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► **To cite this version:**

Betsabe Rodriguez Buitron, Emmanuelle Cor, Elise Monnier, Fabien Perdu, Yvan Reynier, et al.. Ecodesign approach based on prospective life-cycle assessment, to support R&D decision making for new generations of batteries. SETAC Europe 33rd Annual Meeting, Apr 2023, Dublin, Ireland. cea-04130883

HAL Id: cea-04130883

<https://cea.hal.science/cea-04130883v1>

Submitted on 16 Jun 2023

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Ecodesign approach based on prospective life-cycle assessment, to support R&D decision making for new generations of batteries

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1. Introduction

About 80% of the environmental footprint of new technologies is determined at the design phase [1]. Thus, the highest levels of environmental performance are achieved when ecodesign aspects are introduced in the early stages of the design and development process. Defining ecodesign objectives at the R&D level at these stages is therefore a major challenge for improving environmental footprint of technologies and the availability of information on environmental impacts throughout their life cycle remains essential.

Nowadays, many studies analyze the environmental impacts of these technologies with the Life Cycle Assessment (LCA) methodology. However, integrating environmental requirements represents a difficult criterion to consider during design decision making in a technological research context, where LCA is mainly applied at a low level of technology maturity. In order to identify the levers of ecodesign, researchers face difficulties relating to available data lacking over the entire life cycle of the systems analyzed, to results transposing of an LCA carried out on a pilot scale to the industrial scale, to understanding the variation in terms of results, etc.

This work aims at responding to this problematic of environmental performance criteria integration into technological developments of future generations of batteries and will be applied to three case studies with different maturity levels: the advanced Li-ion, Lithium-Sulphur and all-solid-state battery technologies. The objective is to propose an ecodesign approach to support researchers through design decision making by helping them to understand the environmental issues and to identify the levers for improving the environmental performance of new generations of batteries. This proposal is based on a toolbox built on adapted R&D prospective LCA principles.

2. Materials and Methods

The methodological framework proposed by Blessing and Chakrabarti [2], called "Design Research Methodology" (DRM) was adopted as a reference to address this work. This approach enables the production of design knowledge and supports in order to cope with the complexity of design research in terms of the need for multidisciplinary knowledge [2]. This is the case of the current study application field where different research teams, with different areas of expertise, work together to design new battery technologies across the value chain, from the synthesis of active cell materials to the end-of-life management of battery packs. This methodology consists of four steps: Research Clarification, Descriptive Study I, Prescriptive Study and Descriptive Study II. Figure 1 (a) presents an overview of the methodology.

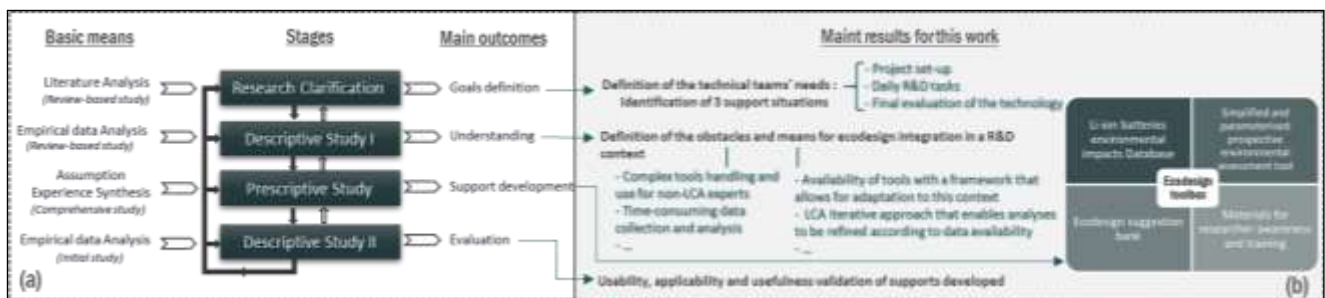


Figure 1: (a): Design Research Methodology (DRM) framework adapted from [2]. (b): Main results of this work related to the application of the DRM approach.

The application of this framework has made it possible to define the R&D context in which the different technical research teams work and to have an overview of the current integration of environmental criteria in this context of technological development. Semi-structured interviews were conducted with twelve experts, with

different roles in the design of the battery technologies with no LCA background. This has enabled the identification of resources and needs in terms of environmental assessment as well as action levers and limits in ecodesign. This identification exposed three different moments of support where environmental evaluation is needed: **project set-up, daily R&D tasks and final evaluation of the technology.**

Similarly, a review of the environmental assessment/ecodesign methods and tools available in the literature was carried out to determine the obstacles and means for their sustainable implementation in technological research organisations. This was compared with the information defined during the exchanges with the researchers. **The specifications of the ecodesign method** to be developed should therefore consider all the information identified and it should be adaptable to the three support moments.

3. Results and Discussion

The ecodesign method proposed to meet the needs presented above is based on a prospective life cycle assessment approach to support the teams. This approach is recognised as the most effective multi-criteria approach for identifying and predicting the environmental issues of emerging technologies [3] and will be deployed through a toolbox allowing its implementation in the design process.

To address the challenges of LCA in a R&D context, prospective LCA principles [3] were applied for the development of a parameterized tool. By varying technical parameters that are uncertain during the R&D stages and that influence environmental performance, design, use and end-of-life scenarios can be performed. These scenarios can respond to the new design objectives imposed by the Batteries Regulation 2020/353 [4], to the trends in the deployment of electric cars, to changes in electricity supply, etc.

In order to capitalise and share knowledge to support design decision making at the three accompanying situations, the ecodesign toolkit consists of four operational tools that will be made available to the technical teams. This with the aim of reducing time and effort of accessing information during the identification of global and specific technological issues in their area of action. Figure 1 (b) shows the general view of its composition.

The Li-ion batteries environmental impacts Database provides a collection of LCA publications containing technical and environmental performance data for the 3 new battery technologies (advanced Li-ion, Li-S and all-solid-state) and commercial reference technologies. The chosen structure for this DB will make it possible to harmonise the LCA results from the literature and compare it to new LCA performed in the application labs of this study. The simplified and parameterised assessment tool is a computer tool for prospective environmental assessment of battery systems whose modelling can be broken down to different levels of detail depending on the needs/resources/skills of the researchers and with a specific assessment of material criticality. The ecodesign suggestion bank presents a collection of ecodesign tools (Design rules-according to "DfX" approaches, guides for creativity sessions and environmental requirements in the regulation battery sector) adaptable to the 3 moments of support identified. The materials for researcher awareness and training represent a series of short videos that explain the LCA methodology and the main environmental issues and challenges arising from the battery sector.

4. Conclusions

The set of tools that support the new method are being developed and their usability, applicability and usefulness will be validated during the last phase of the DRM [2].

With this proposal, it is expected that the analysis of environmental hotspots, the characterisation of the contribution of sub-systems, and the identification of levers for improvements, will guide researchers in their decision making all along the design process: externally, with the definition of ecodesign objectives for future technological choices in industry, and internally, with the proposal of new research themes in their work teams.

5. References

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Acknowledgement - This work was supported by the French Environment and Energy Management Agency (ADEME) and the French Alternative Energies and Atomic Energy Commission (CEA).