EUROPEAN LI-ION BATTERY ADVANCED MANUFACTURING FOR ELECTRIC VEHICLES

ECO-DESIGN OF LITHIUM-ION BATTERIES
Methodologies & tools for improved environmental performance
ECO-DESIGN OF LITHIUM-ION BATTERIES

Methodologies & tools for improved environmental performance

An eco-design product is a product which is designed to minimize its environmental impact throughout its life cycle. In order to perform eco-design, methodologies and tools can be applied.

Approach in ELIBAMA project

PE INTERNATIONAL is responsible for the eco-design and life-cycle assessment within the ELIBAMA project. The approach used is based on the integration of eco-design standards (ISO 14062) and LCA standards (ISO 14044).

Eco-design process steps are defined in the ISO 14062 and followed in the ELIBAMA project.

LCA methodology is used for assessing the technological developments in the different phases of the project. This assessment provides the partners with feedback in terms of the different environmental indicators considered.

Eco-design, LCA, ISO & ELIBAMA project

Product development steps within:

- ISO 14062
  - Planning
  - Conceptual/detailed design
  - Testing/Prototype
  - Production
- ELIBAMA project
  - Planning phase
  - Pilot/demonstration phase
  - Demonstration phase
  - Product review

Eco-design tool: learnings from ELIBAMA
Furthermore, based on the models and on the knowledge acquired during the ELIBAMA project, PE International developed an eco-design tool. This tool has the goal of making the eco-design more flexible, allowing the partners to perform their own assessments and explore different scenarios, even without having specialized knowledge in LCA methodology.

Life Cycle Assessment - Methodology

ISO 14040 and ISO 14044 establish standards for the LCA methodology, defining LCA as a ‘compilation and evaluation of inputs, outputs and potential environmental impacts of a product system during its lifetime’.

ISO 14040 and ISO 14044 establish standards for the LCA methodology, defining LCA as a ‘compilation and evaluation of inputs, outputs and potential environmental impacts of a product system during its lifetime’.

LCA is designed to consider all phases of the life cycle, from ‘cradle to grave’ (see Erreur ! Source du renvoi introuvable); however, it can also be applied to any part of the life cycle. The ELIBAMA project considers the production/manufacturing phase and end-of-life. The use phase was excluded, as it is considered to be out of the scope of the project.

Manufacturing phase

This study considers different baseline scenarios for each battery manufacturer within who participated in the ELIBAMA project: SAFT, Renault and Daimler. These scenarios are used as a reference point against which to compare new technologies.

No comparisons are made between the different baseline scenarios or ELIBAMA scenarios, only between each baseline scenario and the scenarios reflecting the new technologies developed by each partner in the course of the project.
The following comparisons are considered:

- **Cell 1**: Anode aqueous based coating process
  - Baseline: Polyvinylidene fluoride (PVDF) powder + N-methyl-pyrrolidone (NMP)
  - ELIBAMA: Latex + water
- **Cell 2**: Cathode dry blend process
  - Baseline: Wet blend coating process
  - ELIBAMA: Dry blend coating process
- **Cell 3**: Cathode aqueous based and increased porosity process
  - Baseline: NMP based; standard porosity; at cell level, lithium hexafluorophosphate (LiFP6) is used as electrolyte
  - ELIBAMA: NMP free; increased porosity; at cell level, lithium bis(trifluoromethane)sulfonimide (LiTFSI) is used as electrolyte

**End-of-Life**

End-of-life process are also considered within the scope of the ELIBAMA project, comparing a pyrometallurgical process to a hydrometallurgical process.

![Pyrometallurgical and Hydrometallurgical Processes Diagram](image)

**Environmental Indicators**

Within the ELIBAMA project, the following indicators are used:

- Primary energy demand (PED)
- Fresh water consumption
- Global warming potential (GWP)
- Acidification potential (AP)
- Abiotic resource depletion (ADP)
Life Cycle Assessment - Results

Cell 1: Anode aqueous based coating process
The results presented below correspond to the case of the Cell 1, where there is an improvement of the coating process of the anode through the change of materials and processes.

In terms of materials, the combination of PVDF and NMP used in the baseline scenario was replaced by an aqueous solution of PVDF (latex) and water in the ELIBAMA scenario. This represents a reduction of 38% in terms of Global Warming Potential.

In the case of the processes, there was a general optimization in the mixing, air drying and especially in the coating process. The process of solvent treatment is no longer necessary in the ELIBAMA scenario, as the NMP is no longer used. All of these improvements lead to a reduction of 39% in the Global Warming Potential.
Cell 2: Cathode dry blend coating process

The results presented below correspond to the case of the Cell 2, where there is an improvement of the coating process of the cathode through the change of materials and processes.

In terms of materials, in the ELIBAMA scenario there is no longer the need of using NMP. This represents a reduction of 32% in terms of Global Warming Potential.

In the case of the processes, there was a general optimization in the mixing and coating. The improvements lead to a reduction of 64% in the Global Warming Potential.
Cell 3: Cathode aqueous based process

The results presented below correspond to the case of the Cell 3, where there is an improvement of the coating process of the cathode through the change of materials and processes.

In terms of materials, in the ELIBAMA scenario there is no longer the need of using NMP. This represents a reduction of 10% in terms of Global Warming Potential.

In the case of the processes, there was a general energy reduction, which lead to a reduction of 18% in the Global Warming Potential.
End-of-life

The results presented below reflect the burden and credits in terms of Global Warming Potential which are associated with the EoL of the cells.

In the case of the End-of-Life, it is important to consider:

- Loads: correspond to burden, have origin in the processes of treatment, i.e. dismantling of the batteries and pyrolysis;
- Credits: correspond to the amounts of metals for which mining is avoided, are attributed according to the recycling of the metals – therefore are negative.

In the ELIBAMA scenario, recycling processes have an associated environmental cost of $+113\%$ in comparison to the baseline, but the credits correspond to $-201\%$, more than compensating the loads of the process in the case of the ELIBAMA scenario.
In blue are represented the credits associated to the pyrometallurgical part of the process, which takes place on both scenarios – baseline and ELIBAMA. This credit is mainly related with the recycling of the steel (approximately - 41%) and aluminium (approximately - 18%).

In green are represented the credits related with the hydrometallurgical process, where the cobalt hydroxide accounts with approximately - 11%.

**Eco-design tool**

Within ELIBAMA project, an Eco-design tool was developed in order to facilitate the assessments to the partners. This was only possible thanks to the knowledge gained through the ELIBAMA project.
The tool is based in the models prepared with GaBi 6, where the following aspects are focused:

- **Material composition of the electrodes** – Different materials used for producing the electrode (anode or cathode) – active material, collector foil and solvent.
- **Processes** – Each ‘machine’ represents one of the process steps in the manufacturing of an electrode, including: Mixing, Coating, Calendering, Slitting, Drying.

Through the modification of parameters, it is possible to obtain dynamic results.
The results are presented in aggregated and detailed views. The following possibilities are provided:

- Overall comparison between the baseline and ELIBAMA scenarios for entire process chains and material inputs;
- Breakdown of process chains into single process steps (Baseline and ELIBAMA scenarios);
- Material inputs broken down into material groups – Active material, Solvent and Collector foil (Baseline and ELIBAMA scenarios).

Below is presented an example of charts as they are displayed in the tool.

![Global Warming Potential charts](image)

**Conclusions**

In general, the technologies – materials and processes – developed or improved within the ELIBAMA project contribute to a reduction in the environmental impacts of lithium-ion batteries, either by providing improvements in the anode (replacing PVDF and NMP by latex and water) or by improving the cathode (dry blend process or aqueous based process).

It is recommended for the future to perform a hot spot analysis using LCA prior to starting an eco-design project, in order to ensure that activities focus on those components with the largest contribution to the overall impacts.

In terms of scope, to obtain a better overview of the impacts that a specific technology has, it should also be considered the full battery level. This was considered when the project started, although, due to lack of available data, it was not possible.

Parameters from the use phase such as the number of cycles or the capacity are important in the definition of the functional unit of a battery and in order to fully understand the influence of all of the materials used. For example, in the case of LiTFSI, the assessment performed shows that the use of this electrolyte generates a slightly higher environmental profile in most of the environmental categories.
studied; however, the effect that this would have in the use phase (increasing the life-time of the cell) and at end-of-life (recyclable) were not studied due to the lack of available data.

While the above points could be improved in future projects, the ELIBAMA project did follow best practice in eco-design, as defined within PE International:

Step 1: Align vertically along the supply chain of a specific product and share costs and ideas using life cycle thinking

• This was considered in the ELIBAMA project and different material producers were included in the project with the cell/battery manufacturers, as well as relevant partners for the EoL of batteries.

Step 2: Make measurements, collect primary data at own sites

• The data collection was in ELIBAMA, as in many other projects, one of the main topics; addressing this subject is essential for successful and meaningful environmental assessments, which determine the design of the product.

It is recommended for the future to be more precise, providing more details and being more transparent in the data collection, in order to get more precise, reliable and detailed results.

Step 3: Use environmental indicators as checkpoints against which to measure status

• Environmental indicators can be seen not only as the “end” but also as the “means” towards an end. The impact categories selected for the ELIBAMA project provided reliable checkpoints to see where the project was standing and where it would go in the future.

Step 4: Create an eco-design tool / guidelines to define a strategy that allows changing of technical parameters throughout life cycle

• Within the ELIBAMA project, an eco-design tool and guidelines were provided to the partners in order to make the assessments easier and more flexible.

Contacts

PE INTERNATIONAL: Margarida GAMA
M.Gama@pe-international.com

The ELIBAMA project is granted by the European Commission under the “Nanosciences, nanotechnologies, materials & new production technologies” (NMP) Theme of the 7th Framework Programme for Research and Technological Development.