Battery 2030+ Vision

At the Heart of a Connected Green Society

This draft document is a call to launch an ambitious European initiative for long-term research on ultrahigh-performance batteries to ensure Europe's competitiveness in highly demanding market applications fulfilling end user expectations.

The vision and mission for BATTERY 2030+

BATTERY 2030+ and its consortium call upon Member States and the European Commission to launch a €1 billion European FET Flagship initiative on ultrahigh-performance batteries. **BATTERY 2030+ at the heart of a connected green society,** is preparing for a launch in 2020 within the European H2020 research and innovation framework programme.

Batteries play a central role in Europe's transition from fossil fuels to renewable energy. Versatile and high-performance energy storage systems reduce the carbon footprint of the transport sector, stabilize the power grid, and support a broad range of strategic industries including medical devices, aerospace, and advanced robotics. In nearly all aspects of modern life, batteries enable innovation.

The ambitious vision for BATTERY 2030+ is to **invent the batteries of the future.** Our vision is broad but focalise specific challenges. Fostering an innovative and collaborative community among researchers and industry gives Europe the opportunity to take the lead in a market that will almost certainly drive technology development for a generation.

The mission for BATTERY 2030+ is to **supply revolutionary fundamental and technological breakthroughs to the European battery value chain.** Battery development is at a cross-road. The global demand for batteries is immense and projected to grow even further. At the same time, the current Li-ion technology is approaching its limits. The future is open for new ideas and concepts. BATTERY 2030+ will provide the scientific and high-tech advances needed to provide European industry a competitive edge.

BATTERY 2030+ is an open platform for the diverse views and expertise across Europe to support battery development over the next decade, perhaps even pursuing concepts that can only be imagined today. Therefore, the goals of this initiative are:

- To kick-start highly ambitious, long-term battery research activities and establish European leadership in sustainable industries that demand ultrahigh-performance batteries.
- To expand European scientific leadership and excellence in energy storage with a focus on sustainable battery materials and technologies.
- To make Europe a dynamic and creative region for innovative businesses and investments in the full and sustainable value chain of batteries: raw materials, battery materials and production, novel battery cell architectures in different applications, and recycling.
- To ensure that the UN sustainability goals are met in the attemptto reach ultrahigh-performances and create “smart” batteries.
- To leverage advances in supercomputing, artificial intelligence, machine learning, medicine, sensors, drug delivery, materials discovery, nano-technology, and autonomous robotics to advance battery technology.

Europe needs strategic investments now to lead the discovery and manufacturing of ultrahigh-performance batteries. Building upon its scientific excellence, Europe has the opportunity to create a competitive industry for long-term prosperity and security.

BATTERY 2030+ will achieve ultrahigh-performance, smart and sustainable batteries based on cutting-edge European innovations

Europe's transition to a fossil-free society encompasses advances in a wide array of industries including electric mobility, renewable energy production, smart grids, advanced aerospace concepts, etc. The success of these diverse activities hinges on one key technology: ultrahigh-performance batteries.

Ultrahigh-performance describes affordable and sustainable batteries that surpass the state of the art in specific ways.

These are batteries with

1. accessible energy storage capacities approaching the theoretical limits,
2. strongly enhanced power capability,
3. outstanding combined power and energy capabilities,
4. superb battery cycling lifetime,
5. wide tolerance of extreme temperatures,
6. enhanced safety,
7. accelerated charging times, and
8. sustainable and scalable battery materials and production techniques.

Batteries that meet these specifications will revolutionize current power systems and open new applications, some of which are only imagined today.

Five specific themes have been defined to address the challenge of developing next-generation batteries:

1. Accelerated discovery of new battery materials via a Materials Acceleration Platform (MAP),
2. Determine the Battery Interface Genome (BIG) to enable inverse design of battery interfaces
3. Smart sensing and self-healing functionalities,
4. Manufacturability,
5. Recyclability and sustainability.

These themes spearhead efforts to establish a competitive circular battery ecosystem. BATTERY 2030+ will kick-start an innovative research portfolio, always keeping manufacturability, recyclability and sustainability in mind: the themes n°4 and n°5 should thus be considered as cross-cutting topics.

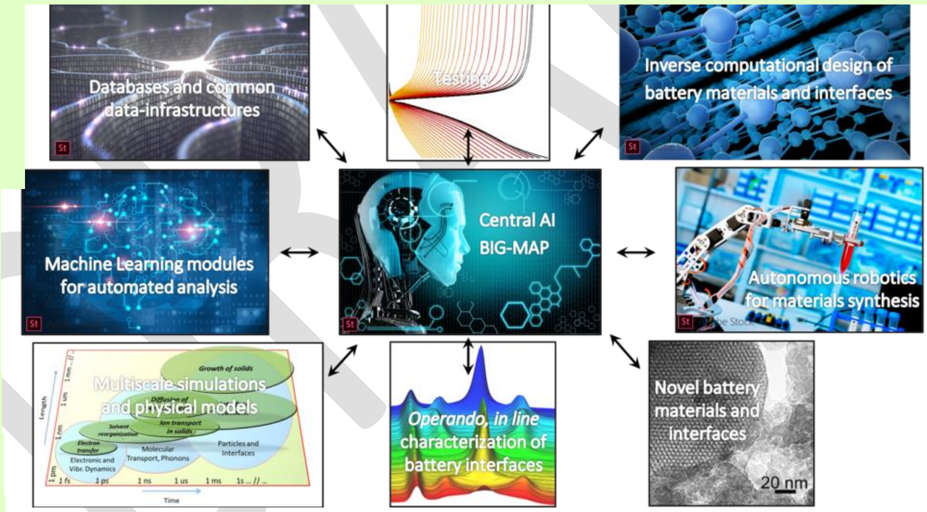
The proposed research directions described in this document are a starting point for BATTERY 2030+. The proposals are chemistry neutral, which means that the research themes can be applied to potentially any current or beyond state-of-the-art battery concepts with impact also on future state-of-the-art systems. The examples discussed here are an initial set of low TRL (typically between 1-3) projects, which will be followed by new innovative and disruptive projects during the ten-year period.

Radically new approaches are needed to accelerate the discovery of ultrahigh-performance battery materials and interfaces for the future

BATTERY 2030+ proposes to develop an entirely new infrastructure for accelerated discovery of breakthrough battery materials, structures and concepts, especially targetting the control of reactions mechanisms at interfaces. Interfaces within the battery cell are critical for the performance, durability and safety of the battery. Determining the **Battery Interface Genome (BIG)** will enable researchers address these challenges and ultimately perform inverse design of the interfaces. To improve the efficiency and cross-collaboration, it will be closely integrated with a **Materials Acceleration Platform (MAP)** into a coordinated **BIG-MAP initiative.** BIG-MAP will be a unique and powerful tool which is missing in the Global research portfolio today.

BIG-MAP in a nutshell

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 boosting the end-to-end discovery time for future ultrahigh-performance batteries tenfold.



The MAP will integrate artificial intelligence and data-driven modelling with predictive multi-scale computer simulations, autonomous synthesis robotics, in-line characterization and manufacturing in a versatile, autonomous infrastructure for accelerated discovery and optimization of ultrahigh-performance battery materials and interfaces.

We will establish a common data-infrastructure for battery materials, bridging all elements of the development cycle, and spanning the European scientific community and industry.

We will combine physical and data-driven models to establish the BIG, which will enable computational strategies for inverse design of battery materials and interfaces.

When combined, BIG-MAP will provide the battery acceleration platform of the future.“Smart batteries” and intelligent functionalities are key to next-generation technologies.

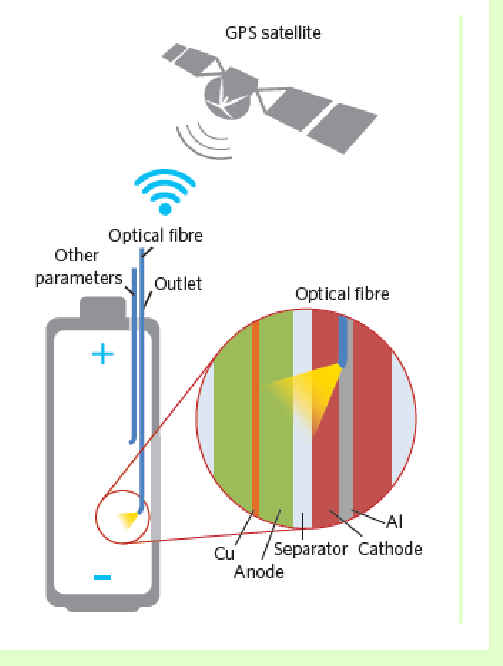
The development of smart battery cells and intelligent functionalities has been a little explored concept but - if brought to fruition - it would enable the realisation of safer and more durable battery chemistries. It is a holy grail for a multi-disciplinary design and may be the effort that allows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

Smart batteries are based on new high-resolution embedded sensor concepts (with refinement far beyond anything available today) monitoring complex reactions in the battery. It 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.

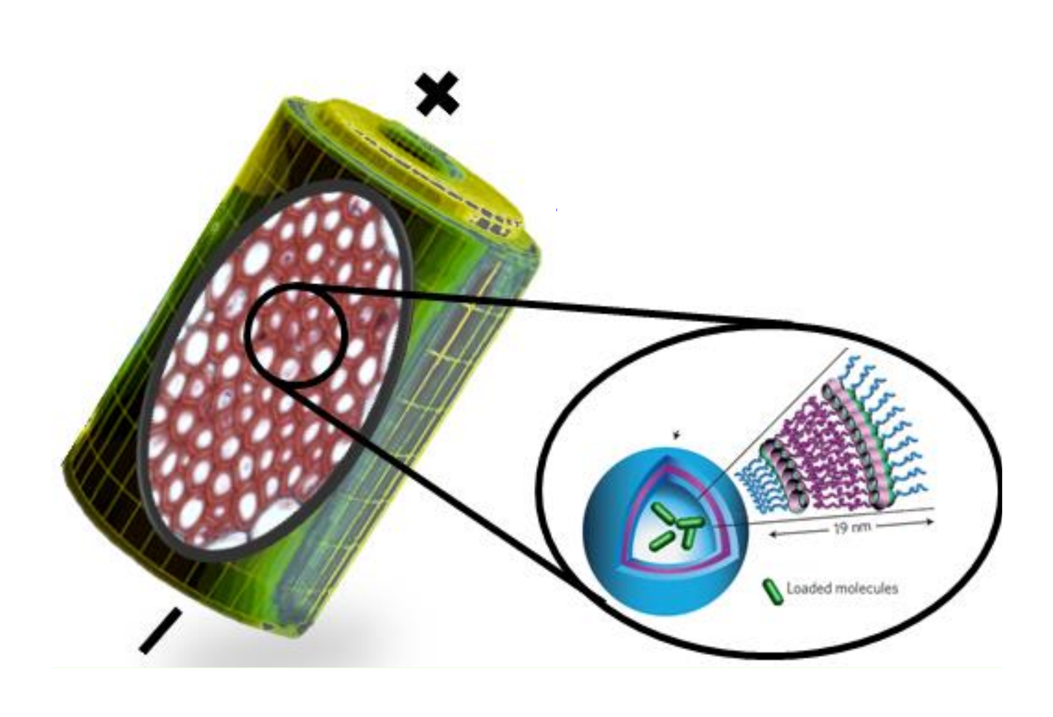
Smart Batteries and sensing in a nutshell

With batteries becoming the heart of future society, safety and intelligence 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 integrated into the battery, capable of spatially and time-resolved monitoring. Our envisioned 2030+ battery will no longer be a black box but will have in additional analytical output to transmit and receive signals. Anticipating such an inevitable paradigm shift is needed for Europe to leapfrog its main competitor over the development of a high QRL battery with the feasibility of forecasting its second life, and lowering its environmental footprint.



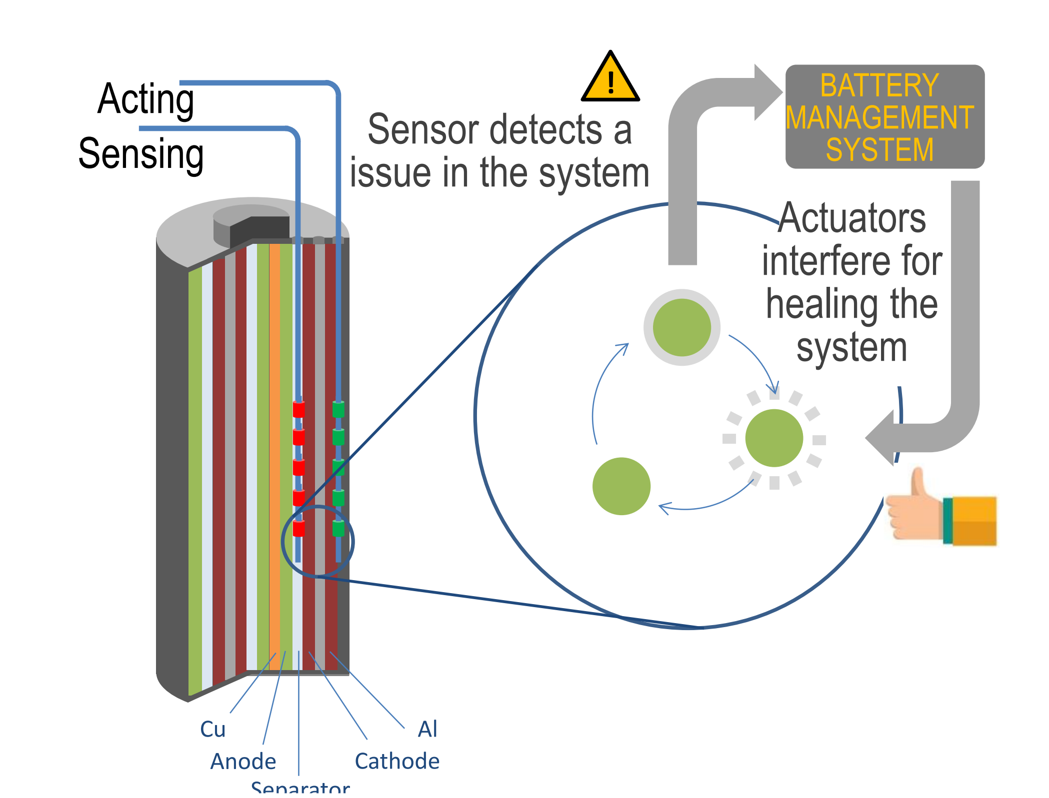
Real-time cell monitoring is invaluable to researchers and engineers, but to truly extend battery lifetime and performance, degradation mechanisms must also be addressed as they occur. Intelligent functionalities including **battery self-healing (BSH)** capabilities are essential to this effort.



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. Similar to the field of medicine - which relies heavily on the targeted delivery of drugs for the treatment of diseases - it will be essential to develop a mechanism within the battery for the on-demand administration of molecules that can solubilize a resistive deposit (e.g. SEI) or restore a faulty electrode within the battery. This is a transformational change within battery science, as nearly nothing has yet been done on this topic. Great challenges await.

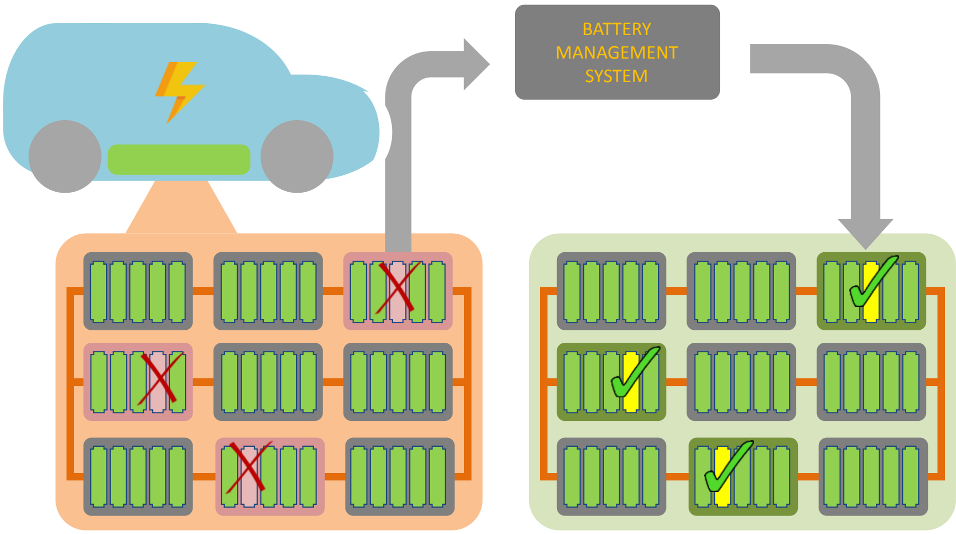
An ambitious long-term flagship must consider this futuristic view, which takes inspiration from advances in the medical field. Failing to capitalize on the benefits of sensing to detect flaws within the battery and envision their repair would be a significant lost opportunity. There is currently no 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 maximize 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, material, and engineering disciplines, for accelerating the healing process, with natural or synthetic materials. New ideas for polymers which could self-heal cracked surfaces via H-bonding or chemical healing are now emerging. However, this field is so far neglected by the battery community. There is a large potential for developing supramolecular architectures, which could be physically or chemically cross-linked to heal electrochemically-driven growth of cracks/fissures in electrode materials.

Therefore, developing a battery self-healing process is certainly among the most-far reaching and challenging issues today. Numerous approaches exist for administering drugs or nanomedicine to humans for treating 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 a strong synergy between electrochemists, biologist, 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. By bringing the battery community together with academic and industrial partners with sensing expertise, a holistic approach could be taken to facilitate the 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 and enjoy economic prosperity.

Manufacturability, recyclability and sustainability

are key concepts in BATTERY 2030+. Any attempt to discover new materials, engineering interfaces, develop new smart battery concepts must be anchored in realistic knowledge about scalability, manufacturability, recyclability and sustainability. Special projects on the manufacturability and recyclability of novel concepts, whether it is a new material, a new combination of materials or a new battery cell architecture including smart functionalities, will be anticipated within the lifetime of BATTERY 2030+.

Battery development must be considered along the entire value chain. If sensors, self-healing chemistries, or other smart functionalities are implemented, it will influence not only manufacturability or recyclability, but also the development of the Battery Management System (BMS) operating protocols, hardware, and software. Sustainability means also to emphasise affordable recycling methods and consider the environmental footprint of each effort within BATTERY 2030+. Life cycle assessment is therefore a natural part of the initiative.