MANIFESTO



BATTERY 2030+

EUROPEAN SCIENTIFIC LEADERSHIP

THIS MANIFESTO IS A CALL TO LAUNCH AN AMBITIOUS LARGE-SCALE EUROPEAN PROGRAMME FOR LONG-TERM RESEARCH ON ULTRAHIGH-PERFORMANCE BATTERIES, ENABLING EUROPE'S LEADERSHIP IN HIGHLY DEMANDING MARKETS FULFILLING END USER EXPECTATIONS.

BATTERY 2030+ INITIATIVE IN A NUTSHELL

Batteries have a central role to play in Europe's transition from fossil fuels to renewable energy. Versatile and high-performance electrochemical energy storage can reduce the carbon footprint of the transport sector, stabilise the power grid, and support a broad range of strategic industries, including medical device production, information and communication technologies, aerospace and advanced robotics. In nearly all aspects of modern life, batteries enable innovation. Europe could capture a battery market of up to €250 billion a year from 2025 onwards.

The European Battery Alliance, launched by the European Commission Vice-President Maroš Šefčovič in October 2017, aims to establish a competitive battery industry in Europe. The Strategic Action Plan on Batteries, published by the European Commission in May 2018, calls for preparing an ambitious, large-scale and long-term research programme on batteries as a complement and support to the European Battery Alliance. Accordingly, the BATTERY 2030+ initiative proposes a 10-year large-scale visionary research programme on future battery technologies.

This Manifesto calls on European stakeholders to embrace this BATTERY 2030+ initiative for a long-term large-scale research programme on ultrahigh-performance, reliable, safe, sustainable and affordable batteries.

As a long-term research programme, BATTERY 2030+ will complement the short-term industrial initiatives launched in the framework of the European Battery Alliance, as well as the short- to medium-term research and innovation programmes implementing the SET Plan roadmap.

The vision for BATTERY 2030+ is to invent the batteries of the future, providing European industry with disruptive technologies and a competitive edge across the full value chain. BATTERY 2030+ will pursue ultrahigh-performance, reliable, safe, sustainable and affordable batteries, by a cross-disciplinary, transformational research approach, leveraging advances in artificial intelligence, robotics, sensors and smart systems. The groundbreaking science and technology developed by BATTERY 2030+ will have an invaluable impact on the ongoing transition towards a carbon-neutral and circular economy.

THE BATTERY 2030+ INITIATIVE WILL GATHER LEADING SCIENTISTS IN EUROPE, AS WELL AS THE INDUSTRY ACROSS THE FULL VALUE CHAIN, TO ACHIEVE A LEAP FORWARD IN BATTERY SCIENCE AND TECHNOLOGY.

WHERE WILL WE BE AFTER A TEN-YEAR PERIOD?

At the end of ten years, Battery 2030+ will have generated a new body of knowledge that will lead to ultrahigh performance batteries with integrated smart functionalities, and will have created novel research fields for future batteries – all in a sustainable framework.

BATTERY 2030+ aims at achieving a paradigm shift in the research & development process, by accelerating by a factor from 5 to 10 the development cycle of novel battery materials, interphases, and interfaces.

Battery 2030+ will target the following achievements:

- Batteries for electric cars that provide a driving range comparable to gasoline-driven cars, for energy storage systems that bring flexibility to the power grid, and for any other applications that will improve the quality of life of European citizens (robotics, internet of things, medical devices, etc.).
- Batteries that can be charged three times faster than today's technology, without compromising on lifetime or performance.
- Batteries with considerably longer lifetime than today, thanks to smart functionalities at battery cell level (among other things self-healing and sensing).
- Safer batteries with advanced control mechanisms using smart functionalities and new cell concepts, tailored to fit the applications in which they are to be used.
- Batteries designed for easy dismantling, better allowing recycling and second life usage.
- Finally, Battery 2030+ will focus strongly on sustainability and achieving the lowest carbon footprint possible for batteries through:
  a. sustainably mined materials;
  b. higher material resource efficiency and smarter functionalities;
  c. greener manufacturing processes, which can be upscaled to enable affordable battery solutions;
  d. design-for-circularity, and more efficient recycling and remanufacturing processes.

OUTLINE

1. WHY EUROPE NEEDS TO ACT NOW 6

2. BATTERY 2030+ IN THE BATTERY R&I LANDSCAPE 10

3. BATTERY 2030+ VISION 11

4. BATTERY 2030+ OBJECTIVES 12

5. BATTERY 2030+ RESEARCH AREAS 13

6. BATTERY 2030+ ROADMAP 21

1.
WHY EUROPE NEEDS TO ACT NOW

Technologies to reduce greenhouse gas emissions and mitigate climate change are vital for Europe and the world, and present opportunities for the European research and industrial communities. Batteries are among the key technologies to achieve a deep decarbonization of the European energy system, notably in the transport sector (with electro-mobility) and in the electric power sector (with the storage of intermittent renewable energy sources).

In the transport sector, Europe's position as a global leader in the automotive market is being seriously challenged by the transition to electro-mobility in which batteries are estimated to count for up to 40% of the value of the car. The battery market, dominated by lithium-ion technology, is clearly strategic for Europe in many aspects.

In the near future, new generations of ultra-high-performance, reliable, safe, sustainable and affordable batteries will be necessary, primarily driven by the accelerating transition to electric vehicles. Competition to develop future battery technologies is already high but still very much open.

This offer a technological opportunity for Europe which can build on its scientific and industrial assets to become a major player in a future battery market estimated to reach up to €250 billion a year from 2025 onwards. It is also an industrial and economic opportunity, with the possible creation of 4-5 million jobs.

Substantial investments in research are required to encourage a cross-sectoral holistic approach in future battery technologies and can provide a long term competitive advantage to the European industry.

Developing breakthrough battery technologies will require truly immense multi-disciplinary and cross-sectoral research efforts. Europe has the potential to take the lead, thanks to very active R&I communities covering the full, wide range of required disciplines:

- chemistry, electrochemistry, physics, materials science, quantum chemistry,
- computational design, artificial intelligence and deep learning, big data analytics, information and communication technologies
- manufacturing and recycling technologies, mechanical/electrical engineering, systems engineering, industry digitisation,
- techno-economic assessment, and social sciences and humanities.

Europe can gain a decisive advantage by efficiently linking and channelling these disciplines in a large-scale joint effort. The long term challenge-based approach of the BATTERY 2030+ initiative seeks to overcome the risk of fragmented European action mostly driven by short to medium term industrial priorities.

TO BECOME A WORLD LEADER IN THE BATTERY INDUSTRY ACROSS THE FULL VALUE CHAIN, EUROPE NEEDS TO ACT NOW. IT SHOULD SUPPORT SHORT-TO-MEDIUM-TERM INDUSTRIAL AND RESEARCH INITIATIVES, WHILE AT THE SAME TIME LAUNCHING A LONG-TERM AMBITIOUS RESEARCH PROGRAMME FOCUSED ON HIGHLY DISRUPTIVE BATTERY TECHNOLOGIES – BATTERY 2030+, THAT CAN PROVIDE A COMPETITIVE ADVANTAGE TO EUROPE AND OPEN NEW INDUSTRIAL OPPORTUNITIES FOR SMART HIGH PERFORMING BATTERIES 'INVENTED AND MADE IN EUROPE'.

WE NEED TO ACT NOW!



If we act together across Europe now, we can become global leaders in the battery market and secure strategic technologies for the energy transition towards a low-carbon and circular economy.



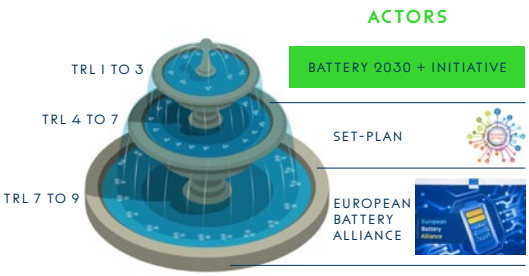
"BATTERIES ARE AT THE HEART OF THE INDUSTRIAL REVOLUTION AND I AM CONVINCED THAT EUROPE HAS WHAT IT TAKES TO BECOME THE WORLD'S LEADER IN INNOVATION, DECARBONISATION AND DIGITISATION."

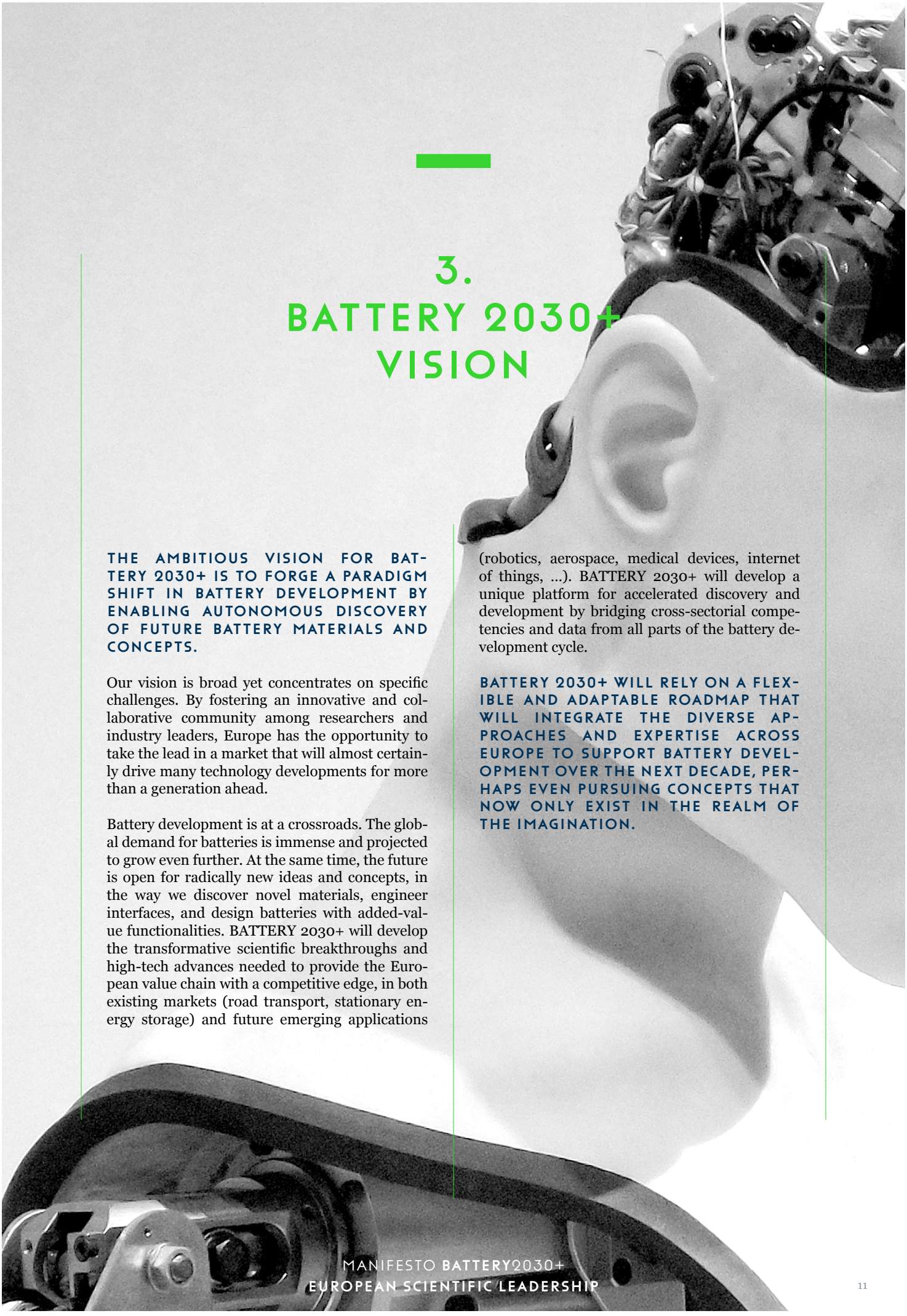
Maroš Šefčovic, Vice-President for Energy Union

2.
BATTERY 2030+ IN THE BATTERY R&I LANDSCAPE

A long-term action over 10 years with a focus on disruptive technologies, the BATTERY 2030+ initiative will concentrate on low TRL transformational research (TRL 1 to 3). It complements the short-term initiatives launched in the framework of the European Battery Alliance to develop large-scale manufacturing capacities, and the short-to-medium term research and innovation projects undertaken within the Horizon 2020 and Horizon Europe work programmes. The European Battery Alliance will foster the development of a strong industry ecosystem in Europe, which will bring to the BATTERY 2030+ initiative the industrial perspective required to reach its ambitious objectives.

The BATTERY 2030+ roadmap will go well beyond the current SET Plan roadmap, by proposing a vision for inventing the batteries of the future. The BATTERY 2030+ initiative will exploit the untapped potential of radically new materials, chemistries, smart functionalities and cell designs. Reaching and moving beyond the SET Plan milestones, it will improve next generations battery technologies, lay the groundwork for radically new future battery technologies introduced in the market after 2030 and secure European leadership in batteries for both established applications and emerging markets.





3. BATTERY 2030+ VISION

THE AMBITIOUS VISION FOR BATTERY 2030+ IS TO FORGE A PARADIGM SHIFT IN BATTERY DEVELOPMENT BY ENABLING AUTONOMOUS DISCOVERY OF FUTURE BATTERY MATERIALS AND CONCEPTS.

Our vision is broad yet concentrates on specific challenges. By fostering an innovative and collaborative community among researchers and industry leaders, Europe has the opportunity to take the lead in a market that will almost certainly drive many technology developments for more than a generation ahead.

Battery development is at a crossroads. The global demand for batteries is immense and projected to grow even further. At the same time, the future is open for radically new ideas and concepts, in the way we discover novel materials, engineer interfaces, and design batteries with added-value functionalities. BATTERY 2030+ will develop the transformative scientific breakthroughs and high-tech advances needed to provide the European value chain with a competitive edge, in both existing markets (road transport, stationary energy storage) and future emerging applications (robotics, aerospace, medical devices, internet of things, ...). BATTERY 2030+ will develop a unique platform for accelerated discovery and development by bridging cross-sectorial competencies and data from all parts of the battery development cycle.

BATTERY 2030+ WILL RELY ON A FLEXIBLE AND ADAPTABLE ROADMAP THAT WILL INTEGRATE THE DIVERSE APPROACHES AND EXPERTISE ACROSS EUROPE TO SUPPORT BATTERY DEVELOPMENT OVER THE NEXT DECADE, PERHAPS EVEN PURSUING CONCEPTS THAT NOW ONLY EXIST IN THE REALM OF THE IMAGINATION.

4.
BATTERY 2030+ OBJECTIVES

Europe's energy transition and digital transformation encompass advances in a wide array of industries, including electric mobility, renewable energy storage, internet of things, robotics, etc. The long-term success of these diverse activities hinges on the availability of ultrahigh-performance, reliable, safe, sustainable and affordable batteries.

Based on ground-breaking European science, the objective of BATTERY 2030+ is to supply disruptive battery technologies featuring:

- energy & power densities approaching the theoretical limits,
- outstanding lifetime & reliability,
- enhanced safety,
- environmental sustainability,
- transformation of the battery development cycle to enable accelerated, autonomous discovery of future battery materials and concepts,
- scalability, to enable large-scale production of batteries at a competitive cost.

BATTERIES THAT MEET THESE SPECIFICATIONS WILL REVOLUTIONISE THE CURRENT ENERGY SYSTEM AND OPEN THE WAY TO RADICALLY NEW APPLICATIONS, SOME OF WHICH CAN ONLY BE IMAGINED TODAY.

5.
BATTERY 2030+ RESEARCH AREAS

FOUR MAIN RESEARCH AREAS HAVE ALREADY BEEN DEFINED TO ADDRESS THE CHALLENGE OF DEVELOPING NEXT-GENERATION BATTERIES, WITH MORE AREAS TO FOLLOW. THE FOUR RESEARCH AREAS DEFINED SO FAR ARE:

1. Accelerated discovery and design of battery materials, interphases, interfaces and concepts.
2. Smart sensing and self-healing functionalities
3. Manufacturability
4. Recyclability.

The proposed research directions are chemistry-neutral, which means that they can potentially be applied to any battery chemistry, creating an impact on both state-of-the-art and future electrochemical storage systems.

The research actions will span the entire value chain. For example, if sensors, self-healing chemistries, or other smart functionalities are implemented, this will influence not only manufacturability and/or recyclability, but also the development of Battery Management System (BMS) operating protocols, hardware and software.

Manufacturability and recyclability are key cross-cutting topics, which need to be taken into account from the very beginning of the research programme. New battery materials, engineered interfaces and smart battery cell architectures will be developed bearing in mind the manufacturability, scalability, recyclability, and life-cycle environmental footprint of the novel technologies.

The proposed research directions should be seen as a starting point for BATTERY 2030+. Flexibility is a key factor for the success of a long-term and large-scale research programme.The BATTERY 2030+ initiative will therefore be open to new research areas identified later on by the European research community..



ACCELERATED DISCOVERY AND DESIGN OF BATTERY MATERIALS, INTERPHASES AND INTERFACES

RADICALLY NEW APPROACHES ARE NEEDED TO ACCELERATE THE DISCOVERY AND DEVELOPMENT OF ULTRA-HIGH-PERFORMANCE BATTERY MATERIALS , INTERFACES AND CONCEPTS.

BATTERY 2030+ proposes to disrupt the existing sequential battery development cycle and establish an autonomous Materials Acceleration Platform (MAP) to enable the accelerated discovery of breakthrough battery materials, structures and concepts. We will specifically target the control of reactions and mechanisms at interfaces within the battery cell, as they are critical to the performance, durability and safety of all batteries. Despite their importance, the fundamental understanding of interface processes remains poor and far from the point where battery interfaces can be proactively designed and dynamically controlled.

BATTERY 2030+ will establish the Battery Interface Genome (BIG), which will enable European battery researchers and industry to control interface formation and dynamics, and ultimately enable inverse design of battery interfaces directly for their intended operating conditions.

Our vision is to integrate the BIG into an autonomous Materials Acceleration Platform (MAP) to establish a holistic BIG-MAP infrastructure capable of accelerating the discovery and optimisation process for future ultrahigh-performance battery materials, interfaces and technologies.

The MAP will utilise artificial intelligence (AI) and data-driven approaches guided by physical understanding and models to control, orchestrate and synchronise communication between all branches of the materials discovery cycle. The MAP will be capable of performing autonomous analysis and interpretation of data by bridging multi-scale computer simulations with in-line characterisation and data from synthesis and manufacturing to determine, for example, the next generation materials composition or structure, and provide suggestions for electrochemical testing parameters for subsequent experiments.

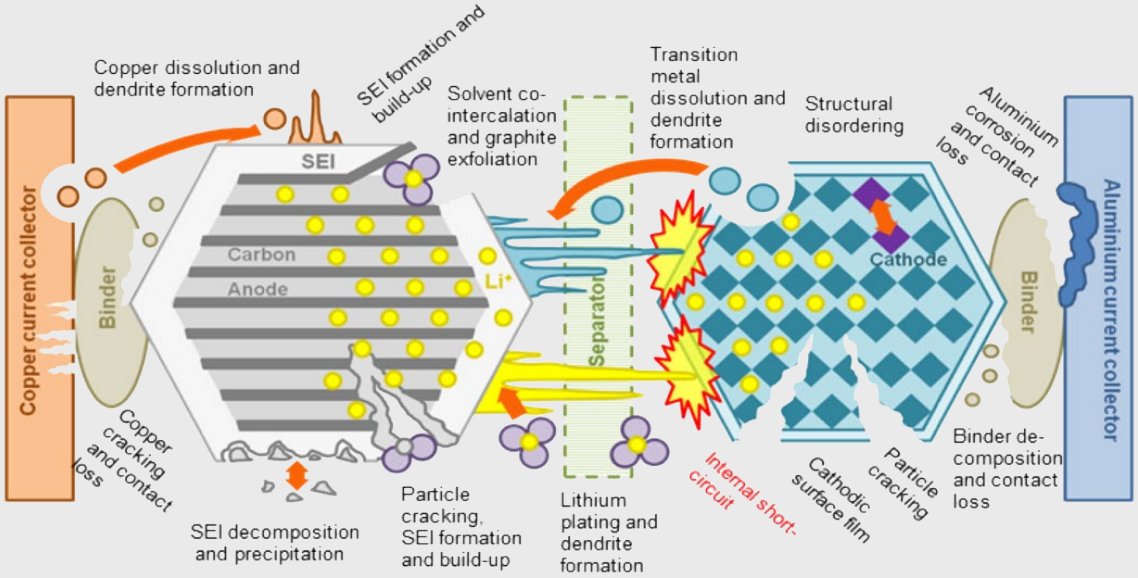
THE BATTERY INTERFACE GENOME (BIG) IN A NUTSHELL

Battery interfaces like the Solid Electrolyte Interphase (SEI) constitute an enigma in battery research and establishing a fundamental understanding of the mechanisms and parameters controlling their formation and dynamic properties is a key element in the development of future battery chemistries.

We will combine multi-scale physical and data-driven models with advanced characterisation and testing techniques to establish the Battery Interface Genome (BIG). BIG will enable researchers to address the challenging interfaces proactively and ultimately perform inverse design of interfaces.

THIS FIGURE DESCRIBES DIFFERENT PROCESSES LEADING TO LOWER LIFE-TIME AND CAPACITY LOSS OF A BATTERY.

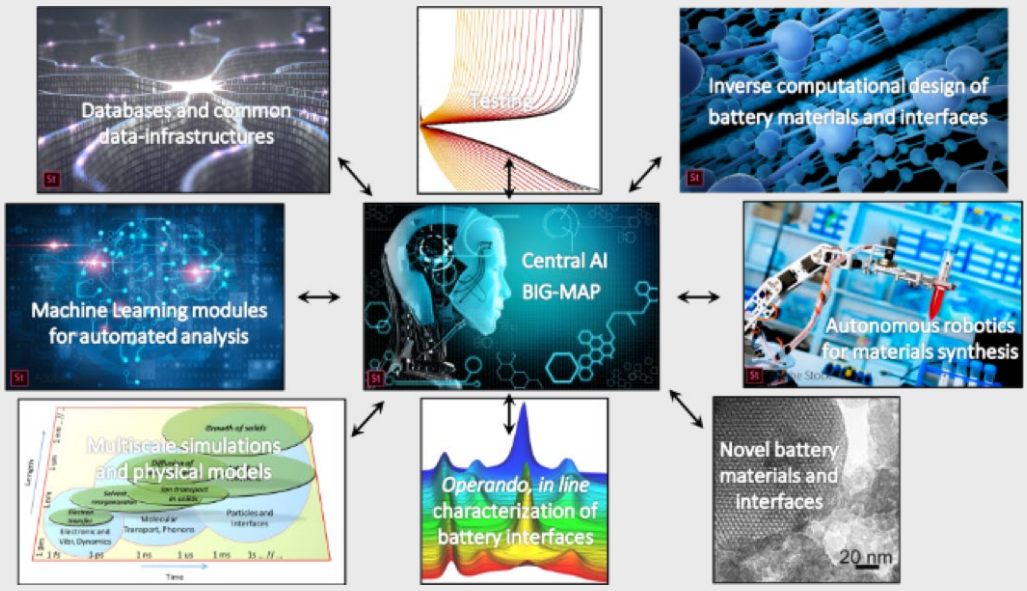
SOURCE: EPG - OXFORD. COPYRIGHT: CHRISTOPH R. BIRKL, ET AL., J. POWER SOURES 341 (2017) 373 (OPEN SOURCE PAPER).



BIG-MAP: AN AUTONOMOUS PLATFORM FOR ACCELERATED DISCOVERY OF FUTURE BATTERIES

A disruption of the existing discovery, development, and manufacturing processes for battery materials and technologies is needed for Europe to leapfrog its main competitors. The Battery Interface Genome–Material Acceleration Platform (BIG-MAP) will provide an autonomous, high-throughput innovation and acceleration platform capable of reducing the end-to-end discovery time for future ultra-high-performance batteries tenfold.

BIG-MAP will establish a unique data infrastructure for battery materials, bridging all elements of the development cycle, and spanning the scientific and industrial battery communities in Europe.



SMART SENSING AND SELF-HEALING FUNCTIONALITIES

‘Smart batteries’ and intelligent functionalities are key to next-generation technologies. The development of smart battery cells and intelligent functionalities has been a little-explored concept but – if brought to fruition – would enable the realisation of safer and more durable battery chemistries. It is a holy grail of multi-disciplinary design and may be the effort that allows European battery research to leapfrog to the highest international level.

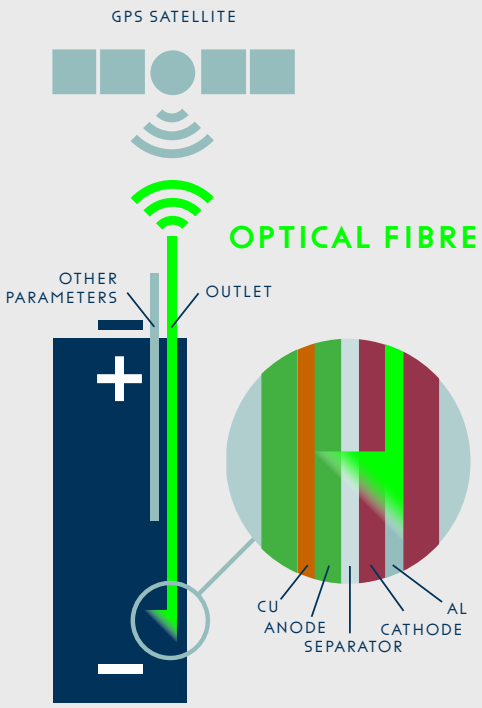
Smart batteries are based on new high-resolution embedded sensor concepts (with a degree of refinement far beyond anything available today) monitoring complex reactions in the battery. This approach can draw inspiration from the field of medical science by developing self-healing concepts to extend battery lifetime and enable the most challenging ultrahigh-performance batteries to be realised in practice.

Real-time cell monitoring is invaluable to researchers and engineers, but to truly extend battery lifetime and performance, degradation mechanisms must also be addressed as they occur. Intelligent functionalities including battery self-healing (BSH) capabilities are essential to this effort.

SMART BATTERIES AND SENSING IN A NUTSHELL

With batteries becoming the heart of future society, safety and smart functionalities must be intrinsic to future batteries. There is a crucial need to increase their quality, reliability and life (QRL) by non-invasive in operando performance monitoring and control of their state of health (SoH), state of charge (SoC), state of energy (SoE), state of power (SoP) and state of safety (SoS). This challenge must be addressed hierarchically on the component, cell, and full system levels.

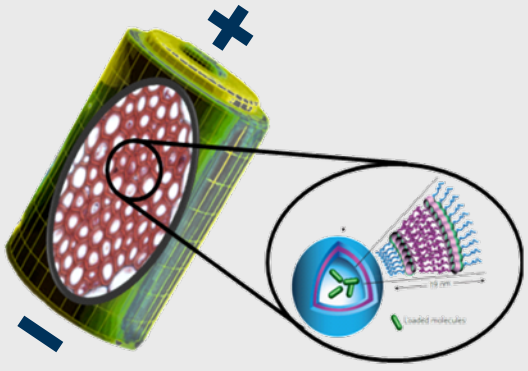
A disruptive vision like this needs smart embedded sensing technologies and functionalities that are integrated into the battery and are capable of spatially and temporally resolved monitoring. Our envisioned 2030+ battery will no longer be a black box but will have additional terminals to transmit and receive analytical signals. Europe needs to anticipate this inevitable paradigm shift to leapfrog its main competitors in the development of a high QRL battery with the feasibility of forecasting its second life, and reducing its environmental footprint.



BATTERY SELF-HEALING (BSH) IN A NUTSHELL

While sensing is the natural instrument to monitor and control battery quality, reliability and lifetime (QRL), it also serves to identify defective components and local spots in the cell that must be repaired. As in the field of medicine – which relies heavily on the targeted delivery of drugs to treat diseases – it will be essential to develop mechanisms within the battery for the on-demand administration of molecules that can solubilise a resistive deposit (e.g. SEI) or restore a faulty electrode within the battery. This constitutes a transformational change in battery science, as virtually nothing has yet been done on this topic. Great challenges await.

An ambitious long-term long-term initiative must consider this futuristic view, which takes inspiration from advances in the medical field. Failing to capitalise on the benefits of sensing to detect flaws within the battery and envision their repair would be a significant lost opportunity. There is currently no coherent European research effort on battery self-healing in spite of the foreseen emerging opportunities that could ensure European leadership in the global market. The BSH objective is to pursue this game-changing approach, which will maximise QRL and improve user confidence and safety.

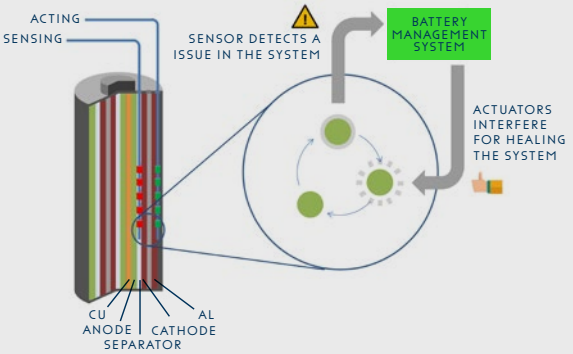


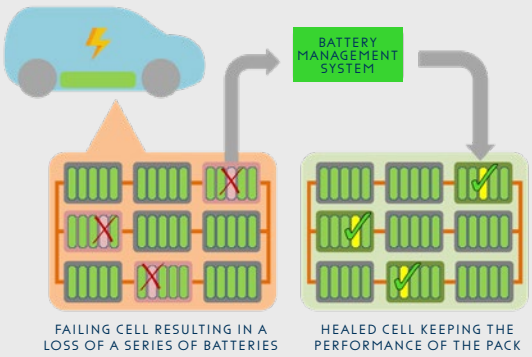
How does self-healing work?

Self-healing of scars, tissues and bones is taken for granted in human bodies. Modern medicine has found a way to leverage these processes to treat diseases. There is a very active underlying science, combining principles from biology, materials, and engineering disciplines, for accelerating the healing process, using natural or synthetic materials. New ideas for polymers that could self-heal cracked surfaces via H-bonding or chemical healing are now emerging. However, the battery community has so far neglected this field. There is great potential for developing supramolecular architectures, which could be physically or chemically cross-linked to heal the electrochemically driven growth of cracks/fissures in electrode materials.

Developing a battery self-healing process is therefore certainly among the most-far reaching and challenging issues today. Numerous approaches exist for administering drugs or nanomedicine to humans to treat diseases. Usually, during drug delivery and absorption, the active molecule must pass several biological membranes. Transport processes across these membranes are regulated by chemical or physical stimuli that are very similar to the processes in batteries. An interesting conceptual analogy is to compare the solid electrolyte interphase (SEI), which results from parasitic deposits that can block the Li-ion transport in a battery, to a cholesterol deposit within an artery that clogs blood flow. Implementing self-healing mechanisms in batteries will require strong synergies between electrochemists, biologists and biomedical researchers in the years to come. Battery 2030+ could be the vehicle to launch this revolutionary approach.

To succeed, this initiative should aim to support strong research and development collaborations on battery sensing and self-healing. By bringing the battery community together with academic and industrial partners with sensing expertise, a holistic approach could be taken to facilitate success in this field. It should also attract the biomedical community and benefit their practice to accelerate the development of novel self-healing mechanisms. An intimate synergy between intelligent battery management systems and self-healing capabilities will further secure success, and enable Europe to lead the world in sustainable technology development.





6.
FIRST ELEMENTS FOR A LONG-TERM ROADMAP

THE FIRST ELEMENTS FOR A LONG-TERM ROADMAP. AN UPDATE ROADMAP WILL BE PRODUCED IN 2019.

RESEARCH PILLARS		MILESTONES		
		3 YEARS	6 YEARS	10 YEARS
ACCELERATED DISCOVERY OF BATTERY MATERIALS AND INTERFACE ENGINEERING	MATERIALS ACCELERATION PLATFORM	- COMPUTATIONAL STRATEGIES AND RELIABLE DESCRIPTORS FOR INVERSE DESIGN OF BATTERY MATERIALS AND INTERFACES - DATA-DRIVEN MODELS GUIDED BY PHYSICAL UNDERSTANDING - AUTONOMOUS ANALYSIS OF EXPERIMENTAL AND SIMULATION RESULTS USING ARTIFICIAL INTELLIGENCE	FULLY AUTONOMOUS AND AUTOMATED PLATFORM, INTEGRATING COMPUTATIONAL MODELLING, MATERIAL SYNTHESIS AND CHARACTERISATION	FULLY AUTONOMOUS AND AUTOMATED PLATFORM, INTEGRATING COMPUTATIONAL MODELLING, MATERIAL SYNTHESIS AND CHARACTERISATION, BATTERY CELL ASSEMBLY AND DEVICE-LEVEL TESTING
	TEST CASES	LITHIUM-ION	MOST PROMISING LITHIUM-ION AND POST-LITHIUM-ION TECHNOLOGIES	MOST PROMISING LITHIUM-ION AND NEXT GENERATION TECHNOLOGIES
SMART BATTERIES	SENSING FUNCTIONALITIES	- ADAPTATION OF EXISTING SENSOR TECHNOLOGIES AND INTEGRATION AT THE BATTERY CELL LEVEL - SPATIALLY AND TEMPORALLY RESOLVED MONITORING OF A FEW SELECTED PARAMETERS (E.G. TEMPERATURE)	- NEW SENSOR TECHNOLOGIES SPECIFICALLY DEVELOPED FOR BATTERY CELL APPLICATIONS - MONITORING OF INTERPHASE AND INTERFACE DYNAMICS	- INTEGRATION OF BOTH SENSING AND SELF-HEALING FUNCTIONALITIES INTO SINGLE BATTERY CELLS - CONTROL OF SELF-HEALING BASED ON CELL MONITORING (BMS ESTABLISHING A FEEDBACK LOOP BETWEEN SENSING AND SELF-HEALING FUNCTIONALITIES)
	SELF-HEALING FUNCTIONALITIES	FIRST PROOF OF CONCEPT OF SELF-HEALING PHENOMENA	SELF-HEALING OF BATTERY CELL COMPONENTS IN OPERATIONAL CONDITIONS	
	BATTERY MANAGEMENT SYSTEM	STATE-FUNCTION ESTIMATORS RELYING ON DATA COLLECTED BY SENSORS AT CELL LEVEL	ALGORITHMS FOR CONTROLLING SELF-HEALING BASED ON CELL MONITORING	
	TEST CASES	LITHIUM-ION	MOST PROMISING LITHIUM-ION AND POST-LITHIUM-ION TECHNOLOGIES	MOST PROMISING ION AND FUTURE BATTERY TECHNOLOGIES

THE CORE GROUP



THE CORE GROUP

UPPSALA UNIVERSITET · WWU MÜNSTER · JÜLICH FORSCHUNGSZENTRUM · NATIONAL INSTITUTE OF CHEMISTRY · VRIJE UNIVERSITEIT BRUSSEL · cea · DTU

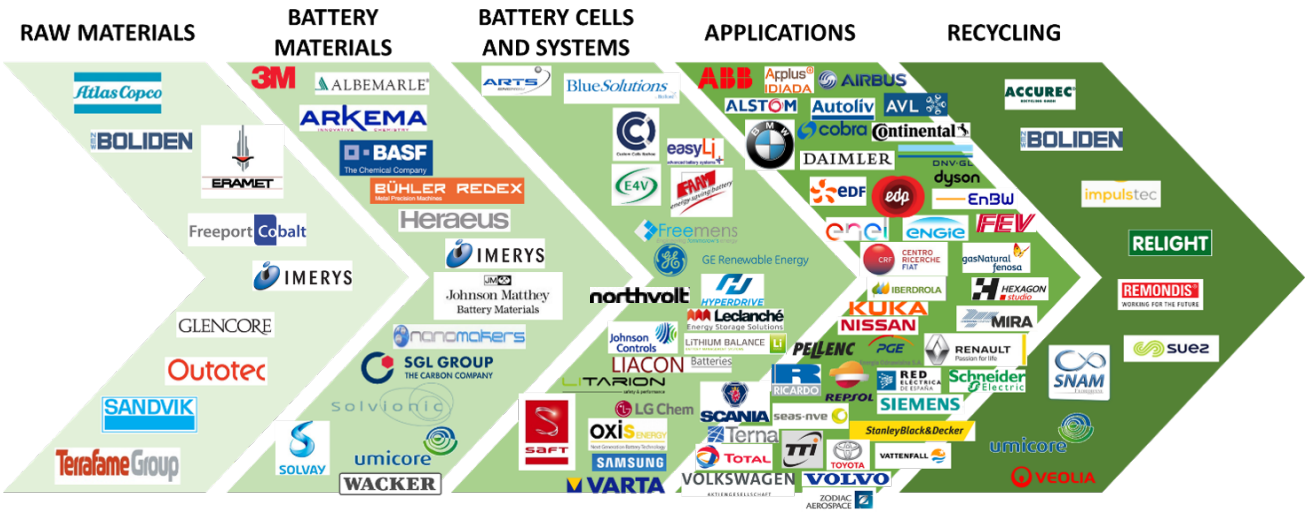
cidetec · SINTEF · cnrs · Fraunhofer · KIT · EMIRI · RECHARGE · EASE · absiskey

SUPPORTING ORGANIZATIONS

EERA European Energy Research Alliance
earpa
EGVI European Green Vehicles Initiative
EUROBAT
ENEA
imec
CIC energiGUNE energy cooperative research centre
Swedish Electromobility Centre
UNIVERSITY OF OXFORD
ALISTORE European research institute
eit InnoEnergy
eit RawMaterials
CLEPA
KLiB Kompetenznetzwerk Lithium Ionen Batterien
ENERGIE RS2E Réseau sur le stockage électrochimique de l'énergie
eucar

INDUSTRY

COMPANIES BELONGING TO THE CORE OR SUPPORTING ORGANIZATIONS



BATTERY 2030+

CONTACT
Kristina Edström
Professor of Inorganic Chemistry at Uppsala University,
kristina.edstrom@kemi.uu.se
+46 (0)70 1679006

BATTERY2030.EU