EUROPEAN COMMISSION

HORIZON 2020 PROGRAMME - TOPIC H2020-LC-BAT-2020

Solutions for large batteries for waterborne transport

GRANT AGREEMENT No. 963560

D3.4 – Final architecture and associated cost reduction of the system

Report details

Deliverable No.	SEABAT D3.4	
Deliverable Title	Final architecture and associated cost reduction of the system	
Deliverable Date	31/12/2024	
Dissemination level	Confidential – member only (CO)	CO
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Document History

Version	Date	Editing done by	Remarks
Layout	26/9/2023	Jonathan Baake	Initial draft
v0.1	29/11/2024	Zhenmin Tao	Draft for external review
V1.0	15/01/2025	Zhenmin Tao	For 2nd external review
V1.1	18/02/2025	Zhenmin Tao	Final deliverable
V1.2 Final	19/02/2025	Cor van der Zweep	Final version for submission

Project Abstract

The goal of the SEABAT project is to develop a full-electric maritime hybrid battery concept that is based on:

- Modularly combining high-energy batteries and high-power batteries,
- Novel converter concepts and
- Production technology solutions derived from the automotive sector.

The modular approach will reduce component costs (battery cells, converters) so that unique ship designs can profit from economies of scale by using standardized low-cost components. The concept will be suitable for ships requiring up to 1 MWh of storage or more.

Public summary

The main goal of SEABAT is to develop a cost-effective hybrid energy storage system (HESS) architecture for large marine applications that is scalable to 1 MWh and beyond. Without loss of generality, the HESS design proposed by SEABAT is validated at a level of 246 kWh, while taking into account virtual upscaling to 1 MWh, which has been reported in D3.3. The purpose of this deliverable is to further refine, consolidate, and formalize the HESS design, based on the detailed design in WP4, assembling practices in WP5, and testing results in WP6. The final architecture taking into account modifications in detailed design, the accompanying lessons learned, as well as the technical issues encountered in the testing phase, are reported in this deliverable.

In addition to reporting the final architecture, a virtual upscaling study has been conducted to identify the applicational boundary of the SEABAT solutions. This study largely based on the sizing tool developed by Flanders Make (https://battery.flandersmake.be/) [1]. The study revealed that, depending on the energy content and peak power, the benefits vary. First, the system cost benefits of modularity are 15 % and 30 %, for HE and HP monotype systems, respectively. This is mainly due to the identical module dimensions and peripherals allows for leveraging economies of scale, in contrast to customized systems (especially the power conversion sub-systems) that is being applied in the industry today. Second, some load profiles can benefit from hybridization between the two types of cell chemistries, namely NMC and LTO. The specific cost reduction amount is highly dependent on the ratio between energy content and power peak. In the best case scenario, 60 % of cost reduction can be achieved.

Following the virtual upscaling, more comprehensive studies have been performed on the five selected DAMEN ships to quantify the cost reduction and emission reduction attributed to the SEABAT solution. In doing so, standardized cost and emission accounting and estimation approaches have been developed to enable quantification of various aspects of benefits brought by SEABAT on a level playing field.

The cost calculation started from the SEABAT prototype system bill of materials (BOM) and its costs. Then, based on the expected market size presented in D7.5, a mass production cost of SEABAT system has been estimated, which serves as input to the final cost reduction analyses. If separated into distinct innovation steps, we are able to quantify step-wise cost savings. The identified innovations are 1) small DCDC converter at module level, 2) application of same DCDC independent of cell chemistry, 3) the ability to combine different cell chemistries at system level. The respective cost savings are found to be 1) 25%, 2) 5% and 3) 10%. Based on the five selected ships and their numbers of new built per year, an economic impact of SEABAT solution has been calculated, leading to 20 M€ - 33 M€ cost saving per year for the construction of the five selected types of ship. Further scaling up to the maritime industry, SEABAT solution leads to 150 – 220 M€ cost savings for the global addressable market segments.

In terms of emission reduction, the SEABAT project demonstrates significant benefits in reducing carbon emissions through the modular DCDC converter design and the hybrid battery configuration. By utilizing modular converters rather than a single large unit, SEABAT achieves enhanced reliability and operational flexibility. This modular approach reduces the impact of potential individual converter failures on overall system performance, minimizing downtime and improving service continuity. Notably, modular converters not only contribute to increased redundancy, which is crucial in maritime environments for continuous power availability, but also have a lower carbon footprint compared to a single large unit (up to 6 %), further enhancing the system's environmental efficiency (according to our calculations). The hybrid battery architecture (SEABAT Solution), which combines High Energy and High Power modules with small modular DCDC converters, further enhances SEABAT's sustainability profile. The results of this Life Cycle Assessment clearly show that hybrid configurations tend to have a lower carbon footprint than three other configurations across all life cycle phases, with the most

significant reduction amount (Tons of CO_2-eq) occurring during the use phase, along with additional reductions in raw material extraction and manufacturing stages. Across applications, hybrid configurations yield up to a 6 % reduction in carbon emissions compared to monotype systems. This underscores the environmental advantage of hybrid battery solutions, particularly when optimized for specific load cycles and energy demands. Additionally, placing these battery-related emissions within the context of total emissions from electric energy consumption during vessel operation highlights the transformative potential of a zero-emission energy grid. The carbon emissions associated with charging the battery packs, which contribute the most substantial share of SEABAT's overall emissions, could be drastically reduced if energy were sourced from renewable, zero-emission sources. Currently, the use phase emissions make up between 83 % and 98 % of the total lifecycle emissions, depending on the battery configuration and use case. By eliminating these emissions through renewable energy, the carbon footprint of the SEABAT system would become largely dependent on the initial phases of material extraction and manufacturing, which already demonstrate potential for further reduction, especially when Europe-based production is prioritized.

To thoroughly evaluate the performance of the SEABAT design today, a Key Performance Indicators (KPI) evaluation has been performed against the key value propositions of SEABAT, concluded that the SEABAT solution outperforms the commercially available solution in almost all aspects with one point of improvement being volumetric energy density.

14 Acknowledgements and disclaimer

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

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1	FM	FLANDERS MAKE
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This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 963560. The information and views set out in this publication does not necessarily reflect the official opinion of the European Commission. Neither the European Union institutions and bodies nor any person acting on their behalf, may be held responsible for the use which may be made of the information contained therein.