term step toward translating R&I excellence into industrial leadership.

CONCLUSION

Batteries are foundational to Europe's competitiveness, security and climate neutrality. They underpin zero-emission mobility, renewable energy integration and grid resilience, and they are now equally central to defence, economic security and strategic autonomy. Europe's continued dependence on non-European battery supply chains exposes it to economic, geopolitical and technological risks that fragmented or technology-neutral interventions cannot address on their own.

Europe holds the essential ingredients for leadership: a world-class research base, a strong industrial heritage, and the most advanced sustainability and circularity framework in the world. What has been missing is the sustained, coordinated R&I investment that converts those assets into industrial reality. Recent rollbacks in announced gigafactory capacity are a clear signal that industrial ambition, without a stable and coherent innovation engine behind it, is not enough.

A dedicated Batteries Partnership under FP10 is the instrument that provides that engine. It brings the full value chain, from raw materials to recycling, under a single coherent framework. It maintains a portfolio across chemistries and applications, avoiding lock-in while serving mobility, stationary storage, defence and emerging markets alike. It aligns research, industrial scale-up and regulation, and it shares the risks that no individual actor can carry alone. In doing so, it delivers what standalone instruments cannot: the integrated governance and long-term direction the sector requires.

The Partnership does not stand apart from Europe's wider toolbox; it makes that toolbox work. Building on the proven impact of BATT4EU, it ensures coherence with the European Competitiveness Fund, the Innovation Fund, the IPCEIs and national and regional programmes, mobilising the whole ecosystem, industry, research, SMEs, regions and Member States, around shared roadmaps and measurable outcomes. It is the connective tissue that turns Europe's research excellence and industrial ambition into globally competitive, European-made batteries.

This is not only an industry position. Through the SET Plan, Member States have themselves called for a dedicated battery partnership to be maintained beyond the current Framework Programme. The direction is set and the consensus exists. What remains is the commitment to act on it.

ANNEX

ANNEX A: BUILDING ON BATT4EU SUCCESSES: RESULTS THAT ARE MOVING THE EUROPEAN BATTERY VALUE CHAIN FORWARD

Since the launch of the first wave of BATT4EU projects under Horizon Europe in 2022, the programme has built a strong and diverse portfolio spanning the entire battery value chain[31]. By July 2026, over twenty of these projects have reached completion, supported by almost 150 Mil. Euros funding and delivering tangible results across cell manufacturing, next-generation battery technologies, recycling and circularity, raw materials processing, and sustainability assessments such as life-cycle analysis.

With the first outcomes now available, it shows the technologies advanced, the capabilities developed, and the strategic gaps addressed. The following section highlights the achievements of these projects and demonstrates how their combined progress strengthens Europe's battery ecosystem, accelerates innovation, and builds a more resilient and competitive value chain.

Competitive and Sustainable Battery Manufacturing Technologies

Battery manufacturing is among the most energy- and chemical-intensive stages of the entire battery value chain, and it is precisely here that Europe faces its most acute industrial competitiveness challenge.

Chinese gigafactories, led by CATL and BYD, along with Tesla have invested significantly in optimising conventional electrode processing that use N-methyl-2-pyrrolidone (NMP), a hazardous solvent requiring expensive recovery infrastructure. For Europe, the strategic imperative is therefore not merely to match these competitors on cell energy density or cost per kWh, but to compete by establishing a generation of advanced manufacturing technologies that are inherently cost-efficient, less energy-hungry, and more compatible with the continent's regulatory environment and industrial heritage. BATT4EU's portfolio in this domain reflects a deliberate and complementary strategy. Rather than funding a single approach, the partnership has backed four projects that together cover the full spectrum of alternatives to solvent-intensive manufacturing: the elimination of toxic NMP through dry-electrode and water-based processing (NoVOC), the integration of sustainability and digitalisation tools into production chain design (BatWoMan), the development of a high-performance silicon-anode cell architecture built on solvent-free cathode extrusion and AI-supported processes (greenSPEED), and the design-to-manufacture development of generation 3b LNMO-based cells using both wet and dry solvent-free routes alongside digital twin infrastructure (GIGAGREEN). Each project targets a different segment of the manufacturing bottleneck, and their results, when taken together, provide European industry with a credible technology portfolio from which to build next generation gigafactory processes.

The four projects in this portfolio each address a distinct segment of the manufacturing challenge. First, **greenSPEED** functions as Europe's most integrated systems demonstrator: it assembles solvent-free cathode extrusion, high-silicon anodes, electrochemical prelithiation, and AI-supported process control into full 21700 cylindrical cells, providing automotive OEMs with a validated reference architecture for next-generation green cell production.

[31] BATT4EU Project Portfolio

BatWoMan, operates at the factory design level: it quantifies the energy and cost savings achievable by reducing dry-room footprint, optimising formation protocols, and embedding a publicly deployed Digital Product Passport aligned with the forthcoming EU Battery Regulation.

NoVOC, takes a deliberately risk-mitigated approach by developing aqueous wet-processing and dry-electrode routes in parallel for both cathode and anode, targeting automotive-grade cells at 75 to 85 EUR/kWh.

GIGAGREEN, pushes further up the chemistry value chain by coupling these same solvent-free manufacturing innovations to a next-generation LNMO/Si-C cell chemistry targeting 370 Wh/kg and over 3000 cycles, demonstrating that achieving step-change performance does not come at the expense of green manufacturing.

Taken together, these projects provide to the European industry a publicly validated, multi-route technology portfolio for NMP-free battery manufacturing, backed by life cycle assessment, digital infrastructure, and demonstrators across multiple cell chemistries and formats.

GIGAGREEN's own LCA makes the strategic case for European location: manufacturing the same cell in Belgium rather than China reduces the energy-related carbon footprint from 72.8 to 15.2 kg CO_2 equivalent per kWh, a 79% reduction, driven by Europe's cleaner electricity mix.

Solid-State Batteries

Solid-state batteries (SSB) are widely regarded as the defining technology transition for the battery industry over the next decade. By replacing liquid electrolytes with solid materials, they promise step-change improvements in energy density, safety, and operating temperature range: the three barriers that currently limit electric vehicle range, constrain aviation electrification, and complicate battery integration in demanding environments. Toyota, Samsung SDI, CATL, and QuantumScape have each committed billions to SSB development, and both China and the United States have made SSB industrialisation an explicit industrial policy priority. Europe enters this race with a structural advantage it must not squander: a broad, publicly funded research base that has been de-risking the core scientific challenges since Horizon 2020, and which is now producing results at prototype scale under BATT4EU projects.

Between 20 and 30% of the total BATT4EU budget has been channelled directly or indirectly at SSB technology: a deliberate, escalating programme running from materials science (EUR 32M under Horizon 2020) through manufacturing development and interface science, to an almost EUR 100M co-development envelope in 2026 Work Programme.

Crucially, Europe is not placing a single technology bet. The funded portfolio covers the three main SSB electrolyte families: halide ceramics, polymer systems, and hybrid oxide-sulphide ceramics, each with distinct safety profiles, processing routes, and application targets. This diversification mirrors the industrial reality that no single SSB chemistry has yet proven itself at scale, and it positions Europe to be a relevant partner or supplier across whichever pathway reaches commercialisation first.

Importantly, this diversification extends beyond materials to end-use applications, spanning not only automotive but also sectors such as aviation, where performance requirements drive different battery design choices. These varied application pathways also provide valuable opportunities to develop manufacturing expertise and scale-up strategies that can support much larger demands of electric vehicles.

The three projects HELENA, PSIONIC, and ADVAGEN, collectively demonstrate that European research has moved decisively beyond proof-of-concept.

HELENA (halide electrolytes) has progressed from 2 mAh laboratory cells to 10 Ah multilayer pouch prototypes assembled in an industrial environment, the scale at which Tier 1 suppliers begin serious evaluation. It has simultaneously developed a recycling framework for halide SSBs, anticipating the EU Battery Regulation's end-of-life requirements before the technology has even reached market.

PSIONIC (polymer electrolytes) is exploiting an existing European industrial asset: the coordinator (Blue Solutions) already manufactures solid polymer electrolyte batteries commercially, and the project is engineering the next generation of that process, specifically solvent-free extrusion, and UV crosslinking, to achieve high-voltage compatibility and room-temperature operation. This is not laboratory chemistry being handed to industry; it is industry driving the chemistry.

ADVAGEN (hybrid ceramic electrolytes) is the furthest from commercialisation and the most technically ambitious, targeting room-temperature solid-state cells for mainstream EVs using a hybrid electrolyte architecture designed to combine the conductivity advantages of sulphides with the stability advantages of oxides.

Battery Recycling & Circularity

Europe's dependence on imported CRMs is one of the most acute strategic vulnerabilities of the battery value chain. Closing the loop through domestic recycling is not only an environmental imperative but a geopolitical and industrial one. The EU Battery Regulation sets binding recovery targets (Ni, Co, Mn >95%; Li >80% by 2031), and the race to build compliant, competitive recycling capacity is now underway globally. Four BATT4EU projects — RESPECT, RHINOCEROS, FREE4LIB, and BATRAW — have collectively demonstrated that Europe has the scientific and engineering depth to lead this transition.

The most significant shared innovation across these projects is to move away from conventional shredding of entire battery packs towards earlier, more targeted intervention.

RESPECT has demonstrated at pilot scale a pre-treatment line that separates graphite from copper current collectors at the module level — before contamination occurs — yielding graphite fractions with over 95% carbon purity and reversible capacity of 351.6 mAh/g, fully matching battery-grade specifications. This is a breakthrough with direct industrial relevance: battery-grade graphite has been predominantly sourced from China, and a European recycling route for this material addresses a strategic gap that primary mining cannot quickly fill.

On hydrometallurgy, **RESPECT** and **BATRAW** have both demonstrated pilot-scale production of high-purity leachates and metal sulphate salts. RESPECT processed 100 kg batches of Ni-rich black mass with near-complete removal of Cu, Fe, and Al impurities, and crystallised Mn and Co sulphate salts at greater than 99.6% purity — the precursors needed for new cathode synthesis. BATRAW developed and patented a selective Mn recovery process achieving 100% Mn recovery as $Mn_xO_y(OH)_z$ during leaching and validated electrochemical lithium recovery on real leachates. These are not only laboratory discoveries: they are results at a scale and purity level that industrialists can evaluate for commercial deployment.

Direct recycling — regenerating cathode active materials without full dissolution — represents the next frontier, and European projects are at its leading edge. **FREE4LIB** demonstrated that hydrothermal relithiation of spent NMC622 cathode material restores performance to commercial quality, confirmed by XRD and electron microscopy. **RESPECT** is combining solvent and thermal binder-removal strategies for direct recycling of both NMC and LFP black mass. If these routes scale successfully, they offer energy savings of up to 75% and CO_2 reductions of up to 90% versus conventional processing — figures that would make European-recycled materials not only cleaner but cost-competitive.

The projects have also addressed the upstream challenge of dismantling, where the diversity of EV battery pack designs creates a major bottleneck. **FREE4LIB** achieved a 50% reduction in dismantling time using a robotic system trained on AI vision at TRL 5. **RHINOCEROS** developed reinforcement-learning-based disassembly planning at the University of Agder, now transitioning to a digital twin environment. Both approaches are essential if recycling throughput is to scale with the wave of end-of-life EVs arriving from 2027 onwards.

BATT4EU projects like **BatteReverse, Rebelion, Recirculate**, and **Reinforce** are also tackling the complementary challenge of reverse logistics, developing scalable systems to efficiently collect and channel the growing volumes of end-of-life batteries into the recycling pipeline.

Finally, the four projects have together advanced the digital infrastructure that the circular battery economy requires. BATRAW and FREE4LIB have both deployed Battery Passport platforms with blockchain-anchored traceability, AI-assisted querying, and tiered data sharing.

In addition to these recycling projects, the **TranSensus LCA** project delivered a key result by establishing a harmonised and consensus-based life cycle assessment methodology for zero emission road transport. It provided consolidated guidelines covering environmental and social LCA, along with clear reporting rules, enabling consistent and comparable sustainability assessments across the battery value chain. Supported by validation with industry stakeholders, the project also introduced a European wide data structure for life cycle inventories, addressing a critical gap in robust and scalable impact assessment. Together, these results created a foundation for integrating LCA into future regulation and industrial decision making.

ANNEX B: WHAT TO TARGET: STRATEGIC AREAS FOR A RENEWED BATTERIES PARTNERSHIP

Europe's battery research and innovation landscape must span the full value chain, from raw material supply to end-use integration, including advanced materials, and cell design and manufacturing. Across these domains, a consistent structural challenge emerges: bridging the gap between technological research excellence and industrial competitiveness at scale, while ensuring cost efficiency, resilience, and sustainability.

At the upstream level, securing reliable and sustainable access to primary and secondary raw materials remains a critical bottleneck. This challenge is compounded by the need to establish economically viable recycling systems capable of processing diverse and evolving battery chemistries. Progress in this area requires a combination of supply chain diversification, optimisation of refining and recycling processes, and the implementation of lifetime extension and design-for-recycling strategies.

In parallel, Europe must accelerate the industrialisation of advanced materials, translating strong research capabilities into scalable manufacturing. This requires investment in pilot and validation infrastructure, the development of environmentally sustainable and safe processing routes, alignment of material innovation with manufacturability and multi-chemistry compatibility, and the design of novel active and non-active materials to enhance overall cell performance.

At the cell level, competitiveness hinges on mastering high-yield (i.e. low scrap rate), flexible, modular, and energy-efficient manufacturing processes, while enabling the transition to next-generation chemistries and addressing the specific challenges they entail.

Digitalisation, advanced process control, early defect detection, and the development of a robust domestic equipment base and supply chain are key enablers for Europe to close the gap with global leaders.

Downstream, both mobility and stationary applications highlight the importance of system-level integration. In mobility, this includes aligning battery performance with infrastructure constraints, enhancing safety and reliability, and enabling adaptable, cost-effective pack designs. In stationary storage, large-scale deployment depends on regulatory harmonisation, streamlined permitting, and the development of bankable solutions, including long-duration batteries and second-life strategies through battery repurposing. Emerging applications—such as defence, robotics, and other growing sectors—introduce additional technical and operational requirements, underscoring the need for a holistic strategy and resilient midstream and downstream value chains.

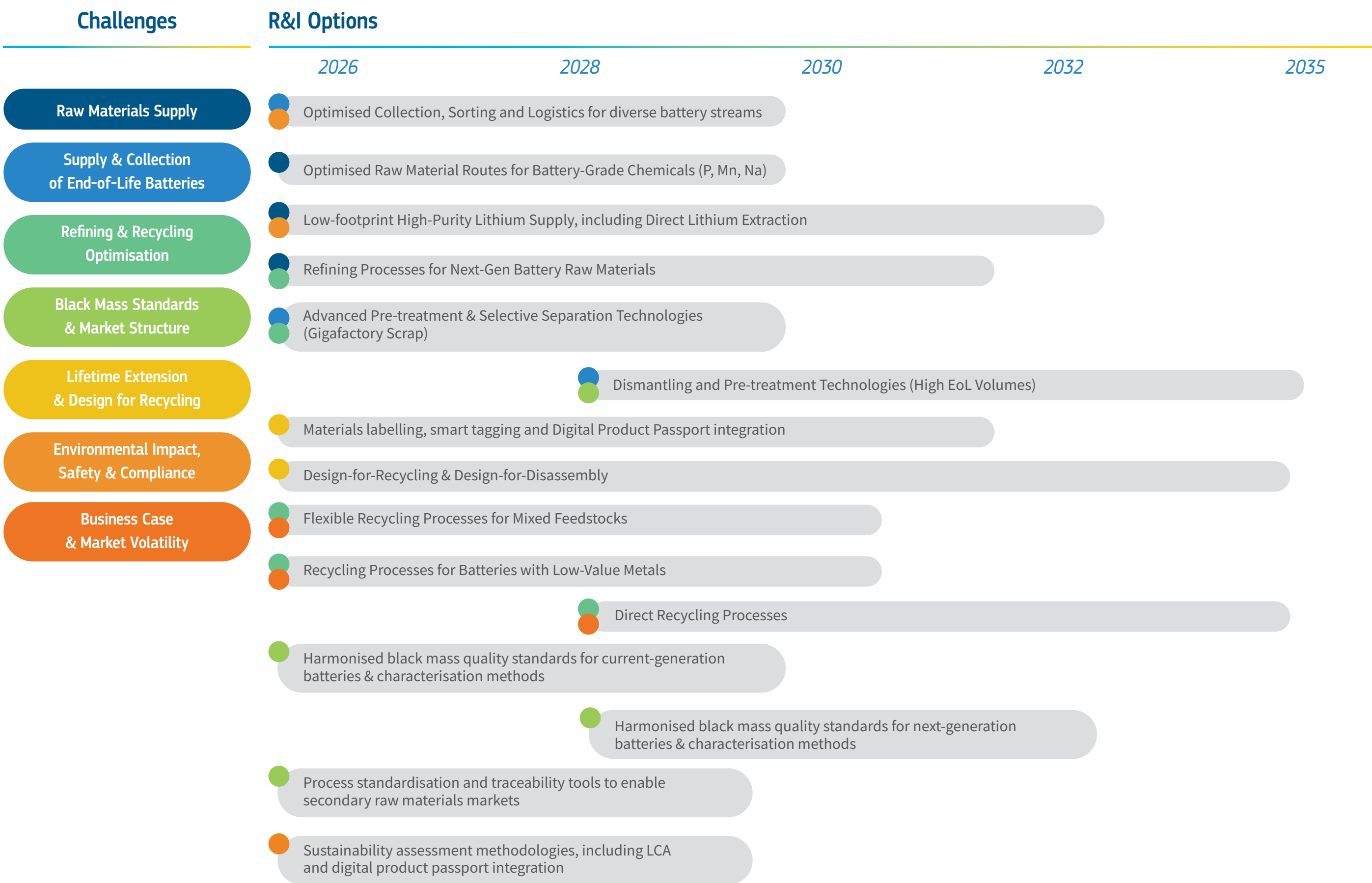
Across all segments, several cross-cutting priorities emerge: sustainability by design, standardisation, digitalisation, workforce development, and critically, the creation of integrated value chains. Europe's success will depend on its ability to coordinate efforts across the entire ecosystem, ensuring that innovation translates into industrial leadership and large-scale deployment. The competitiveness of the emerging battery sector requires a dedicated and coherent strategy to ensure that batteries can effectively power a wide range of strategic industries.

RAW MATERIALS & RECYCLING

This section addresses the full raw materials and recycling value chain, from the sourcing of primary and secondary materials to end-of-life battery collection, processing, and circular recovery. Strengthening Europe's position requires advancing R&I solutions that enable secure, cost-effective, and sustainable feedstock supply, alongside the development of economically viable recycling models adaptable to diverse and evolving battery chemistries.

Innovation plays a key role in unlocking technological progress in energy-efficient refining and flexible, multi-chemistry recycling processes. Avoiding European black mass being shipped to Asia is crucial to ensure it is being recycled in Europe and therefore reducing our raw material dependency with third countries. In parallel, research efforts on design-for-recycling approaches at cell and pack level can significantly enhance material recovery rates and system circularity.

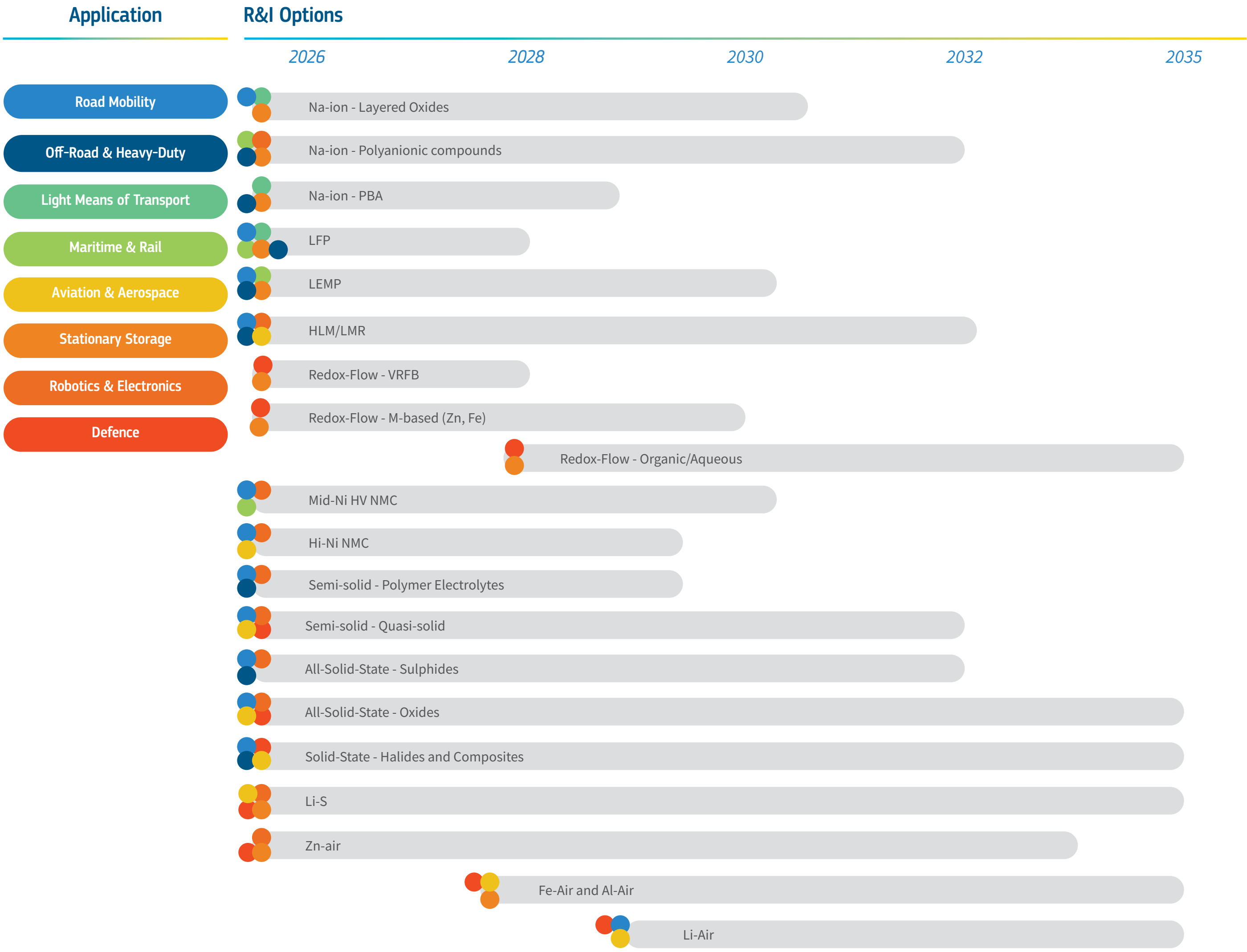
This is the segment where Europe's external dependency is most acute and where research alone cannot close the gap. The actions below are therefore shaped by conditions that sit outside the laboratory: the regulatory classification of black mass, which continues to impede cross-border movement of recycling feedstock; permitting timelines for refining and recycling capacity; the economics of recovering low-value chemistries against a volatile secondary-materials market; and the social licence on which mining, processing and recycling operations depend. Where an action responds to one of these conditions rather than to a purely technical barrier, that is deliberate.



ADVANCED MATERIALS

This section is presented in two parts. The first sets out the “battery chemistry” roadmap: which material systems Europe should advance, for which applications, and over what period. The second sets out the actions on advanced materials process innovation that must run alongside it.

The organising principle is the double diversity of the European battery ecosystem: a diversity of chemistries matched to a diversity of applications. No single chemistry serves automotive, grid storage, heavy-duty transport, aviation and defence equally well, and a portfolio narrowed prematurely to one winning technology would leave European industry exposed on the applications it does not fit. The roadmap below is therefore deliberately plural, while recognising that a portfolio cannot be funded indefinitely in parallel: staged down-selection is built into it, informed by application requirements rather than by technology preference.

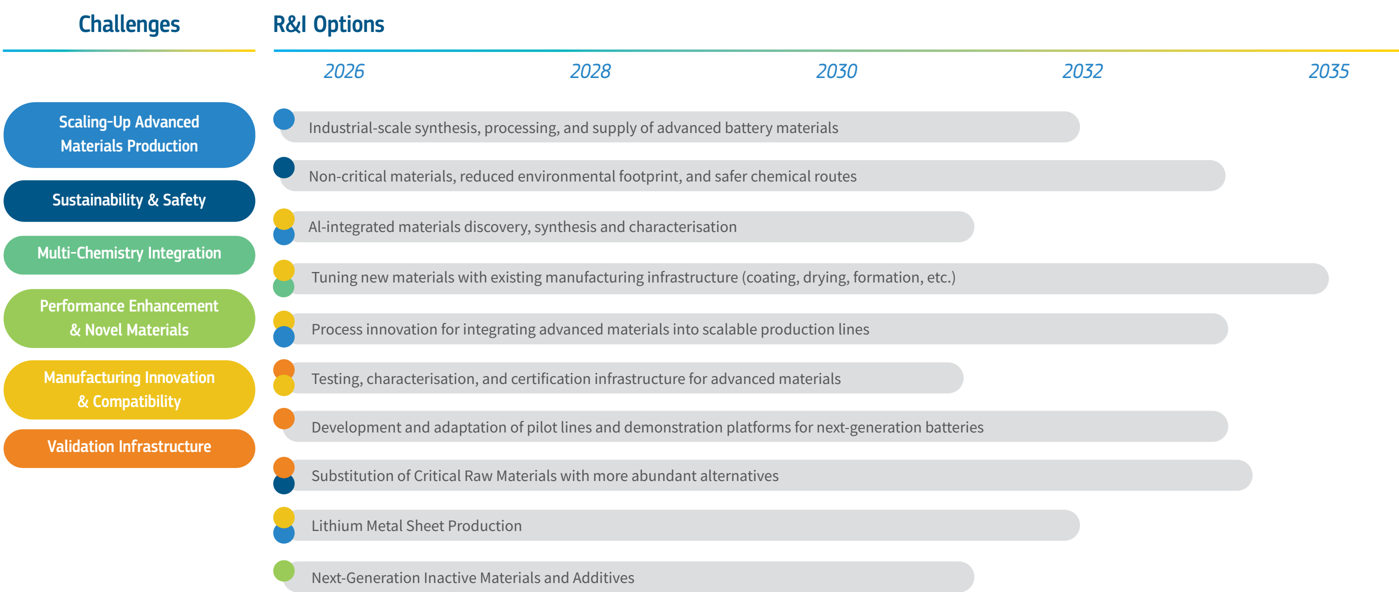


ADVANCED MATERIALS PROCESS INNOVATION

Advanced materials cannot be reduced to a roadmap of chemistries. A material that performs in the laboratory does not become a European industrial product simply because its chemistry has been demonstrated: it has to be synthesised in kilogram and tonne quantities, validated in full cells, made compatible with existing and future production equipment, and qualified against the safety and sustainability requirements of the application it serves. These are overarching actions that apply across every chemistry in the roadmap above, and without them the roadmap does not materialise.

Three bottlenecks recur across the portfolio. The first is scale-up: the gap between laboratory synthesis and the quantities needed for cell-level validation, compounded by a shortage of open-access material scaling pilot infrastructure in Europe, which is far scarcer than cell pilot capacity. The second is interfaces: performance and lifetime in most emerging systems are governed by buried interfaces and interphases rather than by the bulk material, requiring dedicated characterisation, engineering and scalable coating routes. The third is the enabling chemistry around the active material — electrolytes, separators, binders and additives — where fluorine-free and intrinsically safe formulations must be qualified to production standard.

These actions are continuous enabling capabilities rather than discrete projects with a defined start and end: they are required from the outset and must remain available throughout the period covered, running in parallel with each chemistry as it progresses along the roadmap.

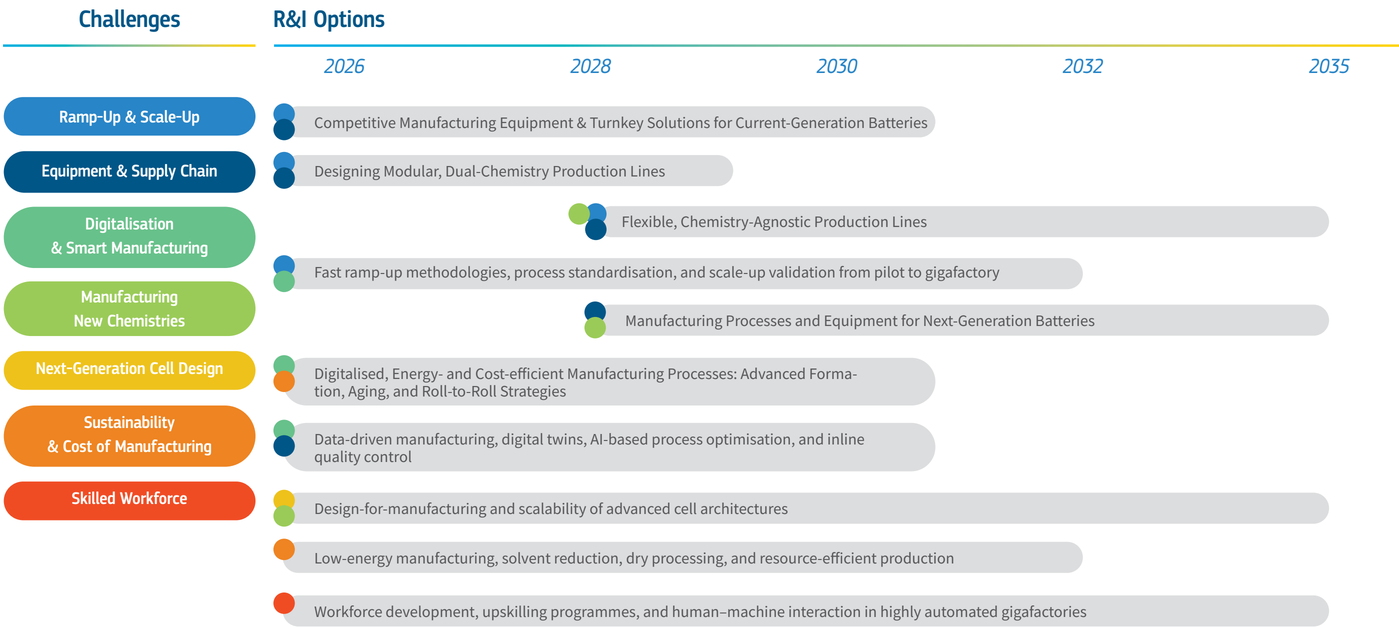


CELL DESIGN & MANUFACTURING

This section covers cell design and manufacturing from pilot-scale validation to gigafactory production. Strengthening Europe's position requires advancing R&I solutions that enable high-yield, cost-efficient, and scalable manufacturing, while ensuring flexibility to accommodate multiple chemistries and evolving cell architectures. Bridging the gap between laboratory innovation and industrial deployment remains a critical challenge, particularly in achieving rapid and reliable ramp-up, reducing scrap rates, and ensuring consistent quality at scale.

Innovation is essential to support the transition towards next-generation manufacturing processes, including digitalised and data-driven production systems, advanced process control, and modular, chemistry-agnostic production lines. Developing a robust European equipment and supply chain ecosystem is equally critical to reduce external dependencies and enable fully integrated manufacturing solutions. In parallel, efforts to align cell design with manufacturability combined with low-energy, resource-efficient processes and workforce upskilling, will be key to ensuring that Europe can deliver competitive, sustainable, and resilient battery production at scale.

Manufacturing is where Europe's cost disadvantage is decided. The gap is not principally one of cell design but of yield, energy intensity, ramp-up speed and the maturity of the equipment ecosystem around the factory — areas where incremental process research delivers disproportionate competitive return. The actions below assume that European production must accommodate several chemistries on shared assets rather than one, and they depend in turn on access to pilot-line capacity, on a workforce with the specialised competences gigafactory operation requires, and on equipment suppliers developing in step with cell producers rather than behind them.

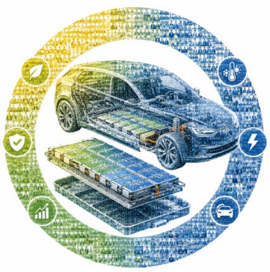


MOBILITY BATTERY INTEGRATION

The mobility segment is structured differently from the others. Here the contributors are end users and integrators, not battery developers: their role is to define what batteries must achieve in each transport mode, the requirements and key performance indicators, leaving the research solutions to the upstream segments. Each application below is therefore presented as its application requirements and KPIs, the technical challenges and targets, and the proposed R&I responses.

PASSENGER CARS & LIGHT-DUTY ELECTRIC VEHICLES

Batteries are the central factor in the competitiveness of the European automotive industry. Cell cost, performance, safety and availability translate directly into vehicle range, charging capability and affordability, and they account for a substantial share of the technological value created in an electric vehicle — which is why the shift of that value creation outside Europe bears so directly on the sector's position. Competitive cells at serial scale require sustained investment across the whole pathway, from materials research and cell development through pilot-line validation and automotive qualification to production engineering, ramp-up and volume manufacturing. R&I for this application therefore has to connect technology development to industrialisation rather than stopping at demonstrated performance.



Battery pack and vehicle-level design

Pack design determines whether cell-level performance survives to the vehicle, under simultaneous pressure from cost, fast charging and chemistry diversity.

Application requirements & KPIs

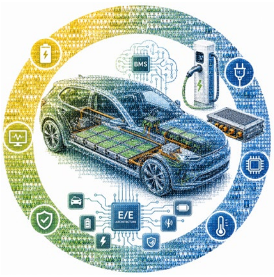
Application requirement (KPI)	Target / value
Fast-charge capability	Pack architectures supporting >1000 A charging currents, with thermal management sized accordingly
Chemistry and format agnosticism	Interchangeable pack designs accepting multiple cell chemistries and formats without redesign
Integration level	Cell-to-pack and pack-to-body architectures reducing mass and part count at competitive cost
Circularity at pack level	Design-to-recycling, repairability and serviceability built in from the outset

Technical challenges & targets

Technical challenge
Charging above 1000 A imposes severe thermal and electrical loads at pack level
Cost targets and safety requirements pull pack design in opposite directions
Each new chemistry has historically required a new pack design, and brings unfamiliar failure modes
Development cycles are too long relative to competitor time-to-market

R&I Options

Develop cell- and format-agnostic pack architectures that absorb chemistry substitution without platform redesign, with safety concepts qualified for the new chemistries
Develop AI-assisted multiphysics pack modelling to shorten development and validation cycles
Develop thermal management for sustained high-current charging, with cost reduction as an explicit design objective
Develop design-for-recycling and repairability at pack level, interfacing with Raw Materials & Recycling



Battery management, charging electronics and E/E architecture

Battery management and charging electronics determine charging experience, battery health and a growing share of system cost, and are the layer through which vehicles interact with the grid.

Application requirements & KPIs

Application requirement (KPI)	Target / value
BMS chemistry coverage	Chemistry-agnostic BMS supporting LFP, NMC, LMFP and emerging systems
Charging capability	Fast, high-power charging with bidirectional and off-grid capability as standard
Component integration	BMS, DC/DC and charging electronics integrated to reduce part count, complexity and cost
Architecture simplification	Simplified, more robust HV/LV architectures, including low-voltage and LV-free concepts

Technical challenges & targets

Technical challenge
BMS is typically tuned to a single chemistry, constraining multi-chemistry platforms
Battery state estimation limits usable capacity and lifetime
Software-defined functions raise functional-safety and cybersecurity requirements
Bidirectional and grid-interactive charging is not yet a default capability

R&I Options

Develop chemistry-agnostic BMS with embedded AI for state estimation, building on the battery-intelligence actions under Cell Design & Manufacturing

Develop integrated BMS, DC/DC and charging-electronics architectures reducing complexity and cost

Develop bidirectional, V2G-capable charging electronics, interfacing with the grid-integration actions under Stationary Applications

Develop functional-safety and cybersecurity validation for software-defined battery functions

System integration, thermal management and periphery

System integration is the level at which the battery meets thermal, structural and safety requirements set by the vehicle rather than by the cell.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Thermal integration	Synergistic HVAC and battery cooling, with liquid and immersion architectures where justified
Structural safety	Cell properties preserved at system level, with crash robustness and thermal-runaway containment
Serviceability and upgrade	Simplified HV/LV connectors and upgrade-friendly architectures extending platform life
Validation capability	Model-, software- and hardware-in-the-loop through to vehicle-in-the-loop validation

Technical challenges & targets

Technical challenge
Component-level optimisation does not aggregate into system-level efficiency
Thermal management is developed separately for battery, power electronics and cabin
Cell-level safety properties are not preserved through pack and vehicle integration
Physical testing across extreme conditions is slow and costly

R&I Options

Develop co-simulation-driven thermal management covering battery, power electronics and cabin as a single system
Develop virtual validation chains through to vehicle-in-the-loop, extended by data-driven methods across extreme conditions
Develop system-level safety validation preserving cell and pack safety properties to vehicle level
Develop upgrade-friendly platform architectures with defined battery interfaces, supporting repair, replacement and second-life recovery

Trucks, Buses & Heavy Commercial Vehicles

High utilisation, long routes and depot/megawatt charging drive distinct requirements from passenger cars. EU fleet decarbonisation targets make this a strategic priority for 2030–2035.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Energy capacity per vehicle	>800 kWh per truck pack (from current 400–600 kWh); modular / swappable architecture
Charging rate	Megawatt Charging System (MCS): >1 MW (from current 150–350 kW CCS)
Lifetime & cycles	>10 years / 1 million km; cell-replaceable packs (from current 5–7 yrs / 500k km)

Technical challenges & targets

Technical challenge
Megawatt charging generates extreme thermal and electrical stress on cells
Pack weight reduces payload — gravimetric energy density is a hard constraint
Depot and en-route charging infrastructure requires BESS buffering at grid connection point
Long daily range requirements demand very high energy per vehicle
Multi-year fleet electrification requires confidence from OEMs and fleet operators

R&I Options

Charging protocols and cell designs capable of sustained >1 MW without accelerated degradation
Develop degradation-aware fast-charging strategies and adaptive BMS adjusting profiles based on real-time cell state
Develop operational frameworks for coordinated depot BESS and MCS management minimising peak grid demand
Pilot demonstrations at 10+ vehicle fleet scale with independently validated lifetime data

eVTOL, Regional Aircraft, UAM & Hybrid-Electric

Zero-emission aviation is a strategic EU priority (Clean Aviation Joint Undertaking). Weight constraints are extreme, safety certification pathways are long, and energy density requirements far exceed current Li-ion. Clean Aviation JU targets entry into service by 2035.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Cell energy density	Up to 500 Wh/kg (CAJU target); from current ~250–300 Wh/kg
Pack energy density	Up to 400 Wh/kg (CAJU target); system demonstrator ≥250 Wh/kg at TRL5 by 2028
Cycle life	>2,000 cycles/year; >20-year service life (from current ~500–1,000 cycles)
Peak discharge rate	Up to 5C peak discharge; 2–3 sustained charge/discharge cycles per mission

Technical challenges & targets

Technical challenge
No approved EU aviation battery safety certification standard exists
Gravimetric energy density must approximately double vs. current state for meaningful routes
Thermal runaway in flight is unacceptable — intrinsic safety is non-negotiable
Fast ground turnaround (15–30 min) requires extreme C-rate charging without degradation
Pack must be replaceable and upgradeable over aircraft service life
CAJU TRL roadmap: demonstrator 2028 → in-flight demo 2030 → entry into service 2035

R&I Options

Prioritise R&I on Li-S and solid-state chemistries at TRL4–6 targeting aviation-grade energy density; validate through Clean Aviation Joint Undertaking demonstrator path
Develop modelling and simulation frameworks for aviation pack safety with emphasis on non-propagation and intrinsic material safety
Coordinate BEPA R&I timeline with Clean Aviation Joint Undertaking milestones

Ferries, Inland Waterways & Short-Sea Shipping

Ferries and inland vessels represent the most immediately realisable marine electrification opportunity. Nordic and Baltic ferry routes already demonstrate viability. Power demands for fast turnaround charging are among the highest in any mobility application.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Discharge duration	Up to 8–12 hours for coastal vessels (from current 30 min–4 h ferry operations)
Charging power	Up to 20–50 MW for fast ferry corridor charging (from current 1–10 MW)
Operational lifetime	>20 years with saltwater corrosion resistance (from current 10–15 years)

Technical challenges & targets

Technical challenge
Turnaround charging at MW scale requires BESS buffering at port
Salt air and humidity impose stringent pack enclosure and corrosion requirements
Battery placement affects vessel stability and weight distribution
IMO and class society certification pathways for marine batteries are immature
Long-duration coastal shipping requires energy densities beyond current ferry BESS
Second-life integration from EV packs could reduce marine BESS cost

R&I Options
Develop coordinated port-BESS and vessel charging frameworks;
Validated second-life battery integration protocols for marine environments including safety qualification

Battery-Electric & Hybrid Rail Vehicles

Battery-electric rail fills a critical gap on non-electrified lines (30% of EU rail network). Requirements differ markedly from road: predictable duty cycles, high reliability, long maintenance intervals and depot/pantograph charging.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Energy capacity per train	Optimised for route length; modular expansion capability (current 200–600 kWh range)
Cycle life	>6,000 cycles over 30-year train lifetime (from current 2,000–3,000 cycles)
Opportunity charging	<5 minutes at stations via pantograph (from current depot overnight charging)

Technical challenges & targets

Technical challenge
30-year train lifetime far exceeds current battery cell warranty periods
Predictable routes allow aggressive BMS optimisation not possible in road EVs
Fire safety in tunnels imposes strict thermal runaway containment requirements
Pack must survive vibration, mechanical shock and temperature extremes over 30 years
Opportunity charging requires very high power in very short time windows
Cost competitiveness vs. diesel hybrid or overhead line electrification must be demonstrated

R&I Options

Develop engineering guidelines for cell-replaceable rail battery packs compatible with standard maintenance intervals
Develop adaptive BMS algorithms leveraging route predictability for lifetime-optimal charge/discharge control

Unmanned Aerial Vehicles, Satellites & Space Systems

Two extremes of the performance frontier. Drones and UAVs demand ultra-high power density and rapid recharge for commercial and defence logistics. Space applications require near-zero maintenance, radiation tolerance and extreme temperature operation — a long-term R&I frontier.

Application requirements & KPIs

Application requirement (KPI)	Target / value
Specific power (UAV pack)	>1,500 W/kg with <5 min recharge for logistics drones (from current 500–1,000 W/kg)
Operating temperature range	-40°C to +60°C (UAV); -60°C to +120°C (space) — vs. current -20°C to +45°C commercial
Space reliability	Zero maintenance; >15-year LEO operational lifetime with radiation tolerance

Technical challenges & targets

Technical challenge
UAV packs require simultaneous high energy AND power density — a fundamental trade-off
Space batteries must survive radiation, vacuum and extreme thermal cycling without servicing
Commercial drone regulations (EU UAS) are evolving — safety certification is a moving target
Defence UAV applications require supply chain sovereignty
Logistics drone operations require sub-5-minute turnaround recharging at depot
Space qualification timelines are very long — R&I must start well ahead of mission need dates

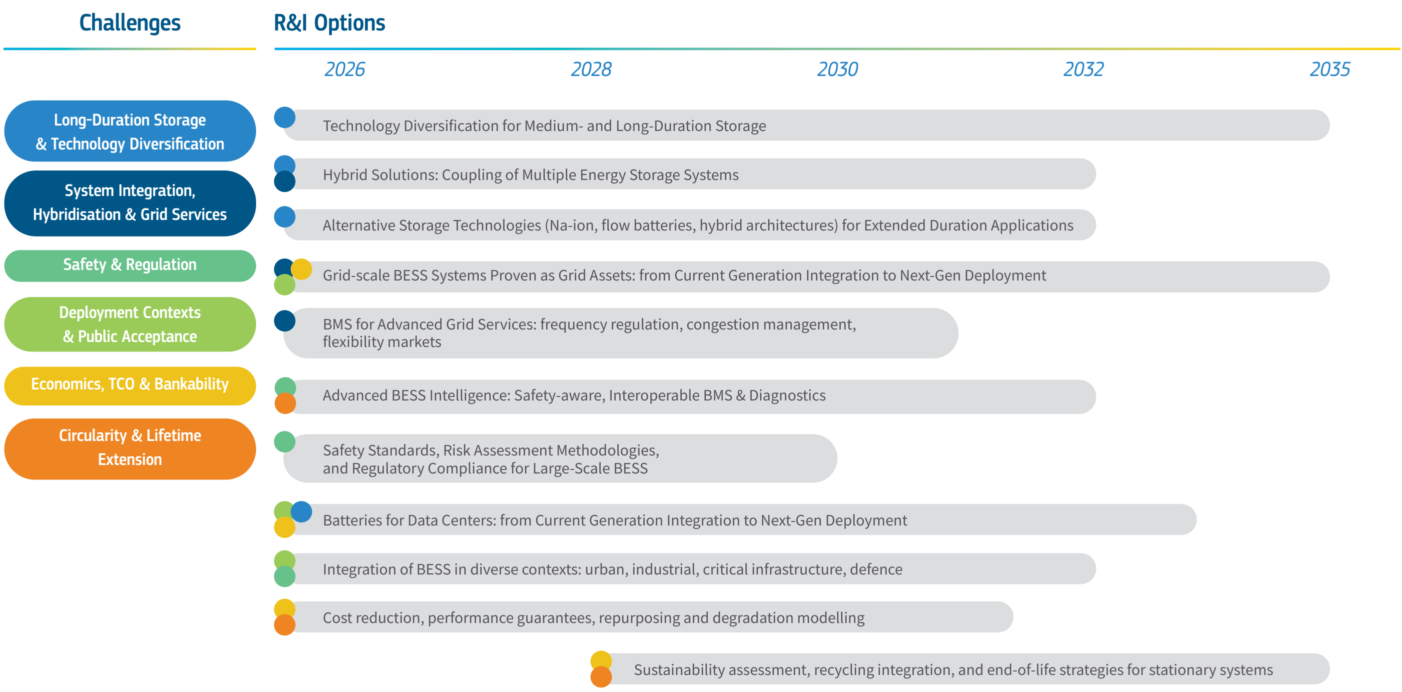
R&I Options
Chemistry or system architecture enabling >400 Wh/kg and >1,500 W/kg at pack level
Develop comprehensive development strategy for EU-manufactured battery cells and packs for defence UAV applications
Collaboration with EASA UAS certification working groups to define battery performance and safety standards for logistics drone category
Develop cell chemistries and charging protocols supporting >6C sustained charge rates for UAV duty cycles

STATIONARY BATTERY INTEGRATION

Stationary storage is the fastest-growing segment of global battery demand: in 2025 it grew by 51% year-on-year against 26% for electric vehicles, with roughly 315 GWh installed worldwide.[1] Europe took some 25 GWh of that[2]. EU policy sets the scale expected: the Electrification Action Plan targets 200 GW of storage by 2030 and 500 GW by 2040, from roughly 55 GW in 2026[3]. Demand is also being reshaped by data centres, whose EU electricity consumption is expected to more than double by 2030 and where grid connection has become the binding constraint on expansion[4]. On-site storage is central to the response, underpinning reliability and enabling facilities to operate on reduced firm capacity.

Meeting this requires more than deploying today's technology faster. Integrating variable renewable generation means durations well beyond eight hours, extending to multi-day coverage, which lithium-ion does not economically provide; the chemistries that can — iron-air, zinc-based, flow batteries and other systems built on abundant materials — are largely not yet at commercial maturity. And Europe has almost no cell or component production dedicated to stationary storage, the segment having been served by capacity and cell designs originally intended for vehicles. Storage-specific cells and the industrial base to make them are a distinct requirement, not a by-product of automotive scale-up.

The destination is clear: by 2040, batteries providing the full spectrum of grid services across both durations, second life matured from demonstration into regulated practice, and end-of-life hubs directing batteries towards reuse, repurposing or recycling. Innovation is what converts that into deployable capacity. These outcomes are limited less by ambition than by evidence that does not yet exist: safety data regulators can act on, lifetime models financiers can underwrite, diagnostics that make a retired pack tradeable, and chemistries proven at multi-MWh scale with credible cost trajectories. The actions below are directed at generating it.



[1] Benchmark Mineral Intelligence

[2] InfoLink Consulting, global energy storage installation data for 2025, reported April 2026.

[3] European Commission, Electrification Action Plan (2026), and the accompanying Tripartite Agreement on Energy Storage, under which Member States, developers, manufacturers and financial institutions have pledged an initial 30 to 35 GW for 2026 to 2028: https://ec.europa.eu/commission/presscorner/detail/en/ip_26_1426

[4] ENTSO-E, Data centres and the power system (April 2026), and the European Commission proposal for a Cloud and AI Development Act, which targets a tripling of EU data centre capacity within five to seven years.

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