Beilage 2:

# Erläuterungen zur Batterieforschung (inkl. Schweiz) und Wasserstoffforschung

## Battery research

### At the European level:

Batteries Europe is the European Technology and Innovation Platform (ETIP) bringing together all relevant stakeholders in the European batteries research and innovation ecosystem in order to develop and support a competitive battery value chain in Europe.

BATT4EU is a Co-programmed Partnership established under Horizon Europe that aims to achieve a competitive and sustainable European industrial value-chain for e-mobility and stationary applications. It is a contractual public-private Partnership gathering – on the public side – the European Commission; and – on the private side – BEPA, which regroups all the battery stakeholders from the European Research community.

The **Batteries European Partnership Association (BEPA)** is the international non-profit making association representing the privateside of the BATT4EU Partnership. It gathers the European battery community willing to contribute to the ambitious upcoming Research & Innovation Batteries Partnership under Horizon Europe.

BEPA includes 75 research organisations (universities and research institutions). The complete list can be found here and should give a good overview of the research institutions active in battery research across the continent (including Switzerland).

***Difference between Batteries Europe and the BATT4EU Partnership**: Batteries Europe and the BATT4EU Partnership have a similar ambition. However, while Batteries Europe aims mainly at identifying, in a holistic way, all the R&I needs across the battery value-chain at every TRL level; the BATT4EU Partnership focuses on prioritising (within the strategic inputs provided mainly by Batteries Europe), the most urgent R&I priorities to be addressed within the Horizon Europe Work Programme in order to make the European battery industry more competitive and sustainable.*

BATTERY2030+ is a large scale, long term European research initiative with the vision of inventing the sustainable batteries of the future. It aims to provide European industry with disruptive technologies and a competitive edge throughout the entire battery value chain.

BATTERY 2030+ has established a long term-roadmap for forward looking battery research in Europe. The roadmap has defined 5 research pillars:

1. **Battery Interface Genome in combination with a Materials Acceleration Platform (BIG-MAP)**: develop physics-aware machine and deep learning models to examine and predict how battery materials and interfaces evolve in space and time.
2. **Self-healing**: explore different methods that can autonomously or non-autonomously enhance life and capacity of the battery.
3. **Sensing**: sensing projects measuring sensor data like battery temperature, voltage, impedance, and pressure externally and internally, in order to improve and increase the safety and performance of batteries.
4. **Manufacturability**
5. **Recyclability**

BATTERY2030+ is constituted around six research projects which address these different research themes:

1. BIG-MAP: BIG-MAP relies on the development of a unique R&D infrastructure and accelerated methodology that unites and integrates insights from leading experts, competences and data across the entire battery value chain with Artificial Intelligence (AI), High Performance Computing (HPC), large-scale and high-throughput characterization and and autonomous synthesis robotics. In short, BIG-MAP aims to reinvent the way we invent batteries and to develop core modules and Key Demonstrators of a Materials Acceleration Platform specifically designed for accelerated discovery of battery materials and interfaces.

Self-healing:

2. BAT4EVER : The BAT4EVER project aims to tailor the materials of Li-ion batteries by modifying their well-established state-of-art ancestors and inducing self-healing functionalities (mechanical, structural and chemical) and thus to achieve innovative, higher performant, capable of extended lifetime, safe and reliable Li-ion batteries.
3. HIDDEN: The HIDDEN project develops self-healing processes to enhance the lifetime and to increase the energy density of Li-metal batteries 50% above the current level achievable with current Li-ion batteries.

Sensing:

4. INSTABAT : INSTABAT is intended to monitor in operando, key parameters of a Li-ion battery cell, in order to provide higher accuracy states of charge, health, power, energy and safety (SoX) cell indicators, allowing us to improve the safety and the quality, reliability and life (QRL) of batteries.
5. SENSIBAT : SENSIBAT's overall objective is to develop a sensing technology for Li-ion batteries that measures in real-time the internal battery cell temperature, pressure (e.g. mechanical strain, gas evolution) conductivity and impedance (separately for the anode, cathode and electrolyte). The data and insights from these new sensing technologies will be used for the development of improved state estimator functions based on an improved understanding of how, where and when degradation and failure mechanisms occur. These functions will be included in the BMS. More accurate control stretches the possibilities of fast charging and discharging, increases the usable battery capacity and therefore range in different weather conditions and gives a detailed usage history. It allows for better battery state forecasting, resulting in a longer lifetime and more economical use during its 1st and 2nd life. Sophisticated lifetime prediction models enable improved (preventive) maintenance schemes. SENSIBAT's technology that will be developed for all Li NMC battery types, and can be transferred to serve other battery chemistry types.
6. SPARTACUS : The SPARTACUS project aims to develop a multifunctional sensor array technology for various types of batteries combined with an advanced battery management system ensuring improved charging behaviour and maximized battery lifetime. The optimized detection of battery health and battery function will make it possible to recharge in a safe but fast way – much faster than before.

Manufacturability and Recyclability are not individual projects in BATTERY 2030+, but a cross-functional part of all six research projects. Over-time this might however change.

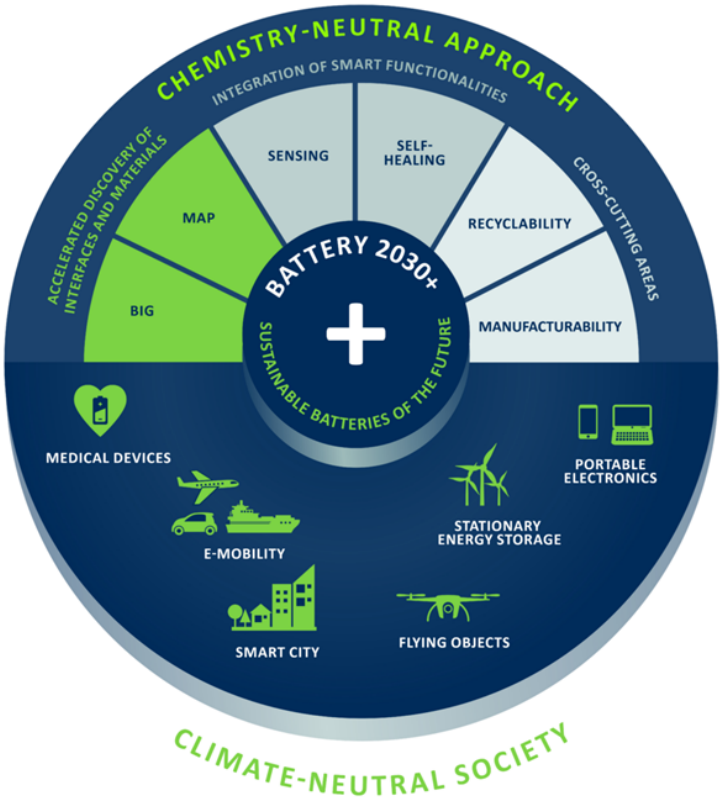



*Abb: An overview of the approach of BATTERY2030+ is illustrated in the diagram*


*Abb: The core partners of BATTERY 2030+ are represented on the map*

An exhaustive list of EU research projects can be found here, where a total of 279 projects are registered adding up to an overall contribution of 206 M€.

**At the Swiss level:**

iBAT Association: represents industry, authorities and research institutions along the complete value chain from manufacturing to recycling and strengthens Switzerland's competitiveness in this core technology.

List of research partners belonging to iBAT Association:

- BFH
- CSEM
- Empa
- EPFL
- ETHZ
- OST
- PSI
- SIPBB
- University of Fribourg

These can be considered as the main research institutes involved in battery research in Switzerland.

A map showing the landscape of the Swiss battery industry across the entire supply chain has been established by iBAT: https://ibat.swiss/swiss-battery-landscape/

CircuBAT: Innosuisse funded research project aiming to advance the technical and economic potential of a circular economy for batteries.

- **Who?** CircuBAT connects the major stakeholders along the complete lifecycle of lithium-ion batteries. Among them are partners from Industry, Governement and NGOs along the complete value chain of a lithium-ion battery lifecycle.
- **Why?** Extending the usable lifetime in first-use applications and increasing the amount of second-use and second-life opportunities allows to minimize the total CO2-footprint of lithium-ion battery systems during the lifetime.
- **How?** Maximizing metal recovery and resource efficiency will provide materials for use in a future manufacturing process and avoid that the battery enters a landfill or other disposal facility with no recovery of any of its remaining value.

## Hydrogen research

### At the European level:

Hydrogen Europe : Hydrogen Europe is the European association representing the interest of the hydrogen industry and its stakeholders and promoting hydrogen as an enabler of a zero-emission society. With more than 400+ members, including 25+ EU regions and 30+ national associations, we encompass the entire value chain of the European hydrogen and fuel cell ecosystem. Our vision is to propel global carbon neutrality by accelerating European hydrogen industry.

The list of Hydrogen Europe members can be found here. This association is not really focused on research and therefore there are not many research institutions among their members.

Hydrogen Europe takes part in a number of Europen projects which can be found here.

Hydrogen Europe Research is an international, non–profit association representing the European scientific community involved in the development of a new, industrial ecosystem based on hydrogen and committed to moving towards a circular, carbon-neutral economy. It is composed of more than 140 Universities and Research & Technology Organisations (RTO) from 29 countries all over Europe and beyond. The list of members can be found here and are also represented on the map below.

Clean Hydrogen Partnership : The Clean Hydrogen Partnership (as per its legal name Clean Hydrogen Joint Undertaking) is a unique public private partnership supporting research and innovation (R&I) activities in hydrogen technologies in Europe. It is composed of three members: the European Commision, Hydrogen Europe and Hydrogen Europe Research.

A total of 314 projects were funded under the Clean Hydrogen Partnership (see list here) representing cumulated project costs of 1.5 B€ (of which approx. 0.8 B€ are funded by EU).

An overview of the research carried out within the frame of the Clean Hydrogen Partnership can be found in the programme annual report (latest version 2022). The projects are categorised in 7 pillars corresponding to the different stages of the value chain:

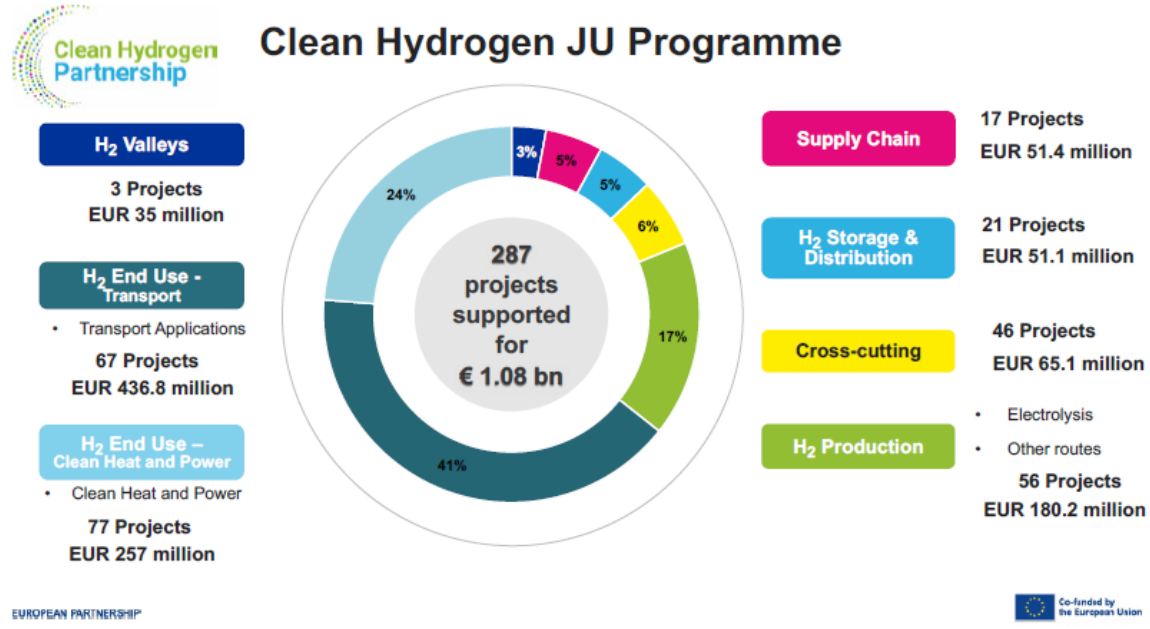
1. Pillar 1: Hydrogen Production
2. Pillar 2: Hydrogen Storage and Distribution
3. Pillar 3: Hydrogen End Uses - Transport
4. Pillar 4: Hydrogen End Uses – Clean Heat and Power
5. Pillar 5: Cross-Cutting Issues
6. Pillar 6: Hydrogen Valleys
7. Pillar 7: Hydrogen Supply Chains

The pillars are further divided into research areas which are listed in the table below:

| PILLARS | RESEARCH AREAS | RESEARCH TOPICS |
|---|---|---|
| 1) Hydrogen Production | 1 - Low temperature electrolysis | Projects targeting AEL, PEMEL and AEMEL |
| | 2 - High-temperature electrolysis (incl. co-electrolysis) | Projects targeting SOEL and PCCEL |
| | 3 - Other hydrogen production methods | Projects covering reformer development for distributed hydrogen production and thermochemical hydrogen production are covered in this review |
| 2) Hydrogen storage and distribution | 4 - Aboveground storage | Projects addressing optimisation and deployment of large-scale solid state storage solution |
| | 5 - Underground storage | Projects targeting the feasibility, risks and impact of $H_2$ underground storage |
| | 6 - $H_2$ in the natural gas grid | Projects assessing the effect of $H_2$ on transmission (High pressure) Natural Gas (NG) pipeline |
| | 7 - Liquid $H_2$ carriers | Projects focusing on the improvement of the roundtrip efficiency of conversion and system cost |
| | 8 - Compression, purification and metering solutions | Projects demonstrating feasibility of direct separation of $H_2$ from NG and material research on proton conducting ceramic electrochemical cells (PCC) |
| | 9 - $H_2$ refuelling stations | Projects addressing reliability and availability issues indicated by operation of existing Hydrogen Refuelling Stations (HRS) |
| | 10- Hydrogen transportation (pipelines, road transport and shipping) | *currently not covered by any projects* |
| | 11 - Hydrogen distribution (pipelines) | *currently not covered by any projects* |
| 3) Hydrogen end uses - transport | 12 - Building Blocks | Projects focusing on material, design and system optimisation for LT and HT PEMFC |
| | 13 - Heavy Duty Vehicles | Projects addressing optimisation of BoP components and architectures design to meet Heavy-Duty Vehicles (HDV) needs |
| | 14 - Waterborne Applications | Projects focusing on improving access to the market for hydrogen, its derivatives and FCs, initially on smaller vessels |
| | 15 - Rail Applications | Projects with the objective of enabling hydrogen to be recognised as the leading option for trains on non-electrified or partially electrified routes |

| PILLARS | RESEARCH AREAS | RESEARCH TOPICS |
|---|---|---|
| | 16 – Aviation Applications | Projects addressing optimisation of Balance of Plant (BoP) components and architectures design to meet aviation needs |
| | 17 – Bus/Coaches | Projects with the objective of improve the deployment of hydrogen in this segment |
| | 18 - Cars | Projects with the objective of improve the deployment of hydrogen in this segment |
| 4) Hydrogen end uses – Energy | 19 - m-CHP | Project exploring the deployment of PEMFC and SOFC for micro-Cogeneration |
| | 20 - Commercial Size CHP | Demonstration projects for commercial size CHP using SOFC and HT PEMFC |
| | 21 – Industrial Size CHP | Project exploiting PEMFC technology at industrial size |
| | 22 – Off-grid/back up/genset | Demonstration projects exploring the application of Proton Exchange Membrane (PEM), Solid Oxide and Alkaline hydrogen technologies (FC and electrolysers) |
| | 23 – Next generation degradation and performance & Diagnostic | Exploration projects for utilization of biogas fed with a SOFC CHP system and use of Electrochemical Impedance Spectroscopy (EIS) technology for monitoring & diagnostic purposes |
| 5) Cross-cutting topics | 24 - Sustainability, Life Cycle Sustainability Assessment, recycling and eco-design | Projects addressing needs to define guideline for sustainability assessment |
| | 25 - Education and Public Awareness | Projects aiming to increase the knowledge on hydrogen technology at educational level (schools /universities) |
| | 26 - Safety, Pre-Normative Research and Regulations, Codes and Standards | Projects focusing on improving knowledge on hydrogen risk of utilization and definition of protocol for permitting |
| 6) Hydrogen Valleys | 27 – $H_2$ Valley | Projects aiming to develop a hydrogen integrated system when favourable conditions at industrial or geographical point of view |
| 7) Hydrogen Supply Chains | 28 – Manufacturing for stationary applications | Projects addressing optimisation of materials and/or BoP components and architectures design to meet stationary application needs |
| | 29 – Manufacturing for transport applications | Projects addressing optimisation of BoP components and architectures design to meet transport application needs |

The overall project number and budget distribution of the Clean Hydrogen JU programme among the different pillars is represented in the pie chart below. It can be observed that projects related to end use transportation applications make up 41 % of total funding and is therefore the predominant field in hydrogen research.




Source: Clean Hydrogen JU