Ecodesign of Greenlion Li-ion Module

Advanced Manufacturing Processes for Low Cost Greener Li-Ion Batteries

Introduction

Ecodesign is the action to consider environment at design step of a product in order to reduce, as far as possible, the pressure on environment it will generate all along its life cycle, from raw materials providing to its disposal.

The task has been performed in three steps :

1. Main environmental hotspots of baseline lithium-ion module have been identified performing an environmental and regulatory assessment of baseline module and a scientific literature review,
2. An ecodesign work was performed by all the partners and leaded by Rescoll in order to improve ecoprofile of the module,
3. A final environmental assessment of the "Greenlion" module was performed and compared to first and second generation in order to quantify benefits brought by the project.

Baseline Environmental assessment

In order to focus consortium's efforts on the most important issues, environmental and sanitary hotspots of lithium-ion module have been identified thanks to several sources and studies :

1. Regulatory assessment
2. LCA of production step of baseline module
3. LCA coming from literature on whole life cycle of Li-ion modules

Main conclusions of the regulatory assessment were the following one :

- The most hazardous element of the batteries used in baseline module is obviously the **NMP** which shows reproductive toxicity (Category 1B). So, companies using it for their production have to implement special safety measures in order to protect environment and employees.
- **Carbon black** and **graphite** powders show risks associated with the handling of powders but depending on the particle size. Risks may occur, especially for submicronic particles.

A first Life Cycle Assessment has been performed on the first version of the module at month 12 of the project. The anode was made of graphite and other components of the anode were carbon black, CMC, styrene-butadiene-rubber and a copper collector. The cathode was made of $LiFePO_4$ and other components were PVDF binder, carbon black, NMP and an aluminum collector. Electrolyte was mainly based on $LiPF_6$ and module was designed with a liquid epoxy isolating frame and cells.
Results showed that **electricity consumption** has the greatest contribution for four of five categories assessed:

- Acidification (48% of global acidification impact category)
- Global warming (46% of global warming potential impact category)
- Ozone depletion (33% of ozone depletion impact category)
- Photochemical smog (38% of photochemical smog impact category)

This is due to high electricity consumption of Glove Box at laboratory scale.

In the case of Eutrophication, the **supply of the cathode's components** has the greatest impacts (65% of global eutrophication impact category).

Among battery components, **the cathode** is the major contributor for four of five impacts categories assessed:

- Acidification (24% of global acidification impact category)
- Eutrophication (65% of global eutrophication impact category)
- Global warming (25% of global warming potential impact category)
- Photochemical smog (21% of global photochemical smog impact category)

The most contributing materials of the cathode's impacts are **LiFePO4** for Acidification (16%), Global warming (15%) and Photochemical smog (13%) impact categories and NMP for eutrophication (55%) and Ozone depletion (11%) impact categories.

As a conclusion, the critical environmental issues of baseline module are 1. Electricity consumption that occurs at production step mainly due to use of glove box to maintain dry conditions 2. Supply of cathode's components and more specifically their production mainly due to their high mass percentage into the module 3. Use of hazardous component (NMP).

Ecodesign

Taking into account the previous information, the consortium defined indicators and goal to reach within the project duration.

	Environmental indicators	Goal	Comments
1	Module recyclability	60%	50% is the minimum value to comply with EC/2006/66 (at battery level). We proposed to do better than just enough to comply with regulations in order to prepare for future regulations that may be more restrictive.
2	REACH compliance and use of hazardous substances	0 substance on candidate list, annex XIV and annex XVII	Goal was higher than position of baseline module (1 substance on REACH candidate list = NMP) This indicator permitted to check, all along the project, position of new substances regarding REACH regulation (authorization and restriction process)
3	Energy consumption through the production step	Decrease in comparison with baseline module	This indicator is very linked to cost reduction goal of the project. Calculations were based on LCA methodology (important regarding use of recycled part used in the battery). Different scenarios will be contemplated.
4	Improve materials ecofriendliness by use of recycled or biobased materials	Increase in comparison with baseline module	Goal of that indicator is to study use of supposed ecofriendly materials (from recycled materials or biobased) in the product manufacturing. This indicator included development planned in the DoW on natural binder and aqueous electrodes but also ecodesign of the module.

1. Module recyclability

Environmental improvement ways of module recyclability have been investigated. Results can be divided into two main categories:

1. Development of an innovative cell's recycling treatment
2. Design of the module for recycling

The first topic is detailed in another chapter, so, this document will only deal with the second one : design of the module for recycling.
All topics were studied in collaboration between Rescoll and other partners.

Following topics about reuse options were studied:

1. Possibility to change only the defective cell in the module and not the entire module in case of failure of only one cell
2. Possibility to reuse the module in an other application (for instance energy storage) at end of life of the battery (in an electrical vehicle)

Following topics about improvement of module recyclability were studied:

1. Separation of thermal paste and aluminum heat sink in order to allow the aluminum part to be well recycled
2. Development of a new assembly of cell and frame without glue or screws that can be easily disassembled at module's end of life
3. Development of a new assembly of cells into the module that can be easily disassembled at module's end of life
4. Separation of mechanical foam from the cell and frames in order to allow them to be recycled separatly

Following topics about improvement of materials' recyclability were studied:

1. Choice of frame's material was made in order to increase its recyclability and in order to limit total number of plastics used in the battery
2. Choice of cover's material was made in order to increase its recyclability and in order to limit number of plastics used in the battery

Following topics about display of information on the module in order to improve its recycling were studied:

1. Give information on cell's chemistry – The logo showed bellow was proposed to be put on the module
2. Engrave plastics regarding existing standards requirements

2. REACH compliance and use of hazardous substances

Technical work on REACH compliance was focused on :

1. Elimination of NMP (N-méthyl pyrrolidone) from the cathode and the anode.
   A whole work package has been dedicated to this development and is detailed in another chapter.
2. Replacement of the current used binders (such as PVdF) with water-soluble, non-fluorinated binders.

A whole work package has been dedicated to these investigations. They are detailed in another chapter.

3. Energy consumption through the production step

At the beginning of the project we identified that the drying step was responsible for a big part of module life cycle energy consumption. That is why technical developments focused on limitation of the use of dry room at electrodes manufacturing step and cell manufacturing step.

Mondragon assembly performed an analysis on three types of module manufacturing line which could be implemented : automatic, semi-automatic and manual indicating which one was the less energy consuming. This allowed to choose the final line considering energy consumption.

Manz also performed a detailed assessment of electricity consumption of laser cutting in order to be able to perform a comparison between die-cutting and laser-cutting.

4. Improve materials ecofriendliness by use of recycled or biobased materials

The technical work performed in this field mainly focused on use of biobased polymers as binders in lithium-ion battery electrodes. The following materials have been investigated :

- Alginate (from brown algae)
- Xanthan gum (from Xanthomonas campestris)
- Guar gum
- Carrageenan
- CMC

Recycled plastics were also used as far as possible in module design.

Final comparative Life Cycle Assessment

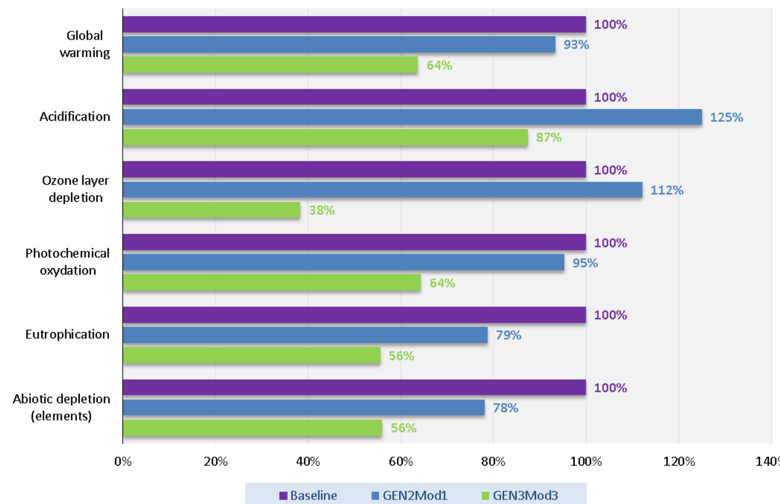
Final comparative Life Cycle Assessment was performed for 1/ Baseline module 2/Module geenration 1 and Cell generation2 and 3/Module generation3 and cell generation 3.

In the final module version (Module generation 3 and cell generation 3), the anode was made of graphite and other components of the anode are carbon black, CMC, styrene-butadiene-rubber and a copper collector. The cathode was made of NMC (Nickel-Metal-Cobalt) and other components were CMC, acrylic binder, H_3PO_4, water and aluminum collector. Electrolyte is mainly based on $LiPF_6$ and module is composed of 29 cathodes / 30 anodes / 58 separators stack which can be separated.

First, a comparison between three generations of Module and cell was performed on their whole life cycle.

The side figure shows a graphical representation of the results for all the environmental indicators. Baseline impacts was fixed to 100% for each indicators. As you can see Baseline has the highest global impact for GWP, POCP, EP and ADP indicators whereas GEN2Mod1 has the highest global impact for AP and ODP indicators. GEN3Mod3 has impacts 36%, 13%, 62%, 36%, 44% and 44% lower than Baseline, respectively, for GWP, AP, ODP, POCP, EP and ADP indicators.

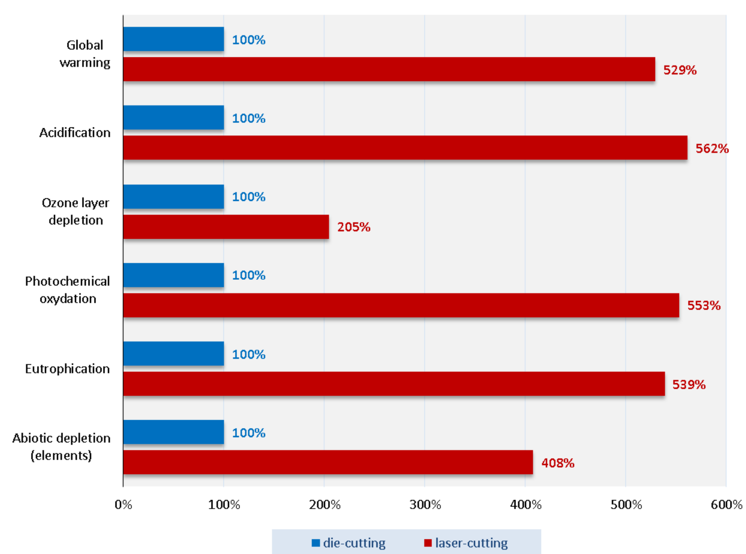
Comparative impacts analysis for the three modules life cycles



Then, a sensitivity analysis was performed between die-cutting process and laser cutting.

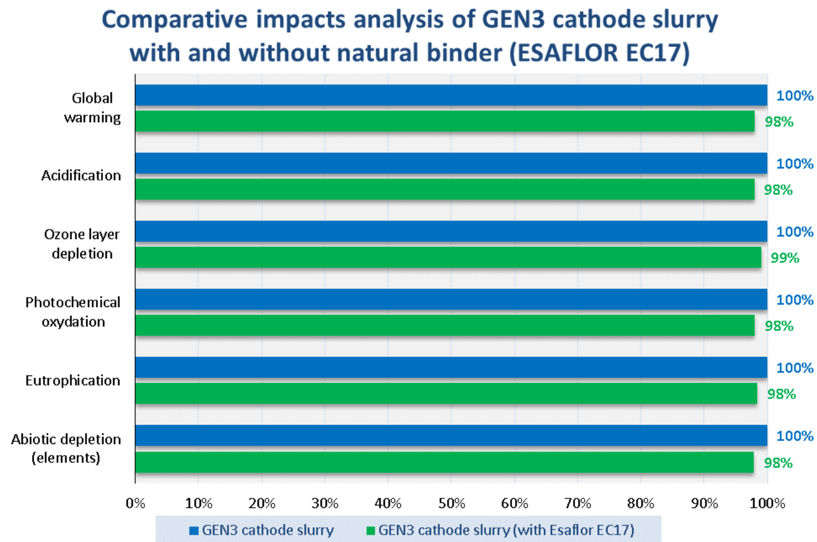
The side figure shows a graphical representation of the results for all the indicators. "Die-cutting" impacts were fixed to 100%.
Laser-cutting has the highest impact for all the indicators due to a more important electricity consumption.

Comparative impacts analysis of GEN3 cathodes die-cutting and laser-cutting



Finally, a sensitivity analysis was performed between cathode slurry with and without natural binder.

The side figure shows a graphical representation of the results for all indicators. Comparison has been performed for cathode slurries (including chemicals manufacturing and supply transports) with and without natural binder. Cathode slurry with baseline binder was fixed to 100%.
Results are equivalent (2% less for cathode slurry with natural binder for all the indicators).



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