Strategic Research & Innovation Agenda

September 2021

BATT4EU

Batteries European Partnership

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List of abbreviations

BAT	Best available technology
BESS	Battery Energy Storage Solution
BMS	Battery Management System
CRMs	Critical Raw Materials
CSA	Coordinated and Support Action
DSO	Distribution System Operators
EoL	End-of-Life
ETIP	European Technology and Innovation Platform
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse gas
GO	General objective
HDV	Heavy-Duty Vehicles
IPCEI	Important Project of Common European Interest
IPP	Independent Power Producer
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LCI	Life Cycle Inventory
MS	Member State
NRCGs	National and Regional Coordination Groups (of the ETIP Batteries Europe)
OEM	Original Equipment Manufacturer
PEFCRs	Product Environmental Footprint Category Rules
PHEV	Plug-in Hybrid Electric Vehicle
R&I	Research and Innovation
RTO	Research and Technology Organisation
SDG	Sustainable Development Goal
SET-Plan	Strategic Energy Technology Plan
SO	Specific objective
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Level
TSO	Transmission System Operator

Executive Summary

The EU aims to achieve climate neutrality – that is, become an economy with net-zero greenhouse gas (GHG) emissions – by 2050.[1] Currently, over three-quarters of global GHG emissions result from fuel combustion used in energy production, construction and transport.[2] To achieve the clean energy transition, electrifying the most GHG-intensive sectors – transport and energy – is a must. Batteries, which are currently responsible for 30% of global GHG emissions reduction, can enable the clean energy transition by helping to decarbonise transport and enable a higher uptake of renewable energy technologies.[3]

The demand for batteries is therefore continuously growing and it is key for Europe to become a competitive player in the global battery production for those applications that will contribute to large GHG emission reductions (the EU industries are not focusing on batteries for consumer electronics and tools). However, less than 1% of global lithium-ion battery cells are currently manufactured in Europe, compared to over 90% in Asia. In this context, Europe needs to catch up in this important area and it will do so by putting environmental sustainability at the heart of European battery production in order to address the ambitions of the green energy transition. Research and Innovation (R&I) is the fundamental pillar of this strategy and will be used to develop a variety of differentiated technologies that will result in a competitive and sustainable European battery value chain.

In 2019, the European Commission launched the European Technology and Innovation Platform (ETIP) Batteries Europe to bring together, in a holistic approach, battery stakeholders from the European battery community to identify the main gaps and needs, create more cooperation and synergies and develop strategic battery research roadmaps paving the way for scaling-up and bringing innovative technologies on the market. The "BATT4EU" public-private co-programmed partnership between the European Commission and the European battery community will mobilise and focus the European R&I resources on developing and delivering the next generation of sustainable batteries. Only such an intense partnership (i.e., a long-lasting and coordinated effort involving industry, research and the public sector) can guarantee the following profound impacts on the European battery value-chain; ensure complementarity between already existing EU battery initiatives; and, give the impetus to accelerate R&I efforts in Europe. Complementary, the upcoming Sustainable Batteries Regulation from the European Parliament and of the Council will ensure that batteries developed for the EU market meet the set standards of safety and sustainability throughout their lifetime.[4]

The vision of BATT4EU is to establish the world's best innovation ecosystem in Europe by 2030; boost a competitive, sustainable and circular European battery value chain; and, drive the transformation towards a carbon-neutral society. It will do so by preparing and equipping Europe to commercialise the next-generation battery technologies by 2030, which will enable the rollout of zero-emission mobility and renewable energy storage.

To achieve this objective and the goals set by the European Commission, BATT4EU has developed a Strategic Research and Innovation Agenda (SRIA). This initial version is expected to be updated from time to time. The current SRIA details six key R&I areas that need to be addressed in order to improve the competitiveness and sustainability of the European battery sector:

Area 1: Raw materials and recycling.

European Li-ion battery end-users are dependent on imported Li-ion batteries and battery producers still import a significant amount of raw materials. More investments are therefore needed in raw material sourcing in Europe. In addition, more focus is needed on recovering valuable metals and materials from end-of-life electronics as this will generate some of the necessary raw materials for the growing Li-ion battery manufacturing sector in Europe. An efficient collection of, and an industrial recycling network for, the end-of-life batteries will also contribute to meeting the high demand for raw materials.

Area 2: Advanced materials and manufacturing.

As advanced materials (cathode, anode, separator and electrolyte materials) largely determine the performance of batteries and make up around 70% of the battery cell cost, it is crucial to focus R&I activities on advanced materials towards improving their performance and reducing their cost. In addition, developing a high-performing European battery cell and mass production capability is crucial. The manufacturing industry will have to benefit from innovation actions in different parts of the battery cell making process focusing on productivity, low environmental impact and quality consistency.

Area 3: Battery end-uses and operations.

The different mobility modes represent around 25% of total CO_2 emissions in the EU and it is expected that mobility demand, as well as resulting emissions, will continue to grow.[5]

Therefore, significant R&I is needed in the field of battery systems for transport and mobile applications to help decarbonise the different modes of transport. In addition, more investment is needed in developing cost-effective energy storage as a precondition to improving grid flexibility and stability which will be critical preconditions for ensuring a higher uptake of renewable energy.

Area 4: Safety.

More investment is needed in developing battery safety, particularly the intrinsic safety of the electrochemical components, to ensure the confidence in and widespread adoption of e-mobility and electrical energy storage. Especially since batteries will form the core of a future circular business model, the overall safety of working with batteries will have to be fool proof to reach the highest economic value (even beyond the first application in transport applications).

Area 5: Sustainability.

Sustainability, with its three key dimensions – economic, social and environmental – has the possibility of becoming the key differentiating factor and competitive edge of the EU battery technologies. More investment is needed to ensure that the sustainability of batteries is developed from a holistic perspective, including tools such as environmental and social life cycle assessments and multi-criteria decision analysis.

Area 6: Coordination.

Since there is still quite some innovation headspace in all parts of the battery value chain, and the use of these batteries in mobile and storage applications is only in an emerging stage, comprehensive and coordinated research and technology roadmaps must be developed both in the short-term as well as long-term. Furthermore, as it will be critical to develop low environmental impact batteries and ensure their reuse and recycling, reliable strategic coordination and alignment across the value chain will be crucial to create tangible economic impact from the research and innovation efforts.

BATT4EU will cover the whole industrial value chain and a wide range of technology readiness levels (TRLs), which will allow for efficient coordination of the selection, implementation and execution of the proposed R&I activities as well as the dissemination of key findings and outcomes. It will do so by, among other things, providing recommendations for calls supported within the Horizon Europe Pillar II work programme; supporting the portfolio of projects funded under the partnership work programme; creating and maintaining networks between the industry, Research and Technology Organisations (RTOs), universities and other battery stakeholders; working with other partnerships to ensure effective collaboration in R&I efforts; ensuring wide dissemination of key outcomes; and, helping increase innovation uptake in the market. The fact that the partnership will be supported by the European Commission on the public side and an association of private entities, including industry actors, research organisations and other associations, on the private side, will help ensure that the partnership considers both the voices of a wide variety of battery stakeholders and the benefits for the general public resulting from the R&I initiatives.

1. INTRODUCTION

The BATT4EU Partnership, and this Strategic Research and Innovation Agenda in particular, are the result of a broad consultation with stakeholders from the European battery value chain. It is thanks to the expertise and hard work of industry and research organisations, an expert shadow group,the inputs by the European Commission and many members of BEPA that you can read this document today. We will count on our stakeholders in the future to keep this document up to date.

Introduction

The European Commission initially approached three associations, EMIRI, RECHARGE, and EUCAR, about the possibility of establishing a European partnership on batteries as part of Horizon Europe. The three aforementioned associations volunteered to lead the process of elaborating the private sector vision for the future possible partnership. They were later joined by EASE and EERA. Together, these associations represent the vast majority of important players from the different segments of the European battery value chain:

- EMIRI for the advanced materials industry and the research community active in battery materials, cells and recycling;
- RECHARGE for the cells and battery industry;
- EUCAR for the automotive application market;
- EASE for the stationary storage applications market;
- EERA for the energy research community.

These associations guarantee a high alignment of positions and worked together to develop the initial partnership proposal. To fill the gap until BEPA, the Batteries European Partnership Association, gathered the private-side stakeholders of the European battery community, a temporary Battery Partnership Shadow Group was put in place. It included industry and research actors representing different segments of the battery value chain. For the sake of efficiency and to guarantee a smooth transition and continuity with the future governance of the partnership's private-side association, preference was given to representatives already well engaged in EU R&I policy, from companies and institutions who could become active members of the partnership's private-side association.

The shadow group included representatives from the following organisations:

Raw Materials and End-of-Life:	METSO OUTOTEC (Finland)
Advanced Materials	UMICORE (Belgium) SOLVAY (Belgium)
Cells and Batteries	NORTHVOLT (Sweden) SAFT (France) MANZ Italy SRL (Italy)
Mobility Applications	TRATON (Germany)
Stationary and Other Applications	EDF (France) ENEL (Italy)
Research Organisations	CIDETEC (Spain) CSIC (Spain) CEA (France) UPPSALA UNIVERSITY (Sweden) SINTEF (Norway)
Supporting Organisations	EMIRI RECHARGE EUCAR EASE

By the end of September 2020, the temporary shadow group had two main objectives:

- Prioritising R&I topics for the Horizon Europe 2021-2022 Work Programme;
- Elaborating a draft of the SRIA of the BATT4EU Partnership.

This version of the SRIA was finalised at the beginning of May 2021 and, for the sake of consistency, still relied on the members of the initial shadow group. For future updates, BEPA will rely on the inputs of its members, mostly through the working groups. The drafting phase was coordinated in a transparent manner with input from all stakeholders willing to actively contribute to the preparation of the document. The shadow group was responsible for building on the blueprint provided by the partnership proposal document that was published in June 2020. The SRIA preparation was open to any stakeholder along the value chain interested in contributing their expertise to the discussions and drafting of the document. Broad stakeholder involvement was ensured with the direct participation of a large variety of public and private organisations and support from the European associations and technology platforms serving as a multiplier for the community. Representatives of other partnerships were also invited to contribute.

The SRIA drafting process, led by the shadow group and supported by the associations representing relevant segments of the whole battery value chain, used, as a basis, inputs from several documents recently published or under finalisation, including BATTERIES EUROPE Strategic Research Agenda; BATTERY 2030+ long-term roadmap; STRIA roadmap on Electrification; SUSCHEM SIRA.

The BATT4EU Partnership SRIA thus includes a description of research and innovation activities needed to achieve competitive, sustainable European battery manufacturing and to enable zero-emission mobility and renewable energy storage integration. It details the technical and specific objectives, sets milestones and provides a timeframe for R&I activities and their expected outcomes.

The document covers the following aspects:

- **Overall context:** State of the art on R&I batteries and links with EU policy objectives.
- **Challenges, vision, objectives and scope of the partnership:** the added value of having a Batteries European Partnership, vision and ambition, strategic objectives and expected impacts.
- **Identified R&I areas, multi-annual agenda and planning process:** Implementation plan and timeframe for each R&I activity identified.
- **Implementation aspects:** budget and needed investments, governance, openness and transparency of the partnership; synergies with other initiatives.

2. OVERALL CONTEXT

The BATT4EU Partnership and this Strategic Research and Innovation Agenda do not exist in a vacuum. They are part of the European Green Deal and the global push for sustainable development. This chapter will show how the activities of the Batt4EU Partnership tie in to these global and European challenges, and how the Batt4EU Partnership fits within the European battery research landscape.

2.1 Context setting and links with EU objectives and climate targets

The EU aims to be climate-neutral– an economy with net-zero greenhouse gas emissions - by 2050. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement.[6]

To achieve the Green Deal objectives, Europe has to implement an accelerated transition from fossil fuels to renewable energy sources. Over three-quarters (76.7%) of greenhouse gas (GHG) emissions are due to fuel combustion. This includes fuel combustion to generate electricity and heat; produce goods; construct buildings and infrastructure; and, move freight and persons.[7]

This transition can mainly be achieved through electrification of key industrial sectors – transport and energy – and batteries are a key enabling technology for both sectors.

As highlighted in a recent report published by the World Economic Forum and the Global Battery Alliance[8], batteries are a key technology to achieve the targeted GHG emission reductions. They are driving reductions accounting for more than 30% of the worldwide GHG emission reductions:

- Enabling decarbonisation of road, rail, air and waterborne transport which account for 16% of global GHG emission reductions;
- Enabling massive use of variable renewable energies, contributing to energy security and quality, and enabling access to electricity in developing countries, which accounts for 23% of global GHG emission reductions.

2.1.1 CONTRIBUTION TO SUSTAINABLE DEVELOPMENT GOALS

Besides decarbonisation, this report also illustrates how batteries contribute to the UN SDGs (Sustainable Development Goals) directly and indirectly (see Figure 1). For example, they enable decentralised and off-grid energy solutions. Bringing energy to the 850 million people without access to electricity today can increase productivity, improve livelihoods and improve health on a large scale. The benefits of bringing electricity to off-grid communities reach beyond access to affordable clean energy. Providing power solutions to these communities contributes to the following SDGs:

SDG 2. Zero hunger: batteries enable better food storage through refrigeration, enable the use of electric pumps for land irrigation and ensure the supply to off-grid zones.

SDG 3. Good health and well-being: battery-based technology replaces fuel-based lighting and cooking sources, thereby reducing toxic fumes; batteries also help to stabilise the medical cold chain and to power remote local health centres.

SDG 4. Quality education: batteries enable children to study after sunset and provide electricity to schools in remote areas.

SDG 6. Clean water and sanitation: batteries improve clean water supply as they enable the use of electric pumps.

SDG 7. Affordable and clean energy: by providing energy storage solutions, batteries contribute to increasing grid flexibility and stabilisation as well as bringing electricity to off-grid communities.

SDG 10. Reduced inequalities: batteries help improve economic opportunities as they provide access to basic services, such as lighting, phone charging and access to (nutritious) cold chain products.

Batteries could also create 10 million safe and sustainable jobs around the world, with a direct or indirect impact on SDGs 1 (no poverty), 2 (zero hunger), 5 (gender equality), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure) and 16 (peace, justice and strong institutions).

From this perspective, there is a need to set up the Batteries European Partnership to ensure more effective coordination in moving challenging but very promising technologies to higher TRLs, demonstration activities and pre-industrialisation. The partnership commits to being consistent with and actively contributing to the above-mentioned sustainable development goals.

2.1.2 ZERO EMISSIONS MOBILITY TO REDUCE GHG EMISSIONS AND IMPROVE AIR QUALITY

The major reform of the EU road transport sector policy, known as the "Strategy for Low Emissions Mobility", and its three mobility packages, "Europe on the Move", happened over the past several years. The first (31 May 2017) was an agenda for a socially fair transition towards clean, competitive and connected mobility for all. It contained a Transport Research Agenda (STRIA; SWD (2017)223) with seven roadmaps for areas including transport electrification, and a chapter on batteries.[9] The second (8 November 2017) was about delivering low-emission mobility, with a focus on protecting citizens, industry and workers. A legislative proposal on CO2 standards for cars and vans was finalised and, as a result, emissions will have to decrease by 15% in 2025 and 30% in 2030 for both cars and vans.[10] The third mobility package included the first ever legislative proposal on CO2 standards for Heavy-Duty Vehicles (HDV); and the Action Plan on Batteries.[11]

Zero-emission vehicles are key to enabling the transition to zero-emission mobility and they have a dramatic effect on improving air quality for citizens as well as overcoming health problems, especially in urban areas. Electric vehicle (EV) 'tank-to-wheels' efficiency is a factor of about three higher than internal combustion engine vehicles and emit no tailpipe CO2 or other pollutants, such as NOx, NMHC and PM, at the point of use.[12] EVs also provide quiet and smooth operation and consequently create less noise and vibration.

Even though the battery EV market is rapidly growing, currently only about three out of a hundred new cars are fully electric.[13] The battery contributes to about 50% of the cost and/or value-added of an EV, so the competitiveness of EV with regards to the conventional car largely depends on the battery. The main critical points for battery improvement for zero-emission vehicles are energy density, power and costs.

2.1.3 ENERGY STORAGE TO INTEGRATE MORE RENEWABLE ENERGY

In 2019, the EU completed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy. The new rules introduced by the Clean Energy For All European package will bring considerable benefits from a consumer, environmental and economic perspective.[14] By coordinating these changes at EU level, the legislation also underlines EU leadership in tackling global warming and provides an important contribution to achieving carbon neutrality by 2050 in line with its "2050 long-term strategy". [15]

Considering the intermittent nature of some renewable energy sources, such as solar, wind or ocean energy, the challenge is to secure a constant large-scale energy and electricity supply at all times. At the same time, energy must remain affordable for citizens. Currently, pumped hydro storage is vastly dominating energy storage in the context of electricity systems, with well over 80% share. However, the situation is predicted to change considerably by 2030, with installed battery capacity reaching at least half of the pumped hydro storage capacity.

Hydrogen and e-fuels will become similarly important by then. However, while hydrogen is mainly attractive for its capability for high-volume and long-term storage, batteries are unbeatable from the efficiency point of view and present key assets for energy storage such as cycle life and costs. Batteries are a very promising solution to complement existing ancillary services for grid stabilisation.

2.1.4 CIRCULAR ECONOMY TO SECURE SUSTAINABILITY, JOBS AND GROWTH

The new Circular Economy Action Plan, for a cleaner and more competitive Europe (COM (2020) 98 final) from March 2020[16],requires the consideration of the rules on recycled content and measures to improve the collection and recycling rates of all batteries to ensure the recovery of used materials. Furthermore, it asks for a definition of sustainability and transparency requirements (such as carbon footprint and responsible sourcing or security of supply) to provide guidance to consumers and facilitate reuse, repurposing and recycling.

The Batteries Directive, the only piece of EU legislation entirely dedicated to batteries, is currently being revised. While the evaluation of the directive (published on 9th April 2019) has adopted a broad perspective, some points have received particular attention, namely the management of hazardous substances in batteries, the collection and recycling of waste batteries and the directive's capability to keep pace with technological change. Enabling measures, like those on labelling and information, have also been looked at[17]. Research and innovation will thus play a significant role in introducing new concepts and meeting the possible new targets imposed by the revised directive.

Driven by the ongoing clean energy transition and the uptake of zero-emission mobility, demand for batteries is growing rapidly, making this market an increasingly strategic one at a global level. The European Commission has proposed that the European industry takes up the challenge of becoming a global leader in sustainable battery cell and pack manufacturing, able to compete with current manufacturing bases, mostly located in Asia.

Thus, in October 2017 the European Commission launched the European Battery Alliance[18] cooperation platform and in May 2018 endorsed a Strategic Action Plan on Batteries[19] as part of the "Europe on the Move" package. The action plan aims to put Europe on a steady path towards leadership in this key industry, supporting jobs and growth in a circular economy, while ensuring cleaner mobility and an improved environment and quality of life for EU citizens. Within this action plan, the Commission proposed to explore the feasibility of a public-private partnership to accelerate European battery R&I. In the European Green Deal (COM(2019) 640 final), the Commission announced that it would "continue to implement the Strategic Action Plan on Batteries" and thus continue with developing the Batteries European Partnership.[20]

In line with the priorities of the New Industrial Strategy for Europe, in May 2020, the industry proposed an Acceleration Plan set to create up to 1 million jobs in a European battery ecosystem worth EUR 210 billion by 2022. The European Investment Bank has also supported battery projects along the entire value chain: loans amounting to EUR 1 billion having so far been allocated by the bank, leveraging EUR 4.7 billion in total.

The COVID-19 crisis has further highlighted the importance of the rationale behind the European Partnership in R&I – to bolster Europe's resilience and strategic autonomy in critical industrial sectors and key, game-changing technologies. Moreover, the Commission's Recovery Plan published in May 2020 underlines the importance of the battery value chain several times and states: "the Commission will also focus on unlocking investment in clean technologies and value chains, notably through the additional funding for Horizon Europe."[21]

The initiatives under the partnership will support the European Union's recovery, aimed at building a more sustainable, competitive and resilient economy. In line with policy ambitions, the proposed European partnership will deliver across the following cross-cutting priorities:

- **Climate & environment** - as introduced in the EU Commissions SEP study[22], batteries are critical in efforts to cut GHG emissions and mitigate climate change through their role in bringing secure supplies of clean, low-carbon energy to homes, businesses and vehicles. The use of batteries also allows greater penetration of (intermittent) renewables in the power sector and, thus, helps avoid the negative environmental impacts of fossil fuel-based power.
- **Circular economy** - in relation to resource efficiency, materials in batteries can be recovered, used in multiple lives or recycled, some of them indefinitely, whereas fossil fuels – which are valuable for purposes other than energy production – are burned and lost forever.
- **Health** – the elimination of fossil fuels from the mobility and energy sectors will improve air quality and thus reduce dangerous levels of hazardous particles impacting human health, especially in cities. Electromobility is also important to cut the noise pollution in densely populated areas.
- **Competitiveness** - according to some forecasts [23], from 2025 onwards Europe could capture a significant share of the batteries market, which may, in the long-term, reach a value of EUR 250 billion per annum. The immediate challenge to create a competitive and sustainable battery manufacturing industry in Europe is immense, and Europe has to move fast in this global race.
- **Technological sovereignty and reliability of supply** – safeguarding the security of supply and European industry's ability to export its products as part of a global value chain are vital components of the EU strategic autonomy needed to avoid creating new dependencies and vulnerabilities across the economy and society.

Battery **technological development, efficient and low emission production and widespread use across the value chain** are imperatives for Europe on its transition towards a climate-neutral continent. R&I in these areas is crucial to ensure that European batteries are performant, affordable, sustainable and safe.

2.2 Building industrial leadership for batteries in Europe

2.2.1 GROWING BATTERY DEMAND, GROWING MARKET BALANCE RISK

The demand for batteries is steadily growing. The total rechargeable battery market worldwide in 2018 had a value of EUR 73 billion, of which 44% (EUR 32 billion) were Lithium-ion batteries representing a capacity of over 150 GWh. While the market for energy storage based on NiMH, NiCd or Li-ion technologies has been historically driven by battery demand for consumer electronics, mobility and stationary storage applications are arising as areas offering further opportunities. As illustrated in Figure 2, the mobility sector is expected to drive significant growth in the next decade: by 2030, more than 80% of the demand is expected to come from mobility.

These forecasts are in line with a recent JRC report,[25] which concludes that in the longer term (towards 2040), annual sales of Li-ion battery cells for stationary use and mobility are expected to grow exponentially. Their market value increases from EUR 24 billion in 2017 to about EUR 65 billion in 2025. Even under the most pessimistic projections, by 2040 the number of EVs will be 50 times what it is today (Figure 3).

Figure 2 | Annual Battery Demand (GWh) - forecasted evolution of the electric mobility, stationary power storage, consumer electronics and machinery application areas from 2016 to 2030.

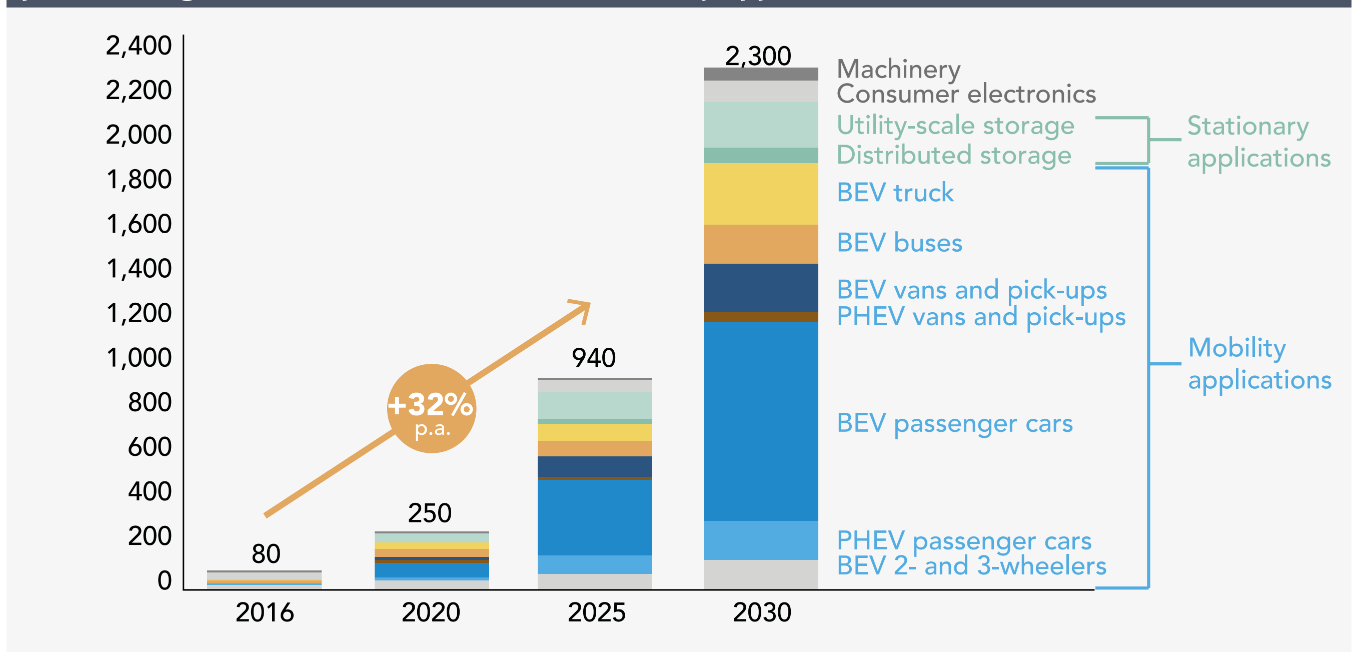
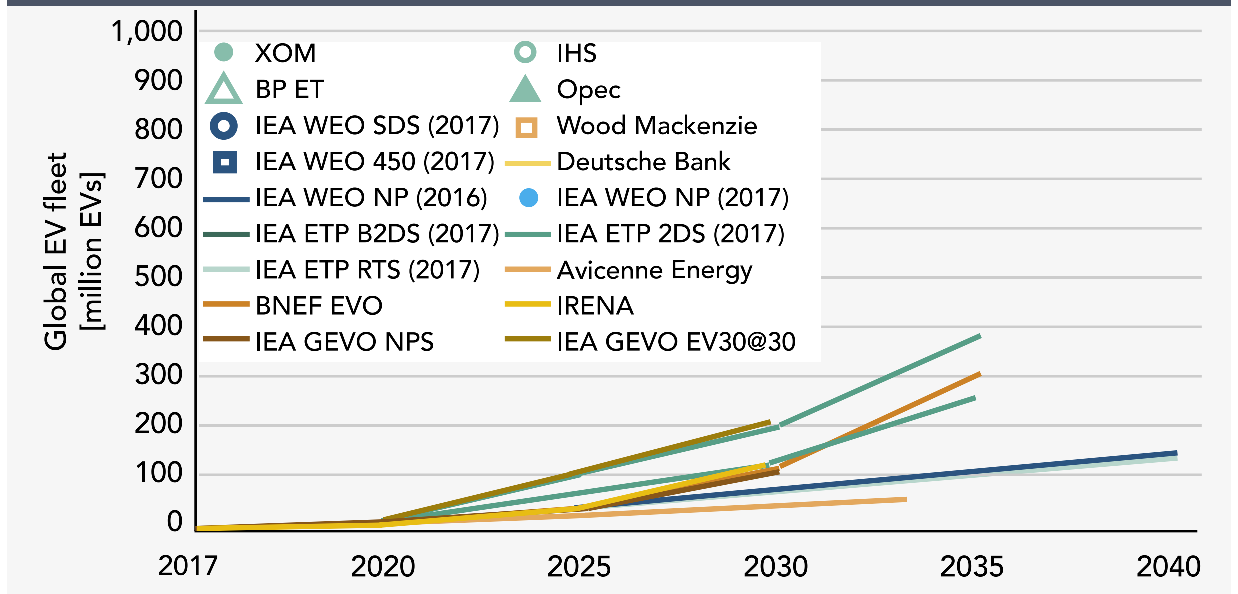


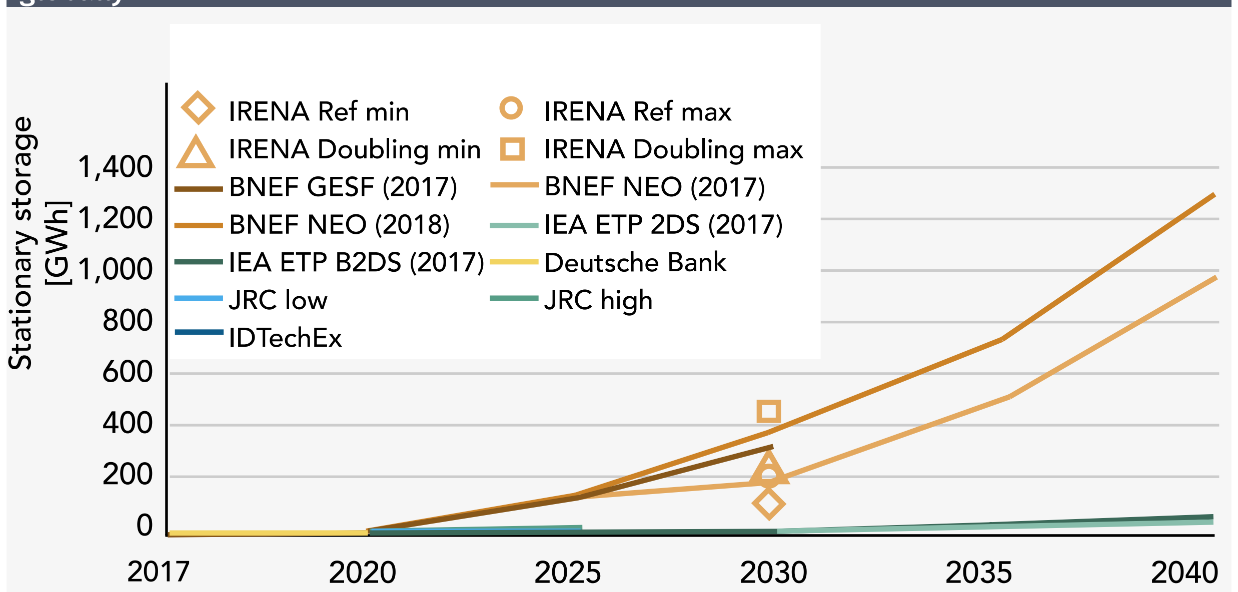
Figure 3 | Projections of the global EV fleet over time. Source: JRC (ref.6) based on different studies and scenarios.



Moreover, more ambitious scenarios (in terms of climate targets) lead to higher levels of EV deployment, and with this, also a rising demand for batteries. EVs alone are projected to demand 65–80%, 80–95% and 90–95% of the total production of Li-ion batteries by 2020, 2025 and 2030, respectively, compared with about 55 % today. In the long-term, the global market for EVs may exceed EUR 200 billion yearly.

The same report concludes that, from a niche application today, Li-ion batteries for stationary storage are projected to increase rapidly over time. In the short-term, most projections see an increase from about 8 GWh deployed in 2019 to between 40 and 80 GWh of annual deployments by 2025. Beyond 2025, the projected steep growth continues: the lowest estimates range from 8 to 100 GWh, and the highest estimates reach 400 GWh in 2030, ultimately leading to cumulated storage installed (covering all battery technologies) of 1,300 GWh in 2040 (Figure 4).

Figure 4 | Projections of total stationary storage installed front- and behind-the-meter globally



The expected global market growth of lithium-ion batteries according to the JRC estimates highlighted in the European Commission communication on the Implementation of the strategic action plan on batteries (April 2019)[26] is further illustrated in Figure 5.

As mentioned in the figure 5, the market demand risk is almost non-existent; the challenge is to ensure the supply. The capacity of industrial lithium-ion battery cell manufacturing in Europe is critically low. Figure 6 represents the market share for lithium cell manufacturing worldwide.

More than 90% of global manufacturing capacity is located in Asia. However, not only the industrial capacity but also know-how, processes, skills and supply chain are concentrated around the regions dominating the market. In addition to the issue of the limited economic benefits due to the small market share, the dependence on the Asian countries raises strategic stability concerns for Europe.

This situation is particularly critical when it comes to the development of EVs in Europe. Indeed, it appears that the vast majority of EVs manufactured in Europe depend on the import of battery cells manufactured in Asia. The status of this value chain has been analysed in a 2017 JRC report,[28] which concludes that EU industries have a production base in all segments of the battery value chain, but it is far from being self-sufficient.

Raw and advanced/processed materials, cell component and cell manufacturing value chain segments in Europe holds a minor share of the market, whereas, in the battery pack and vehicle manufacturing and recycling segments, Europe is among the market leaders. Within the car manufacturing segment, the European industry is expected to maintain its position as it transitions to EV production. The manufacturing of electronic appliances in Asia has represented a significant advantage for the Asian battery industry, facilitating the supply of locally manufactured lithium batteries. In addition, development and support of the battery industry have been considered a strategic objective in Japan, China and Korea for years, leading to strong support for local investment. China has played a predominant role in recent years and the competition is fierce.

As highlighted in the SGI 2019 survey,[29] in the EU, far greater attention is paid to environmental policies, while R&I policies, which deliver the technology to reduce environmental impacts, are less supported. As an example, Figure 7 below illustrates the relative performances of R&I and environmental policies in Europe, the USA and South Korea: R&I support policy in the EU is assessed as less favourable than in the US and South Korea while the reverse is observed for environmental policies.these changes at EU level, the legislation also underlines EU leadership in tackling global warming and provides an important contribution to achieving carbon neutrality by 2050 in line with its "2050 long-term strategy".

Considering the intermittent nature of some renewable energy sources, such as solar, wind or ocean energy, the challenge is to secure a constant large-scale energy and electricity supply at all times. At the same time, energy must remain affordable for citizens. Currently, pumped hydro storage is vastly dominating energy storage in the context of electricity systems, with well over 80% share. However, the situation is predicted to change considerably by 2030, with installed battery capacity reaching at least half of the pumped hydro storage capacity.

Both environmental and R&I policies should go hand in hand. The combination of an accelerated innovation with an improved regulatory framework will provide a strong foundation for European industry's competitiveness. In particular, it is expected that new sustainability requirements applicable to batteries put on the market in Europe (such as carbon footprint or Corporate Social Responsibility) will enable a new competitive field."[30]

Figure 5 | Factsheet based on the JRC Science for Policy Report, Tsiropoulos I. et al. (ref.6).

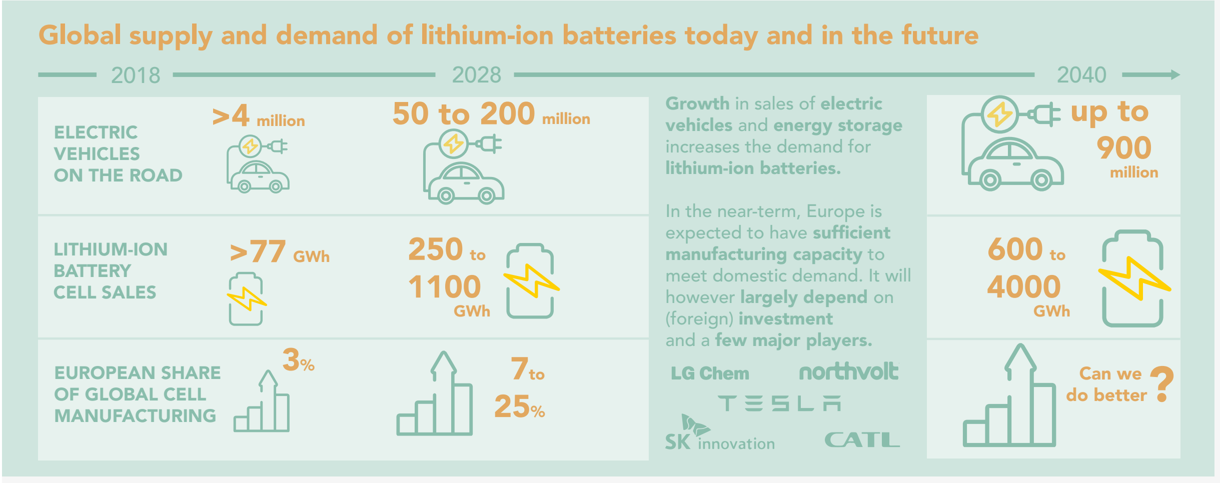


Figure 6 | . Lithium-ion batteries cell production in the world[27]

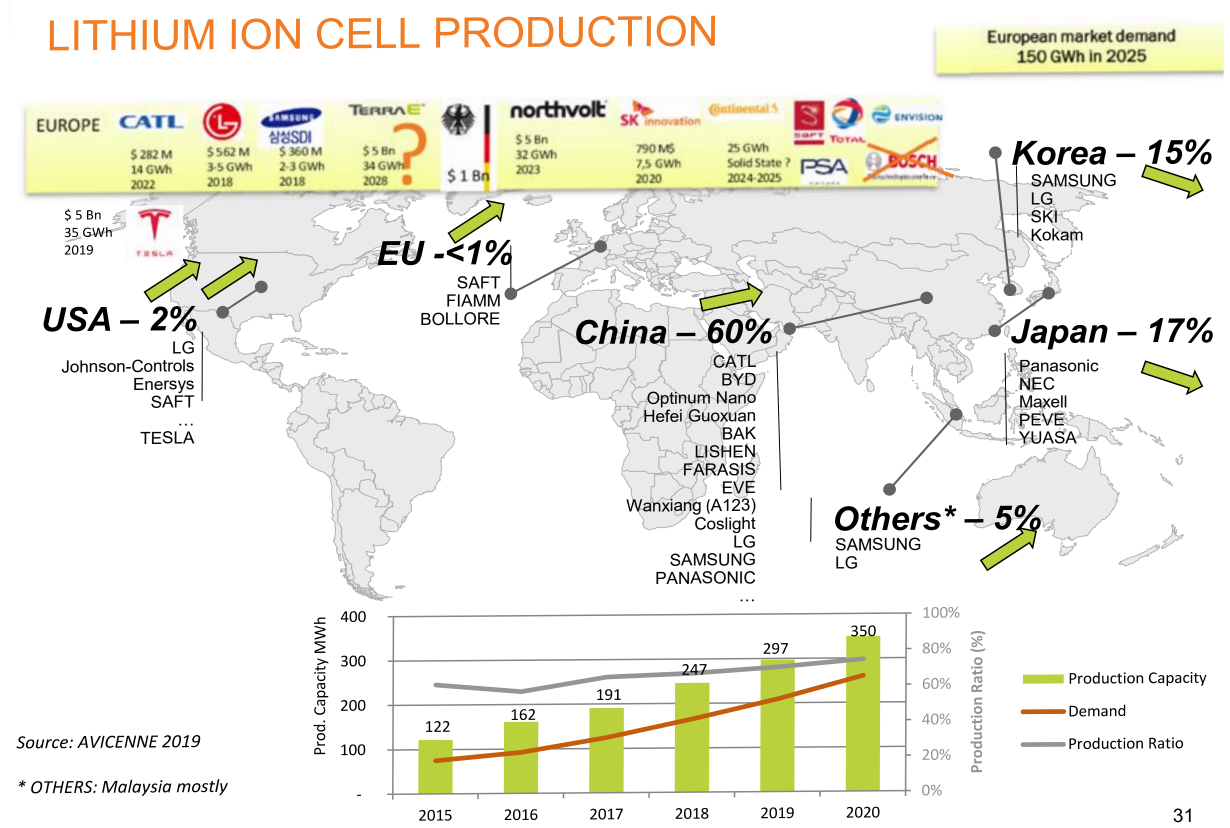
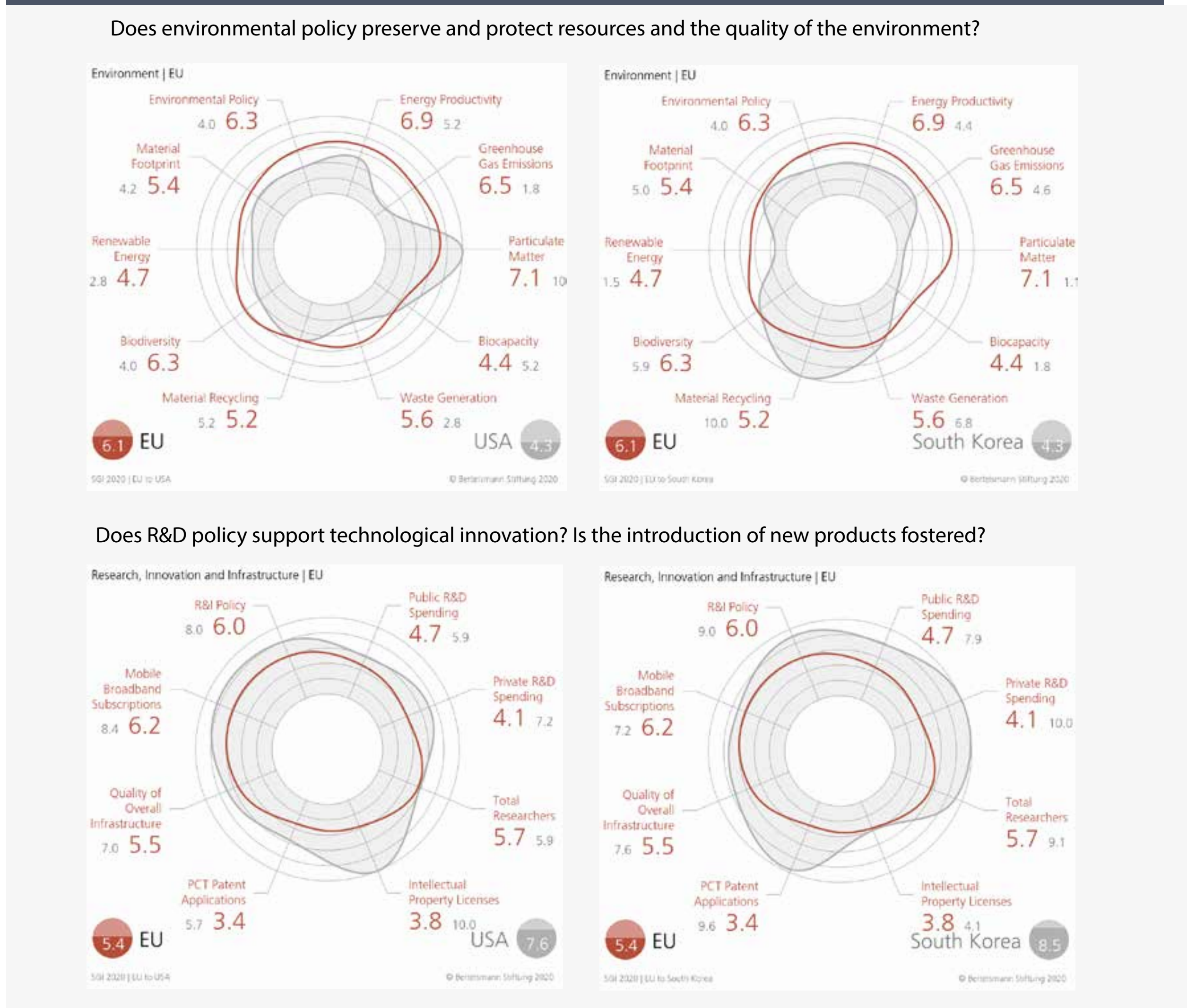


Figure 7 | Comparison of R&I and environmental policies performances in the EU, USA and South Korea. SGI 2020 Survey - © Bertelsmann Stiftung 2020



2.2.2 ESTABLISHING INDUSTRIAL CAPACITY IN EUROPE

Several strong industrial and innovation alliances are springing up across the value chain, including:

- Mining in Finland, Portugal, Spain and the Czech Republic;
- Cathode materials in Belgium, Finland, Germany and Poland;
- Other battery materials in Belgium, France and Italy;
- Cell manufacturing in Sweden, Germany, France and Italy, with additional announcements in Slovakia and the Czech Republic;
- Battery packs in Germany and Poland; and,
- Recycling in Belgium, Germany and Poland.

In December 2019, the European Commission approved a first Important Project of Common European Interest ("IPCEI")[31] under EU State aid rules. The project was jointly notified by Belgium, Finland, France, Germany, Italy, Poland and Sweden to support research and innovation in the common European priority area of batteries. The seven Member States (MSs) will provide in the coming years up to approximately EUR 3.2 billion in funding for this project, which is expected to unlock an additional EUR 5 billion in private investments (Figure 8).

Figure 8 | The direct participants, the Member States supporting them and the different project areas of the 1st IPCEI on batteries.

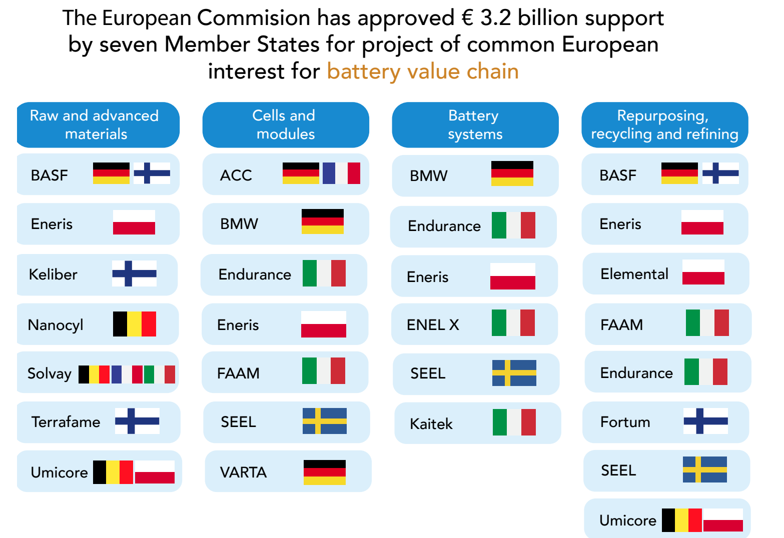


Figure 9 | The direct participants, the Member States supporting them and the different project areas of the 2nd IPCEI on batteries.

A second project complements the first IPCEI and using the same investment scheme was approved by the Commission in January 2021. Called "European Battery Innovation", this project was jointly prepared and notified by twelve Member States (Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain and Sweden) who will provide up to EUR 2.9 billion in funding in the coming years to further support research and innovation in the battery value chain (Figure 9).

The "EuBatIn" IPCEI is more open to embracing different types of cell chemistry and battery technology and employing novel production processes, i.e., more flexible and energy-efficient processes such as dry coating or battery cell formation procedures with a reduced CO_2 footprint. These processes aim to diversify battery production for differentiated application, not only in the mobility sectors but also energy storage and industrial, marine and consumer electronics.

The quick establishment of these two IPCEI project consortia is vital for Europe to prepare the deployment of its own manufacturing capacity at scale, thereby establishing a competitive European battery industry. This is only possible thanks to R&I, which is beyond state of the art, and pre-commercial activities supported by these projects. These MS investments in companies are critical for reinforcing the autonomy and technological sovereignty of Europe in a key industrial sector such as automotive, one of the big employers of the European economy (which represents 2.5 million jobs in manufacturing in the EU).

2.3 European research and innovation on batteries so far

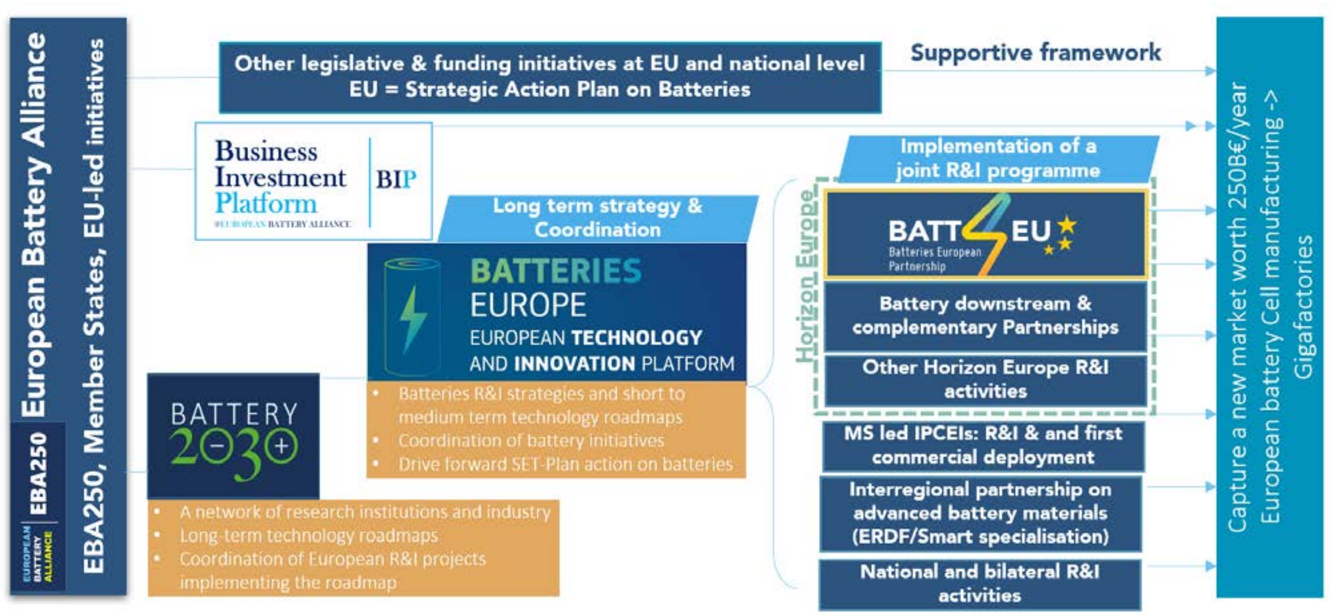
2.3.1 SET-PLAN & BATTERIES EUROPE: EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

The Strategic Energy and Technology Plan (SET-Plan), adopted by the European Union in 2008, was a first step to establishing an energy technology policy for Europe, covering a broad range of energy technologies, including Action 7 on batteries. A temporary working group was created in March 2017, which made the first attempt at setting technological targets, identified R&I activities and proposed relevant funding opportunities.

In 2019, the Commission upscaled and formalised the work done in the temporary working group and launched a European Technology and Innovation Platform (ETIP), “Batteries Europe”, to advance battery research dialogue bringing together the industry stakeholders, the research community and the EU MSs to foster cooperation and synergies between relevant battery research programmes.

This platform elaborates the global strategic R&I agenda for batteries – overarching all TRLs, stages of the value chain and applications – and delivers a broad range of technology roadmaps. It monitors and coordinates the numerous battery-related research programmes launched at EU and national levels, as well as private sector initiatives.

Figure 10 | Anticipated scheme of the European battery R&I ecosystem.



An EU R&I partnership is now needed to ensure timely and effective take-up of the opportunities – provided by the next generations of sustainable batteries – that have been identified and implement a coherent and strategic R&I agenda through mobilising resources and commitments from industry, research and other organisations with the support of Member States. The involvement of a broad stakeholder base ensures a joint vision on priorities across the battery value chain and enables participants in all MSs to join forces on the selected R&I activities.

2.3.2 HORIZON 2020 SUPPORT FOR BATTERIES R&I

Horizon 2020 alone has granted EUR 1.34 billion (2014-2020) to projects for energy storage on the grid, low carbon mobility and more, including battery energy storage. Up to 2018, batteries research was scattered across the priority areas; however, the funding level remained substantial – over EUR 250 million were allocated to battery projects in the first four years of Horizon 2020. In 2018, a new dedicated cross-cutting call – “Building a low carbon, climate-resilient future: next-generation batteries” – was included in the revised H2020 Work Programme. The budget for 2019 within this call was EUR 114 million and covered seven topics. As a result, 82 proposals had been received with the total requested EU contribution of almost EUR 500 million, involving almost a thousand participants. Following the evaluation phase, 21 proposals were selected for funding. This demonstrates the high level of engagement and dedication from the R&I community and industry. which requires support to create a firm foundation of knowledge for the growing European battery industry.

One of the strategically most important initiatives funded so far is the coordination and support action “Battery 2030+”. In March 2020, this initiative published the Battery 2030+ roadmap, which advocates research areas that will provide the European battery industry with lower TRLs, disruptive tools and battery technologies to be developed in the long term. Among the budget of EUR 132 million allocated to batteries in the H2020 work programme for 2020, EUR 42 million is allocated to calls in line with the Battery 2030+ roadmap, to start implementing its ambitious goals. Moving forward, the Battery 2030+ initiative will facilitate and monitor the progress of the implementation, ensure access to competences across Europe and identify future research needs and gaps for long-term research.

3 THE PARTNERSHIP'S OBJECTIVES

BATT4EU Partnership is established around a common vision to establish the world's best innovation ecosystem for batteries in Europe by 2030. It aims to boost a competitive, sustainable and circular European battery value chain and to drive the transformation towards a carbon-neutral society. This vision has been translated into concrete objectives what will accelerate the transfer of R&I knowledge to industrial manufacturing and thereby support the development of a competitive EU battery industry beyond 2025.

3.1 Common vision and ambition of the partnership

3.1.1 MAIN CHALLENGES TO BE ADDRESSED

Europe has to move fast. In order to achieve the ambition in the general context described under Section 2., the sector has to face four major, interdependent challenges:

- **Competitiveness:** It must be possible to produce competitive battery solutions in Europe; otherwise, the established players in Asia will further expand their market domination and capture the growing market potential in Europe and elsewhere. Competitivity embraces technical performance, such as energy and power density or lifetime, and affordable costs. R&I is crucial to reach ambitious performance targets; introduce abundantly available, low carbon-intense and low-cost materials; enhance efficiency and lifetime; and, develop cost-effective material processing, cell manufacturing and recycling processes and machinery. Only the combined effects of economies of scale (high volume manufacturing) and technology innovation along the battery value chain will enable Europe to catch up with Asia.

- **Sustainability:** Whilst batteries will indirectly enable massive reductions in GHG emissions, it is crucially important that battery manufacturing itself is done at the lowest possible environmental footprint and in respect of UN Sustainable Development Goals, embracing transparency and respect of international good practices along the entire value chain, including raw materials. Furthermore, the carbon and environmental footprint during the operational life of batteries and at their end-of-life need to be minimised. The industry needs to shift towards a circular value chain. Besides the fundamental work in material research, R&I is necessary to reduce the carbon intensity of industrial processes like refining and manufacturing, to enhance the depth and efficiency of recycling and contribute to implementing a circular economy for batteries.

- **Industrial upscaling:** To satisfy future market demand in Europe, construction of high-volume giga-factories with manufacturing capacities of several 10's of GWh of battery cells is needed. Upstream industries like mining and refining, and components production, as well as downstream industries for battery system manufacturing and integration, will need to multiply their current capacities. Such industries need to be highly automated, energy and material-efficient with the lowest possible environmental footprint, and able to manufacture future battery technologies. Investments will only be executed if the industry can demonstrate its ability to achieve future-proof, cost-effective and sustainable industrial processes exceeding the current state-of-the-art of Asian manufacturers. R&I for advanced refining, manufacturing and recycling methods and machinery, strongly interconnected with material research, will allow these ambitions to be achieved.

- **Market uptake:** Successful and fast market uptake will depend on a number of technical and non-technical aspects. First of all, the integration of batteries into the various functional systems they power is key for customer and market acceptance and can represent up to 50% of the entire system value. Integration needs to be user-specific and user-friendly and faces significantly different challenges between sectors such as automotive, rail, air or waterborne transport, industrial or stationary usages. Integration also needs to take into account the necessary infrastructure (charging, grid connection) as well as end-of-life measures like re-use and dismantling. Furthermore, market uptake depends on policy and regulation concerning materials, logistics, end-of-life as well as application or segment-specific frameworks ruling the usage of the functional system as such. R&I is needed in all these fields, some of which will be very application-specific (e.g., battery modules for EVs), whilst others are transversal across several or all applications (e.g., safety, digital passport and information systems). Finally, strong upstream interaction with policymakers is needed in order to ensure policies and regulation sufficiently anticipate the innovations to come.

The ambitious objectives of mobility, energy storage and industrial strategy can be reached by mobilising financial investments in establishing the manufacturing bases in Europe. However, the goal is not only to catch up but also to become world leaders in battery energy storage technology and its manufacturing. Only through R&I can we deliver breakthrough innovation and disruptive inventions to push the boundaries of the technological performance of materials and chemistries, to increase the effectiveness of manufacturing processes, to ensure smart integration in applications and to guarantee reuse or recycling and sustainability of the whole battery value chain in an affordable way.

Results of R&I developed in the partnership are expected to be rapidly taken up by the emerging industry. Notably, most of the industrial players are taking part in the partnership, thus also considerably shortening the time from lab to market.

3.1.2 VISION AND AMBITION

In light of the aforementioned challenges, the vision and ambition of BATT4EU are as follows:

BATT4EU Partnership 2030 **vision** is to have the best innovation ecosystem in the world in Europe. Thus boosting a competitive, sustainable and circular European battery value chain and driving the transformation towards a carbon-neutral society.

The partnership's **ambition** is to prepare and equip Europe to commercialise the next-generation battery technologies by 2030, which will enable the rollout of zero-emission mobility and renewable energy storage.

3.2 Strategic objectives of the initiative

3.2.1 GENERAL OBJECTIVES OF THE PARTNERSHIP

Mobility and energy sectors face drastic environmental, societal and political pressure to shift towards clean technologies and at the same time maintain jobs and growth. The partnership's general objectives, therefore, encompass (GO1) contributing to climate neutrality through the widespread adoption of e-mobility and stationary electrical energy storage; (GO2) ensuring sustainable growth and industrial leadership by supporting the development of an innovative, competitive and sustainable battery manufacturing industry; and, (GO3) contributing to improving air quality and environmental conditions by providing safer and more sustainable batteries and processes.

General Objective #1:

Contribute to making Europe the first climate-neutral continent by 2050 through widespread adoption of e-mobility and stationary electrical energy storage.

Batteries are a key technology required to decarbonise the European energy system, both:

- in the transport sector (electrification of transport, enabling a shift to sustainable mobility); and,
- in the power sector (stationary energy storage of intermittent renewable energy sources, enabling a clean and secure energy supply).

Supporting the power sector will also have a positive impact on decarbonising industry (via electrification of industrial processes). To make this happen, affordable, sustainable batteries must be quickly available and broadly adopted as key enablers:

- for e-mobility, substituting combustion engines across all transport sectors (road, off-road, rail, air, water); and,
- for an energy system based on renewables, providing the necessary flexibilities, system capacity and grid stability needed under high penetration of variable renewable generation.

In order to provide an overview of the outcomes that could reasonably be expected from the BATT4EU Partnership and in order to be able to monitor and report on the progress of the partnership towards its objectives, a list of Key Performance Indicators (KPIs) was elaborated within the BATT4EU Monitoring Framework (Annex 1). Being successful in achieving the targets suggested in this Monitoring Framework will not entirely rely on the BATT4EU Partnership actions. While the partnership will carry out additional activities to tackle some of the above-mentioned challenges related to market, societal and regulatory uptake, many of them are not under the control of the partnership and will also need to be carried out in parallel. The BATT4EU Partnership will also bring a major contribution to broader additional outcomes not listed (for example the transformation of the energy production system, zero-emission urban areas, market accessibility, leadership position in exports...).

The KPIs identified for the General Objective 1 are the following:

- EU sales of EVs for different transport modes using batteries manufactured in Europe.
- EU installed capacity of EU manufactured battery energy storage systems connected to the grid.

General Objective #2:

Enable European leadership in the battery industry across the value chain and create economic growth and quality jobs in a circular economy, by supporting the development of an innovative, competitive and sustainable battery manufacturing industry and a skilled workforce in Europe.

Batteries represent a new and fast-growing market for Europe across the full value chain. Europe can pave the way towards a circular battery value chain to reduce the raw material and carbon footprint of the European economy, leveraging the European assets in terms of industrial know-how (recycling industry) and regulatory framework (updated batteries directive). The partnership will have to pay particular attention to initial and lifelong education, as skills will be a condition for Europe to catch up in the field of batteries. To make this happen, massive industrial upscaling in Europe needs to occur and be based on:

- available advanced battery materials;
- competitive cell and battery technologies; and,
- BAT (Best Available Technologies) in manufacturing and recycling.

The KPIs identified for General Objective 2 are the following:

- EU battery manufacturing's capacity to be competitive with respect to the rest of the world.
- Creation of new jobs and skills.

General Objective #3:

Contribute to achieving zero pollution for a toxic-free environment, by providing safer and more sustainable batteries and processes in the context of the circular economy (along the whole value chain, including recycling).

Batteries will enable the deployment of fully electric vehicles with zero local emissions of air pollutants (such as NOx), in particular in urban areas. Likewise, batteries will enable other mobility and transportation segments (trucks, buses, rail, off-road, waterborne and aviation) as well as fossil-based power generation to significantly reduce or eliminate emissions. In addition, the entire value chain of battery production and dismantling will be optimised to achieve a fully sustainable process over the whole battery life cycle – from battery-grade raw materials to recycling processes – with minimal carbon emissions and environmental impacts. This will lead to an improved environment and quality of life for European citizens. To make this happen, batteries made in Europe must have the world's lowest carbon and environmental footprint throughout their life cycle, which embraces materials, manufacturing, usage and recycling.

The KPIs identified for the General Objective 3 are the following:

- % of improvement of environmental impact in terms of CO_2 and toxic material.
- % of recycled materials.

3.2.2 SPECIFIC OBJECTIVES AND DETAILED TARGETS OF THE PARTNERSHIP

The BATT4EU Partnership will, in a coordinated manner, generate knowledge and innovations to accelerate the learning curve and fill in the current gaps in the European battery value chain. Innovations fit to be industrialised will be rapidly implemented while more ambitious concepts will be nurtured with a view of developing and sustaining a long-term competitive edge.

The dimension of the global battery ecosystem also has to be taken into account. Due to the current lack of development and a very limited market share of cell manufacturing in Europe, there is also a lack of development of the related supply chain: from the specific chemicals, mechanical and electronic components, to the specialised manufacturing equipment, as a large number of the more competitive companies in the supply chain are based outside Europe. This has a significant impact on the ability of the battery industry to become competitive with a European manufacturing base.

The need to import competences has been identified by the first companies developing industrial capacities in Europe (e.g., Northvolt), but the target for the longer term is to make Europe globally competitive and independent from foreign technologies. The partnership will coordinate R&I efforts to identify and develop the key technologies required for an innovative, competitive and sustainable supply chain in Europe, developing at the same time the much-needed skills and trained workforces.

In line with the general objectives, the specific objectives of the partnership are as follows:

Specific objective #1:

Support the development of differentiating technologies in battery materials, cell design and manufacturing and battery recycling, leading to demonstrations of new chemistries, cells, production lines and proof of concept of recycling logistics and methods.

The European share of global cell manufacturing is projected to increase from 3% in 2018 to a significant share by 2030 (more than 15% by 2028 according to the JRC estimates[32]). This will lead to more than 200,000 direct and indirect jobs in cell manufacturing by 2028.

One of the most crucial aspects of battery development – in which Europe needs to build competencies and a world-leading knowledge base – is battery components and cell manufacturing. Environmentally sustainable and cost-effective manufacturing will be essential to give Europe a competitive edge. Currently, the level of processing of battery's raw materials and the production of advanced materials in Europe is marginal. Improving yields and material performance in minerals and metals processing as well as in advanced materials production whilst reducing energy consumption and CO_2 footprint of battery materials will be essential to achieve sustainable battery material production in Europe. Furthermore, given the rapid growth of the e-mobility and energy storage industries, Europe will face a serious challenge to effectively handle a large number of used Li-ion batteries. The stream/flow throughout the value chain of Li-ion batteries across Europe is very diverse.

The large variety of battery types, sizes, shapes, connections and chemical compositions make it very difficult to dispose of them effectively. One way this could be achieved is by re-directing some used batteries to second life applications after expert diagnosis and assessment of state-of-health. Sorting technologies are therefore another area to be further developed.

The BATT4EU Partnership will strongly contribute to creating and maintaining a cell manufacturing base in Europe, by providing the European industry with differentiating technologies in the fields of raw materials (battery-grade); advanced materials (for example, in the case of the state-of-the-art lithium-ion battery cells, advanced materials represent between 50% and 70% of the cost structure); cell design and manufacturing processes; and, battery recycling processes. The upstream materials industry also projects huge investments, with associated job creation. The entire life cycle, from raw materials across cell/battery manufacturing to recycling, will be designed with sustainability and minimal environmental impact in mind.

The KPIs identified for the Specific Objective 1 are the following:

- The number of EU-funded projects on novel chemistries at TRL 4 or higher.
- The number of EU-funded projects on cell architectures at TRL 4 or higher.
- The number of demonstrations of production lines.
- EU recycling capacity (tonnes/year).

Specific objective #2:

Accelerate the development and deployment of sustainable and affordable battery solutions for clean mobility, by building a strong innovation ecosystem with downstream partnerships leading to joint demonstrations in different transport modes.

Transport in general, and the personal vehicle sector in particular, will dominate growth in demand for battery cells in the mid-term, as is already the case today. This will play a key role in driving down costs thanks to significant economies of scale. However, large scale and specialised batteries will also be developed for the waterborne and aviation sectors.

Solutions developed within the partnership will contribute to offering the same or greater usability and safety than conventional means of transport at similar or reduced cost level (total cost of ownership), while achieving decarbonisation targets. The innovative technologies developed by the partnership on batteries will target mobility applications, in particular, road transport (which will remain the largest battery market by far in the foreseeable future), but also other modes such as waterborne or airborne transport. The sustainability of batteries should become a competitive and differentiating advantage for the EU, in line with the European Green Deal objectives.

The KPI identified for Specific Objective 2 is the following:

- The number of joint demonstration projects addressing different transport modes.

Specific objective #3:

Enable a cost-effective integration of renewable energy sources in the power grid, by developing affordable batteries for stationary energy storage applications, leading to demonstrations of different scales of storage systems.

The innovative technologies developed by the BATT4EU Partnership will also target stationary energy storage applications, which are key to providing a sufficient level of flexibility to the power grid when increasing the share of variable renewables in the energy mix, supporting the utilisation of industry 4.0 and boosting the development of small, robotised devices dedicated to the industry or private households. This will also guarantee the energy sector's decentralisation and empower individuals through flexible energy solutions.

The KPI identified for Specific Objective 3 is the following:

- The number of demonstration projects for stationary electricity energy storage.

Figure 11 summarises the intervention logic for the partnership, highlighting (the green sections of the arrows) the key challenges to be tackled for each specific objective.

With progressing deployment, the specific objectives of the partnership will trigger positive trends and contribute to the general objectives that will yield the expected impacts.

3.2.3 TECHNOLOGICAL SCOPE AND OPERATIONAL OBJECTIVES OF THE PARTNERSHIP

The BATT4EU Partnership will mainly cover R&I activities dealing with the upstream segments of the battery value chain, from raw materials to battery cells manufacturing, regardless of the chemistry/technology (as long as it matches the objectives of the partnership). It will also cover circular economy actions. While R&I will be performed on all parts of the value chain, advanced materials and battery cell design and manufacturing are seen as the key activities of the partnership, for which well-structured coordination will allow Europe to develop the most differentiating technologies. These parts of the value chain have been identified in a recent JRC report as the ones requiring key R&I activities in order to achieve the goal of a competitive EU battery industry.[33] In addition, battery recycling and secondary raw materials are also a key priority of the partnership.

The partnership will, therefore, allocate a substantial part of its resources to the advanced materials and battery cell manufacturing and design segments, along with circular economy activities:

- innovative active materials and related components (battery-grade raw materials, cathodes, anodes, current collectors, binders, electrolytes and in particular solid-state future electrolytes), new processes and equipment to manufacture them and novel methods for accelerated discovery and engineering of materials and interfaces;
- other materials (separators, casing, mechanical components, etc.);

Figure 11 | Scheme of the intervention logic for the BATT4EU Partnership.

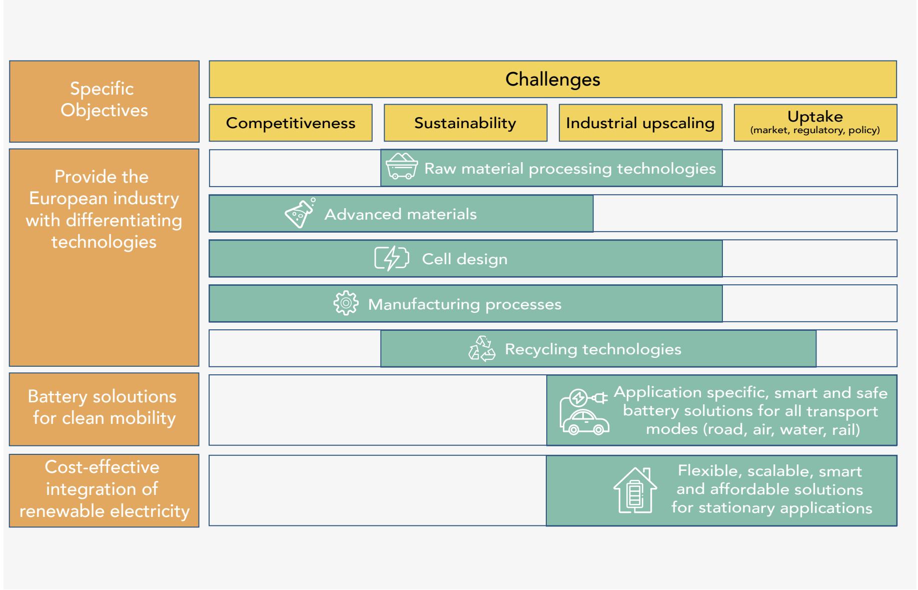
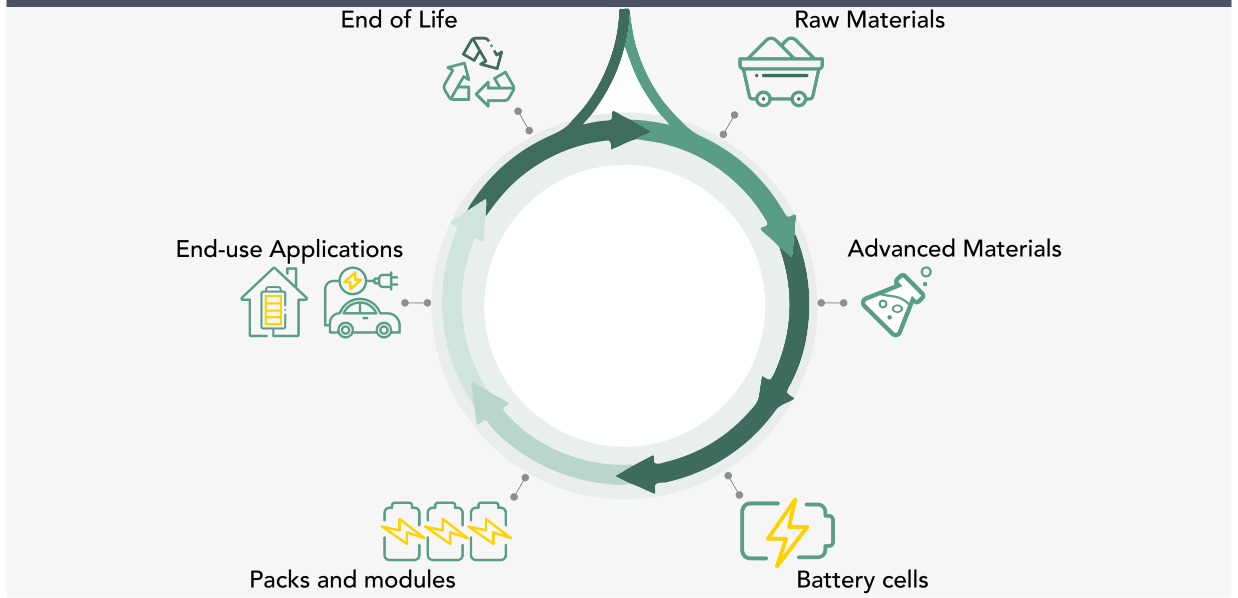


Figure 12 | Technological scope of the partnership (focus areas in green).



- cell assembly technologies (the transition to solid-state batteries will create the opportunity to invest in new manufacturing technologies to compete worldwide);
- battery recycling processes and secondary raw materials.

In terms of TRLs, both the enhancement of close-to-market Li-ion technologies (TRL 5-8), as well as new promising and longer-term breakthrough technological solutions (TRL 2-4) are included, provided they significantly contribute to achieving the defined specific objectives and to the long-term directionality of the proposed partnership within a reasonable timeframe. The partnership aims at creating industrial impact as soon as possible, while, at the same time, nurturing the European knowledge base in the field of batteries. By securing the development of future disruptive technologies within Europe, the European battery value chain will get ahead in the global race for the future generation of sustainable batteries. The partnership has taken the utmost care to ensure an appropriate balance between the short-to-medium term and the long-term R&I activities.

In order to achieve the specific objectives and respective outcomes, the partnership identified the following operational objectives which will benefit all markets segments (in line with the ambitious targets of the SET-Plan Action 7):

Operational Objective #1:

Increase battery energy density (+60% compared to 2019 values).

Operational Objective #2:

Increase battery power density and charging rate.

Operational Objective #3:

Improve cycle lifetime (at least by a factor of 2 compared to 2019 state-of-the-art values).

Operational Objective #4:

Reduce battery cost (-60% compared to 2019 values).

Operational Objective #5:

Ensure battery safety in the different targeted application sectors.

Operational Objective #6:

Implement worldwide best available technologies (BATs) in manufacturing and recycling operations (plants generation 4.0 or 5.0).

Operational Objective #7:

Enhance the sustainability of the main supply chains of battery's raw materials and achieve the lowest possible carbon footprint of the supply chain from raw material extraction through battery manufacturing, use and recycling.

While some of these operational objectives may, at first sight, appear less directly relevant for some specific applications than others, they are consistent with the main application sectors identified by the partnership (electrified transport and stationary storage applications):

Increasing energy density is a key requirement for road transport applications, as well as for other transport modes (such airborne transport); in addition, increasing the energy density (in kWh/l or kWh/kg) will usually lead to cost reduction (in EUR/kWh), which is crucial for stationary and waterborne applications (requiring a low cost in terms of EUR/kWh/cycle).

Increasing the power density is mandatory both for transport applications (e.g., for fast charging) and stationary applications (for grid services with a short time scale, such as frequency regulation).

Reducing battery cost is essential for all applications.

Ensuring battery safety is also a key requirement for all applications, although the required level of safety can change depending on the application sector; the development of battery technologies with higher levels of safety (urgently required for waterborne and airborne transport) can only have a positive impact on other applications such as road transport and stationary energy storage.

Recyclability and sustainability are essential requirements in the framework of the European Green Deal in order to decarbonise and ensure materials supply in the value chain; to decrease European dependence on Critical Raw Materials (CRMs) and, to establish EU industry standards as worldwide leading references for sustainability.

The KPIs identified for the corresponding operational objectives are the following:

- % of battery energy density increase (target +60% compared to 2019 baseline).
- % of battery power density and charging rate increase (target at least +30% compared to 2019 baseline).
- % of cyclability and lifetime increase (target factor >2 increase compared to 2019 baseline).
- % of cost reduction (-60% compared to 2019 baseline).
- Development and adoption of safety assessment methodologies (target EUCAR safety level 4 for automotive, level 2 for aviation and waterborne).
- The number of innovative manufacturing and recycling processes demonstrated.
- Recycling efficiency in % and CO_2 footprint of batteries over their full life cycle.

The partnership has a very high ambition in terms of technology development. In particular, increasing the energy density by +60% will require the development of radically new cell chemistries and technologies such as solid-state batteries incorporating lithium metal anodes. Furthermore, reaching the ambitious SET-Plan targets will also require the development of new methods and tools to accelerate the discovery and engineering of battery materials and interfaces, such as the Materials Acceleration Platforms proposed in the "Battery 2030+" research agenda, which are based on a combination of artificial intelligence, multi-scale modelling and high-throughput material synthesis and characterisation.

For Europe to be able to grow its market share in the future, it has to accelerate the development of the know-how in electro chemistries, materials, manufacturing processes and integration, notably by the digitalisation of the R&I pipeline. The BATT4EU Partnership will greatly contribute to closing this gap and bringing closer industry-research collaborations to develop the knowledge and skills and accelerate the implementation of innovations in the battery industry in Europe.[34]

3.3 Expected impact and needed investments in R&I

3.3.1 R&I INVESTMENTS NEEDED TO ACHIEVE THE OBJECTIVES OF THE PARTNERSHIP

The typical level of investment in R&I in the battery value chain industry, required to maintain the battery technology at a competitive level, is expected to be more than 5% of the battery market turnover. In addition, battery cell manufacturing is an investment intensive industry, requiring high volume and highly automated manufacturing processes. Capital costs per unit of battery manufacturing capacity trends converge at about 90-100 million EUR/GWh in 2019.

The industry investment in the final phases of the new technologies (moving from TRL 7 to TRL 9) is important, as significant pre-industrial validation is needed: pilot equipment, product design for manufacturability updates, etc. The partners' assessment is that the achievement of the partnership's objectives is estimated to require an overall mobilisation of R&I resources of at least one billion Euros per year over the next decade.

Depending on the projects and programs, it is expected that a part of the pre-industrial investment will be supported by/pooled from cohesion policy funds, IPCEIs and other public investors – like EIB – having financial products for pilot lines and demonstrators.

3.3.2 THE ADDED-VALUE PROVIDED BY A EUROPEAN BATTERIES PARTNERSHIP

As stated in the diverse objectives of the BATT4EU Partnership, its ambition is to support the creation of an innovative, competitive and sustainable industrial value chain for batteries in Europe. It is a highly challenging endeavour, given the narrow time frame left for Europe in the context of extremely strong international competition. The partnership will focus on differentiating technologies that are key to supporting the competitiveness of the European battery industry in the short, medium and long term. The usual forms of support to R&I from the EU Framework Programme are not suited given the scale and speed of investment needed to create a world-leading European battery industry. It is crucial to work in parallel (not in sequence) on the entire value chain, including manufacturing (largely neglected in the past). This needs close cooperation, in a holistic and integrated manner, between R&D and industry players from different sectors, e.g., raw materials, advanced materials, cell development and manufacturing, industrialisation, recycling and others, as well as cross-sectional sectors, including AI specialists, data sciences and LCA.

Only a partnership, i.e., a long-lasting and coordinated effort involving industry, research and the public sector, can live up to the challenge and bring predictability to European battery value chain stakeholders. By pooling Europe's resources and knowledge, partnerships have demonstrated their efficiency for accelerating the development, industrialisation and deployment of strategic technologies that underpin growth and jobs in key sectors of the European economy.

More specifically, the BATT4EU Partnership will provide the following key advantages:

- **Long-lasting and continuous industrial support and commitment for a common R&I vision in the field of batteries. T**he partnership will ensure that a consistent R&I programme is designed and implemented over a period of 7 years, which will give the necessary timeframe and predictability to develop innovative battery technologies and bring them to higher levels of technological and manufacturing readiness.
- **R&I action portfolio management.** The partnership identified and will implement joint strategic R&I activities, not only by proposing a sound R&I programme but also by monitoring the execution phase of the funded R&I actions and consequently reporting the advancements to the wider battery community, mainly through ETIP Batteries Europe. Following the progress made by the individual funded projects (in particular, checking whether they are able to reach their quantitative targets and contribute to achieving the key performance indicators defined in the strategic R&I agenda and the SET-Plan Action 7), it will provide extremely valuable inputs to design the next phases of the R&I programme. Such an R&I action portfolio management, i.e., the establishment of a "feedback loop" between the outputs of the funded R&I projects and the inputs of the R&I programme, together with additional activities supporting market take-up, will maximise the impact of R&I.
- **Leveraging technical and financial resources from both the public and private sectors** (see section 5 for more details).
- **Aligning R&I policy with industrial, environmental and education and training policies.** The partnership brings together industry, research and the European Commission, which will ensure that the R&I programme is well aligned with the other relevant European policies, including industrial, environmental, education and training policies. A strong alignment between the different policies is mandatory to achieve the ambitious goal of creating a competitive and sustainable battery manufacturing industry in Europe, as clearly explained in the European Commission Strategic action plan on batteries.[35] Collaboration with national and regional initiatives will also be essential (as described in section 5).system, zero-emission urban areas, market accessibility, leadership position in exports...).
- **To strengthen the European batteries value chain, research across the value chain must be better coordinated.** The proposed partnership will bring together actors across the value chain and ensure that: (1) research and innovation is targeted to tackle each industrial segment's needs within the same overarching objective; (2) results are further adopted in consequent links of the value chain; and (3) two-way communication is constant in defining requirements and targets.

3.3.3 EXPECTED IMPACT AND SUPPORT TO A BROADER R&I ECOSYSTEM

The timing of this initiative is crucial (in coordination with the preparation of the Horizon Europe programme) to maximise the impact of the investments made by Horizon Europe and the batteries industry across the full value chain (from raw materials to advanced materials, battery cells, modules, packs, applications and end-of-life management). The BATT4EU Partnership will deliver on this ambition by supporting the European battery ecosystem. It will enable the coordination of the targeted strategy covering the entire battery value chain, from cradle to grave, across the full spectrum of technologies used in the "ecosystem of batteries", for the key applications (electrified transport and stationary energy storage).

The role of a partnership is indeed essential when it comes to the coordination and coherence assessment of the R&I funded programs. A partnership is necessary to fulfil and complete the required support, in the framework of a multi-year and multi-project context, and to successfully achieve the transition to industrial investment and manufacturing. A practical core objective of the partnership is to accelerate the transfer of R&I knowledge to industrial manufacturing and thereby support the EU battery industry development beyond 2025. A key example is the transfer of generation 4 of lithium batteries technologies (solid-state batteries, TRL 2-4) to industrial manufacturing: there is an urgent need for coordinated support to efficiently help the public and private research organisations move this highly challenging technology through the TRLs 4 to 7.

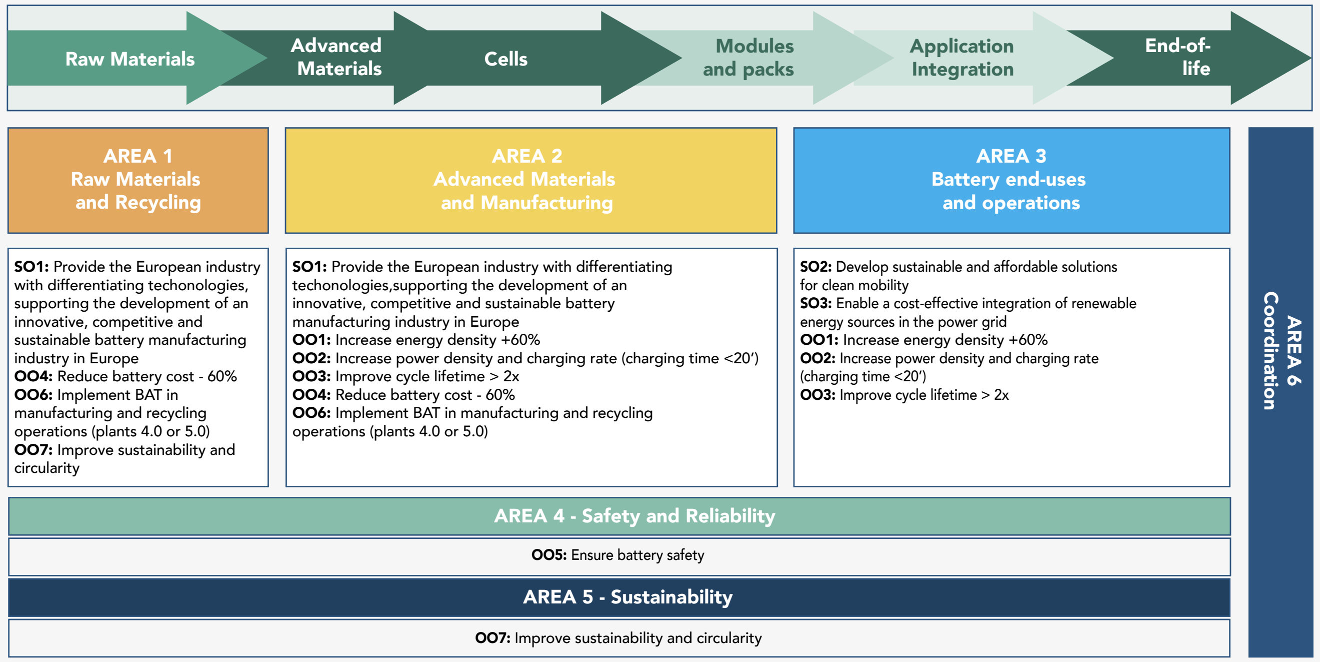
4 R&I FOCUS AREAS

Based on the objectives of the Partnership as described in the previous chapter, six distinct R&I areas have been identified as key to achieving a competitive, sustainable and circular European battery value chain. These focus areas have been translated into strategic actions that will be rolled out over the next seven years according to a multi-annual agenda. This agenda will be updated regularly within the Technical Working Groups of BEPA.

Introduction

Based on the objectives of the partnership described above, six distinct R&I areas have been identified as key to achieving a competitive, sustainable European industrial battery manufacturing capability and enabling zero-emission mobility and renewable energy storage integration. Each specific R&I area is contributing to the achievement of the specific objectives (SO) as well as the operational objectives (OO) of the partnership, as shown in Figure 13 below. This section thus describes, for each R&I area, the specific challenges and objectives to be tackled, the expected outcomes of the R&I efforts by 2030 as well as the foreseen scope of actions.

Figure 13 | R&I areas in line with the specific and technical objectives of the partnership.



Each area also contains a timeline to represent, in a simple way, the cascade effect of R&I activities for each strategic action identified in the SRIA until 2030. The arrows in the timeline indicate the TRLs that the strategic action is aiming to achieve and the timeframe within which they should be achieved.

Figure 14 | Colour code used in the timelines for each relevant TRL.

1	TRL 1 - basic principles observed	6	TRL 6 - technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies
2	TRL 2 - technology concept formulated	7	TRL 7 - system prototype demonstration in operation environment
3	TRL 3 -experimental proof of concept	8	TRL 8 - system complete and qualified
4	TRL 4 -technology validated in lab	9	TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies – or in space)
5	TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)		Scale up & Market introduction

4.1 Area 1: RAW MATERIALS AND RECYCLING

The e-mobility sector is booming, yet Li-ion battery end-users, and specifically European car manufacturers, are still dependent on imported Li-ion batteries. There are already investments being made to build battery manufacturing capacity in Europe, which will support the independence of the European car industry in the close future. However, the investments in sourcing raw material in Europe are still developing much slower (reasons being that the mining industry normally is a slow mover, investments have risks, permission procedures are slow, etc.) and it will take time for the already planned investments to become operative.

With the rapidly increasing electrical vehicle fleet in Europe, the number of batteries in European cars will increase rapidly forming a fast-growing demand in the use of raw materials, which are later (even after more than 10 years) available for recycling (after the possible second life use). Due to the relatively long life of EV batteries, the Li-ion battery recycling industry in Europe is currently mainly dependent on the batteries coming to end-of-life (EoL) from electronics and portable instruments. These kinds of EoL batteries create a large challenge in the collection and reverse logistics. Furthermore, the chemistry of these batteries varies a lot. However, the materials in these batteries are valuable when recycled and recovered, and are needed to support the growing Li-ion battery manufacturing in Europe. At the same time, the recycling industry is preparing for future challenges, in order to be ready when large amounts of EV batteries are available for recycling.

Vision: Europe's global leadership in the automotive and battery industries is built on a solid supply of transparently and sustainably extracted and processed primary raw materials from both European and non-European sources, as well as on comprehensive and sustainable recycling of the raw materials from the batteries installed and used in Europe.

4.1.1 PROCESSING OF BATTERY-GRADE PRIMARY AND SECONDARY RAW MATERIALS

a) Specific challenges and objectives

Raw materials[36] represent a major part of the battery value as well as carbon footprint. Therefore, raw materials have a high impact on the sustainability of batteries, which highlights the importance of continuous R&I in this field. Currently, the level of extraction and processing of raw materials for battery from European resources is marginal. To keep up with the demand, exploration, mining and refining capacity need to be developed and increased. Along with the primary raw material sources, recycling of batteries and other related secondary materials is needed to support the material supply in the future. This requires the development of the current recycling and refining base in Europe. Ramping up the recycled feed will however be a more long-term process, so the primary feed is of utmost importance for the foreseeable future.

The dependency on imported materials not only poses a strategic supply risk for European battery manufacturers but also is a responsible operation and branding issue as the sustainability and traceability of raw materials from non-European sources can be very difficult to define. Building up European capacity in extraction and processing would serve the diversification of supply chains, thus, limiting supply risks. Here it must be highlighted that the mining is beyond the scope of the SRIA, but recovery of materials from different grades of intermediate materials is included (i.e., extraction). Furthermore, it also serves the future recycling of batteries, as the recycled materials can be at least partially integrated into the existing primary processing facilities.

These goals require Europe to be at the frontline of technological development of metallurgical production, where innovations in processes and unit operations are required. These developments should aim at improved yield, better process control, flowsheet flexibility, improved product purity and quality, improved impurity management and improved recovery from secondary streams. In some places, these innovations can be complementary unit operations to existing process flow sheets, while in others like European Li or pCAM (Precursor for Cathode Active Material) production, completely new flowsheets and operating methodologies are needed. This type of development action is expected to bring added value for the European battery metals and materials production.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- European low-grade deposits and secondary material sources such as tailings (e.g., as a source of nickel, cobalt and lithium) are taken into use and the local refining capacity to battery-grade purity is extended, reducing the European dependency on imported materials.
- Battery grade intermediates such as lithium hydroxide and precursor materials are produced and refined in Europe in a sustainable and socially acceptable way, improving the competitiveness and value of European battery and mobility industries.
- Reduced carbon emissions, increased energy efficiency, and more efficient resource use are achieved, for example by combining secondary materials into existing primary processing.
- New business opportunities and models for EU industry will emerge. Joint efforts of different industrial players as well as building on scale will allow European junior miners to get into operation. This will create additional jobs along with the increase in processing and refining capacity in Europe.

c) Scope of actions

Strategic Action 1 – Sourcing, sustainability and traceability of raw materials

It is important that the European battery industry can rely on a harmonised and straightforward way to source metals in the current complex and intertwined global extraction supply chains:

- Harmonised approach for estimating the resource/reserve basis in Member States.
- Understanding of sustainability requirements for raw materials sourced outside of the EU.
- Responsible sourcing and traceability across the global supply chains.
- Development and evaluation of tracing and labelling technologies as well as digital ledger technologies.

Longer term:

- Tracing and labelling of the certified materials through the whole life cycle (cradle-to-grave).

Strategic Action 2 - Sustainable processing of battery-grade raw materials

Developing metallurgical processing solutions for the most crucial elements needed in the battery chemistries over the next ten years (Li, Ni, Co, Mn and graphite), which are to be applied to both domestic and imported raw materials treatment:

- Efficient and sustainable processing methods for battery-grade metals such as Li, Ni, Co, Mn as well as graphite.
- Support implementation of new technologies in the processing of battery metals to reduce carbon emissions; increasing energy and resource efficiency, raw material flexibility and substitution of fossil fuels.
- Zero waste and zero discharge during the refining of metals and processing of battery chemicals including energy cascading and waster valorisation.
- Development of continuous processes for pCAM to replace the currently used batch processing.
- New smelting and slag engineering technologies to reduce Ni and Co losses in smelting.
- Creating advanced processing methods to produce battery-grade lithium hydroxide without having to pass through intermediate products such as lithium carbonate.
- Develop leaching and extraction processes with efficient, stable and proven reagent circulation resulting in low chemical need and hence low environmental load.
- Establish European graphite production from both primary and secondary sources – with vertical integration into the European battery production
- Create new business models for co-processing and process integration (industrial symbiosis).
- Process modelling competence combined with environmental impact evaluation (including LCA analysis) for individual primary processes.

Longer term:

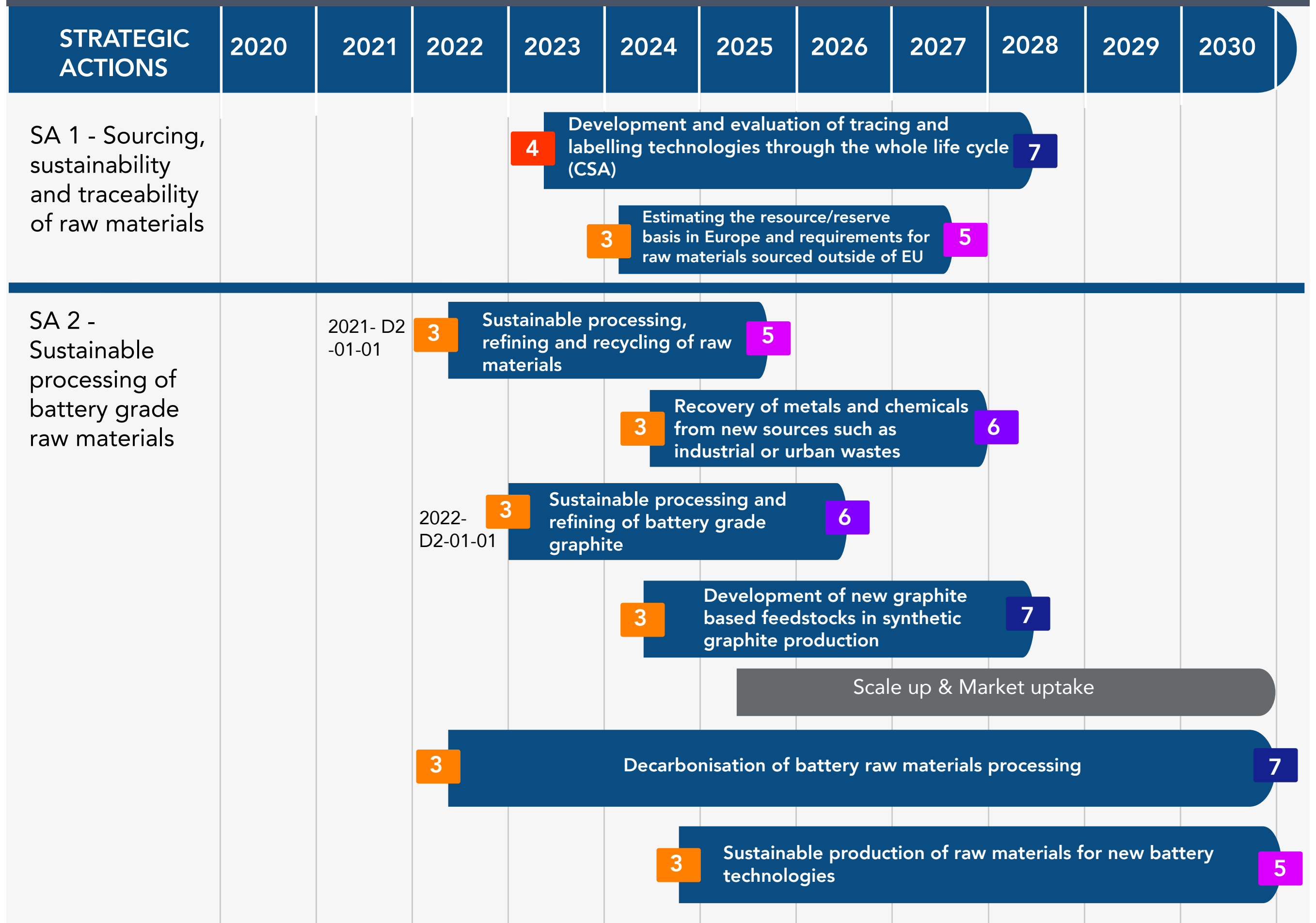
- Recovery of metals and chemicals from new sources such as industrial or urban wastes.
- Development of financially and technically robust and feasible methods for battery metal processing and recovery.
- Substitution of petroleum-based feedstock in synthetic graphite production.
- Decarbonisation of battery raw materials processing.

d) Strategic action timeline

Figure 14 summarises the key strategic research and innovation actions within the 2030 Horizon related to the processing of battery-grade primary and secondary raw materials. The activities highlight the goal of improving European independence in terms of raw materials for batteries and the need for the implementation of tools that support the availability and use of sustainable and traceable raw materials in the electrifying society.

To keep the European raw material industry competitive and to support the battery manufacturing industry to reach its sustainability targets, the raw material industry needs to maintain its position as the frontrunner in sustainable, low carbon footprint, raw material production and needs to focus on developing the industry to match the changing demands and rapid growth of the battery industry. While sustainable production and refining primary materials have the development priority in addressing the goals, Europe needs to start preparing to be at the frontline of utilizing secondary materials, as shown in the strategic actions foreseen for the coming years.

Figure 15 | The timeline of the strategic actions in Area 1.1 - processing of primary and secondary battery-grade materials.



4.1.2 END-OF-LIFE MANAGEMENT: COLLECTING, SORTING, DISMANTLING AND RECYCLING

a) Specific challenges and objectives

Today EoL batteries are not standardised (form, chemical composition, etc.). Consequently, their management and recycling are mainly based on manual processes, with a higher risk of accidents as the integrity of the batteries/cells are no longer guaranteed.

Within 2-4 years, the number of EoL batteries from e-mobility and stationary applications will surge, completely transforming the recycling value chain. This means that both the number and capacity of recycling facilities need to increase. The new capacities need to be automated to reduce costs and reduce safety risks in all parts of the value chain.

Due to the lack of standardisation, data about the form, composition, assembly modes, state of health, etc. are of utmost importance. The battery passport is seen as an enabler in this respect and should be fully developed within this time frame (integration of a battery labelling system within the battery passport)

To fully implement the circular economy, second life (of e-mobility batteries into stationary batteries) is promoted. The second life starts with dismantling the large e-batteries to check whether their sub-systems are fit for a second life or to be refurbished whenever possible. This step shall not only be automated; refurbishing and safety procedures shall also be defined, whatever the battery model.

The Battery Directive is currently under revision and the whole recycling value chain (including second life) will need to comply with the new requirements (within the same period of 2-3 years). The target is to develop the value chain at an industrial scale so that the requirements of the new directive will be met or exceeded in an economically beneficial way.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Raw material independence is improved within the EU by fully utilising the materials already installed in batteries.
- Allowing the management of end-of-life batteries in a safe way when facing the future significant increase of the EoL batteries (reduction of accidents by developing safety procedures).
- Automating the dismantling of e-mobility and stationary batteries, reducing costs by avoiding manual work and improving sorting of parts for their replacement or recycling.
- Achieving the objectives of the circular economy by enabling the second life of batteries and exceeding the targets of the Battery Directive in a cost-competitive way (recycling rates and material recovery).
- To ensure a sustainable and at-scale recycling chain for batteries, in terms of products, economics and environmental impacts while ensuring a strategic alternative to the supply of primary raw materials.
- Recycling cost and environmental impact are reduced through new and disruptive concepts for very high-efficiency recycling.
- Development of a community for actors involved in the management of the recycling value chain for batteries (including second life) for sharing best practices (health and safety, transport, dismantling, refurbishing, recycling).
- More flexible battery waste recycling. This means the ability to recycle a wider variety of EoL batteries or production scrap. This can also mean intelligent process design integrating selected fractions into existing industrial infrastructure or other innovative integration of fractions or processes.

- Materials are recovered at high purity and brought back to the battery value chain. Vertical integration to component/cell manufacturing is improved.
- Improved health and safety in the EU within battery recycling processes. Identification of health and safety hazards and new safety practices related to the holistic treatment of battery waste throughout all metallurgical recycling process units.
- Industrialising closed loops and recycling technologies to return low-value chemicals from manufacturing processes to high-value; further creating necessary inputs for the battery manufacturing industry.

c) Scope of actions

Strategic Action 1 - Collection, reverse logistics, sorting and dismantling

To develop comprehensive technologies for safe and effective handling of the growing battery streams before they finally enter the recycling process.

- R&I on new technologies and devices for quick and easy battery State-of-Health (SoH) assessment at the end-of-life.
- R&I on standardised diagnostic protocols and cut-off criteria between product (2nd life application) and waste (recycling).
- Development of standardised and cost-efficient storage and transportation containers with visual and thermal load monitoring systems and, if necessary, an inert atmosphere.
- R&I on discharge technologies and devices equipped with energy recovery systems.
- Development of a standardised battery labelling system and potential integration with battery passport database that goes down to battery cell level or even further.

- R&I on discharge technologies and devices equipped with energy recovery systems.
- Development of a standardised battery labelling system and potential integration with battery passport database that goes down to battery cell level or even further.
- R&I on automated battery sorting and dismantling technologies to increase material recovery and safety and decrease manual labour.
- Risk and safety: at all stage of the dismantling chain.

Longer term:

- Design for sustainable recycling.
- Modularity: enabler of automatic dismantling operation.
- Sorting for materials.
- Assembling method (for example, glue vs. screws).

Strategic Action 2 - Metallurgical recycling processes, industrial integration and secondary material-based precursors

Efficient processing technology for batteries, able to recover the valuable (or hazardous) raw materials at scale with the lowest possible environmental footprint and costs. Such processes ensure that the recycled materials fulfil the sustainability targets set for raw materials by the European battery manufacturers with the goal of achieving and maintaining competitiveness in Europe and the global markets.

- Recycling for Li-ion battery and NiMH chemistries and cell formats, which are in large-scale production today.
- Creation of feasible, holistic recycling processes that can effectively exploit the vast amounts of EV battery waste reaching its EoL in the next 10 years, as well as the production scrap. Recycling processes recovering the highest amount and value of resources present within these secondary raw materials with the process being based on an innovative combination of optimised existing and new unit processes which may also partially utilise the existing metallurgical infrastructure.
- Downcycling or safe disposal of the non-metallic elements like the electrolytes, separators and electrode binders.
- Further development of metallurgical tools and modelling, enabling techno-economic comparison of the technology alternatives.
- Developing intrinsically safe recycling processes and safety protocols.
- Reduction of environmental impacts of the recycling processes.
- Conversion of intermediate products from reprocessed mine tailings into battery chemicals

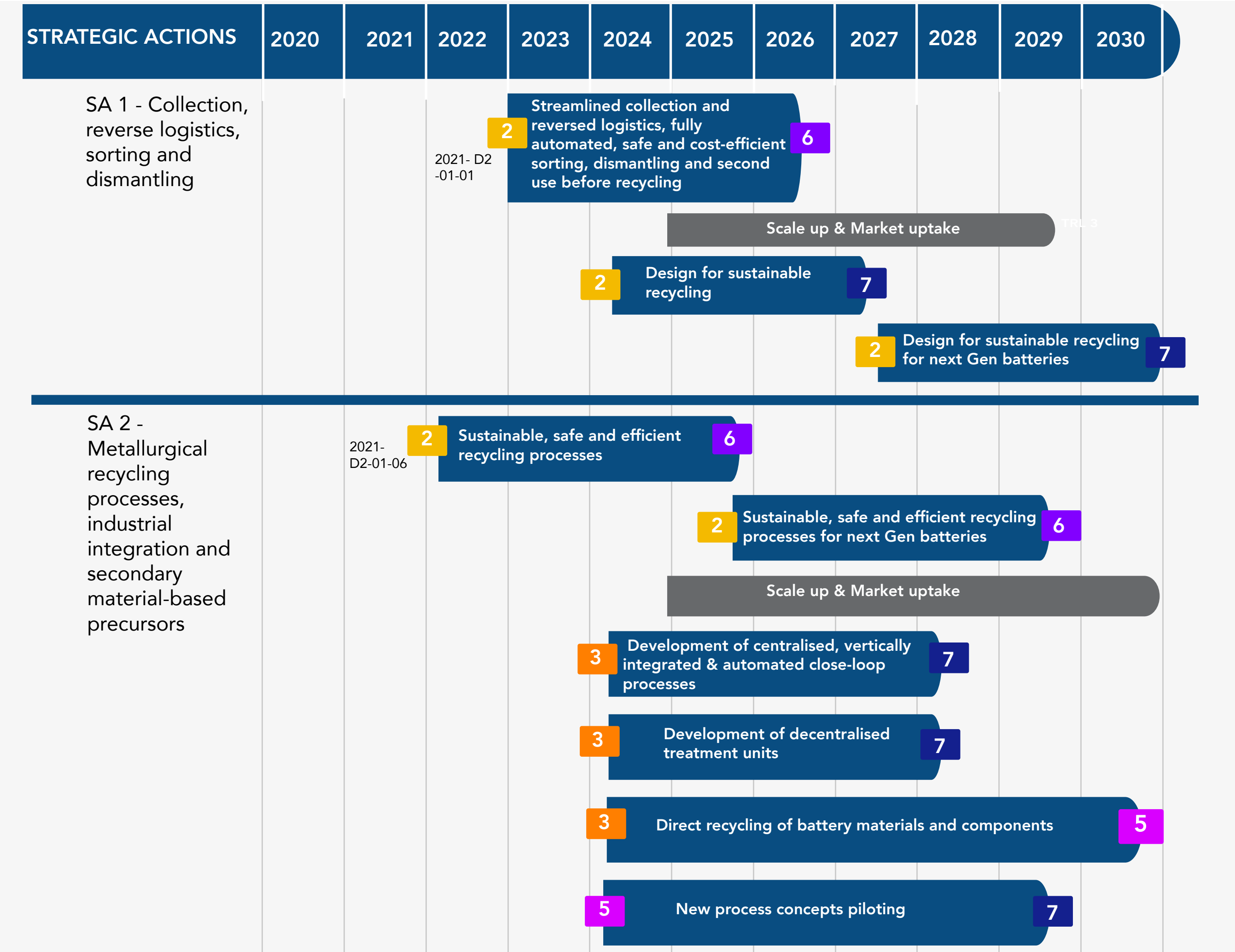
Longer term:

- Development of centralised, vertically integrated and automated close-loop processes.
- As an alternative, de-centralised (local or mobilised) metallurgical treatment units for flexible battery waste treatment to minimise the transportation (the optimal solution may comprise a combination of the centralised and de-centralised unit operations).
- Direct recycling of battery materials and components.
- Zero waste recycling where also the non-metallic elements are recycled back to battery use.
- Piloting new process concepts.

d) Strategic action timeline

Figure 16 summarises the key strategic research and innovation actions within the 2030 Horizon related to EoL management: collecting, sorting, dismantling and recycling. End-of-life battery management plays a key role in supporting Europe's raw material independence, while it also addresses critical safety and life cycle aspects of the whole electrifying society. Developing technically and commercially functioning EoL battery ecosystems targeting the optimization of the principles of circular economy is essential. While the opportunities for Europe to differentiate lie along the wide end-of-life ecosystem, the highest priority is set for understanding the cut-of-criteria for second life and recycling and further developing the path to significantly increase the economically and environmentally sustainable degree of recycled components and elements of a battery, without compromising on safety.

Figure 16 | Timeline of strategic actions in Area 1.2: End-of-life management: collecting, sorting, dismantling and recycling.



4.2 Area 2: ADVANCED MATERIALS AND MANUFACTURING

4.2.1 ADVANCED MATERIALS

a) Specific challenges and objectives

With about 70% of the cost of a battery cell being the cost of the cathode, anode, separator and electrolyte materials, it is obvious that advanced materials are key to further cost reduction and the resulting market uptake. Ongoing R&I in advanced materials allows the development of more cost-efficient, better performing, safer and more sustainable battery cells. The main driving force behind R&I in battery materials deals with increasing the energy density of battery cells to enable better performance and cost-competitiveness of the specific applications. Various battery chemistries exist and are being further developed nowadays and they may differ depending on the application focus beyond mobility or stationary usage. In the mobility space, R&I is on liquid-state batteries (generation 3) with a drive towards solid-state batteries (generation 4) while R&I is also conducted on generation 5 battery chemistries. In the stationary storage space, next to Li-ion batteries, there are numerous developments focusing on Na-ion batteries, redox-flow batteries and metal-air batteries. For all these battery chemistries, further R&I is needed to develop the most appropriate advanced materials as detailed below. By 2030, Li-ion technologies will remain the dominant technology in mobility applications due to successful market uptake, an established industrial value chain and continuous improvement of the technology. The main focus of the R&I will be to improve the energy density while delivering on the other application-relevant KPIs. Solid-state batteries (generation 4) and generation 5 (post-Li-ion) chemistries will also receive significant attention that may lead to some inroads in specific application segments. For stationary usage, next to Li-ion batteries, we will have a broader choice of technologies. Beyond 2030, we expect to see several new chemistries to start being proposed.

The different battery generations can be summarised as follows[37]:

From present commercial Li-ion to Advanced Li-ion (Gen.3) to solid state Li-ion (Gen. 4a,4b and 4c) to >2035 post Li-ion (Li Air, Li S...) (Gen.5):

- High capacity/high voltage stable active cathode materials combined with high-capacity anodes and new liquid electrolytes (additives, composition, etc.), separators with reduced thickness and cost, NMP free processing, etc.: Gen.3
- Solid state electrolyte Li-ion:(organic, inorganic, hybrid): Gen.4
- NMC cathode + C/Si composites + Solid electrolyte: 4a
- NMC cathode + Li metal + Solid electrolyte: 4b
- High voltage cathode + Li metal + Solid electrolyte: 4c
- Post Li-ion: Li-Air, Li S, Na-ion, multivalent metal-ion, metal-air, redox-flow, etc: Gen. 5

Additionally, novel tools based on artificial intelligence - supported by multi-scale and multi-physics modelling, autonomous synthesis robotics and advanced characterization and testing - need to be developed and implemented, to guide and accelerate the development of future high-performance battery materials, interfaces and cells.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Differentiating technologies providing Europe with key leadership opportunities for the development of an innovative, competitive and sustainable battery (materials) manufacturing industry.
- Advanced batteries delivering on cost, performance, safety and sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by the e-mobility sector as well as other applications.
- Broader acceptance and accelerated technology uptake (both for mobility use and stationary use) will help to reduce GHG emissions of the transport sector and energy sector to support the EU's efforts to become climate-neutral by 2050.

c) Scope of actions

Strategic Action 1 – Research & innovation on Generation 3 Li-ion batteries for mobility applications

- **Challenge:** Developing advanced materials enabling higher energy/power density thanks to higher capacity and/or operating at a higher voltage. Focus is on adapting the cathode materials (high-nickel NMCs for capacity, spinels/Li-rich Mn NMCs for high voltage), the silicon-based materials (silicon carbon composites, silicon oxide composites, or pure silicon materials), the electrolytes (salts, solvents, additives) which can maintain good stability with silicon and high voltage cathode materials (stabilised formulations), the binders and their interplay.
- **Impact (KPIs):** Gravimetric, volume energy density at cell level of 350-400 Wh/kg, 750-1000 Wh/L respectively. Power density at cell level 700 W/kg and 1500+ W/L. For high voltage application, operation at 4.7+ Volt. 3000+ and 2000+ deep cycles for high capacity and high voltage applications respectively. Cost at pack level < 100 EUR/kWh
- **Time to market:** 2025(+)

Strategic Action 2 – Research & innovation on Generation 4 Li-ion batteries for mobility applications

- **Challenge:** Developing solid-state electrolytes, cathode materials and anode materials (including additives) enabling higher thermal and electrochemical stability while targeting higher energy/power densities, fast charging, cyclability and improved safety. Developments should range from using conventional materials (Gen. 4a) to using Li metal-based anode (Gen. 4b) with(out) high voltage cathode materials.
- **Impact (KPIs):** Gravimetric, volume energy density at cell level of 400+ Wh/kg (Gen. 4a), 800+ Wh/l to 500+ (Gen. 4b & 4c), 1000+ Wh/l respectively. Cycle life up to 3000 and ability to operate at a charging rate of 3-5C. Cost at pack level down to below 75 EUR/kWh.
- **Time to market:** 2030(+) (depending on tech.)

Strategic Action 3 – Research & innovation on Generation 5 batteries for mobility applications

- **Challenge:** Developing the various materials systems to enable batteries to deliver on energy/power density, cycle life and cost. Various technologies are considered such as metal-air, metal-sulphur and new ion-based systems.
- **Impact (KPIs):** Gravimetric, volume energy density at cell level of 500+ Wh/kg, 1000+ Wh/l respectively. Cycle life of at least 800 cycles at 80% DoD. Cost at pack level < 75 EUR/kWh.
- **Time to market:** 2030+

Strategic Action 4 – Research & innovation on Li-ion batteries for stationary storage applications

- **Challenge:** Develop the various materials systems (cathode, anode, electrolyte, binders, etc.) to enable stationary Li-ion batteries to be used in utility-scale applications (> 100 MW, P/E < 1/3) and in commercial high-power applications (< 100 MW, P/E > 4). Material strategies are very diverse and range from improving conductivity to improving energy density and the lifetime in utility-scale applications, while also improving conductivity and capacity for high-power applications.
- **Impact (KPIs): For commercial high-power applications** - Volumetric energy density of 500+ Wh/l, lifetime of 6000+ cycles, rate capability of 5-6 C (back up charging stations), cost at pack level <75 EUR/kWh. For utility-scale applications - Volumetric energy density of 500+ Wh/l, lifetime of 10000 cycles+, cost <0.05 EUR/kWh/cycle.
- **Time to market:** 2030

Strategic Action 5 – Research & innovation on beyond-Li batteries for stationary storage applications

- **Challenge:** Developing the various safe and sustainable materials systems to enable beyond-Li-ion batteries to deliver on energy density, long cycle life and low cost, and a reduced dependence on scarce raw materials. Various technologies are considered such as Na-ion, redox-flow and metal-air.
- **Impact (KPIs): Na-ion batteries** - Gravimetric volume energy density at cell level of 180 Wh/kg and 500 Wh/l. Cycle life of 6000+ cycles. Cost <0.05 EUR/kWh/cycle. Redox-flow batteries – Gravimetric volume energy density to reach 100 Wh/kg and 50+ Wh/l for a cycle life of 15000+ cycles and an energy cost <0.05 EUR/kWh/cycle (cell level). Metal-air batteries – Gravimetric volume energy density at cell level to reach 200+ Wh/kg and 800+ Wh/l for a life of 2000-5000 cycles and an energy cost <0.05 EUR/kWh/cycle. Next to Na-ion batteries, redox-flow batteries and metal-air batteries, various other technologies may fall within the scope of this strategic action.
- **Time to market:** 2030(+)

Strategic Action 6 – Research & innovation on advanced materials to reduce the weight of cell and battery packaging

- **Challenge:** Developing new lightweight materials based on glass fibres, carbon fibres, new plastics, high strength steels ... and demonstrating high strength-to-weight ratio suitable for structural and functional battery parts.
- **Impact (KPIs):** Weight reduction cell/pack battery packaging of 70%, driving range of EVs extended by 20+% compared to state of the art, with a focus on improved recyclability.
- **Time to market:** 2025(+)

Strategic Action 7 – Research & innovation on advanced materials to enable ultra-fast charging

- **Challenge:** Developing the various materials systems enabling user-friendly, safe and reliable ultra-fast charging stations with power transfer capability exceeding 350 kW. Materials systems include advanced material technologies (insulation, conductors, cooling) and connection methods for safe, reliable and easy-to-handle 350kW charging cables and plug connections (conductive or contact-less).
- **Impact (KPIs):** Charging time below 10 minutes, power transfer capability at 350+ kW and low energy losses due to ohmic resistances during the charging process, energy loss <2%.
- **Time to market:** 2025

Strategic Action 8 – Accelerated battery material discovery and interface engineering

- **Challenge:** Autonomous closed-loop materials discovery through the use of artificial intelligence to orchestrate data acquisition and analysis from multi-scale computer simulations, experiments and testing. It includes the development of autonomous high-throughput synthesis robotics and experiments, also utilising the European large-scale characterisation infrastructures such as synchrotron and neutron facilities.

- **Impact (KPIs):** Up to 10-fold increase in the rate of discovery of novel materials and interfaces.
- **Time to market:** 2030 and beyond for a fully autonomous and versatile materials acceleration platform (while intermediate results can be exploited before 2030).

d) Strategic action timeline

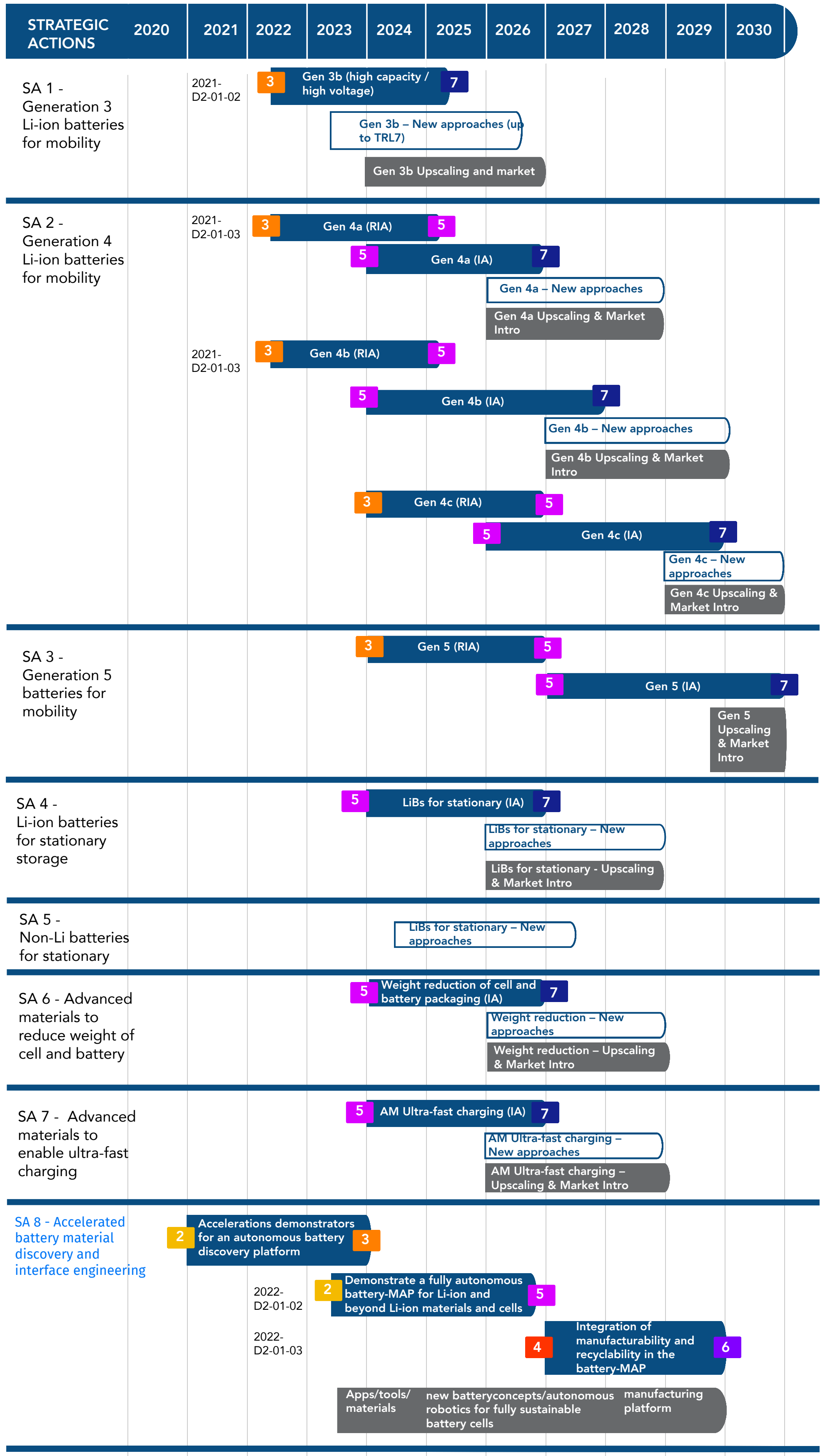
With about 70% of the cost of a battery cell being the cost of the advanced materials, an ambitious R&I programme in advanced materials is key to more cost-efficient, better performing, safer and more sustainable battery cells enabling market uptake of battery technology, while building strong industrial leadership in Europe and delivering on the EU's Green Deal agenda.

The activities outlined in the schematic cover the typical innovation journey from research and innovation action (or innovation action for more developed technologies) all the way to upscaling and market introduction as well as the integration of a dimension allowing for "new approaches" integrating feedback from the market and new discoveries coming from the research field.

While investing in R&D on liquid-state batteries (gen. 3b) is still needed, we advocate for a strong and ambitious drive towards solid-state batteries (gen. 4a, 4b and 4c), which will be the key technology on which European industry has to invest with the support of public authorities. R&I on generation 5 battery chemistry (Li-air, Li-Sulphur) is also expected with a horizon for industrialization further in time, with possible early-bird applications in specific segments. In the stationary storage space, next to logical research and innovation support on Li-ion batteries, there are numerous developments focusing on Na-ion batteries, redox-flow batteries and metal-air batteries which also need to be supported.

By 2030, Li-ion technologies (gen. 3 and gen. 4) will be the globally dominant technology in mobility applications. In the stationary space, next to Li-ion technology, we will see other technologies as well. Provided an ambitious, effective and efficient funding programme is put in place in Europe to support the industrial investments and the research ecosystem, the European battery value chain will demonstrate leadership with sustainable, cost-competitive and high-performance batteries innovated and made in Europe.

Figure 17 | Timeline of strategic sections in Area 2.1: Advanced materials.



4.2.2 CELL DESIGN AND MANUFACTURING OF BATTERY CELLS

a) Specific challenges and objectives

For the industrial strategy of Europe – the ambition to be competitive and independent in the new era of electrification and decarbonisation – it is mandatory to fully develop its own battery mass production manufacturing capabilities through all the value chain, with special focus at the battery cell level. Nevertheless, this action plan wouldn't be of value unless several specific challenges are appropriately faced:

- **Competitiveness:** Develop battery cells with advanced design and technical performances beyond state-of-the-art at an affordable cost. In view of the promising, new battery technologies to come (i.e., solid electrolyte lithium cells, Li metal battery and advanced Li-ion battery technology), innovation in cell design and effective large-scale manufacturing processes is a must, not only to keep the necessary pace but to stay at the forefront internationally.
- **Sustainability:** So far one of the largest contributors to carbon footprint through the product lifetime, battery cell manufacturing itself needs to be produced at the lowest possible environmental impact. R&I is necessary to enhance the energy efficiency of the battery cell manufacturing processes, including new design concepts facilitating reuse and disassembly, and hence a circular economy.
- **Industrial upscaling:** Current and forthcoming giga-factories will demand highly automated, digitally controlled, energy and material-efficient, high yield cell manufacturing processes developed by fully digitalised production machinery and at the lowest environmental footprint. The 'digital giga-factories' must be flexible to be adapted to future advanced battery materials and next-generation mass production process technologies as they overtake the state of the art.
- **Market Update:** Integration is needed for the significantly different challenges of different sectors and applications, i.e., fast charge, calls for specific cell designs, including end-of-life issues, 2nd life, guided disassembly for recycling, enhanced intrinsic safety, regulatory issues, digital passport and more.

The specific objectives to be addressed within the BATT4EU Partnership to face these challenges are identified as:

- **Efficient translation of battery materials into cell products:** taking care that cell electrodes and cell design preserve intrinsic material-specific performance as much as possible, e.g., specific energy density when transferred to the cell environment. Make sure from the conception phase that these designs are suited for fast, efficient, high-quality manufacturing processes.
- **Environmentally sustainable**, fully automated and flexible manufacturing techniques applied in mass-scale manufacturing providing the highest quality and consistency, safety and performance at the cell level at a competitive cost.
- The **digitalisation of cell design** put in place. Enable smart functionalities for specialised markets and/or on first industrial pilots for mass manufacturing. Digitalisation and increased use of virtual tools, machine learning and artificial intelligence applied to mass-scale manufacturing processes for enhanced flexibility, preventive troubleshooting and quality consistency in the production environment.
- **Innovative concepts** from cell design to production plant level, including the idea of flexibility in production to increase manufacturing efficiencies (also in terms of cost), applied in mass-scale manufacturing, including solid-state cells.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Highly performing battery cells available with a range of designs suiting a wide range of sectors and applications, with high product quality, consistency and reliability, covering the state of the art lithium ion as well as next-generation technologies like solid-state batteries.
- Electrode and cell manufacturing with the lowest carbon impact due to high efficiency, flexible processes, mainly through dry and high-solid water-based processing of battery materials in advanced, highly efficient machinery.
- Smart battery cells, integrating sensing functionalities (to feed the battery management system with real-time data at the material, interface, component or cell levels), as well as self-healing functionalities (to restore a defective interface or component inside the cell, with the possibility to trigger the healing process with a signal sent by the battery management system).
- Digital modelling tools available both for electrode and cell design, leading to a significant shortening in electrode and cell design and optimisation, encompassing state of the art as well as innovative breakthrough battery technologies to come.
- Digital twins for manufacturing lines allowing accelerated process optimisation, reduction of material waste, energy efficiency and product consistency to deliver state of the art cells, but also to new battery cell technologies, i.e., solid-state cells.
- Digital Giga factories to decrease capital expenditures and operational expenses for battery manufacturing, i.e., by sector coupling of materials, energy and supply flows in holistically designed production sites.

c) Scope of actions

Strategic Action 1 - Environmentally sustainable processing techniques applied to large scale electrode and cell component manufacturing for Li-ion batteries

Manufacturing of commercial Li-ion battery (Gen. 1 to Gen. 3) porous electrodes involves the wet coating of the active high energy materials in organic dispersing media such as NMP, a toxic and expensive solvent, also requiring complex recovery systems to collect the evaporated NMP in the drying process.

Water-based wet coating systems are already being explored and still show significant room for improvement i.e., by increasing the content of solid and reducing the solvent fraction, thus reducing the energy demand of the drying step. Moreover, fully dry coating processes that could completely remove the need for energy-consuming drying would allow a significant step to further reduce the carbon footprint of the electrode fabrication process.

Also, there are other new concepts that can benefit from the implementation of dry manufacturing techniques such as 3D patterning of active electrode layers, graded electrode coatings for increased functionality, electrode structuring or hydrophobic surface treatment of electrodes with next-generation materials. The process should be scalable, safer, cheaper, cleaner and less energy-consuming compared to state of the art technologies.

Impact (KPIs): Reduction of the carbon intensity of 25% CO_2/kWh through lower inactive materials deployment at cell level. Reduce the production costs for the investigated process step by at least 20% referring to the state of the art of lithium battery cell production costs.

Strategic Action 2 - Manufacturing technology development for solid-state batteries (Gen. 4a - 4b batteries)

There is a critical need for the development and manufacturing of new solid electrolytes that can be coupled with traditional active materials (Gen. 4a) and metallic lithium at the anode (Gen. 4b), leading to significantly enhanced energy density.

As a consequence, in parallel to the progress in new materials developments, there is a growing need to develop appropriate processing techniques for solid type electrolytes including all current foreseen technological options: polymer-based, hybrid polymeric, inorganic and other alternatives such as gel-like semisolid electrolytes.

The new manufacturing techniques for the solid-state battery generations 4a/4b should focus on cost, performance, safety and sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by the e-mobility sector.

Impact (KPIs): The manufacturing techniques to be developed for solid-state battery cells should improve over Li-ion by at least 20% in terms of environmental impact (e.g., carbon intensity gCO2/kWh), energy consumption (e.g., kWh consumed per kWh stored), production costs (e.g., EUR/kWh) by the end of the action.

Strategic Action 3 - Towards creating an integrated manufacturing value chain in Europe: from machinery development to plant and site integrated design

In order to build cost-competitive Li-ion battery (LIB) cell production plants in Europe, the complete production value chain from machinery to plant and site development and optimisation must be considered holistically.

On one side, Europe must develop a leading position in the production of resource-efficient, smart electrode and cell manufacturing machinery. Innovation in manufacturing machinery and processes must make improvements in terms of process capability, reduction of material waste, energy efficiency and product consistency to deliver state of the art cells, but also to fit new processes oriented to new battery cell technologies (i.e., solid-state cells) circularity and digitalisation concepts.

On the other side, for sustainable success, the horizontal integration of the European supply chain for battery process equipment into the growing expansion of giga-scale battery cell factories is a major challenge.

Therefore, there is a need for closing the gap and enabling deeper collaboration between industrial-scale cell manufacturing, battery process equipment companies, energy suppliers, material suppliers and other industrial sectors potentially benefitting from sector coupling with cell manufacturing.

Impact (KPIs): Increase in manufacturing production rate by 10-15% referring to the state of the art of lithium-ion battery cells; increase of battery cell production overall effectiveness efficiency (OEE) > 90%; reduce the cost of equipment - capital investment per GWh down to 80M EUR by retrofitting; reduce energy consumption by 25%.

Strategic Action 4 - Advanced digital twins for optimisation of current battery cell production lines and to accelerate the set-up of effective manufacturing processes for the next-generation battery cells

In order to increase battery cell manufacturing competitiveness, battery cell manufacturing needs to take advantage of high-performance computational tools. A digital twin of current production lines will facilitate the development of more flexible and more productive battery production lines and can be adapted to specific requirements in real-time during production, answering what-if questions and reducing trial and error approaches in the manufacturing process, therefore, reducing costs and environmental impact.

On the other side, in view of the expected rapid emergence of new battery technologies, it is necessary to develop an integrative modelling approach ("smart digital twin") able to simulate and optimise fabrication processes of this new generation of battery technologies.

First-generation, data-driven digital twins may be suitable for breaking the ground in the field, more specifically in the context of conventional li-ion cell production lines already available. In this regard, the LiPLANET pilot network may play a central role by supplying data, as well as potentially as an initial playground for field trials. On the other hand, the smart digital twin approach, coupling both physics-based and AI-based models, should also be complementary with the Battery Interface Genome–Material Acceleration Platform (BIG-MAP) established by the BATTERY 2030+ Initiative, contributing to reducing the end-to-end discovery time for future ultrahigh-performance batteries.

Impact (KPIs): Increase in production rate by 10-15% compared to today's Li-ion battery cell; reduce the cost of capital production equipment investment by GWh close to 80M EUR by 25-30% through retrofitting; reduce energy consumption by 25% compared to today's energy consumption for Li-ion battery cell production.

Strategic Action 5 – Integration of smart functionalities in battery cells

Embedding smart sensing functionalities and/or functionalities enabling battery self-healing inside battery cells will significantly enhance the performances, lifetime, reliability and safety of the whole battery system. Sensors integrated into battery cells will communicate real-time data to the battery management system (BMS) for a better diagnosis and prognosis of the cell status. Furthermore, the BMS will be able to react to the sensor outputs and trigger active self-healing processes at the cell level. This action encompasses the development and integration of non-invasive sensing and/or self-healing mechanisms inside battery cells, as well as the coupling of sensing and active self-healing functionalities via the BMS. Sensors and self-healing functionalities need to be adapted to the detection of the critical ageing processes. A link with the activities related to accelerated battery material discovery and interface engineering can be established.

Impact (KPIs): Battery cells with smart functionalities implemented should lead to improvements in performance, lifetime and reliability of at least 20% by the end of the action, as well as enhancement of the safety level.

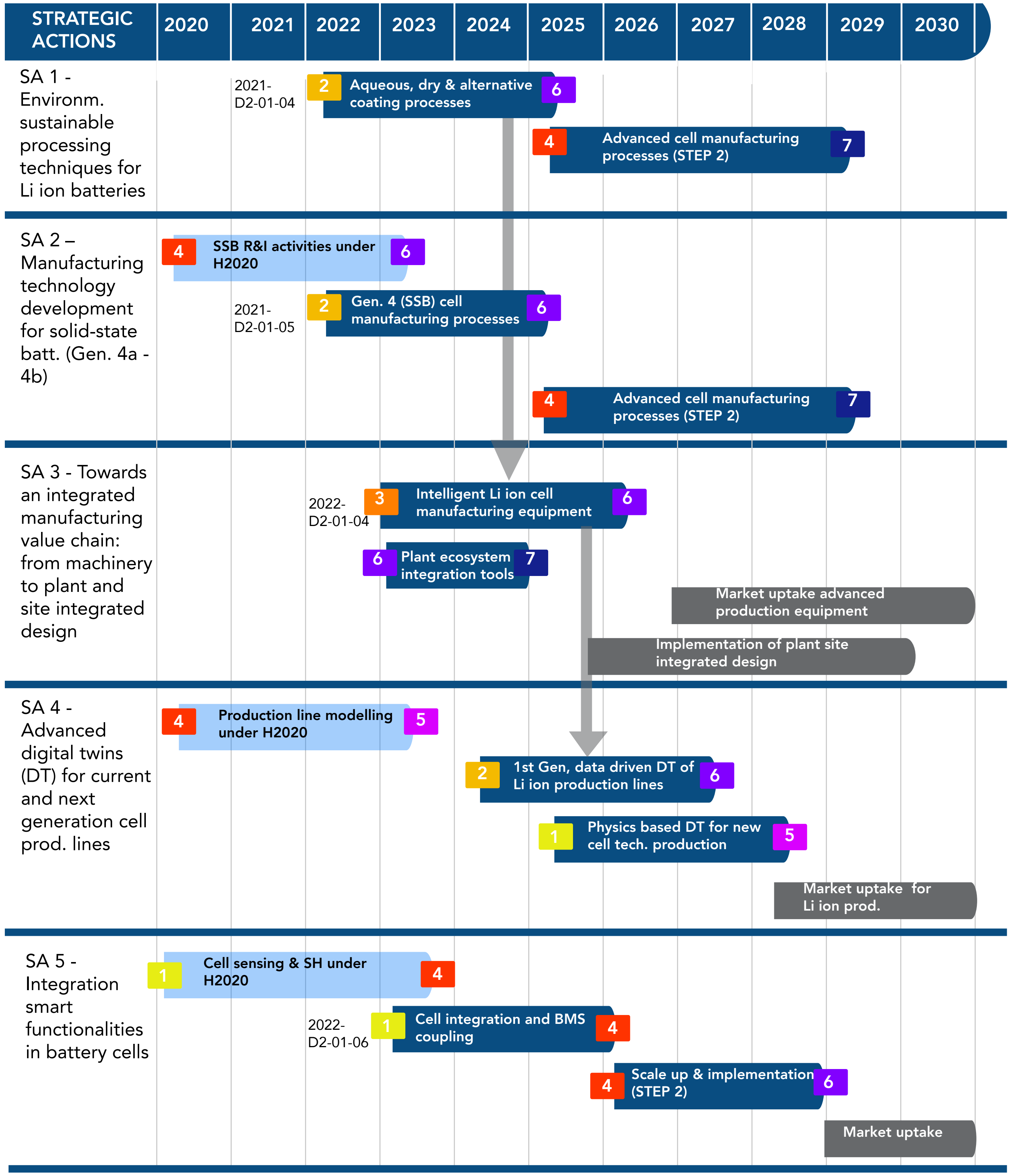
d) Strategic action timeline

The activities proposed cover several dimensions from basic technology generation to its implementation in practical equipment and industry 4.0-friendly tools. These actions (Figure 17) will deliver manufacturing tools and techniques that will enable European cell manufacturers to benefit from local manufacturing technology with ultimate features in terms of sustainability, digitalization, efficiency and environmental impact (e.g., low or no side emissions and low energy consumption).

These actions are designed to deliver results in a cascade-like mode. Strategic actions on advanced cell electrode, electrolyte and other key cell components manufacturing techniques (SA1, SA2) are aimed to be implemented into intelligent, efficient and interconnected equipment development (SA3). In this way, such equipment will channel the market impacts of the process development strategic actions. Such advanced equipment will then be at the foundation for complete digital twins of production lines (SA4) that will allow real-time monitoring, optimisation and troubleshooting of the manufacturing processes. These will also be the basis for an intelligent design of factory site, local energy and materials ecosystems design (SA4) in order to optimise energy and material flows in terms of availability and logistics. The timeline of these actions can be seen in Figure 18.

Some of the actions proposed a focus on current short- and medium-term dominant technology of Li-ion, while at the same time provision is made to facilitate the uptake of new battery technologies to come in the medium- and longer-term, such as Gen. 4 (solid-state) and others (SA2). Longer-term targeted innovative battery technologies and tools foreseen under initiatives like Battery 2030+ are also reflected, as it is the case of physics-based, advanced production line digital twins (SA4) and the integration of smart functionalities like sensors and self-healing solutions at cell level (SA5).

Figure 18 | Timeline of strategic actions in Area 2.2: Cell design and manufacturing of battery cells.



4.3 Area 3: BATTERY END-USES AND OPERATIONS

4.3.1 BATTERY SYSTEMS FOR TRANSPORT AND MOBILE APPLICATIONS (INCLUDING INDUSTRIAL/OFF-ROAD)

a) Specific challenges and objectives

The different mobility modes (road, waterborne, airborne, rail) together represent around 25% of total CO2 emissions in the EU[38]. Significant efforts have led to efficiency improvements (for example, the average emissions from new passenger cars[39], measured in g[CO2]/km, decreased by 30% between 2000 and 2018). However, mobility demand continues to grow, and the sector remains the only one that has not been able to reduce its CO2 emissions (the EU transport emissions have increased by around 20% compared to 1990 levels, while the EU total emissions have decreased by around 20% in the same period). Batteries are playing an increasingly important role in decarbonising light-duty transport[40] (in particular, passenger cars and vans, which represents around 50% of current EU transport sector CO2 emissions). Batteries can also contribute to the decarbonisation of heavy-duty transport (trucks, trains, ships, planes, etc.) and non-road mobile machinery (construction, agriculture, mining, etc.). It should be noted that integrating batteries into vehicles will not only enable the deep decarbonisation of the transport sector but will also play a major role in supporting the shift towards more renewables in the power sector thanks to vehicle-to-grid energy storage.

In this context, R&I in the field of battery systems for transport and mobile applications is strongly needed. The application requirements, hence, the battery key performance indicators (KPIs), vary from one application segment to the other (for more information, the reader can refer to the KPI tables established by the European technology and innovation platform, BATTERIES EUROPE). Nevertheless, it is worth exploiting synergies between the different application segments, by developing new technologies at the battery system level (considering mechanical, electrical and thermal engineering aspects, as well as battery management software and hardware) that will have an impact on several application segments. The different application segments in the transport sector share the same key challenges, in particular:

- Market uptake and competitiveness: enabling the electrification of mobility modes (including road, waterborne, airborne and rail transport, as well as non-road mobile machinery) with battery systems that offer the required level of performances (energy density, power density, fast charging capability, cycle and calendar lifetime, reliability, etc.), cost and safety; safety is a particularly important aspect for the market uptake of batteries for transport and mobile applications.
- Industrial upscaling: supporting industrial upscaling, with battery systems that are designed for manufacturability and with new digital tools for battery system design, manufacturing and testing.
- Sustainability: contributing to the establishment of a circular economy, with battery systems that are designed for end-of-life management (dismantling, recycling, reuse, remanufacturing).

To address those challenges, the partnership proposes developing sustainable and affordable battery solutions for clean mobility (partnership specific objective #2). The focus will be on the battery system level, i.e., in the integration of battery cells into a battery system (e.g., a battery pack). It will complement the R&I actions to be undertaken at the raw material, advanced material and cell levels (see previous sections). It should be noted that R&I actions related to the integration of battery systems into larger systems (e.g., into vehicles), are out of the scope of the Battery Partnership, and will be addressed by application-oriented European partnerships.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Enabling the cost-efficient electrification of several transport and mobile applications (including road, waterborne, airborne and rail transport, as well as non-road mobile machinery).
- Competitiveness of the European battery industry in the transport market.
- Increased performances, lifetime and reliability.
- Reduced cost of battery system design, manufacturing, operation and testing.
- Reduced cost of battery system EoL management.
- Safety and technical reliability of battery applications in the various mobility modes.

c) Scope of actions

Strategic Action 1: High-performance and safe-by-design battery systems

This action aims at developing innovative battery systems technologies that will benefit several transport and mobile applications, by significantly improving performance and safety, as well as environmental sustainability and cost. The action focuses on the battery system level, i.e., on the integration of battery cells into a battery system (e.g., a battery pack), considering mechanical, electrical and thermal aspects. The integration of battery systems into larger systems (e.g., into vehicles) is beyond the scope of this action. The action considers new technologies (battery system materials, mechanical design, electrical architectures, thermal management strategies, etc.) for enhancing performances and safety. It also addresses manufacturability and recyclability in order to reduce the manufacturing, dismantling and recycling costs of the new battery systems. This action will cover several mobility modes, in order to maximise the impact on the European industry and carbon footprint reduction.

Strategic Action 2: Advanced battery management for optimised battery utilisation

(valid both for mobility and stationary applications) – see area 3.2.

Strategic Action 3: Digital twins for battery system manufacturing

This action aims at developing digital twins of battery system manufacturing units in order to accelerate the development of manufacturing processes, increasing the manufacturing unit uptime, decreasing the manufacturing cost and improving the quality of the battery systems which are manufactured. Digital twins can also facilitate rapid reconfiguration of manufacturing units and the development of new business models and organisational approaches. This action will include the adaptation of battery system manufacturing units to integrate sensors and data communication means, as well as the development of real-time models. This should also include a traceability system leading to increased transparency in the value chain leading to increased opportunities to include sustainability metrics as evaluations of battery systems.

Strategic Action 4: Digitalisation of battery testing

This action aims at providing digital tools, platforms or methods for accelerating and improving the battery testing processes, with particular attention given to the assessment of battery performance, lifetime, reliability and safety. It will lead to a new paradigm based on the intelligent design of experiments; the smart combination of physical and virtual testing; and, the use of advanced battery models leveraging physics-based as well as data-driven approaches.

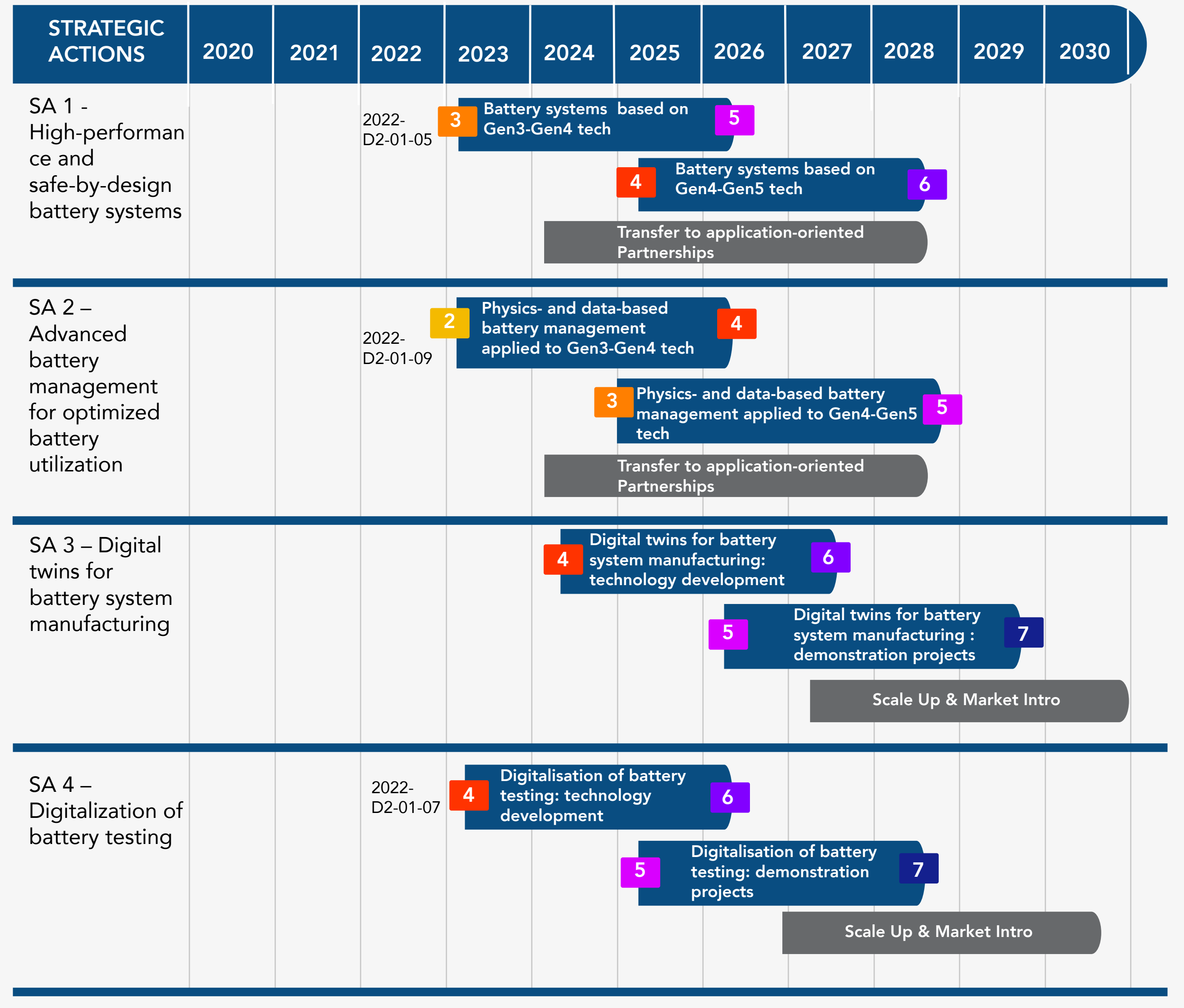
d) Strategic action timeline

The timeline of activities currently foreseen for each of these strategic actions is presented in Figure 18.

Concerning the first two strategic actions (high-performance and safe-by-design battery systems, and advanced battery management for optimised battery utilisation), the R&I activities will focus successively on the integration and management of different generations of battery cells (in particular Gen. 3, Gen. 4 and possibly Gen. 5 technologies). In parallel, the novel technologies developed in those fields will be progressively transferred towards the application-oriented partnerships (devoted to road, waterborne, airborne and rail transport) in order to bring the technologies towards higher TRLs in the framework of demonstration projects.

Concerning the other two strategic actions (digital twins for battery system manufacturing and the digitalisation of battery testing), the proposed approach is the first to develop the core technologies (in the laboratory and relevant environments) and then to demonstrate those technologies at higher TRLs (in operational environments).

Figure 19 | Timeline of strategic actions in Area 3.1: Battery systems for transport and mobile applications.



4.3.2 BATTERY SYSTEMS FOR STATIONARY STORAGE APPLICATIONS (INCLUDING 2ND LIFE APPLICATIONS OF EV BATTERIES)

a) Specific challenges and objectives

Cost-effective energy storage is a key element for achieving European Green Deal targets[41], clearly representing an enabler[42] to contribute to the security of the electricity supply in the EU.[43] Thus, it improves grid flexibility and allows higher penetration levels of renewable energy sources to create a decarbonised and more electrified society while contributing to the diffusion of distributed generation and following a sustainable and circular approach, for instance by mean of leveraging second-life batteries.

Different energy storage technologies will coexist and be applied to the most suitable use case, where batteries are a winning option for many applications.[44] The stationary storage battery's main markets will be grid services (domestic-, industrial- and utility-scale), telecom, back-up, power quality and micro-grid (both on-grid and off-grid)[45], where mature chemistries together with innovative ones hold room for market opportunities. Interoperability, digital twins and multi-services are also key enablers for improving the usability and competitiveness of battery-based energy storage systems.

Moreover, R&I in the field of battery systems for energy storage applications is greatly needed. The application requirements, hence, the battery key performance indicators, vary from one application segment to the other.

However, key challenges requiring strong R&I efforts for stationary storage applications remain, such as:

- **Competitiveness:** massive deployment of stationary storage, both behind the meter (such as residential, commercial and industrial prosumers premises) and front of the meter (such as large-scale installations, both stand-alone and integrated into power plants) requires effective and cost-competitive battery systems in terms of performances (such as energy and power density, long life time, high reliability, low self-discharge, high round trip efficiency, etc.). A strong focus shall be kept on the optimisation of the total cost of system ownership (including both upfront capital and operational costs), in order to address and exploit potential business cases, which are currently still limited or not affordable. Such targets shall be addressed by leveraging digitalisation and ensuring the maximum level of safety.
- **Sustainability:** as an enabler of distributed clean energy, energy storage is intrinsically aligned with global sustainability goals. Nevertheless, actions such as R&I for increased usage of reliable and cost-effective second-life batteries can further improve a sustainable approach. The challenge is also to contribute to the establishment of a circular economy, with battery systems that are designed for optimal application function and with responsible EoL management (dismantling, recycling, reuse, remanufacturing).
- **Industrial upscaling:** supporting industrial upscaling, with battery systems that are designed for manufacturability and recyclability, and with new digital tools for battery system design, manufacturing and testing. Cost optimisation of battery systems, solutions for medium to long-duration storage for intermittent large renewable power plants and grid congestion management, as well as improvement of advanced digital tools for ensuring a seamless integration of intermittent renewable generation able to provide grid stabilisation services, are key factors to be addressed for a massive deployment of stationary storage.
- **Market uptake:** the integration of batteries in the several applications belonging to stationary storage is a key factor for market acceptance; efforts must ensure developing digital tools are able to model and thus predict properties of systems in different fields of applications. Meanwhile, integration is also needed for effectively enabling usage of second-life batteries as well as emerging technologies. Finally, a crucial aspect is to enable energy storage in electricity grids with battery systems that offer the required level of performances (energy and power-related footprint, cycles and calendar lifetime, reliability, etc.), cost and safety.
- **Safety:** enabling adaptations and development of safety approaches and designs, including standards, requires a large initial investment and will require a more holistic approach from cell level and up to the use case of the equipment.

In order to address those challenges, the partnership proposes implementing actions to enable the optimal design of stationary battery systems and allow cost-effective integration of renewable energy sources in the power grid (specific objective #3), leveraging digital solutions and novel technologies for storage, while always using a sustainable approach.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Increasing the penetration of intermittent distributed renewable generation, also providing services to the grid.
- Enabling new use cases for large-scale renewable generations and grid congestions leveraging innovative medium to long-term storage solutions (arbitrage and others).
- Increased performances, lifetime, reliability and safety of battery systems for stationary storage.
- Reduced upfront capital costs and optimised and safe operation thanks to effective digital solutions (open access Battery Management System (BMS), multi-services management systems, digital twins) for real-time use and degradation diagnostics and off-line ageing modelling.
- Competitiveness for the EU manufacturing industry thanks to the higher performance standard with cost-effectiveness.
- An environmentally sustainable circular value chain for Battery Energy Storage Solutions (BESS), leveraging second-life batteries and promoting an efficient process for recycling EoL batteries.

c) Scope of actions

Strategic Action 1 - Modelling and standardisation of second-life EV batteries for stationary energy storage

The aim of the action is to develop processes to reuse EV batteries in second-life applications through the modelling of battery ageing during second life usage and the methodology for reconditioning and validating their safety and durability. Development of test protocols and formats for tests/characterisation data - allowing the sharing of databases of packs' behaviour, as well as test protocols in order to predict residual usable capacity - are part of this action.

Sustainability and second-life use of batteries are ways to increase the utilisation of batteries. However, (i) a number of significant challenges still need to be addressed to allow the uptake of second-life applications, such as the durability and performance of second-life batteries and safety risks due to aged batteries; (ii) effective business models are to be demonstrated and; (iii) cost-effective technologies and eco-design for the dismantling the battery packs and repurposing for second life are to be developed.

Strategic Action 2 - Innovative battery solutions for stationary medium- to long-term storage with low discharge and high efficiency (including, but not restricted to, redox flow, lithium, sodium and new chemistries)

This action aims to develop and demonstrate cost-effective battery energy systems (including BMS) for longer-term storage (5+ hours) with still high round trip efficiency and very low monthly self-discharge rate. Affordable and sustainable batteries for energy storage such as new generations of Li-ion batteries, non-conventional redox-flow batteries and other novel technologies for stationary storage applications - up to hybrid battery systems - will be developed.

Indeed, the spread of renewable and sustainable energy sources in the framework of the decarbonisation of energy at the continental level requires the availability of energy storage in periods when primary sources, e.g., solar and wind, are inadequate. The challenge is to develop cost-effective systems and technologies for back-up, arbitrage, renewable sources generation shifting and grid congestion avoidance, among other uses.

Also part of this action are the development of performance models for storage systems including advanced modelling of thermal effects, the evaluation and prediction of instantaneous and residual performances of storage systems during ageing through physical and semi-empirical modelling.

Strategic Action 3 - Advanced battery management for optimised battery utilisation (valid both for mobility and stationary applications)

This action aims at developing a secure, real-time, knowledge-based and data-based open access battery management system, to ensure an optimised and safe utilisation of the battery system during all modes of operation; also ensuring open access to all the battery system information, which are required by end-users for optimal usage.

Improved BMS computational capability can also enable applications requiring real-time control. It will significantly enhance the performances, lifetime, reliability and safety of the battery system through a dynamic update of battery usage limitations and the possibility to widen the battery operating range in a controlled manner, eventually by means of active management. It will also facilitate battery maintenance and EoL management, by providing an accurate assessment of the battery state and an evaluation of how it will evolve in the future and even preventing faults - thus optimising interventions and decreasing insurance costs. In order to maximise the impact on the European industry and carbon footprint reduction, this action will cover several transport modes as well as stationary applications. Open and interoperable BMS will support the creation and up-take of a second-life applications market for EV batteries at the end of their first life, thus contributing to the overall sustainability and competitiveness of batteries. Advanced and interoperable BMS will also allow the hybridisation of the system, contributing in a wider extent to smart energy integration.

Strategic Action 4 – Industrial upscaling and manufacturing of battery systems applications for stationary energy storage

This action aims to develop innovative energy storage systems and increase the industrialisation of the next generation of battery solutions for stationary applications. This will lead to a lower total cost of ownership; increase safety and performance; and increase European competitiveness in the design, manufacturing and performance of the battery systems. It will consider the mechanical, electrical, thermal and software engineering of battery systems. It will also address manufacturability and recyclability to reduce the manufacturing, dismantling, maintenance and recycling costs of the battery systems for stationary storage applications – leveraging on more standardised system design with a modular approach.

Current and future factories for large scale energy storage systems will demand highly automated, digitally controlled, energy and material-efficient high yield manufacturing processes developed by fully digitalised production machinery, and at the lowest environmental footprint with battery application recyclability in focus.

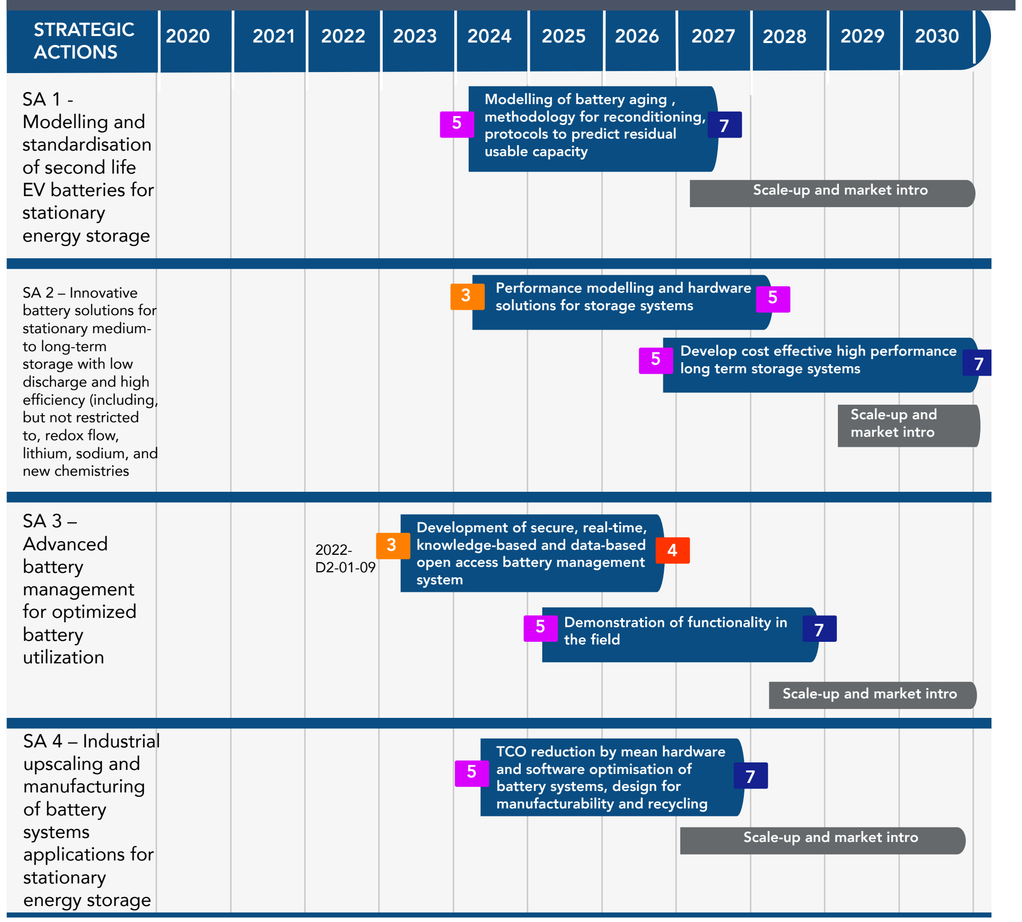
d) Strategic action timeline

Figure 19 is reported the timeline for the above-mentioned strategic actions, showing the path leading from the development stage to industrial deployment and market adoption. In particular, lower TRL SA3 will require validation for introducing novel long-duration storage technologies with enhanced performances into the intended environment up to a large-scale prototype. A second phase of demonstration systems will follow in order to have them in the medium long period systems ready for market introduction.

Concerning advanced battery management for optimised battery utilisation (topic common with mobility), the R&I activities will focus successively on the integration and management of different generations of battery cells, being then developed up the demonstration stage in a second phase, ready to be introduced in the medium period.

The remaining actions concern higher TRL actions, showing the same approach in the research of optimised solutions with a strong interest in sustainability and safety but focusing on notably different objects such as second-life batteries and new battery systems. In particular, SA1 will involve a phase of demonstration projects aiming to address the challenges of adopting second-life batteries in terms of technical, potential safety and economical risk, lack of standardisation causing higher system costs. The demonstration projects will aim to introduce a safe and cost-effective solution into the market in the medium period. Similarly, SA4 aims to introduce novel battery systems with a lower total cost of ownership and a low environmental footprint in two stages, with such a solution ready for market adoption in the second part of this decade.

Figure 20 | Strategic actions timeline for Area 3.2: Battery systems for stationary storage applications.



4.4 Area 4 – Cross-cutting topic - SAFETY

Most research efforts focus on improving battery performance and durability; however, battery safety is paramount to ensuring confidence and widespread adoption of e-mobility and electrical energy storage in our society. Battery research outcomes are increasing and further usage-state development are quickly reached. All these advances need to be foreseen and aligned with safety protocols or processes in order to provide safe and quick solutions to the battery market. Accordingly, standardisation bodies like ISO, IEC, SAE, CEN-CENELEC, etc. provide the needed standards to proceed safely with battery solutions.

Whereas we can consider that today's battery systems have reached a reasonable level of safety, it must be noted that it comes with substantial efforts at different system levels to detect and mitigate possible hazards. Further improvements in battery safety - in particular those impacting the intrinsic safety of the electrochemical components - are needed to facilitate technology acceptance, reduce costs and improve reliability.

Safety needs to be seen from the whole battery chain perspective. The improvement of safety at any specific level on the value chain, for example at the material level, should be beneficial for all levels. This implies that safety should not only be considered during active use but in a much larger scope along the complete value chain of batteries.

a) Specific challenges and objectives

It can be expected that new battery technologies will be associated with enhanced safety aspects. It is, for example, expected that solid-state technology will be a way to get rid of the hazards of organic electrolytes. Nevertheless, specific safety control methods will need to be developed, which are relevant for the specific safety risks of the new technology. There is a need for this safety approach to become an integral part of the R&D innovation program, suited to the specific properties of the technology under study, but based on improved, generic and standardised safety requirements.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes, complementary to the outcomes achieved by the relevant strategic actions proposed in the other areas of this program:

- The development and harmonisation of the safety standards for manufacturing are key steps to enabling a safe development of the new businesses associated with re-manufacturing or repurposing the batteries, as well as the strong development of the recycling industry in the next 10 years.
- Smart technical solutions for safety - including prevention, mitigation and protection systems, based on materials properties, cell and battery design and battery management system including both real-time control and advanced software able to prevent faults - are expected to reduce the global cost of safety and increase the simplicity and reliability of the battery system; this is a major step to facilitate the batteries acceptance in multiple applications until 2030.
- There is a need to carry out battery safety modelling work at different scales. From the mesoscopic scale to the scale of the complete system. Targeted methods of detecting battery system safety statuses are also expected. The knowledge resulted from this work will make it possible to diagnose the safety state of a battery according to different types of use.
- It is expected that the development of reliable testing methods for safety will generate the required level of confidence in the control of the potential hazards associated with batteries, particularly for the new applications and large systems considered in energy storage.
- Based on the progress of the safety controls and methodologies applied to the existing lithium batteries, a generic and harmonised approach for safety can facilitate the transition to new technologies post lithium.

c) Scope of actions

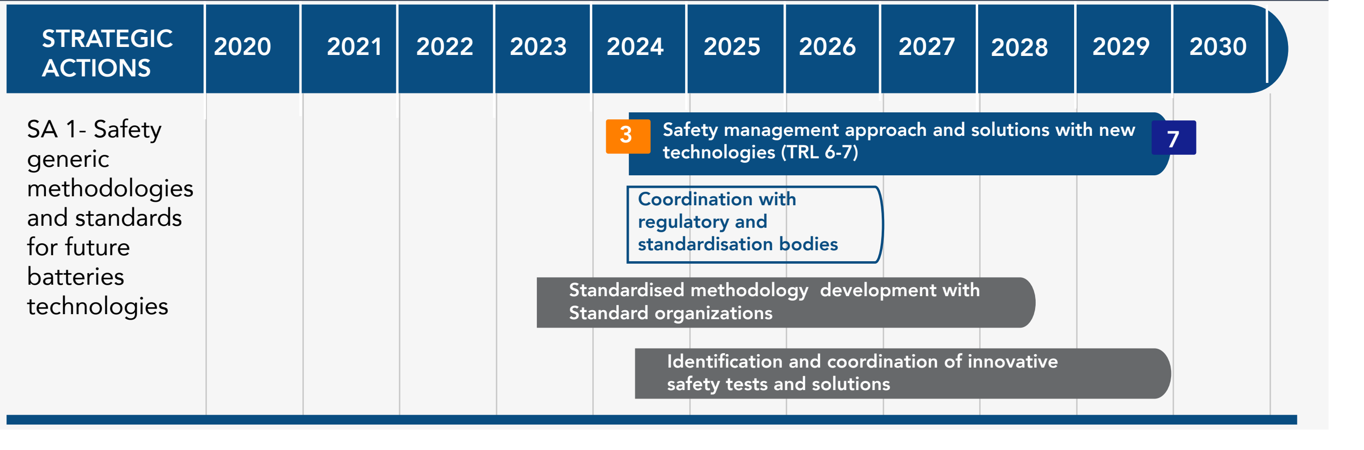
Strategic Action – Safety: Generic methodologies and standards for future batteries technologies

This action proposes generic safety approaches for batteries that can become an integral part of the R&D innovation program, suited to the specific properties of the technology under study, but based on improved, generic and standardised safety requirements (to be proposed for standardisation groups, potentially based on a functional safety approach).

d) Strategic action timeline

The Coordinated and Support Action (CSA) action supporting safety has to be related on one hand to the development of the new technologies described in this SRIA in order to develop safety management solutions suitable for the new technologies. On the other hand, the work to develop a standardised approach has to be initiated and coordinated with the potentially involved standardisation organisations, in parallel with the technology development. Therefore, the CSA action for safety should start as soon as questions of safety management are raised in the actions of this SRIA and the organisation of the safety management activity with the relevant standardisation bodies becomes necessary. The initiation of the CSA is proposed in 2023 and continuously coordinated with the input of the other actions from this SRIA.

Figure 21 | Strategic actions timeline for Area 4: Safety.



4.5 Area 5 – Cross-cutting topic – SUSTAINABILITY

Sustainability, in its three dimensions, will be a major differentiating factor of EU battery technologies within the international competitive landscape. R&D is not only needed to achieve ambitious KPIs at product and process levels but also to implement methods, indicators and rules across the industry to ensure the desired impact. This also needs close cooperation with policy-makers to establish an adequate regulatory framework to ensure the competitiveness of European industry.

Tools and methodologies that perform environmental and social life cycle assessment (LCA and S-LCA) to quantify the sustainability performance of batteries must be further developed from a holistic perspective. R&I actions are needed to develop data sources and expand methodologies to cover the broad range of sustainability aspects and ensure transparency and comparability in sustainability aspects between all types of batteries as well as other energy storage technologies. Innovation must also address the fact that sustainability is a cross-cutting issue with many conflicting objectives. Multi-criteria decision analysis (MCDA) can address the different dimensions of sustainability to analyse and evaluate future technologies.

a) Specific challenges and objectives – Economic sustainability

The dependency on individual countries outside the EU for raw materials for batteries makes the European battery industry and its supply chains vulnerable to geopolitical sensitivities. Furthermore, the growth of the demand for batteries and the need to secure the supply of raw materials for batteries is leading to international competition that may well affect the geopolitical balance and cause political tensions in exporting countries. EU research and innovation activities can be used to find new sources of primary and secondary raw materials, and to examine different battery chemistries and alternative materials to decrease the high dependency on importing raw materials and components from outside the EU but also to strengthen European suppliers and producers to develop mature technologies and the skills required to support the battery value chain abilities on the European market.

The manufacture of high-value components requires the coordination of a supply chain, which starts in mineral-rich countries and leads towards the assembly of battery modules into a final battery at the site of an automobile Original Equipment Manufacturer (OEM). The ongoing worldwide effort to decarbonise GDP requires that all manufacturing steps be assessed for their contribution to GHG emissions. Creating the scientific and technical foundations for the manufacture and traceability of low carbon footprint components is, therefore, a strategic differentiating feature.

Four possible mechanisms would allow established industry to carry out competitive investments with high sustainability standards:

- Development of competitive sustainable technologies;
- Enabling regulation;
- Change in willingness to pay (customer demand and business models);
- State-aid / funding policies.

Transparency and traceability standards will help consumers ensure good quality batteries. Increased awareness of responsibility issues in the value chain will raise interest in the customers valuing such battery products. Customers are possibly willing to pay a higher price for higher quality products. This will give room for new business cases and encourage producers to use solutions reducing the societal and environmental footprint of batteries. This requires setting ethical, social and environmental indicators to be measured; setting standards for the chain of custody data; active engagement of value chain key players and stakeholders; and more.

Figure 22 | Sustainability's cross-cutting matrix.

Raw materials	- Geophysical and Geopolitical considerations for supply - Lack of raw materials - Traceability	- Workers' rights and social aspects in the value chain	-Use of hazardous materials - Resource use across the value chain
Cell design materials	- New battery chemistries and demand for raw materials - Improve technical performance and costs decrease - Design for circularity	- Workers' rights and social aspects in the value chain - Jobs, reskilling and training - Replacing critical raw materials	- Use of hazardous materials - Resource use across the value chain - Design for circularity
Manufacturing	- Import and sustainability of the production outside the EU -Geopolitical considerations and s upply chain risks - Improve technical performance and costs decrease	- Workers' rights and social aspects in the value chain - Jobs, reskilling and training	-Resource use: chemicals, energy, water and resources in manufacturing - Carbon footprint - New and efficient process techniques
Applications	- New business models enhancing sustainability and competitiveness - Decreased cost of ownership	- Safety, work environment and user conditions	- Resource use across the value chain - New applications; Energy transition and electrification
Recycling	- Recycling aspects; economic feasibility, economic degradation and business models	- Jobs, reskilling and training - Collection of waste batteries	- Resource use - Environmental benefits/negative im-pacts -Recycling
Other	- Regulatory aspects related to R&D projects	- Social life cycle assessment	- Life cycle assessment and carbon footprint calculations

The cost decrease of sustainable unconventional technologies will also be a critical factor to electrification and carbon emission reduction in Europe. The already mature lithium-ion batteries can still be improved with increased performances when it comes to both specific energy and power. Even the life-time can still be improved to a higher number of cycles, which will keep the price low. The technical performance of the production processes as well as the performance of the products can be enhanced by increasing the information tagged with the products and their intermediates. The development of new mechanisms beyond state of the art will make sure that the addition of more information will not lead to breaches of security or confidentiality.

From a circular economy perspective, there is a need to enhance the design and manufacture from recycled sources. To overcome the current symbolic low percentages of recyclates in the mixtures with virgin materials, comprehensive ex-ante life cycle assessment and life cycle material modelling, envisioning new applications for the recycled batteries' materials, are essential prior to any product design. Already in the design phase of new batteries, aspects of recycling (on material, cell and battery level) and sustainability should be included. That means methods like design for recycling or design for sustainability should be used at an early stage and further developed.

b) Specific challenges and objectives – Social sustainability

Batteries in general, and e-mobility batteries in particular, have been identified as key enablers for the decarbonisation of the economy. It is widely agreed that this industry will grow at unprecedented rates over the next two decades. Amongst the key elements of growth are the recognition that the battery industry has to ensure the implementation of due diligence obligations throughout its supply chain with regards to labour rights and environmental protection.

In order to ensure these values are upheld, the battery industry has to implement the six steps of a due diligence plan:

- Get to know the supply chain and identify the risks;
- Encourage transparent public reporting;
- Conduct third party evaluation of suppliers, in line with the identified risks;
- Implement risk mitigation programs where deviations have been identified;
- Deploy a claim gathering mechanism to capture violations;
- Implement a follow-up mechanism to assess the deployment of mitigation measures and their effectiveness.

Transparency through the traceability system would at least allow consumers to make choices based on social issues. It will provide tools both for customer selection as well as regulation. Overall, this is expected to provide advancements in social conditions related to the battery value chain and especially in the production of raw materials for batteries.

Social life cycle assessment (S-LCA) is considered as a comprehensive methodology that aims to assess the positive and negative social impacts of a product or service. However, the different available S-LCA databases are problematic. There is a lack of information on social impacts of the sourcing, production and recycling of batteries. The methodology for S-LCA is still developing; the UNEP/SETAC guidelines on S-LCA are currently being reviewed through UN pilot studies.

Because of the high levels of uncertainty in S-LCAs, it can be difficult to interpret the results. The margins of uncertainty in S-LCAs are often greater than the measured differences between the compared options. The results of S-LCA are more interesting for raw material providers, cell producers or policy-makers. For technology process developers the sourcing of raw materials (of a specific country and related social issues) is less interesting. However, S-LCA offers a complementary approach to considering the social impacts of a process alongside the assessment of environmental impacts using traditional LCA and whole life cycle costing.

Jobs, reskilling and training are prerequisites for a fast transformation to a fossil-free society. The EU expects an increase in battery cell manufacturing capability in Europe. This expectation needs to be met with a growing workforce handling production technology, but also in all parts of the battery value-chain: materials, recycling, applications, etc. From a sustainability perspective, this means understanding how processes at all levels can be made to decrease emissions of CO2. For some of the actors, it means also knowledge about legislation or how toxic batteries, or the production of batteries, can be if not handled correctly.

c) Specific challenges and objectives – Environmental sustainability

The production of batteries and battery applications requires large amounts of resources. Critical inputs across the value chain are raw materials, chemicals, water, electricity and potentially other fuels. The environmental impact of batteries must consider the resource use across the value chain from raw materials and refining through the production process to the use phase and finally the end-of-life. Future research and development activities on batteries must address environmental sustainability by developing methodologies and technologies to optimise battery production, minimise resource and energy use and strive to achieve the lowest possible environmental footprint of batteries. R&D&I activities can contribute to resource-efficient batteries by promoting and developing new products and processes with resource efficiency KPIs.

Possible activities are sustainable processing of elements for active battery components; the production of materials and electrode components that are stable in a water-based process; the treatment of waste-water; circular material and resource flows in manufacturing processes; and, replacing solvents and developing new solvents. The battery technologies of today in many cases also depend on the usage of hazardous substances. An effort is needed across the value chain to ensure the safe management of hazardous materials, the substitution of hazardous materials with safer alternatives if feasible and the reduction of hazardous materials where possible.

The environmental performance of batteries and access to raw materials is heavily dependent on EoL management and recycling technologies. Overall, recycling batteries could potentially reduce energy consumption, greenhouse gas emissions and results in considerable natural resource savings. However, studies show that the benefits of battery recycling are not unequivocal and the environmental benefits are an area in great need of further analysis. Research should also be conducted to ensure that all recycled substances extracted from batteries are refined to the level that allows them to access the widest stream possible, or to the level that causes the lowest sustainability impact.

The early design phase of batteries determines the future recycling options and possibilities. Therefore, as early as possible, the potential for recycling should be considered on material, cell and battery level. Methods like “Design for Recycling” can be adjusted and applied. A major challenge of future recycling will be the potentially very low material value in battery cells. Thus, present recycling technologies are not sufficient, because they require too much energy or chemicals. Here physical recycling technologies could be an option to allow potentially a (rather simple) direct recycling of active materials. In any case, the future recycling options depends on the design decision in low TRLs. Therefore, post-LIB developers must interact with recycling experts as early as possible to ensure low effort recycling technology in the future.

In addition, battery application often stimulates more efficient resource and energy use, compared to the alternative technologies they replace. R&D&I activities increasing the use of batteries and promoting electrification in more sectors will hence be important tools to increase resource efficiency, i.e., by electrifying machinery, powered tools and transport applications.

Business, social, technical and environmental aspects of recycling must be developed and assessed in a holistic approach, from design to end-of-life. Life cycle assessment (LCA) is a methodology used to evaluate the environmental impacts of products and systems. It is standardised by ISO 14040:2006/ 14044:2006 and has been widely applied to batteries and the EC has developed Product Environmental Footprint Category Rules (PEFCRs) on rechargeable batteries. There is a need for the development of models and data required to thoroughly assess all possible environmental impact categories from batteries.

The sustainability criterion obtained from LCAs can be used to compare the environmental performance of different battery products and to choose between alternative process development routes for manufacturing battery components, and technologies for recycling raw materials at end-of-life. Many existing LCAs are based on only a few original primary datasets (like energy and raw material consumption), which increase the uncertainties of the environmental impact results significantly. Thus, there is a need for more and better primary data to support more robust LCA modelling studies. This is especially true for the production process (on an industrial scale), the key raw materials used to prepare the battery precursor chemicals for the active cathode materials (e.g., metal sulphates, etc.) and anode materials (e.g., graphite) and the different recycling processes. These primary data are often represented using proxies and outdated or incomplete datasets. For the pre-chain of raw materials, there is also a need for regionalised LCA data for mining, such as water footprint and harmonised energy source declarations from exploration to products.

Beyond advancements in the data and models for pure LCA studies, the PEFCRs should be extended from the battery product level to also consider primary data for the active electrode materials, and battery components (e.g., cathode, etc.), as well as secondary data from the recycling of battery components at the end-of-life. Current methodologies and data sets must be assessed and developed from a closed-loop perspective to fully capture the nature of the battery landscape as well as the environmental advantages of circular closed-loop systems. The framework also needs to be broadened to cover all possible battery application types as well as ensuring comparability between other energy storage technologies.

b) Expected outcomes by 2030

Projects are expected to contribute to the following outcomes:

- Greater economic sustainability – responsible materials sourcing, new business models and markets to enhance sustainability and competitiveness.
- Greater societal sustainability – responsible sourcing and production, education, jobs reskilling and training and following consumer trends.
- Greater environmental sustainability – reduced carbon footprint, controlled exposure to hazardous substances, proper recycling of critical raw materials and new approaches to design with a focus on recycling and reuse.
- Robust and reliable LCA tools to assess sustainability performance and evaluate optimal battery design with respect to materials and components selection, use of recovered secondary raw materials, manufacturing processes, resource use, production efficiency, logistics, use efficiency, end of life processing and closed-loop systems.
- Robust and reliable S-LCA tools to assess sustainability performance and evaluate optimal battery design with respect to component and raw materials choices, supply chain risks, work environmental conditions and social risk mitigation.
- Increased circularity and circular material flows in the battery value chain.
- Increased reusability and repairability and recycling efficiency of components.
- Increased traceability of raw materials and components in the battery value chain.
- Sound tools and methods to evaluate sustainability – to serve as the basis for European regulation in order to give competitive advantages to products designed, manufactured and used with respect to sustainability performance.

c) Scope of actions

Strategic Action 1 - Design for circularity

Evaluate battery design and materials from a reuse, recycle and repairability perspective. Perform analysis of battery and battery systems design as well as defining common principles, tools and methodologies for evaluation of design for circularity. Identify critical challenges in design and production from a circular perspective.

Strategic Action 2 – Processes enabling industrial closed loops, circular value chains and industrial synergies

Develop processes to enable industrialisation and commercialisation of closed loops to recycle and return low-value chemicals and by-products from active material and battery manufacturing processes to industrial high-value inputs. The aim is to develop new process technologies to stimulate secondary supply chains from Ni, Cu, Co and V flowsheets, where material and chemical recovery is not feasible today, such as recovery of sodium sulphate, gypsum and magnesium sulphate, promoting synergies across factories and industries to increase circular material flows. This action should be done in coordination with Processes4Planet Partnership.

Strategic Action 3 - Develop tools for traceability and risk assessment in the battery value chain

Develop tools and enabling technologies for information sharing, automated identification, data processing, sustainability assessment, traceability and standards for the chain of custody data for raw materials, components and battery applications along the value chain from mining and recycling to end-of-life.

Strategic Action 4 - Develop tools for life cycle assessments (LCA) of batteries

Development and improvement of new holistic and applicable quantitative tools, methodologies and data sets to perform environmental LCAs to quantify environmental sustainability performance of batteries. Development of data sources, evaluation of system boundaries and expanding methodologies to ensure transparency and comparability in sustainability aspects between several battery types, chemistries and battery applications, as well as comparability between energy storage technologies in general. Development and improved quality of data sets for primary and secondary raw materials as input in Life Cycle Inventory (LCI) modelling.

- Open access (LCI) data of raw materials
- Ecolabel of batteries (sustainability requirements)
- Use of LCA early in the design process
- Harmonised energy source declaration of material producing companies from exploration to final products
- Harmonised material flow analysis for battery raw materials
- Reliable raw materials (including chemicals and precursors) LCI
- Reliable recycling LCI data
- Understand the full sustainability (not focus only on one indicator)
- Scrutiny of primary and secondary materials (in terms of energy, costs and other impacts).

Longer term:

- Regionalised LCA for mining, LCI data and LCA of next-generation batteries.

Strategic Action 5 - Develop tools for social life cycle assessments (S-LCA) of batteries

Development of tools, methodologies and data sets to perform S-LCAs to quantify social sustainability performance of batteries. Development of methodologies, system boundaries and impact indicators to quantify social sustainability parameters along the full battery value chain as well as the development of sound data sets and sources.

d) Strategic action timeline

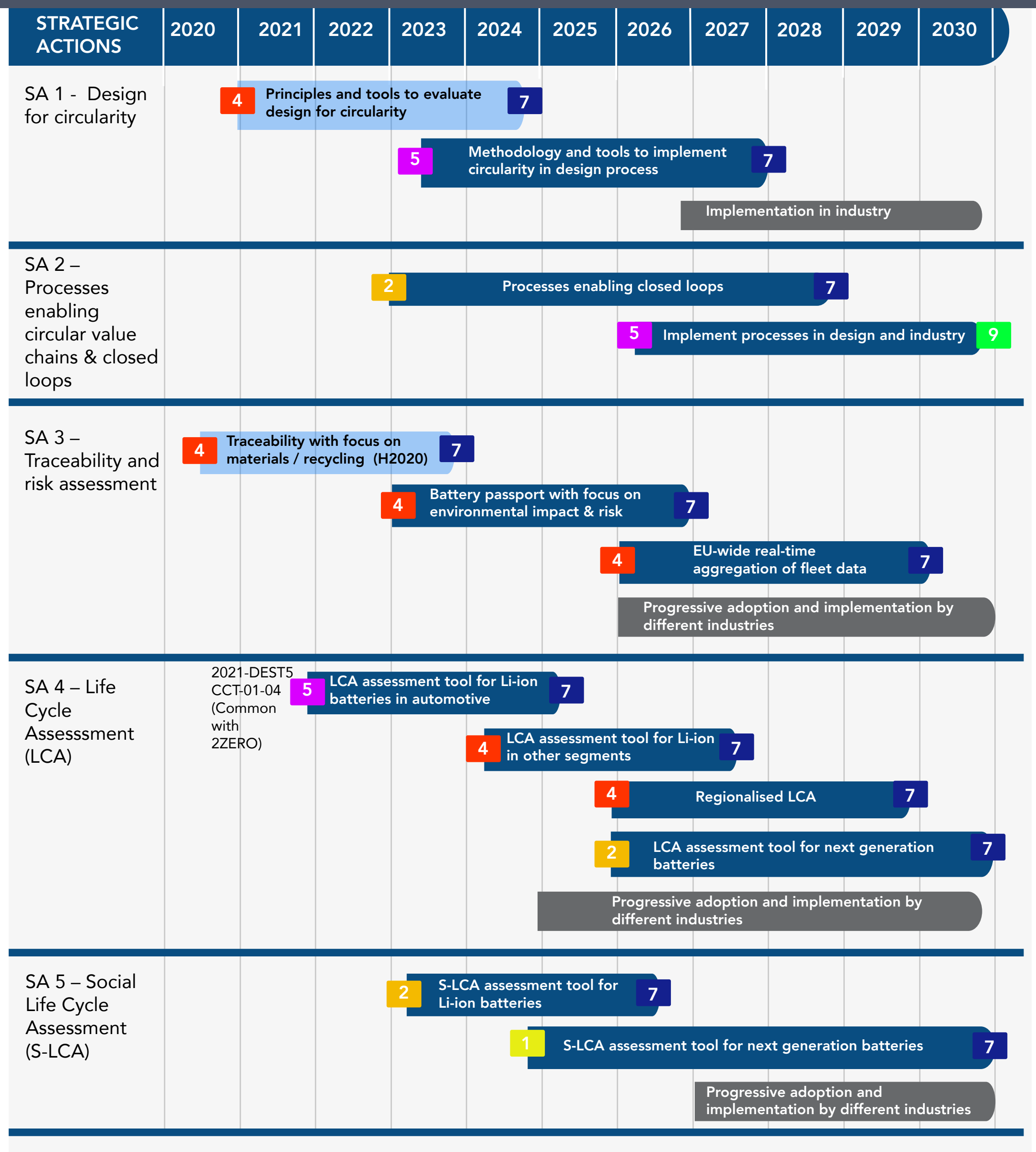
Enhancing sustainability for batteries is a matter of great complexity, due to the different dimensions that need to be taken into account. As previously outlined, the different dimensions embrace:

- economic, environmental and societal aspects;
- the entire value chain of batteries from raw materials to recycling;
- a high number of application areas, each with different

It is therefore important to elaborate, in the first step, a number of tools and methodologies that can be applied across the different layers and that enable the measurement of relevant indicators for sustainability, i.e., circularity, material content, environmental impact and societal impact in a consistent, holistic and comparable manner. This will allow the implementation of traceability and the assessment of the life cycle impact of batteries put on the market in Europe, as well as the enforcement of the corresponding regulatory framework. It is important to implement such methodologies in the first step on the most relevant battery technologies and application areas, enabling further finetuning and identification of best practices for the following generations. Whilst tools and methodologies to assess, measure and report the status quo are a first and fundamental step, they need to be followed by activities effectively improving the sustainability of batteries. Battery designs and processes need to be adopted to achieve higher levels of circularity and reduce their environmental and societal impact. Furthermore, the scope of the application of tools and methodologies needs to be extended to a broad range of end-user segments and industries and needs to be adapted to all battery technologies, i.e., conventional battery technologies, the

the future generation of Li-ion technologies and post-lithium technologies. Finally, data will be aggregated in automated data collection and data mining, enabling further digital intelligence processes to optimise and enhance battery sustainability in Europe. Making global data available will support multiple processes, e.g., it will help scientists to accelerate innovation, enable governments to spur informed decision-making processes on societal aspects, or streamline the adaptation of regulatory frameworks.

Figure 23 | Strategic actions timeline for Area 5: Sustainability.



4.6 Area 6 - COORDINATION

The goal for Europe is to be a leading producer of sustainable batteries. Batteries that rely on raw materials will be readily available and ethically produced. Batteries will be manufactured using energy that leaves no carbon footprint and will be efficiently reused and recycled, resulting in minimal impact on the earth's resources and climate. These batteries do not exist today. More research and development are required and Europe needs to invest in long-term disruptive technologies in parallel to shorter-term research and development that improve current technologies.

We are witnessing and partaking in a huge evolution of the battery industry in Europe, as giga-scale battery cell production and integration are being realised in order to support the green energy transition via electrification of mobility and energy storage for intermittent renewable energy sources. The industry is highly competitive with many established companies based in Asia. A high level and pace of new knowledge and innovation is a necessary success factor to produce sustainable batteries that are required for a climate-neutral society and demanded by the consumers. Europe needs to invest in research that can ensure novel solutions and that can support this green transition in the long term. Investments in long-term research will also stimulate a new generation of excellent young researchers as well as a skilled workforce highly sought after by the European battery industry. All the above needs have been recognised and have led to the establishment of the large-scale research initiative BATTERY 2030+ in 2018. It brings together the highest calibre academic and industrial battery research groups from across Europe and works on new concepts, provides clear direction and coordination based on a newly formulated long-term visionary research roadmap.

Sustained robust growth of the battery industry in Europe requires coordinated, continuous, strategically driven research and innovation across all parts of the battery value chain. To develop a shared vision and common strategic research agenda, good communication and close collaboration between industry stakeholders, research providers and policy/regulatory authorities, addressing the entire value chain are essential on a pan-European level. A well-structured open technology platform provides a "means and place of common connection" for all relevant stakeholders to interact and develop a shared vision and address current and evolving cross-cutting issues. This need has been recognised and led to the establishment of the Batteries Europe - European Technology and Innovation Platform launched in 2019. Within the platform, through extensive stakeholder interactions, top European experts identify research needs and prepare a broad scope strategic research agenda, along with addressing cross-cutting issues via dedicated task forces. The outputs are communicated to national, regional and European representatives along with the wider battery community.

2030 Vision:

Through strong coordination and collaborative actions, European's will have the means to strategically build a solid research base and educate a future generation of scientists and engineers to work in the field. This will in turn continuously deliver innovations to the industry thus resulting in best-in-class, high performance, low cost, sustainable battery technologies, which are made in Europe. The impact will be significant across the entire value chain with a similarly positive effect on integrators of battery systems. By 2030 it can be envisioned that Europe will be recognised as the world leader in battery technology and integration of battery systems and attract top talent from all over the world.

4.6.1 COORDINATION OF A LARGE-SCALE INITIATIVE ON FUTURE BATTERY TECHNOLOGIES

a) Specific challenges and objectives

This coordination and support action addresses the challenge of developing the European research efforts of a large-scale research initiative. This targets long-term goals, including inventing the sustainable batteries of the future, to provide the European industry with novelties, key technologies and a skilled workforce as well as to establish research excellence in Europe. This means bringing together representatives of the field (e.g., academia, RTOs and industry) to formulate and revise the long-term visionary research roadmap BATTERY 2030+, defining the steps and research efforts needed to reach the long-term overall vision. This challenge also has the means to find possibilities for collaboration with European research infrastructures (synchrotrons, neutrons and high-performance computing, etc.) in the most efficient way. This CSA will monitor the content progress in R&I activities in the projects linked to the BATTERY 2030+ initiative, update the BATTERY 2030+ research roadmap, define a joint exploitation plan of the technologies developed by the projects and provide inputs for education and training programmes. The link between BATTERY 2030+ and other relevant European initiatives (for example, the LiPLANET network on battery cell manufacturing) will be further developed.

b) Expected outcomes by 2030

- Fostering the scientific, technological, economic and societal impact of the initiative and paving the way to industrial exploitation of future battery technologies in key energy and transport application domains.
- Well-coordinated European research initiative on future battery technologies gathering excellent scientists and innovators as well as involving other relevant stakeholders and linked with relevant international, national and regional programmes.
- Spreading excellence in future battery technologies across Europe, increasing awareness of European activities and availability of European curricula in the field.
- Increased synergies and collaboration between the relevant research and innovation stakeholders in Europe as well as with major initiatives that already exist or are under preparation.

c) Scope of actions

Strategic Action - Coordination of a large-scale initiative on future battery technologies

Proposals are expected to:

- Coordinate the research activities and the stakeholders participating in the initiative;
- Facilitate communication, dialogue and cooperation on crosscutting topics;
- Monitor the initiative's progress and maintain its roadmap;
- Provide support for its governance;
- Promote and communicate the objectives of the initiative and its achievements, including by ensuring media presence and public visibility by engaging with industry and society and by participating or organising outreach events;
- Identify training and education needs and promote European curricula in future battery technologies.

In particular, proposals should identify and coordinate relevant efforts for modelling and data sharing, standardisation and IPR actions in cooperation with other relevant initiatives at the European level. They should also help with networking and collaboration with other relevant national and international activities in the field. They should cooperate with Batteries Europe, the ETIP on battery announced in the EU Strategic Action Plan on Batteries.

It is expected that such an activity is driven by representatives of the relevant actors of the field (e.g., from academia, RTOs and industry).

4.6.2 COORDINATE AND SUPPORT A PLATFORM TO EFFECTIVELY DEVELOP, CONSOLIDATE AND COMMUNICATE A STRATEGIC RESEARCH APPROACH FOR ALL STAKEHOLDERS THROUGHOUT THE ENTIRE EUROPEAN BATTERY VALUE CHAIN

a) Specific challenges and objectives

Battery technology involves a very broad scope of stakeholders due to the wide variation in battery chemistries and range of end-user applications. A spectrum of competencies is required to take the science from raw materials through manufacturing to integration and finally recycling while ensuring cost competitiveness, sustainability and safe operations. Research and innovation along with regulation and policy developments are necessary for all aspects, especially as Europe sets its goal to establish large scale battery production. Developments in one part of the value chain often have knock-on effects for the entire value chain. Hence it is essential to meet the challenge of providing a holistic communication platform to ensure cooperation across such a broad spectrum of industrial stakeholders, research providers and policy/regulatory bodies.

There are several important battery initiatives across Europe addressing different aspects of battery developments, such as the Battery 2030+ initiative, and different parts of the value chain, such as LiPLANET. A primary challenge is to bring together all these initiatives and to ensure representation of the parts of the value chain which do not have a dedicated initiative. The battery platform is the communication hub for battery R&I in Europe.

Indeed, the manner of scientific reporting of research results varies from sector to sector, often making realistic comparisons and collaborations challenging. A holistic collaboration platform provides the means to communicate and agree upon common reporting methodologies and approaches, thus facilitating synergies between various parts of the value chain.

As battery technology develops various cross-cutting issues become highly relevant, as is currently the case with digitisation. With such dynamic developments, the challenge is to react in a timely manner. A well established and recognised communication platform makes it possible to attract and work with experts from other disciplines to develop an understanding of the possible benefits of cross-sectorial work and to contribute this to the evolving strategic research agenda. The platform will address the challenge of ensuring continuous communication and collaboration, with a readjustment of the strategic research agenda goal as progression is made.

Specific objectives:

The primary objective of supporting the platform is to provide a high level of coordination with extensive expert engagement across the European battery research and innovation community and to continuously build and renew the strategic research and innovation agenda. This involves facilitating, hosting and encouraging communication and cooperation between industry stakeholders, research

research providers and policy/regulatory authorities on a regular basis and ensures synergetic effects thus avoiding duplication of efforts and/or neglect of a specific research need.

The platform aims to communicate and create common acceptance and understanding of research standards and reporting methodologies and thus facilitating high-quality benchmarking of evolving battery technologies. The collection and consolidation of state-of-the-art KPIs along with hosting the development of projected KPIs are key objectives, along with the reporting of these values to the SET Plan. The platform will continue to provide and build on the objective to provide an overview of national programs, events and current battery research projects both EU and nationally via the platform website. The platform is dynamic and as battery technology evolves and cross-cutting issues arise the platform will continue to establish taskforces, with the expertise to identify research needs and opportunities arising. The platform is to be recognised and trusted as an open place of common connection for all stakeholders in the battery community.

b) Expected outcomes

- A more coordinated European battery R&I eco-system acknowledging that R&I throughout the battery value-chain is complementary and contributes to a competitive European battery industry.
- EU and Member States are aligned towards/guided by an up-to-date coherent strategic research and innovation agenda (SRIA) and corresponding detailed roadmaps covering all aspects of the battery value chain.
- Europe has an extensive, open network of battery R&I stakeholders, accessible to all relevant experts. Thus, the battery R&I community is consolidated across the EU and associated countries and across battery-related networks, projects and initiatives (including European, national, regional – HEU Partnerships, IPCEIs, interregional partnership on advanced battery materials, the European Battery Alliance and coordination actions including Battery2030PLUS, LiPLANET).
- Uniform standards and methodologies for the reporting of battery research developments are communicated and implemented across EU and national projects building on existing European and national work/efforts.
- Clear communication of results and progress in battery R&I on both a European and international level.
- EU has a “one-stop-shop” on battery R&I information, including information on national programmes, events, battery projects and national battery networks (via a website and other communication channels).
- Input and dialogue between relevant policymakers/regulators and battery stakeholders involved in research and innovation are facilitated.

c) Scope of actions

Strategic Action - Coordinate and support a platform to effectively develop, consolidate and communicate a strategic research approach for all stakeholders throughout the entire European battery value chain.

A battery R&I coordination platform, covering the complete battery value chain will facilitate overarching cooperation. The platform can play a key role in boosting parts of the value chain that may not have dedicated initiatives. A coordination platform for battery R&I is needed not only to gather appropriate resources but also to contribute to attracting the talent and competences necessary to achieve the technical goals and to support the European industry. The overarching European R&I platform will build on previous efforts and continue to foster pan-European active cooperation and maintain a clear realistic strategic research and innovation agenda for Europe.

In addition to coordinating the creation of the SRIA and corresponding detailed technology roadmaps, the platform will continue to support taskforces focusing on topics that impact the battery industry and research. These groups afford the opportunity for the battery community to work with experts from a different field in a cross-collaborative manner, to identify the challenges and opportunities and thus create guidelines and recommendations on how best to develop synergies. This facilitates a dynamic way to meet the upcoming challenges in this rapidly evolving field of research. In order to ensure high-quality coordination and technical outputs from the battery platform, the management team should possess both technical and operative expertise.

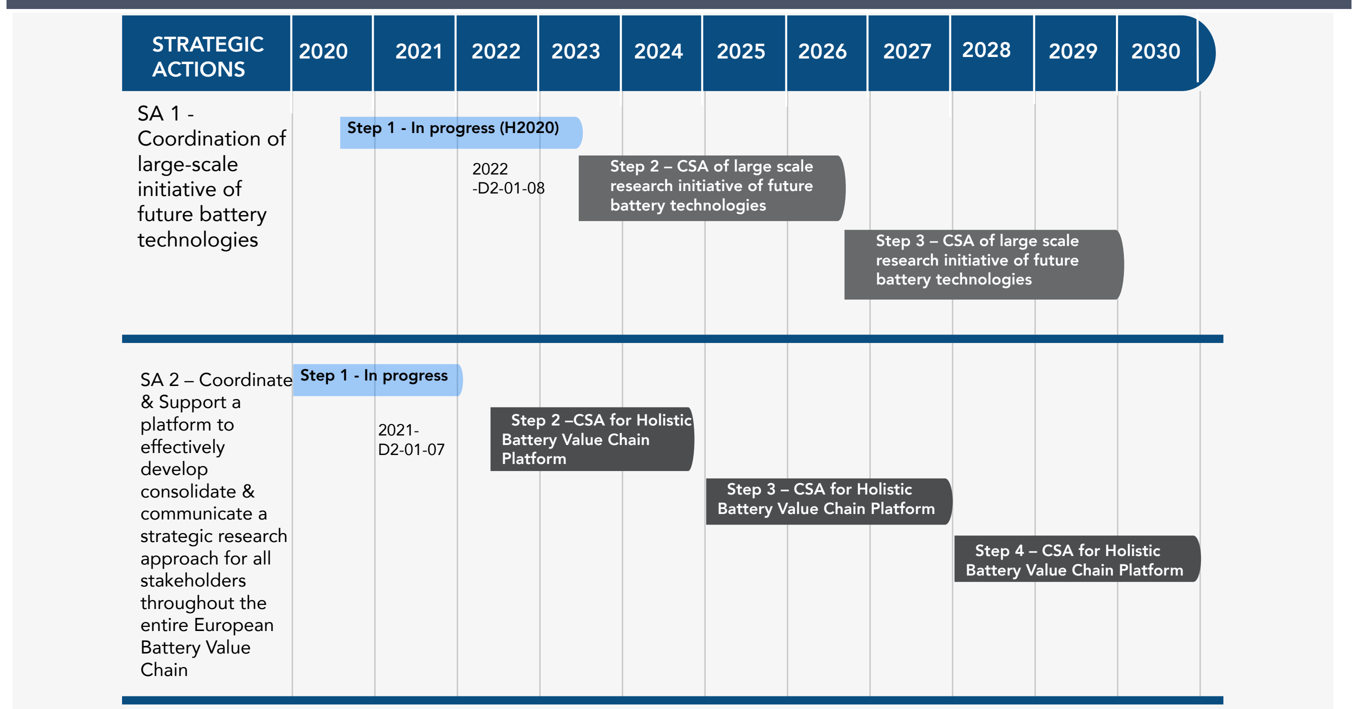
d) Strategic action timeline

Figure 23 illustrates the R&I coordination activities foreseen until 2030. There are three main elements to highlight:

- economic, environmental and societal aspects;
- The need for a large-scale pan-European long-term research initiative for Europe.
- The need to continue to build on the BATTERY 2030+ roadmap shaping the batteries of the future.
- The need for a large effort and the building of a research excellence community comprising academia, RTOs and industry.

The global battery industry is entering a highly competitive innovative phase with the rapid evolution of technology as a prerequisite for success. Europe is simultaneously investing strongly in both R&I activities and building up large scale production. The presence of the above-described open European battery R&I platform is and will become even more central to stakeholder communication across the entire battery value chain, particularly over the next decade. As battery applications and demands evolve, and regulatory requirements change, it will be necessary to have a well-established open community that can respond dynamically and appropriately to tasks, including revising the platforms roadmaps and strategic research agenda, reformulating KPI values and addressing new cross-cutting topics. The coordination activities with national and regional representatives in addition to other key networks will also evolve and be strengthened by sustained efforts of the platform.

Figure 24 | Strategic actions timeline for Area 6: Coordination.



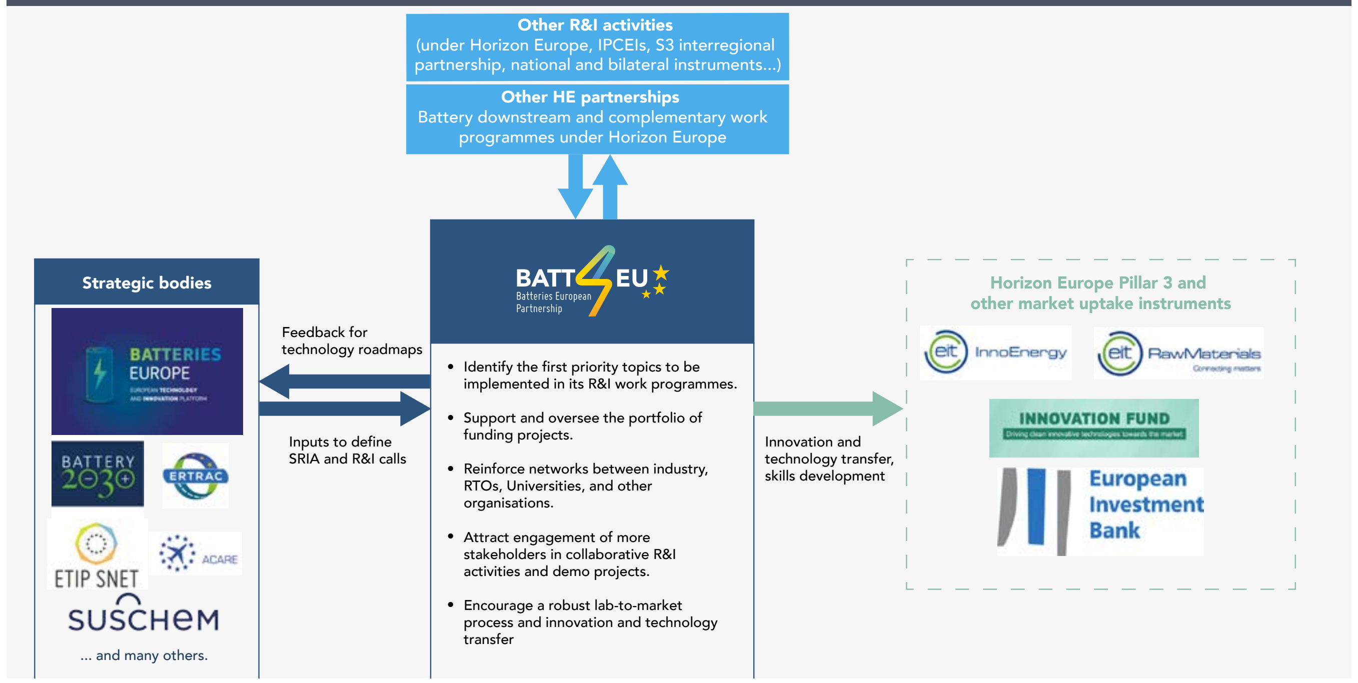
5 IMPLEMENTATION

To ensure the coordination of the selection, implementation and execution of R&I activities and the take-up of results among different key stakeholders along the battery value chain, the industry and research partners have joined forces in BEPA. All of the BEPA activities, its governance and its relations with other organisations are targeted towards establishing a competitive, sustainable and circular European battery value chain.

5.1 Activities and resources

By covering the whole industrial value chain and a wide range of technology readiness levels, the BATT4EU Partnership will efficiently coordinate the selection, implementation and execution of R&I activities and the take-up of results among different key stakeholders along the battery value chain (Figure 25). The main activity of the partnership will thus be to provide input and advice to the European Commission in order to contribute to the identification of priorities of research and innovation activities and the definition of call topics to be included in the Horizon Europe Work Programmes.

Figure 25 | Scheme of the main links/interactions of the partnership with other key stakeholders of the European battery R&I ecosystem.



5.1.1 SCALE OF RESOURCES

The achievement of the partnership's objectives is estimated to require an overall mobilisation of resources of approximately EUR 925 million for actions within the scope of the partnership.

Resources contributed by the private side will include:

- Contributions from the members participating in projects funded by the Union contributions (on the basis of the non-reimbursed eligible costs);
- In-kind contributions to additional activities in the scope of the SRIA not covered by Union funding;
- Investments in operational activities that is spent beyond the work that is foreseen in the SRIA and aligned with the objectives of the partnership.

5.1.2 SCOPE OF IN-KIND ADDITIONAL ACTIVITIES

In-kind additional activities may include:

- Activities contributing to strategic and operational alignment, coordination and synergies with other partnerships and initiatives at EU/national/regional or international level;[46]
- Activities contributing to the development of battery R&I ecosystems at EU/national/regional or international level;
- Communication, networking and outreach activities, including matchmaking and brokerage services on the calls for proposals, and activities ensuring dissemination and exploitation of results of R&I activities in the scope of the SRIA of the European partnership;
- Activities promoting, facilitating or accelerating innovation uptake in the market, including via financing opportunities provided by the European Investment Bank or venture capital funds;
- Scaling-up of technologies at higher TRL and uptake of results from partnership projects, such as pre-commercial trials, proof of concept, improvement of existing production lines for up-scaling or building new production facilities;
- Scaling-up of technologies at higher TRL and uptake of results from partnership projects, such as pre-commercial trials, proof of concept, improvement of existing production lines for up-scaling or building new production facilities;
- Activities supporting regulations and standards activities, especially on safety and sustainability aspects;
- Complementary side/upstream projects not funded by the EU, including:
  - low-TRL research activities, feeding into partnership projects,
  -R&I activities within the scope of the SRIA but not funded by the partnership;
- Activities addressing training and skills development, including contributing to the identification of gaps and needs, and the definition of joint training programmes.

5.1.3 SCOPE OF INVESTMENTS IN OPERATIONAL ACTIVITIES

Investments in operational activities may include:

- Investments in research infrastructures and test facilities;
- Investments in building production facilities;
- Investments in training programmes for workers and the development of curricula that have the potential to be scaled up;
- Investments in other activities required for putting the product/service resulting from R&I activities performed as part of the European partnership on the market.

Based on the scope of in-kind additional activities, the BATT4EU Partnership will elaborate its work plan on an annual basis. For the 2021-2022 period, the Batteries European Partnership Association elaborated a list of priority actions to be launched (Figure 26).

During the lifetime of the partnership, these additional activities will be defined as an integral part of the SRIA within its regular updates.

Figure 26 | Priority actions to be launched by the Batteries European Partnership Association in 2021-2022.

ACTIONS TO BE LAUNCHED IN 2021-2022 / ACTIVITIES INTEGRATED IN MOU	Strategic & operational alignment	Battery R&I ecosystems at EU/national/regional or international level	Communication networking and outreach activities	Innovation uptake in the market	Scaling-up of technologies at higher TRL	Supporting regulations and standards activitie	Complementary side/upstream projects not funded by the EU	Training and skills development
Launch of the Technical Working Groups (TWGs)	✓				✓			
Launch of the Enabling Task-Forces (Innovation uptake, Skills development)				✓	✓			✓
Coordination with other European Partnerships (respective responsibilities, joint calls,...), ETIP Batteries Europe (BE), Coordination with ETIP BE NRCG	✓	✓					✓	
Cooperation with other initiatives on specific topics (e.g. S3 Regional platform on advanced materials, Joint Research Centre, EIT Innoenergy, etc)		✓		✓		✓	✓	✓
Organisation of "Battery Innovation Days" (in coordination with BE and B2030+)		✓	✓					
Organisation of common workshops with other European Partnerships		✓	✓					
Organisation of at least one workshop/webinar on innovation uptake			✓	✓				
Creation of all the communication and dissemination tools			✓					
Dissemination activities focusing on battery projects' results (workshops, website, newsletter, annual report, etc)		✓	✓					
Publication "how to accelerate innovation uptake for battery technologies"			✓	✓				
Mapping of financing opportunities for battery technologies (inc. EIB funds)				✓				
Match-making activities (e.g. online event, match-making platform on Horizon Europe energy related topics)				✓				
Wide stakeholder consultation specifically on regulation / standardisation issues						✓		

5.1.4 CONTRIBUTION FROM INDUSTRY PARTNERS

The partners, other than the Union, envisage dedicating up to EUR 925 million for the period 2021-2030 in research, innovation and other activities in the area of the BATT4EU Partnership, engaging their constituent and affiliated entities to make such investments. These contributions will complement the Union contribution and will at least match the Union contribution.

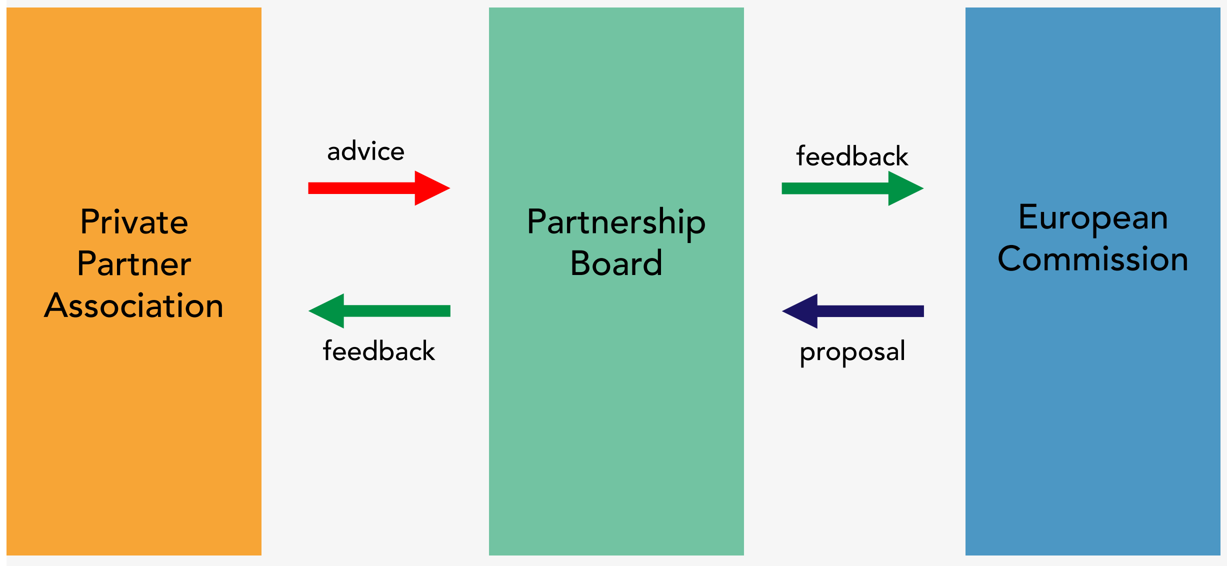
In addition, the private side of the partnership commits to:

- Sharing strategic priorities and entering into a continuous collaborative working scheme on pre-competitive activities;
- Guaranteeing effective outcomes by bringing successful mature innovations to market, liaising with market-oriented bodies (EIT, Innovation Fund, EIB, ERDF, InvestEU and others) on dissemination and market uptake activities all over Europe;
- Fostering the development of the new skills required by the EU battery industry;
- Supporting policy implementation, providing practical and real-field experience and feedback to policymakers, at EU and national levels;
- Acting in an open, transparent and inclusive way.

5.2 Governance

The Memorandum of Understanding between BEPA, the association representing the private-side actors and the European Commission, acting on behalf of the European Union, specifies the governance of BATT4EU.

Figure 27 | Interactions between the private and public stakeholders.



5.2.1 PRIVATE-SIDE ASSOCIATION

The private-side structured itself in BEPA, an international non-profit making association (AISBL) established in Belgium. Membership of BEPA AISBL is open to legal entities active – in a Member State or an Associated Country – in research and development, demonstration, industrialisation, production or deployment of the technologies and services covered by the partnership, as well as sharing and supporting the objectives of the partnership.

The Articles of Association of BEPA foresee three types of membership:

- Industry Members - industrial and commercial companies, including SMEs, active in the field of the battery value chain in Europe.
- Research Members - research and technology organisations and universities active in the field of the battery value chain in Europe.
- Associate Members - trade associations, non-governmental organisations and other stakeholders active in the field of the battery value chain in Europe.

The membership is subject to an annual membership fee to cover the operational costs of the partnership (daily management, events, communication). For 2021, the schedule of membership fees can be seen in Figure 28:[47]

Figure 28 | BEPA 2021 annual membership schedule of fees.

INDUSTRY MEMBERS (inc. for profit research)	Annual Fee
Large (headcount >5000 and turnover >1,5bn€)	9.500,00€
Intermediate (headcount 250-4999 or turnover 50ml-1,5bn€)	7.500,00€
Medium* (headcount 50-249 or turnover 10-50ml€)	5.000,00€
*SME (headcount 50-249 or turnover <50ml€)	2.500,00€
Small (headcount <50 or turnover <10ml€)	1.500,00€
RESEARCH MEMBERS (non profit)	
Large (headcount >250)	4.000,00€
Small (headcount <250)	2.500,00€
ASSOCIATE MEMBERS (membership without voting rights)	
Associations, NGOs and other stakeholders	1.000,00€

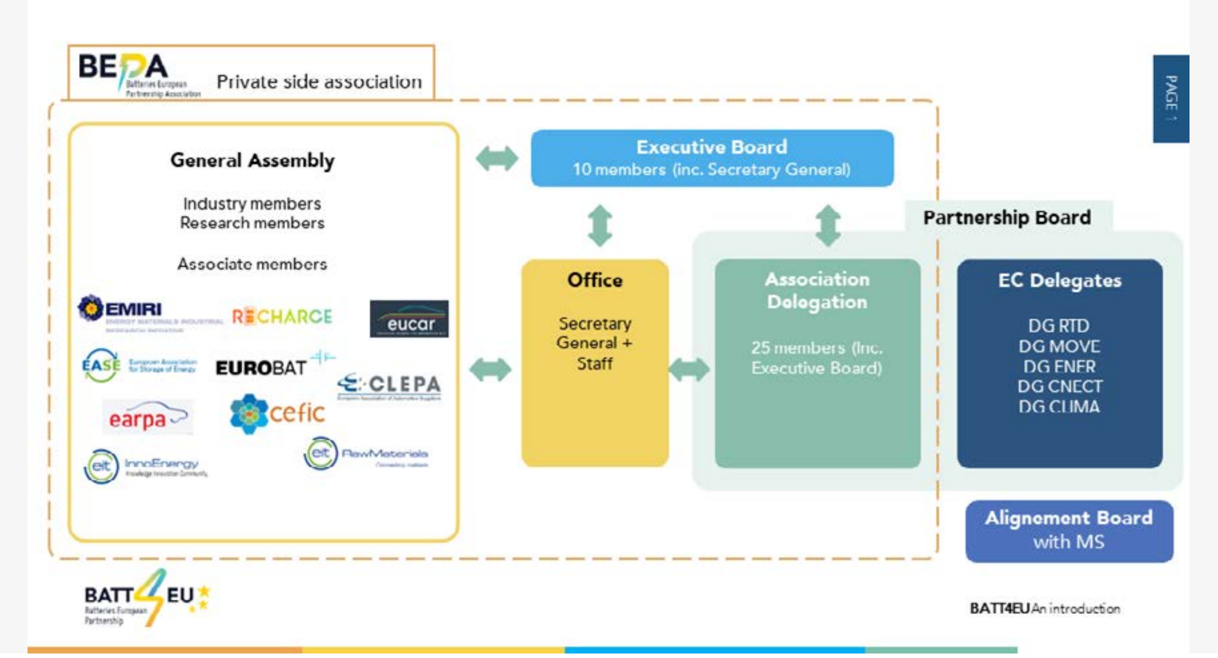
Particular efforts will be launched to reach out to SMEs and promote their participation in funded projects, so they can liaise with other entities across Europe and benefit even more from the European innovation ecosystem. The participation of smaller players bringing more disruptive innovations and new business models will definitely represent an asset for the partnership.

The private-side association has decided on its own governance structures and will implement the appropriate consultation processes, based on openness and transparency, to ensure the adequate involvement of all relevant stakeholders in the preparation of the inputs to the partnership board.

A lean, efficient and agile governance is targeted, similar to the successful governance structures of existing partnership private-side structures (e.g., EGVIA). The partnership private-side association (AISBL) mainly consists of 4 governing bodies (Figure 29):

- the General Assembly (which shall consist of all members of the AISBL);
- the Executive Board (appointed by the General Assembly);
- the Association Delegation (appointed by the General Assembly); and
- the Secretary-General (appointed by the Executive Board).

Figure 29 | Governance bodies.



The association shall be governed by the General Assembly and the Executive Board. The Secretary-General and the office will be in charge of the daily management of the association. The Association Delegation will represent the association in the partnership board, where the joint strategy will be discussed and decided.

General Assembly

- Meeting at least once a year.
- Each industry and research member has one vote; associate members have no voting rights.
- Voting subject to a weighted voting system: the votes of the industry members constitute 75% of all votes and the votes of the research members 25%.
- The General Assembly is the supreme body of the association. The General Assembly approves the general policy of the association on the basis of proposals of the Executive Board and gives recommendations to the Executive Board for its application.

Executive Board

- Follows the resolutions, instructions and recommendations adopted by the General Assembly.
- Implements the policy and the work programme adopted by the General Assembly upon the proposal of the Executive Board.

The association is managed by the Executive Board, composed of a minimum of 6 and a maximum of 10 members:

- up to 1 representative from the battery raw materials industry;
- up to 1 representative from the battery advanced materials industry;
- up to 1 representative from the battery manufacturing industry;
- up to 1 representative from the battery manufacturing supply industry;
- up to 1 representative from the automotive industry;
- up to 1 representative from another application industry;
- up to 1 representative from the recycling industry;
- up to 2 representatives from research members;
- a Secretary-General.

The Executive Board members are elected for a period of 2 years by the General Assembly. The appointments are renewable without limitation, except for the Secretary-General, who is appointed by the Executive Board for a term of 3 years, renewable without limitation. As the Executive Board members represent their sector on the board, their nominations come from the organisations representing the sectors in the partnership private-side association: EMIRI for the advanced materials industry and the research community active in battery materials, cells and recycling; RECHARGE and EUROBAT for the battery industry; EUCAR for the automotive industry; EASE and RECHARGE for the other applications industry; EBRA for the recycling industry. However, any interested organisation with a voting right in the General Assembly will be able to propose its candidature for the Executive Board.

Association Delegation

The private-side association is represented in the partnership board by the Association Delegation, which is composed of a maximum of 25 full members, including:

- the members of the Executive Board; in addition, up to:
- 1 delegate from the battery raw materials industry;
- 2 delegates from the battery advanced materials industry;
- 3 delegates from the battery manufacturing industry;
- 1 delegate from the battery manufacturing supply industry;
- 1 delegate from the automotive industry;
- 1 delegate from the automotive supply industry;
- 1 delegate from the stationary energy storage industry;
- 1 delegate from the other applications industry;
- 1 delegate from the recycling industry; and
- 3 delegates from research and technology organisations or universities.

The Association Delegation may further include up to 2 observers from the associate members, without any voting right. The Association Delegation members are elected for a period of 2 years by the General Assembly, renewable without limitation. As the Association Delegation members represent their respective sector in the Association Delegation, their nominations come from the organisations representing the sectors in the partnership private-side association: EMIRI for the advanced materials industry and the research community active in battery materials, cells and recycling; RECHARGE and EUROBAT for the battery industry; EUCAR for the automotive industry; CLEPA for the automotive suppliers industry; EASE and RECHARGE for the other applications industry; EBRA for the recycling industry. However, any interested organisation with a voting right in the General Assembly will be able to propose its candidature for the Association Delegation.

Technical Working Groups and Enabling Task-Forces

In order to organise the work within the Batteries European Partnership Association (BEPA) and to achieve the objectives of the Batt4EU Partnership, different expert groups will be established.

First, 5 technical working groups which correspond to five of the six distinct R&I areas that have been identified in the BATT4EU Strategic Research & Innovation Agenda (SRIA) will be created. The five areas are:

- Raw materials and recycling
- Advanced materials and manufacturing
- Battery end-uses and applications
- Safety and reliability
- Sustainability

The sixth area (collaboration) will be part of the activities of each working group, as described below. Each specific R&I area is contributing to the achievement of the specific objectives as well as the operational objectives of the partnership.

Involvement of Member States

Member States will play a key role in several areas essential to make the BATT4EU Partnership a success: supporting complementary research and innovation activities, developing the necessary industrial and R&D infrastructures, implementing the appropriate policies and regulations for incentivising market uptake, promoting the development of needed new skills, and supporting standards and business models. Therefore, their involvement will be ensured via a “States Representatives Group”, building on the ETIP Batteries Europe National and Regional Coordination Groups (NRCG) which will be set up as a side-body to align European, national and regional priorities and avoid any duplication of activities.

The National and Regional Coordination Group of ETIP Batteries Europe will actively support the achievement of objectives of the European partnership and ensure complementarity with national policies, priorities and programmes. They will review the information and provide opinions on the progress of the European partnership towards its scientific, economic and/or societal impacts at a national and regional level.

The National and Regional Coordination Group of ETIP Batteries Europe will provide information to, and act as an interface with, the European partnership on the following matters:

- The status of activities performed under national or regional policies, priorities and research and innovation programmes which are relevant to the European partnership and identification of potential areas of cooperation, including concrete actions taken or envisaged for the deployment of relevant technologies and innovative solutions at the national or regional level;
- Specific measures taken at national level or regional level to maximise the impacts of the results achieved, in particular dissemination events, dedicated technical workshops and communication activities;
- Specific measures taken at the national or regional level to support the exploitation, deployment and/or scale-up of the results achieved within the European partnership.

5.2.2 CLOSE COORDINATION WITH ETIP BATTERIES EUROPE

The BATT4EU Partnership builds upon the, so far, excellent mobilisation of the European battery's ecosystem set up in the frame of the European Battery Alliance. Three levers have been identified for smooth articulation with ETIP Batteries Europe to guarantee the most efficient coordination:

- At the governance level, the ETIP Batteries Europe Governing Board will be invited to act at an “Advisory Committee”, to ensure close coordination and avoid duplication of activities. The advisory committee will advise on the priorities to be addressed, in line with the Strategic Research and Innovation Agenda and the Horizon Europe strategic planning, and suggest, in view of the progress of the European partnership, corrective measures or re-orientations to the partnership board, where necessary. The partnership board will meet at least once a year with the governing board of ETIP Batteries Europe;
- At the operational management level, align agendas in order to organise, to the greatest degree possible, back-to-back meetings (general assemblies, workshops, events, ...); favour the organisation of joint events when possible.
- At the communication level, further build a common communication on respective roles and responsibilities.

5.2.3 OPENNESS AND TRANSPARENCY

Accessibility to membership

Membership to the partnership private-side AISBL shall be open to any industry, research organisation, university, and bodies with a public service mission, which are active in research and development, demonstration, industrialisation, production or deployment of the technologies and services covered by the partnership, and who share and support the goals and objectives of the partnership, subject to payment of a membership fee.

To ensure a direct benefit to European citizens, participation will be restricted to organisations performing activities in the European Union or in countries associated with the Horizon Europe Programme. The Articles of the Association and associated bylaws will be fully open/published.

The decision-making process within the partnership private-side governance bodies shall be transparent, consultative and inclusive vis-a-vis all members of the association. Resolutions on selected topics and priorities shall be openly communicated to all members in a timely manner. The partnership will also ensure periodic consultations with broader stakeholders (synchronised with any major update of the long-term roadmap).

Accessibility to information

Horizon Europe calls launched under the Partnership Work Programmes will be fully open. Therefore, any organisation complying with the EC rules for Horizon Europe will be eligible for funding, independently of its membership to the partnership private-side association.

Outreach and dissemination activities organised within the frame of the partnership will be open to the public. In accordance with Horizon Europe rules, funded projects will commit to publicising their activities via websites and any other means that would seem appropriate. The partnership will support the dissemination of results from funded projects by organising annual thematic workshops and large-scale public conferences. The partnership will monitor its KPIs and do regular benchmarking, thereby providing a feedback loop on the progress to the broader community. Exceptions may be made regarding confidential information, i.e., information the disclosure of which could affect the competitive position of the disclosing party.

The partnership will closely collaborate with the European Battery Alliance community, ETIP Batteries Europe, EIT Raw Materials, EIT InnoEnergy and other relevant initiatives to broadly reach all stakeholders active in the different segments of the battery value chain in Europe and recruit those that will contribute to achieving the goals and objectives of the partnership. Particular attention will be paid to achieving a balanced representation among the different sectors and geographical areas of the European Union (especially EU13 countries) and Associated Countries.

5.3 Synergies with other European partnerships, European, national and regional initiatives

In order to achieve its objectives, one of the main activities of BATT4EU will be to work closely with other European partnerships for proper alignment and collaboration and to ensure relevant synergies with other related R&I initiatives at the EU, national and regional levels. These collaborations and synergies are crucial to disseminate activities of the partnership, to coordinate R&I efforts on specific topics of common interests and to avoid any duplication of work.

In order to define concretely the framework and the scope of these collaborations, BATT4EU will formalise cooperation between BEPA and the relevant initiative by clarifying:

- The scopes of BATT4EU and the relevant initiative;
- Common interests shared by both initiatives and scope of the cooperation;
- The cooperation process and the concrete activities that will be implemented.

For now, BATT4EU has identified four categories of initiatives to collaborate with. These categories include:

- Initiatives integrating batteries in their field of applications, especially mobility (waterborne transport, road transport, aviation, etc.).
- Initiatives that are key enablers for battery technologies, which provide innovative tools and methodologies to improve battery technologies and processes throughout the value-chain (focusing on specific issues such as recycling, circular economy, manufacturing robotisation, digitalisation, etc.).
- Initiatives that can help market uptake of battery technologies (such as cooperation with the relevant EIT Knowledge and Innovation Communities).
- Other initiatives or organisations on more specific topics in order to ensure proper alignment and coordination at different levels.

5.3.1 COLLABORATIONS WITH BATTERY END-USERS FOR DIFFERENT APPLICATIONS, ESPECIALLY MOBILITY

In this category, collaboration opportunities have been identified with the following European partnerships:

- Toward Zero-emission road transport (2Zero), the European partnership for achieving carbon-neutrality in road transport by 2050;
- Clean Aviation, the European partnership for accelerating the development and demonstration of integrated aircraft technologies towards deep de-carbonisation;
- Zero-Emission Waterborne Transport (ZEWT), the European partnership for providing and demonstrating zero-emission solutions for all main ship types and services before 2030;
- Transforming Europe's rail system, the European partnership promoting automation and digitalisation for a more flexible and reliable rail system while reducing costs.

For the battery applications sectors with a dedicated partnership (such as road, waterborne, airborne and rail transports) the dedicated application-oriented partnership will take the lead on the downstream R&I segments activities specific to its sector, especially for the integration of batteries in their specific applications.

For example, in the case of road transport with the 2Zero Partnership:

- BATT4EU will be responsible for R&I activities dealing with materials, cells and battery recycling;
- 2Zero will be responsible for R&I activities dealing with the integration of batteries in the vehicle, charging infrastructures, etc.;
- Topics related to battery modules, battery packs and battery management systems will be addressed as an interface between both partnerships. The responsibility will be allocated according to the main research focus, i.e., either upstream (innovations related to materials, cells or battery manufacturing) or downstream (innovations related to vehicle integration).

A similar scheme for dividing responsibilities will be defined with the other partnerships dedicated to a specific application sector, taking into consideration the sector specificities. The share of responsibility on topics and detailed interface boundaries will be defined for all major application sectors and shall be regularly (at least annually) reviewed and updated, via coordination meetings between BATT4EU and application sectors' partnerships.

For the applications sectors without a dedicated partnership (such as the stationary applications, unless these are covered by the Clean Energy Transition partnership or funded under usual calls), BATT4EU will consider the downstream segments of the value chain (battery modules and packs, battery management systems, etc.). On the other hand, for the applications sectors benefiting from a dedicated partnership, this dedicated partnership will take the lead on the downstream segments R&I activities specific to this section.

Figure 30 | Collaboration between BATT4EU (lighter green areas) and the 2Zero partnership on road transport (darker green areas).

5.3.2 COLLABORATIONS WITH KEY ENABLING INITIATIVES FOR BATTERY TECHNOLOGIES

In this category, collaboration opportunities have been identified with relevant European partnerships that are key to enabling the improvement of battery technologies and processes along the battery value chain. Collaborations in this area will focus on specific topics such as digitalisation, robotisation, recycling, circularity aspects, etc.

Similarly, the share of responsibility on topics and detailed interface boundaries shall be defined with every partnership addressing important enabling/ complementary technologies:

- Clean Hydrogen for Europe, the European partnership to enable European hydrogen technologies to live up to their potential in achieving a sustainable and decarbonised energy system. Collaborations with BATT4EU will mainly focus on hybrid solutions, etc;
- Key Digital Technologies (KDTs), the European partnership supporting the digital transformation of all sectors of the economy and society. Collaborations with BATT4EU will focus for example on sensors, electronic components and battery management systems;
- Clean Energy Transition Partnership (CETP), the European partnership aiming at boosting and accelerating the energy transition in all its dimensions. Collaborations with BATT4EU will mainly be on grid flexibility and battery contributions to other SET Plan actions.

Less formalised collaborations may also be pursued with the following partnerships, following agreement of the respective boards:

- Made in Europe, the European partnership to boost European manufacturing ecosystems towards global leadership in technology and towards circular industries and flexibility. Collaborations with BATT4EU will focus on robotisation, automatisation, and other aspects of the manufacturing/assembling/ dismantling and sorting of cells, modules and packs;
- Processes4Planet, the European partnership aiming to transform the European process industry for a sustainable society. Collaborations with BATT4EU will focus mainly on materials manufacturing and recycling and the circular economy.

5.3.3 COLLABORATIONS WITH INITIATIVES ENABLING MARKET UPTAKE OF BATTERY TECHNOLOGIES

In order to support a market update of battery technologies, collaboration opportunities have also been identified with relevant Knowledge and Innovation Communities (KICs). They are part of the European Institute of Innovation and Technology and aim to strengthen cooperation among businesses (including SMEs), higher education institutions and research organisations, to form dynamic pan-European partnerships and create favourable environments for creative thought processes and innovations to flourish. BATT4EU foresees cooperation with these initiatives, especially to support the scaling-up and exploitation of the battery-related project results and the uptake of results from projects into products (per area of activity).

From this perspective, the following KICs have been identified:

- EIT Innoenergy, which aims at accelerating sustainable energy innovations.
- EIT Raw Materials, which aims at enabling sustainable competitiveness of the European minerals, metals and materials sector along the value chain by driving innovation, education and entrepreneurship.
- EIT Manufacturing, which aims at bringing European manufacturing actors together in innovation ecosystems that add unique value to European products, processes and services to inspire the creation of globally competitive and sustainable manufacturing.

5.3.4 OTHER COLLABORATIONS FORESEEN ON SPECIFIC TOPICS

In addition to the initiatives mentioned above, BATT4EU will also create more specific synergies at the EU, national and regional levels. The scope of these collaborations will also be detailed via the signature of a joint declaration. For now, collaboration opportunities have been identified:

- At the EU-level with: the ETIP Batteries Europe, the Battery 2030+ initiative, the Joint Research Centre (JRC);

- At the national and regional levels with: Important Projects of Common European Interest (IPCEIs), the S3 inter-regional platform on advanced materials for batteries, Member States and Associated Countries via the Batteries Europe's National and Regional Coordinators Group (NRCGs).

First, building on the European Battery Alliance R&I ecosystem established by ETIP Batteries Europe and Battery 2030+, BATT4EU will develop R&I collaborations at national and regional levels in close cooperation with ETIP Batteries Europe's National and Regional Coordinators Group. An alignment board gathering NRCGs will be set up to ensure a proper alignment and to reinforce links within the European battery community.

BATT4EU will also seek coherence and collaboration with the following national and regional R&I initiatives focusing on high technology readiness levels:

- Important Projects of Common European Interest in the field of batteries, which are currently under construction; and,
- S3 inter-regional platform on advanced materials for batteries launched at the end of 2018.

The collaboration between BATT4EU and the Member States (and Associated Countries) will have several objectives, including:

- Sharing information about the priorities and R&I project portfolios supported by the partnership on the one hand and the national or regional initiatives on the other hand;
- Tuning the R&I programme of the partnership to avoid (when necessary) duplication of efforts with national efforts; and,
- Facilitating the exploitation of the intellectual property generated by the partnership's R&I actions in order to boost the national and regional initiatives (especially the ones focusing on high technology readiness levels).

Finally, to avoid any duplication of work and make sure that all important topics are supported, BATT4EU will deepen already existing collaborations with the ETIP Batteries Europe and the Battery 2030+ initiative. The ETIP Batteries Europe will serve as an advisory committee facilitating information exchange and coordination between the Horizon Europe partnerships, Member States, relevant regions and other structures directly addressing different parts of the batteries value chain. Moreover, R&I priorities identified by Batteries Europe and Battery 2030+ experts will be taken as inputs by BATT4EU in the elaboration of its SRIA to identify high priority R&I topics for batteries.

5.4 Functional targets of the partnership

Throughout the life span of the partnership, the BATT4EU Partnership aims to achieve the following functional targets:

- continue to increase membership of private side associations;
- establish close working relationships with the other partnerships listed in section 5.3;
- support the related standardisation activities in close cooperation with standardisation bodies;
- provide scientific input for informed regulation and related Union policies;
- ensure a wide communication and dissemination of activities and results;
- contribute to the education of future workers and public awareness.

Several objectives have been elaborated to ensure the progress of the partnership towards these functional targets throughout its whole lifespan. These goals are all linked to the achievement of the specific objectives of the partnership.

5.4.1 CONTINUE TO INCREASE MEMBERSHIP OF THE PRIVATE SIDE ASSOCIATION AND ENSURE A BALANCED REPRESENTATION BETWEEN DIFFERENT STAKEHOLDERS

- By 2021, the key battery sectors for a broad stakeholder coverage will be identified in order to ensure that all segments of the European battery value chain are adequately represented in the association. Key missing organisations from the different sectors will be identified and invited to join BEPA. (SO1, SO2, SO3)
- In addition, the number of SMEs involved as members in BEPA will be monitored on a yearly basis (based on their SME status at the moment of their application). By 2025, the number of SMEs among BEPA members should represent at least 25% of the total number of industry members. (SO1, SO2, SO3)
- By 2025, the number of organisations coming from non-EU-14 countries among BEPA members should represent at least 25% of the total number of members. (SO1, SO2, SO3)

For the battery applications sectors with a dedicated partnership (such as road, waterborne, airborne and rail transports) the dedicated application-oriented partnership will take the lead on the downstream R&I segments activities specific to its sector, especially for the integration of batteries in their specific applications.

5.4.2 ESTABLISH CLOSE WORKING RELATIONSHIPS WITH THE OTHER PARTNERSHIPS LISTED IN THE MEMORANDUM OF UNDERSTANDING

- By 2021, all the European partnerships identified in the Memorandum of Understanding will have been contacted so as to start discussing synergies and potential collaborative actions. (SO1, SO2, SO3)
- By 2021, all the European partnerships identified in the Memorandum of Understanding will have been contacted so as to start discussing synergies and potential collaborative actions. (SO1, SO2, SO3)

- By 2023, R&I priorities for at least two joint/collaborative calls with European partnerships will be prepared. These joint calls can, for example, focus on battery modules, battery packs and battery management systems (to be addressed in coordination with 2ZERO), or on stationary battery applications to enable cost-effective integration of renewable energy sources in the power grid (to be addressed in coordination with the Clean Energy Transition Partnership). (SO2, SO3)
- By 2023, specific areas for action will be identified with at least one "Knowledge and Innovation Communities" (e.g., EIT Innoenergy, EIT Manufacturing, EIT Raw materials) to support the development of differentiating technologies and build up ecosystems that support their market introduction. This will be done within the work of the task-force "Innovation Uptake". This collaboration can, for example, involve the organisation of match-making events in order to bridge battery stakeholders with relevant investors and/or the identification of specific measures to improve the access to risk finance for battery stakeholders. (SO1)
- By 2025, collaborative actions with at least 2 additional European partnerships will be established and specific areas for action will be identified. (SO1, SO2, SO3)
- By 2027, collaborative actions will have been established with all the other partnerships and initiatives listed in section 5.4. These collaborative actions can include the organisation of common workshops/webinars on specific topics, the elaboration of joint calls, the organisation of common online consultations, a joint publication on a specific R&I topic, etc. (SO1, SO2, SO3)

Finally, to avoid any duplication of work and make sure that all important topics are supported, BATT4EU will deepen already existing collaborations with the ETIP Batteries Europe and the Battery 2030+ initiative. The ETIP Batteries Europe will serve as an advisory committee facilitating information exchange and coordination between the Horizon Europe partnerships, Member States, relevant regions and other structures directly addressing different parts of the batteries value chain. Moreover, R&I priorities identified by Batteries Europe and Battery 2030+ experts will be taken as inputs by BATT4EU in the elaboration of its SRIA to identify high priority R&I topics for batteries.

5.4.3 SUPPORT THE RELATED STANDARDISATION ACTIVITIES IN CLOSE COOPERATION WITH STANDARDISATION BODIES

- By 2022, a collaboration with the Joint Research Centre on specific R&I areas, including potential standardisation issues will be established. (SO1)

Additional targets for 2025 and 2027 will be defined in collaboration with the JRC and/or other standardisation bodies.

5.4.4 PROVIDE SCIENTIFIC INPUT FOR INFORMED REGULATION AND RELATED UNION POLICIES

- By 2021, BEPA Technical Working Groups will be launched and structured in order to cover the whole battery value chain. Experts within these working groups will be able to provide scientific input for informed regulation and related Union policies. (SO1, SO2, SO3)
- During the whole duration of the partnership, regular exchanges with policy departments of relevant EU associations focusing on battery policy issues (e.g., EASE, RECHARGE, ETIP SNET) will be created. BEPA could, for example, support the writing of policy papers by providing scientific inputs. (SO1, SO2, SO3)
- On a continuous basis, BEPA will answer and provide recommendations to a significant number of EU consultations on battery-related issues and publish several position papers on battery related policy issues. (SO1, SO2, SO3)

5.4.5 ENSURE WIDE COMMUNICATION AND DISSEMINATION OF ACTIVITIES AND RESULTS

- By 2021, all the online communication platforms and tools (website, newsletter, social media, etc.) will be set up to help to disseminate EU funded projects' outcomes and promote success stories. A detailed communication plan summarising the different communication and dissemination activities foreseen by the partnership will be ready. (SO1, SO2, SO3)
- By 2021, the first BEPA annual report will be published. This annual report will also help to disseminate battery EU projects' outcomes. (SO1, SO2, SO3)
- By 2021, BEPA will co-organise the "Battery Innovation Days" where EU-funded battery projects' results will be disseminated to a wide range of stakeholders. The aim will be also to help to exploit results and to provide networking opportunities to European battery stakeholders, strengthening the battery R&I ecosystem in Europe. This event will be a key opportunity to inform SMEs, civil society and other relevant stakeholders about the Batteries European Partnership and promote their participation. This event is foreseen to be organised annually. (SO1, SO2, SO3)
- By 2024, at least 1 workshop focusing on innovation uptake and match-making activities will have been organised in order to connect project coordinators with relevant investors. This event will be elaborated thanks to the support of the Task-Force on Innovation Uptake and potentially in coordination with the EIT InnoEnergy. (SO1, SO2, SO3)
- By 2025, at least 2 additional workshops, potentially organised in collaboration with other European partnerships, will have been organised on EU funded projects focusing on the development of new battery technologies and concepts and on the development of sustainable and affordable battery solutions for mobility and stationary applications. (SO1, SO2, SO3)

5.4.6 CONTRIBUTE TO THE EDUCATION OF FUTURE WORKERS AND THE PUBLIC AWARENESS

- By 2022, the BATT4EU Partnership – within its task force on "education and skills development" - will identify the specific added value that Batt4EU can bring to the EU ecosystem and, with the already involved stakeholders, will identify relevant gaps in training and skills development in specific battery sectors. (SO1)
- By 2023, an online workshop/webinar aiming at raising public awareness on the crucial role of batteries to achieve the targets of the European Green Deal will be organised. This workshop will especially focus on how innovative battery technologies can help reduce CO2 emissions and on the necessity to develop sustainable and affordable battery solutions for clean mobility and stationary applications. The outcomes of this workshop will be summarised in a publication which will be widely disseminated to all battery stakeholders and in particular to SMEs, civil society organisations (environmental NGOs, European consumers organisations), the general public, etc. (SO1, SO2, SO3)
- A dialogue with EIT Innoenergy will be also established, especially on how the Batt4EU Partnership could support Innoenergy's initiative of a "Battery Academy". (SO1, SO2, SO3)

Additional targets for 2025 and 2027 will be defined within the task force on education and skills development.

6 CONCLUSION

The SRIA for the next generation of batteries detailed in this document has been developed in coordination with a broad range of stakeholders coming from the European battery community. BATT4EU's aim for this document is to summarise the overall European battery R&I priorities and provide guidance for the funding calls that should be provided under the Horizon Europe Pillar II programme. Providing the necessary funding for the next generation battery R&I as well as ensuring effective collaboration, dissemination of findings and market uptake is crucial in order to build an independent, competitive and sustainable European battery value chain.

The six key R&I areas identified in the SRIA should provide guidance on where key investment should be focused until at least 2030. Investment in the sourcing of raw materials in Europe will help ensure the independence of the European battery value chain; while increasing recycling rates will enhance the sustainability of the European battery industry. More investment in the development of advanced materials will help ensure the cost-effectiveness of batteries; while strengthening the manufacturing capacity locally will also contribute to the independence of the European battery sector. Dedicating more resources and research into battery end-uses and operations will help decarbonise transport as well as increase grid flexibility and renewable energy uptake by providing effective energy storage capacity. Increasing the safety of the battery technology will help increase the trust in and demand for European batteries. Taking into account the three key pillars of sustainability – economic, social and environmental – will help ensure that batteries are sustainable from a holistic perspective and thus provide a competitive edge for the European battery industry. Finally, effective coordination will help align the R&I efforts to the greatest benefit of the European battery stakeholders and the general public.

BATT4EU, as a collaboration between the European Commission as well as the battery industry, research organisations and other associations, emphasises the need for continuous support in the form of European and national policy frameworks that enable effective collaboration as well as adequate funding for battery R&I.

6.1 Next steps

The SRIA provided in this document will be regularly updated, subject to approval by the BATT4EU Partnership Board. This work will be one of the main tasks to be conducted by BEPA, via a wide involvement of all the members of the association. R&I priorities will be reviewed and updated periodically in line with progress in the industry and the developments of EU battery policy. As the SRIA will be taken as the reference framework to identify the key R&I battery priorities for the next Horizon Europe Work Programmes, the document will be updated before each prioritisation process. The planning of the next steps can be seen in Figure 31.

Figure 31 | Provisional update timeline of BATT4EU SRIA.

Date	Action
February 2021	Stable SRIA version developed
May 2021	SRIA finalised
September 2021 – January 2022	First SRIA update (pre-requisite to WP23-24 topics elaboration process in 2022)

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