Briefing for Roberto Viola
Workshop on 'The Future of Batteries'

29th of October, Messe Wien Exhibition & Congress Center, Messeplatz 1, 1021 Vienna
Room "Schubert 2", 1st floor.

Scene setter

A year ago, Commission Vice-President Šefčovič in charge of the Energy Union conveyed European industry stakeholders to propose a European Battery Alliance initiative aiming at establishing a full battery value chain in Europe and at defining areas of possible public intervention. This led to the adoption by the Commission of a 'Strategic Action Plan on Batteries' last May. This action plan announces the launch of a FET Flagship initiative on battery.

The present workshop focuses on preparing this FET Flagship on Future Battery Technologies. It follows from a first workshop held last January and builds on the preparatory work done since then by the Battery 2030+ initiative, a group of stakeholders leading the preparation of this Flagship initiative.

The specific objective of this workshop is to prepare a Manifesto that would layout the vision and the key objectives of the Flagship and to prepare the ground for kick-starting the Flagship in 2020. The annexed vision document is a draft of the Manifesto.

80 external participants from academia and industry have registered.

Your will open the workshop and chair the first panel.

Key messages:

- Europe launched a series of initiatives to put Europe back in the picture of countries producing batteries for electro-mobility and stationary energy storage, notably in the context of the European Battery Alliance. Investing in long term disruptive research is one of the important measures for Europe to make a breakthrough in battery technologies. This is the focus of the FET flagship initiative on Future Battery Technologies.

- A FET Flagship provides the means to accelerate the transition to the next generation of battery technologies, enabling European industry to come back as a major player in the global battery market.

- Setting up such a FET Flagship requires an important preparation and a clear and broadly endorsed research and innovation agenda, the first step being to define a manifesto. Today's workshop is an opportunity to discuss and refine the scope and objectives of such an initiative. Preparation will intensify in the coming months. Get engaged.

- The Flagship will be launched in 2020 and is expected to be continued under Horizon Europe.

Opening Speaking points

- Battery technologies are set to play a key role in Europe's energy strategy for reducing our CO2 emission and mitigating human impact on climate change. They are for example a key technology for clean mobility, as well as for the integration of a greater share of intermittent and distributed renewable energy sources in our energy mix.

- The rapidly expanding global battery market has been estimated at 250B€[1] annually from 2025 onwards driven primarily by the needs from the transport sector but also from the energy sector.

- Europe's position as a global leader in the automotive market is 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 is clearly strategic for Europe. It is also an industrial and economic opportunity with the possible creation of 4 to 5 million jobs. Today, it is dominated by Li-ion technology from Asia[2]. Europe cannot afford to lag behind.

[1] Estimate mentioned at a recent event organised by InnoEnergy in the context of the Battery Alliance. For 2019, the market is estimated to reach 120B€, with an annual growth of 7%.

[2] Korea (Samsung SDI and LG Chem) and Japan (Panasonic) are dominating the Li-ion battery market, while China is aggressively stepping up (CATL & BYD).

- In the near future, new generations of ultra-performing batteries, safe and sustainable will be necessary. Competition to develop them is already high but still very much open. No clear winning technology is yet ready for large scale deployment. This could change the game.

- This is an opportunity for Europe which can build on its scientific and industrial assets to come back and become a major player in the future battery market.

- Europe has strong European industrial companies in the upstream part of the battery value chain (e.g. battery material manufacturers, production equipment suppliers) and in the downstream part (tier-1 suppliers like Bosch or Continental, car manufacturers, recycling). But there is today no strong European player positioned in the core design and large-scale manufacturing of battery cells for electric vehicle applications.

- For the automotive, we mean batteries providing at least a similar performance as conventional fuel engine in terms of autonomy, fast charging and safety. **They should enable to drive for at least 700km, they should recharge in a few minutes and have a lifetime of 15 to 20 years while remaining always safe and performing**.

- We need also green and sustainable batteries, meaning for instance batteries with higher energy efficiency, produced with the lowest CO2 footprint (e.g. using green/renewable energy), re-usable (e.g 2nd use for stationary storage) and recyclable. They need to take into account the availability of raw materials, sourced either directly from mining or indirectly through future recycling. They should avoid the use of rare resources. Today, batteries are critically depending on cobalt and lithium the global reserves of which are largely outside Europe[3]. They also need to be economically affordable.

- For this to happen, we clearly need to mobilise all our scientific, technical, industrial and manufacturing expertise across the full battery value chain. We also clearly need scientific and technological breakthroughs to be made at the core of the battery cell to find and engineer new battery materials and chemistries that can fulfil our needs.

- Battery cell chemistry is still today very much unknown and poorly understood in many aspects. They operate very much as a black box. Also, finding new battery chemistries is a very slow process, largely based on iterative experimentation, trial and

[3] Cobalt is mainly source in Republic Democratic of Congo, Lithium is mainly in Chile, China, Australia and Argentina

error, with many promising technologies that fail before reaching the market.

- While there are many promising avenues based on lithium or beyond lithium concepts such as solid-state batteries, organic batteries, sodium-ion, lithium-sulfur and metal-air batteries, no one can really predict the future winning material-chemistries combinations that can best fulfil our diversity of sectorial needs going much beyond the immediate needs of the automotive sector.

- Mobilising our effort for cracking the battery material-chemistry challenge and for accelerating the time to market of new battery technologies is essential and should be at the core of the battery flagship.

- Our experience so far with the running FET Flagships - Graphene and the Human Brain Project, and more recently on Quantum Technologies - shows that these are powerful federating European initiatives. They are ambitious and risky but with high returns in case of success as they can significantly shorten the path from science to innovation and to the market.

- The preparatory work on a FET Flagship started last January with a first workshop hosted in Brussels. Since then, a group of

stakeholders has worked out a vision for a Flagship initiative aiming at ultra-high performance, smart, safe and sustainable batteries. Their vision will be laid out in a Manifesto, which is in preparation and will be at the core of our discussions today.

- They propose to use the power of digital technologies to radically change the way research on new high-performing battery chemistries is performed. One of the ideas is to reverse-engineer battery chemistries by using modelling, simulation and artificial intelligence to explore, discover and validate new materials and chemistries with a desire state of performance in a very much automated way. Another idea is to build smart batteries with embedded sensing capabilities and with self-healing functionalities so that they can be aware of their 'state of health' and can even rejuvenate themselves when necessary.

- These are certainly ambitious and highly risky ideas but at the same time, they are very promising. They seem to have the potential to provide Europe with a decisive competitive advantage and open new industrial opportunities for smart high performing batteries 'made in Europe' and adapted to specific sectorial needs.

- While we are at the very beginning, these first ideas, if well-implemented, could complement the ones proposed in the context of the EU Battery Alliance initiative.

- For the battery flagship, my objective is to kick-start the ramp-up phase of this Flagship in the last year of Horizon 2020 and then to ensure its upscaling and continuation under Horizon Europe.

- This Manifesto needs to provide a strategic and inspiring vision and the major areas of work required with clear targets to reach. It should become the foundation for the batteries Flagship and gather a wide support from all stakeholders, academia and industry but also the public authorities.

The concrete set of questions it should answer are:

1 What are the vision, scope and objectives of the Flagship? What are the major targets to reach and by when?

2 Why should Europe engage in supporting such Flagship? What will be its European added value and why can EU public R&I support make the difference?

3 How should the Flagship be implemented?

- The objective is to have the Manifesto ready for the ICT Conference in Vienna early December.

- Then, your next step should be to develop the detailed strategic research agenda for the Flagship and a suitable governance and implementation approach.

- We aim at presenting a convincing approach at a high-level event which we plan to hold under the Romanian presidency in June next year and that would also mark the launch of the first FET Flagship calls.

- In parallel, I expect the discussion on Horizon Europe to clarify the way FET Flagships will be continued under the next Framework Programme.

- I would like to warmly thank you for coming today and also for having undertaken an in-depth work over the last months in preparing this Flagship initiative. This is very much appreciated and represents a very rich and solid basis for our discussions today.

- I would like now to invite Professor [redacted] and her colleagues to share their vision of this Battery Flagship and to take us in more details through the different research challenges that will be at the core of the Manifesto.

Panel discussion: 'A MANIFESTO for a FET Flagship initiative on future battery technologies'

From 9.10 to 10.20, you will moderate the panel discussion.

It will start with short presentations highlighting the main element of the proposed FET Flagship followed by panel discussion and a Q&A with the audience.

Panellists are :

- [redacted] Uppsala University : [redacted] Battery 2030+ initiative preparig the Battery Flagship
- [redacted] Collège de France: [redacted] smart batteries with sensors and self-healing capabilities
- [redacted] DTU: [redacted] Interface Genome & Material Acceleration Platform (BIG-MAP) that would accelerate discovery of new battery chemistries
- [redacted] EMIRI: [redacted] battery sustainability, manufacturability and recycling

Suggested questions for the panel discussion

1 Question to the audience: Is it the right vision, scope and objectives? Are the key objectives and research challenges proposed for this Flagship the right ones? Do they have the right level of ambition?

2 Question to the audience: What value do you see for industry? How can industry contribute to this initiative?

3 Question to the panellists and to the audience: How should the Flagship be implemented? How to coordinate the various research activities within the flagship but also connect with other ones going on at national or European level?

Annex 1 : Agenda

Annex 2 : Participants list

Annex 3 : Battery 2030 Vision document

The future of batteries

A workshop of the BATTERY 2030+ initiative preparing a
FET Flagship initiative on future battery technologies

29th October, 9-12 AM

To respond to the challenge of creating a competitive and sustainable battery manufacturing industry in Europe, the EC Vice-President for Energy Union Maroš Šefčovič launched in October 2017 the EU Battery Alliance, as an industry driven initiative which led to the publication in May 2018 by the Commission of a Strategic Action Plan.

One of the actions in this plan is the call for preparation of a large scale Future and Emerging Technologies (FET) Flagship research initiative to support high-risk disruptive research on ultra-high performance, smart and sustainable battery technologies that can provide a decisive competitive advantage to Europe in the future. It should complement the short-medium term EU research efforts focused on the next upcoming generation of battery technologies as well as other initiatives focused on accelerating the deployment of manufacturing capacities in Europe.

This workshop aims to present the state of play of preparation of this Flagship initiative and to engage with industrial stakeholders in a discussion on the main technological priorities that it should address as well as on the potential contributions of industry to this initiative.

This workshop is organised by the Battery 2030+ initiative with the support of the European Commission, DG CNECT[1] C4-Flagship Unit.

About Battery 2030+ - at the heart of a connected green society

Following the "Future Battery Technologies for Energy Storage" workshop organised on 10th January 2018, scientists, institutes, and trade associations representing organisations all over Europe got together to prepare a large scale initiative on future battery technologies, named Battery 2030+. The vision of Battery 2030+ is to address the greatest challenge for the future of energy storage: to achieve smart, ultra-high-performance batteries within a sustainable framework. This means a disruptive, long-term research approach complementing other on-going activities in Europe with a clear goal to present new concepts and ideas supporting European companies.

Additional information:

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[1] Directorate-General for Communications Networks, Content and Technology

Registration:

CNECT-FLAGSHIPS-EVENT@ec.europa.eu
Participation is limited to 70 attendees.
Confirmation of registration will be sent by October 5th.

Venue:

Messe Wien Exhibition & Congress Center, Messeplatz 1, 1021 Vienna, Austria
Room "Schubert 2", 1st floor.

The future of batteries

A workshop of the BATTERY 2030+ initiative preparing a
FET Flagship initiative on future battery technologies

Draft Agenda

8.00-9.00 *Registration*

9.00-9.10 Welcome by Roberto Viola, Director General, European Commission

9.10-10.20 A MANIFESTO for a FET Flagship initiative on future battery technologies
Presentation and panel discussion

Moderator: Roberto Viola, Director General, European Commission

Panel:
- , Uppsala University : Battery 2030+ initiative
- Collège de France: Sensors and self-healing
- DTU: Battery Interface Genome & Material Acceleration Platform (BIG-MAP)
- EMIRI: Sustainability, manufacturability and recycling

10.20-10.30 Presentation of parallel sessions

10.30-11.30 Parallel sessions
Discussion leaders: VUB; POLITO; KIT; SINTEF

11.30-11.45 Reporting from parallel sessions

11.45-12.00 Closing
European Commission

First name	Name	Organisation
		AVL List GmbH/ EGVIA
		EASE
		VR / Swedish Research Council
		UNIVERSITA DI BOLOGNA
		ACONDICIONAMIENTO TARRASENSE ASSOCIACION
		University of Latvia
		TNO
		EMPA
		CEA/ INAC
		Politecnico di Torino
		European Commission
		MINECO – AEI
		Trinity College /AMBER Centre (Advanced Materials and BioEngineering Research Centre)
		E-Vision Systems, s.r.o.
		ALBUFERA ENERGY STORAGE SL
		BOLLORE/Blue Solutions
		KEMIJSKI INSTITUT
		Université de Lorraine
		UPPSALA UNIVERSITET
		DIFFER -Dutch Institute for Fundamental Energy Research
	se	NMPB PC - Entreprise Ireland
		CENTRO DE INVESTIGACION COOPERATIVADE ENERGIAS ALTERNATIVAS FUNDACION
		KARLSRUHER INSTITUT FUER TECHNOLOGIE
		SYNKOLA s.r.o.
		University of Limerick
		European Commission
		SOLVAY
		Steinbeis-Europa-Zentrum
		BASF
		SUEZ
		University of Twente
		EMIRI (SOLVAY)
		AIT
		Justus Liebig University
		Aalto University
		European Commission
		European Lithium
		ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG
		Jules Vernes University
		EMIRI
		University of Porto
		Instituto Superior Técnico Lisboa

First name	Name	Organisation
[redacted]	[redacted]	Produktionstechnik und Automatisierung IPA
[redacted]	[redacted]	ENEA - Electrochemical Storage Group
[redacted]	[redacted]	TECHNISCHE UNIVERSITEIT DELFT
[redacted]	[redacted]	VRIJE UNIVERSITEIT BRUSSEL
[redacted]	[redacted]	INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM
[redacted]	[redacted]	Forschungszentrum Jülich - Helmholtz Institute Muenster
[redacted]	[redacted]	AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS
[redacted]	[redacted]	Voltia group
[redacted]	[redacted]	IIT- Graphene Labs
[redacted]	[redacted]	RSE-Ricerca sul Sistema Energetico
[redacted]	[redacted]	CEA
[redacted]	[redacted]	VTT Technical Research Centre of Finland
[redacted]	[redacted]	Global Materials Labs – FCA - EMEA
[redacted]	[redacted]	University College Cork
[redacted]	[redacted]	ENEL
[redacted]	[redacted]	Honda R&D Europe (Deutschland) GmbH
[redacted]	[redacted]	Diderot Univarsity
[redacted]	[redacted]	EHA
[redacted]	[redacted]	European Commission
[redacted]	[redacted]	iPoint-Austria gmbh
[redacted]	[redacted]	University of Münster - Münster Electrochemical Energy Technology (MEET)
[redacted]	[redacted]	Technologieplattform Smart Grids Austria
[redacted]	[redacted]	SINTEF
[redacted]	[redacted]	Absyskey
[redacted]	[redacted]	UMICORE
[redacted]	[redacted]	EDF
[redacted]	[redacted]	BMW / EUCAR
[redacted]	[redacted]	NTNU - Department of Materials Science and Engineering
[redacted]	[redacted]	cyberGRID GmbH & Co. KG
[redacted]	[redacted]	COLLEGE DE FRANCE
[redacted]	[redacted]	University of Aachen
[redacted]	[redacted]	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
[redacted]	[redacted]	Freelance Journalist
[redacted]	[redacted]	Dassault Systèmes
[redacted]	[redacted]	DANMARKS TEKNISKE UNIVERSITET
[redacted]	[redacted]	SPINVERSE
[redacted]	[redacted]	Vilnius University
Roberto	Viola	European Commission
[redacted]	[redacted]	Neumann Aluminium Impact Extrusion
[redacted]	[redacted]	ANR
[redacted]	[redacted]	EUCAR
[redacted]	[redacted]	Juelich

First name	Name	Organisation
[redacted]	[redacted]	Coatema Coating Machinery GmbH
[redacted]	[redacted]	Envirohemp
[redacted]	[redacted]	Cisco System (GMBH)
[redacted]	[redacted]	Warrant group- european funding dicision
[redacted]	[redacted]	TWI
[redacted]	[redacted]	Granta design
[redacted]	[redacted]	Galiboff extrusion ltd

DRAFT

Battery 2030+ Vision

At the Heart of a Connected Green Society

(draft document, as a support for discussion)

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 transportation network, stabilize the power grid, and support a broad range of strategic industries including medical devices, aerospace projects, 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.** Fostering an innovative and collaborative community among researchers and industry leaders 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 technology 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, current Li-ion technology is approaching its limits. The future is open for new ideas. BATTERY 2030+ will provide the scientific and high-tech advances needed to give 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 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 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 production, novel batteries in different applications, and recycling.
- To formulate and act on the Grand Challenges and the UN sustainability goals to reach ultrahigh-performances and create “smart” batteries.
- To leverage advances in artificial intelligence, machine learning, medicine, sensors, drug delivery, materials, nano-technology, and autonomous robotics to advance battery technology.

Europe needs strategic investment 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 batteries that surpass the state of the art in specific ways. These are batteries with

1. large energy storage capacity approaching the theoretical limits,
2. large power capability approaching the theoretical limits,
3. outstanding combined power and energy capabilities,
4. superb battery cycling lifetime,
5. wide tolerance of extreme temperatures (-30 °C to + 120° C),
6. enhanced safety, and
7. accelerated charging times.

Batteries that meet these specifications will revolutionize current power systems and open new applications, some of which are only imagined today.
Five themes have been defined to address the challenge of developing next-generation batteries:

1. Design of new battery materials via a Materials Acceleration Platform (MAP),
2. Interface engineering by defining a Battery Interface Genome (BIG),
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°3 and n°4 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 aims at improving all possible novel and 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 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 materials and interfaces for the batteries of the future

BATTERY 2030+ proposes a tool for faster discovery of new materials and new concepts by specially highlighting reactions at interfaces. Interfaces within the battery cell are critical for the durability and safety of the battery. The **Battery Interface Genome (BIG)** effort will help researchers address these challenges. To improve efficiency and cross-collaboration, it will be combined with the **Materials Acceleration Platform (MAP)** into a coordinated **BIG-MAP initiative**. BIG-MAP is a powerful tool which is missing in the European research portfolio today.

BIG-MAP in a nutshell

A disruption of the existing discovery, development, and production 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 European ultrahigh-performance batteries tenfold. BIG-MAP will:

- Create a flexible infrastructure utilizing artificial intelligence, data-driven modelling, predictive multi-scale simulations, automated synthesis and characterization, that is specifically dedicated to the autonomous discovery and optimization of ultrahigh-performance and durable battery materials and interfaces.
- Develop strategies and approaches for efficient use of exiting knowledge from experimental and computational databases in Europe, as well as 'bad data' from failed experiments and unsuccessful materials compositions, to accelerate the materials discovery process.
- Create computational strategies for inverse design of battery materials and interfaces,.
- Strive towards a holistic ontology for materials data and a modular data-infrastructure shared with European scientific community, to enable cross-utilization of data in the short and long term.
- Establish collaborations with relevant European Centers of Excellence and relevant partners and projects in Mission Innovation, in particular, the Clean Energy Materials Innovation Challenge.

"Smart batteries" and intelligent functionalities are key to next-generation technologies.

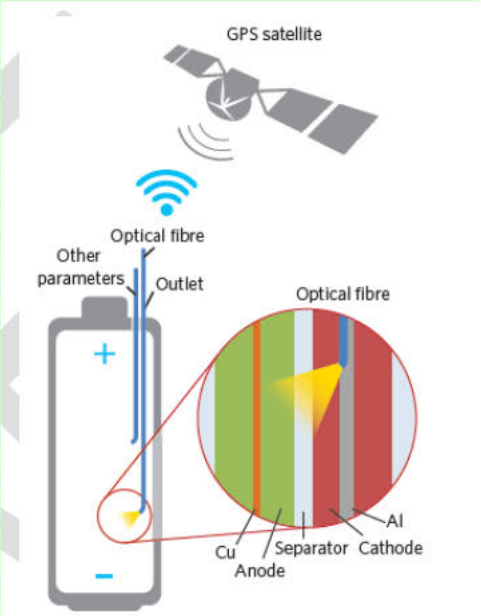
The development of **smart battery cells** and **intelligent functionalities** has been a little explored concept but - if brought to fruition - it would enable the realisation of safer and more

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 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.

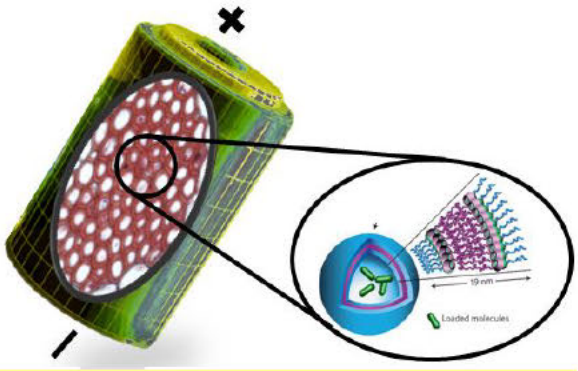


A disruptive vision like this needs smart embedded sensing technologies and functionalities injected into the battery, capable of spatially and time-resolved monitoring. Our envisioned 2030+ battery will no longer be a black box but will have in additional analytical output to transmit and receive signals. 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.

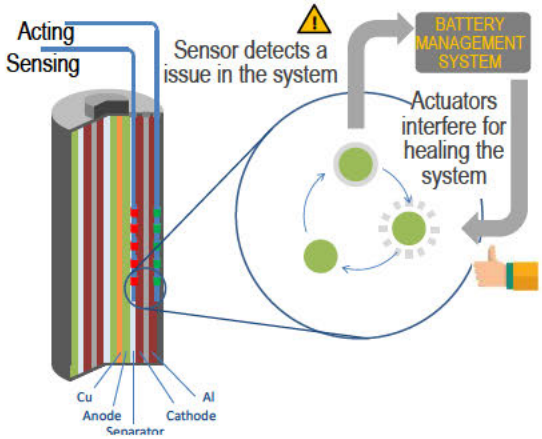


An ambitious long-term flagship must consider this futuristic view, which takes inspiration from advances in the medical field. Failing to capitalize on the benefits of sensing to detect flaws within the battery and envision their repair would be a significant lost opportunity. There is currently no 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?

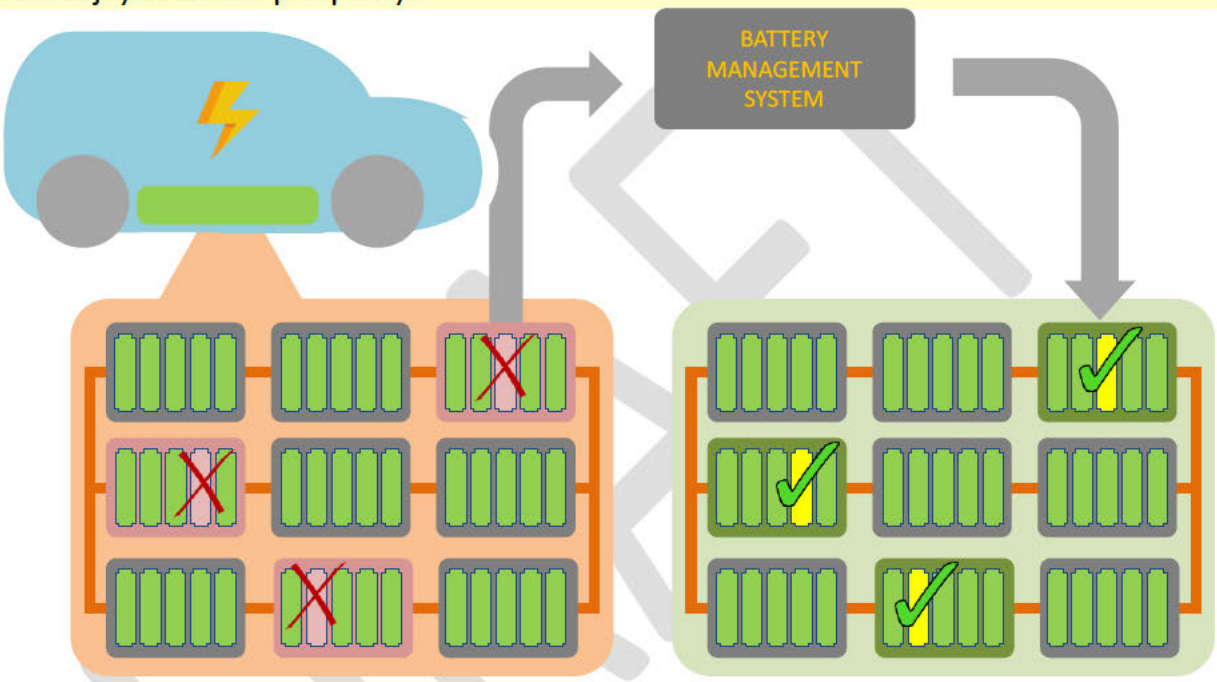
Self-healing of scars, tissues, and bones is taken for granted in human bodies. Modern medicine has found a way to leverage these processes to treat diseases. There is a very active underlying science, combining principles from biology, material, and engineering disciplines, for accelerating the healing 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.



Failing cell resulting in a loss of a series of batteries

Healed cell keeping the performance of the pack

Manufacturability, recyclability and sustainability

Manufacturability, circular economy and sustainability are key concepts in BATTERY 2030+. Every attempt to discover new materials, engineering interfaces, develop new smart battery concepts must be anchored in realistic knowledge about scalability, manufacturability, and recyclability. Special projects on the manufacturability of every concept, whether it is a new material, a new combination of materials or if the battery cell will include some 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 recycling methods and consider the environmental footprint of each effort within BATTERY 2030+. Life cycle assessment is therefore a natural part of the initiative.