‘Toward sustainable batteries based on silicon, sulfur and bio-mass derived carbon’

Sustainable batteries for a greener future

Welcome to the October edition of the 2BoSS Newsletter!

In this 4th edition, we are thrilled to share the latest updates on our **progress** toward developing a competitive and innovative battery solution, as well as our recent participation in events and working groups. We’re also pleased to announce our upcoming **workshop** in Barcelona this November, where we’ll explore the capabilities and applications of various in situ/operando techniques for energy conversion and storage processes. In addition, we’re featuring four valuable **articles** from our partners at *IREC*, all focused on the potential of lithium-sulfur batteries. Enjoy your reading!

WP1: Biomass-derived carbon and cathode assembly

In WP1 significant progress has been made by *IREC* in the development of carbon materials derived from biomass residues generated by the winery industry. These materials were utilized to create high-performance sulfur-based cathodes, successfully achieving the key performance indicators set at the beginning of the project. To reach these high-performance levels, novel catalysts were designed and synthesized, specifically tailored to accelerate and extend the lithium-sulfur reaction at the cathode of the Si-S battery. These catalysts play a crucial role in promoting the electrochemical reactions, improving the overall capacity and cycle life of the battery. As a result, a clear pathway has been demonstrated for enhancing the energy density and long-term stability of Si-S batteries, aligning with the project’s goals toward the development of next-generation energy storage technologies.

WP2: Silicon anode development

The *CEA* team, responsible for developing silicon-rich composites as anode materials for lithium-ion batteries, has synthesized approximately 40 different materials to optimize silicon content, enhancing the anode’s energy storage capacity. Instead of using mined graphite for conductivity, they have replaced it with porous carbon from bio-waste and recycled graphite from used batteries, boosting capacity and supporting sustainability efforts.

Additionally, *CEA* has refined the synthesis process for safe scale-up, as the composite preparation involves high-temperature (400ºC) and high-pressure (over 10 atmospheres) chemical reactions. They successfully achieved a 10-times scale-up in quantity produced in a single batch, while simplifying both pre- and post- processing and reducing energy consumption. Consequently, they can now produce sufficient anode material for small-scale pilot-line battery fabrication in a timely manner.

WP3: Battery assembly and validation

In WP3, the *IREC* team successfully integrated the silicon (Si) anodes developed by *CEA* in WP2 with the sulfur (S) cathodes developed by *IREC* in WP1, resulting in the creation of complete battery cells. A key aspect has been optimizing the electrolyte between the two electrodes, as compatibility is crucial for maximizing performance and stability. Various strategies were explored to enhance the electrolyte's effectiveness at both the anode and the cathode.

One promising approach involved using solid sulfide electrolytes, which significantly improved electrode stability and energy density. These electrolytes form stable interfaces with both electrodes, enhancing cycle life and energy output. This innovation is a critical step toward achieving the project's high-performance targets. By focusing on high silicon and sulfur loading electrodes, the project aims to advance next-generation energy storage systems with improved stability and energy density.

WP4: Battery recycling

In WP4 the development of a specialized recycling process for Li-S batteries represents a significant step forward in advancing the circular economy. *CEA*'s objective is to adapt existing recycling methods to this new type of batteries. By effectively recovering lithium, a key component of these batteries, *CEA* aims to develop a more sustainable production of energy storage solutions. Additionally, the process focuses on valorizing other valuable materials such as sulfur and trace metals, bringing both economic and environmental advantages. This innovative approach not only mitigates our reliance on natural resources buy also significantly minimize the environmental impact of battery disposal.

WP5: Life cycle and environmental assessment

The 2BoSS battery represents an emerging technology currently in laboratory development. To estimate the environmental impacts of potential industrial production, *POLITO* is using a novel approach known as Prospective Life Cycle Assessment (pLCA). Specifically, *POLITO* is focused on three main tasks:

1. **Data collection** from laboratory activities to build a comprehensive bill of materials and upscale inventories at industrial scale.
2. **Environmental prospective LCA.**
3. **Social LCA.**

For the first task, *POLITO* has built a reliable and representative Life Cycle Inventory (LCI) for the 2BoSS battery through detailed analysis of lab processes. Thanks to valuable information on laboratory operations provided by the partners, this dataset has been updated to reflect the latest technological advancements, reducing uncertainties and leading to more meaningful impact assessment results as the project scales up.
LCA is an iterative process, so alongside the LCI, production processes modelling and impact calculations have been done using the Ecoinvent database and Simapro software. These iterations allow fine-tuning the model and verifying inventories. A preliminary impact assessment at a lab scale has been performed for a coin cell, but further analysis is needed for meaningful results at an industrial scale. Initial scale-up efforts for a 2BoSS pouch cell have begun, with results shard among partners. Further steps include:

- Further analyzing electricity requirements and anode production, identified as major environmental hotspots.
- Developing a comprehensive life cycle model for the battery at industrial scale, incorporating scenarios for future technological advancements.

POLITO is also conducting a **Social Life Cycle Assessment (S-LCA)** to evaluate the social and socio-economic impacts associated with the battery's production and lifecycle. This assessment emphasizes the well-being of individuals and communities involved in or affected by the production, use, and disposal processes. A study has been carried out to conduct an S-LCA for the 2BoSS coin cell battery, identifying social hotspots and using the Nickel-Manganese-Cobalt (NMC) battery as a reference for comparison. The LCI from the first task serves as a foundation, with additional geographical data on material origins. A model using the *PSILCA* database and *OpenLCA* software has been created, analysing 1 gram of cathode materials and the complete coin cell, although limitations exist due to lab-scale data for the 2BoSS battery and lack of efficiency metrics. Future developments will focus on refining the model at industrial scale, still using proxies and considering potential advancements in technology.

Lastly, *POLITO* team recently participated in the *SDIMI 2024 Conference* in Torino, Italy, presenting two posters on the 2BoSS project:

- Giulia Pezzin showcased her work on a prospective LCA model for assessing the environmental impacts of the 2BoSS battery.
- Elisa Accorsi presented her S-LCA model for the 2BoSS coin cell battery, developed using PSILCA software.

Battery Pass and Digital Product Passport as implication of value chain data inventory management

As mentioned above a crucial aspect of the 2BoSS project is the Life Cycle Analysis (LCA) and Social Life Cycle Analysis (SLCA) related to the developed battery prototype. This (S)LCA work at WP5, led by project partner *POLITO*, is supported by *Cleopa GmbH*, which also participates in related activities such as sustainable value chain data inventory management.

To provide valuable information into industrial supply chains, the needs of industrial users, and the latest regulatory requirements for batteries, *CLEOPA* has actively participated in the Battery Pass Consortium as an industrial expert. Additionally, *CLEOPA* has joined the related DIN DKE SPEC 99100 working group, which is developing a guideline alongside automotive and battery ecosystem players in Europe to implement the new Battery Regulation. The guideline serves as the first concrete playbook for implementing both the latest battery regulations and the Digital Product Passport (DPP) simultaneously. Developed in collaboration with experts from academia, industry, and the tech sector, it offers practical recommendations that meet the requirements of EU regulations. The Battery Pass Consortium, together with the DIN DKE working group, is set to publish this guideline soon. It brings together insights from leading automotive players like BMW and Audi, academic frontrunners such as Acatech and Fraunhofer, and sustainability and tech experts from Systemiq, Circulor, and cdmm GmBH.

Figure 1. Battery Pass Consortium DIN DKE 99100 group meeting with our 2BoSS project & Cleopa representative Pauliina Harrivaara gathered at Systemiq's eco-friendly and inspiring offices in the heart of Munich.

According to Pauliina Harrivaara from *Cleopa GmbH* and 2BoSS project representative in the DIN DKE 99100 group, the collaborative nature of this effort has been the key success factor: "It's been inspiring to see how the European industrial sector is committed to combining sustainability and digital transformation to stay globally competitive - and this is not just in Europe. This demand for green and digital industrial solutions is global. Experts from leading chemical companies, academic institutions, and product data specialists shared a common goal: to create practical recommendations for implementing the Digital Product Passport in alignment with the realities of the automotive battery and industrial sector companies, both SMEs and big players".

At the recent CircularTech Forum - Battery Pass edition in Cologne, members of the Battery Pass consortium and DIN DKE group discussed the future of green and digital transformation. One key takeaway came from Dr. Freund from *BASF*, who noted that recycling is now recognized as a distinct business division, underscoring that the industrial future is not only green but digital as well.

Laura Martínez, Design & Communication Specialist at *Cleopa GmbH* and for the 2BoSS project, commented: "As someone deeply involved in both sustainability and communications, I believe Digital Product Passports are a game-changer. They not only enhance transparency and efficiency in supply chains but also provide companies with a competitive advantage by ensuring alignment with EU regulations and market demands. Additionally, based on our experience and the needs of our partners across various industries, we recognize the importance of support in designing circular, digital products and services, and we are committed to integrate this into the 2BoSS battery prototype".

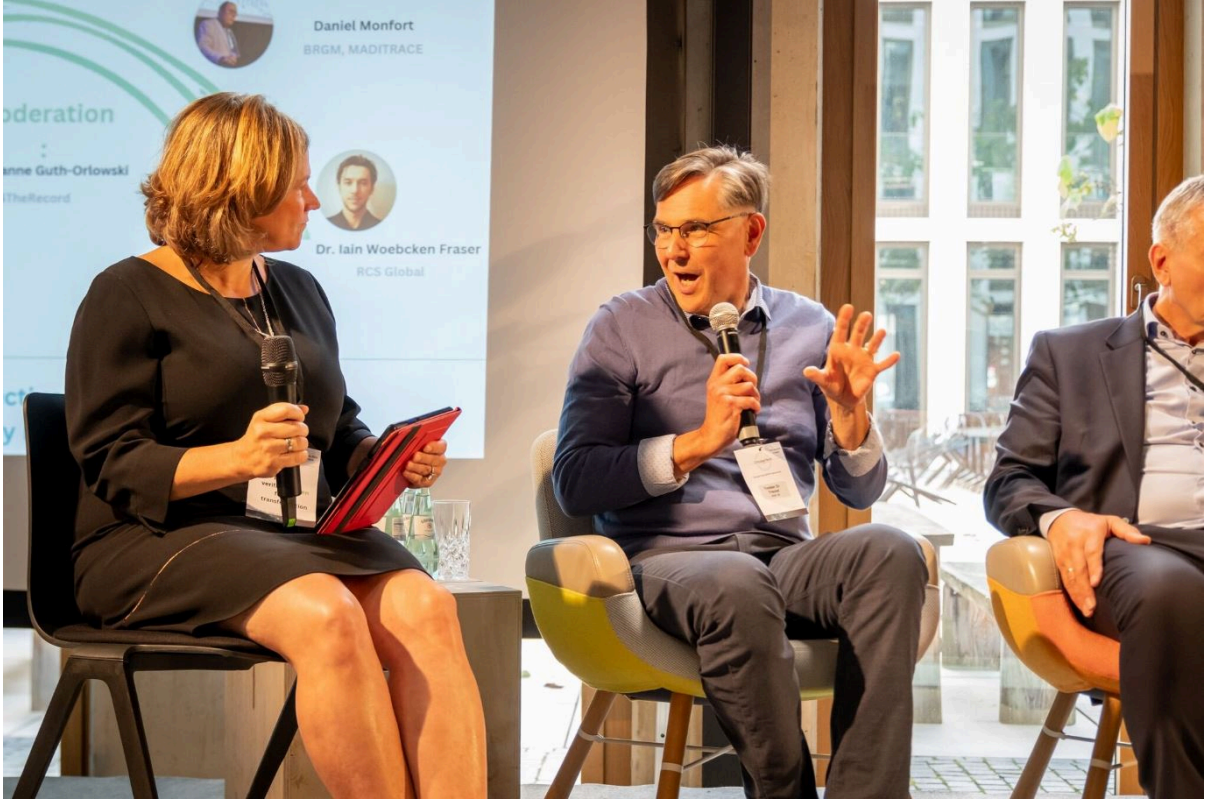

Figure 2. CircularTech Forum, Cologne 2024. Dr. Torsten Freund from BASF and Battery Pass Consortium with the panel moderator Dr. Susanne Guth-Orlowski

2BoSS workshop on In Situ/Operando Characterization of Chemical and Electrochemical Energy Processes

Join us on November 8, 2024, at the ALBA Synchrotron in Barcelona for an insightful workshop focused on in situ and operando techniques for advancing energy technologies. These cutting-edge methods are essential for real-time monitoring of dynamic changes in materials and systems, offering a deeper understanding of processes like battery technology and catalytic reactions.

The workshop will cover a variety of techniques including UV-vis spectroscopy, X-ray diffraction (XRD), and transmission electron microscopy (TEM) among others, with practical case studies and research breakthroughs. This event is mainly tailored for young researchers in energy science, providing valuable knowledge on how to optimize energy materials and processes for future advancements.

Register here before October 31st!

Figure 3. Workshop organizers and supporters

Interested in our research? - Check out our recently published articles!

1. Development of Synergistically Efficient Ni-Co Pair Catalytic Sites for Enhanced Polysulfide Conversion in Lithium-Sulfur Batteries.

This study presents the development of Ni-Co dual-atom catalysts on nitrogen-doped carbon to enhance lithium-sulfur battery performance by speeding up reactions, reducing polysulfide migration and improving overall efficiency. The results shown capacity improvement, stability over 900 cycles, and enhanced performance. **>>** Read the full article here!

2. Electronic Spin Alignment within Homologous NiS2/NiSe2 catalysts to speed up the chemical reactions in lithium-sulfur batteries, improving energy storage, energy capacity and efficiency, and long-term stability and performance.

This article explores the use of NiS2/NiSe2 catalysts to speed up the chemical reactions in lithium-sulfur batteries, improving energy storage, energy capacity and efficiency, and long-term stability and performance. **>>** Read the full article here!

3. Three Birds with One Stone: Multifunctional Separators Based on SnSe Nanosheets Enable High-Performance Li-, Na-, and K-Sulfur Batteries.

This study introduces a multifunctional SnSe nanosheet-based separator that enhances the performance of lithium-, sodium-, and potassium-sulfur batteries. It improves reaction efficiency, prevents harmful compound migration, and boosts battery life and capacity retention. **>>** Read the full article here!

4. Tungsten phosphide on nitrogen and phosphorus-doped carbon as a functional membrane coating enabling robust lithium sulfur batteries.

The article discusses the development of a new membrane coating for lithium-sulfur batteries, using tungsten phosphide nanoparticles combined with nitrogen and phosphorus-doped carbon. This material enhances battery performance by accelerating reactions and minimizing compounds loss, leading to improvements in capacity, efficiency, and stability. >> Read the full article here!

Interested in partnering with 2BoSS?

We welcome new customers, users, and business partners to join us in building the innovative battery solution of tomorrow. **Contact the Cleopa team**, who is responsible for the business modelling, the go-to-market phase and the DPP implementation. Join our ongoing Living Lab actions and let's explore how we can innovate together for a sustainable future.

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The **2BoSS project** aims at developing a battery technology based on silicon, sulfur, and biomass-derived carbon, supported on a cobalt-free Li2S based cathode and a graphite and lithium-dendrite-free silicon-based anode. It's being designed for a circular economy, minimizing the use of Critical Raw Materials (CRMs) while optimizing performance and incorporating effective recycling strategies, overall aiming to reduce negative environmental, health, and safety impacts.

For more information about the 2BoSS project, please visit our website

The 2BoSS website

IREC Shaping Energy for a Sustainable Future

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 2BoSS has received funding from the European Research & Innovation Program on raw materials to foster circular economy under ID:235

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