iModBatt

Industrial Modular Battery Pack Concept Addressing High Energy Density, Environmental Friendliness, Flexibility and Cost Efficiency for Automotive Applications

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D7.2 – Baseline Life Cycle Assessment (LCA)

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This document summarizes the first results obtained following LCA methodology for baseline modules and battery packs from consortium partners. The study allows to identify the less sustainable manufacturing substeps for battery pack in order to focus the eco-design works. A comparative LCA with battery pack developed in IMODAT project will be the subject of a final deliverable at the end of the project.

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Document History

Date	Version	Name	Changes
05/10/2018	1	Mickael Le Goff (RSC)	Version 1
05/10/2018	1	Iosu Cendoya (CID)	Revision of the version 1
12/10/2018	2	Mickael Le Goff (RSC)	Version 2
22/10/2018	3	Mickael Le Goff (RSC)	Version 3 after revisions/comments from consortium partners

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1 Introduction

The aim of the task 7.2 is to quantify environmental impacts of the li-ion battery pack developed in iModBatt project in comparison to baseline battery packs from consortium partners (REN, EGO, TYVA) and to validate some assumptions for the sustainable end of life management scenarios.

Life Cycle Assessment (LCA) methodology framed by ISO 14040-44 standards and ILCD handbook (European referential for LCA) is the most recognized method to evaluate environmental impacts all along product life cycle. A Life Cycle Assessment consists of four phases (ISO 14040). In the Goal and scope definition phase, the aim of the LCA is defined and the central assumptions and system choices in the assessment are described. In the Life Cycle Inventory (LCI) phase, the emissions and resources are quantified for the chosen products. In the Life Cycle Impact Assessment (LCIA) phase, these emissions and resource data are translated into indicators that reflect environment and health pressures as well as resource scarcity. This calculation is based on factors which represent the predicted contribution to an impact per unit emission or resource consumption. These factors are generally calculated using models. In each phase, in the Interpretation phase, the outcome is interpreted in accordance with the aim defined in the goal and scope of the study.

RESCOLL is in charge of the LCA until the end of the iModBatt project. This deliverable D7.1 (M12) is the subject of the baseline LCA corresponding to targeted battery packs from REN, EGO and TYVA consortium partners. The final comparative LCA results will be submitted at the end of the project considering the battery pack developed in the project and will be the subject of the deliverable D7.3 (M36).

2 Work performed

2.1 Goal, definition and scope of the study

2.1.1 Goal

The aim of this first LCA is to quantify the environmental impacts of the baseline modules and battery packs consider in iModBatt project and to identify the main environmental impacts origins in order to anticipate some sustainable improvement ways considering eco-design task leads by RESCOLL all along the iModBatt project (WP7).

The following baseline li-ion modules / battery packs were assessed:

- RENAULT - Battery pack of the ZOE Q90 ZE 40,
- EGO - Battery pack of the e.GO Life 60,
- TYVA - Module MODULOO A4+: this was the initial concept of the module that will be the core part of the iModBatt battery pack concept.

The Table 1 shows the different modules and battery packs (including modules) assessed.

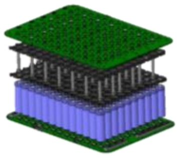
RENAULT (REN) *BP of ZOE Q90 ZE 40*	**EGO** *BP of e.GO Life 60*	**TYVA** *Module* *MODULOO A4+*
		

Table 1 – Modules and the battery packs assessed in the baseline LCA

2.1.2 System boundaries

Considering the state of progress of the Life Cycle Inventory (LCI) it was decided to focus the assessment only on the manufacturing steps of the three scenarios including (Figure 1):

- Raw materials extraction/mining,
- Raw materials transformation,
- Materials transformations,
- Manufacturing of the different parts.

No functional unit was defined for the assessment because it includes unitary modelling of 2 battery packs and 1 module with no comparison. At this stage of the project is not useful to compare environmentally the three modules and battery packs because they don't have the same technological requirements due to their different applications.

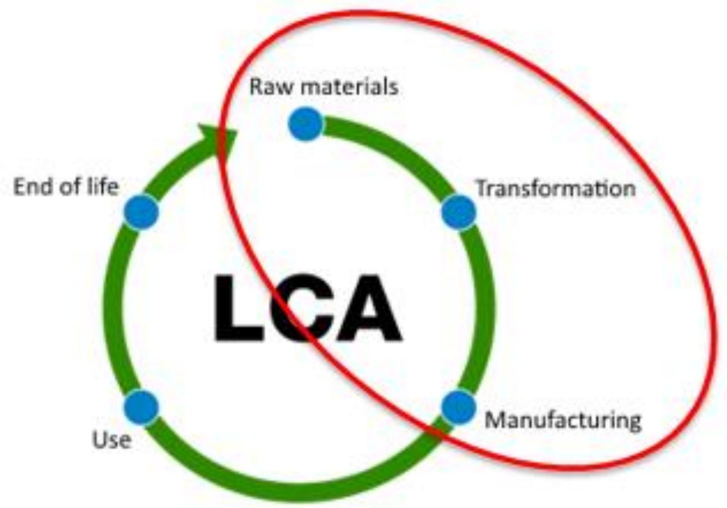


Figure 1 – Boundaries considered in the baseline LCA

2.1.3 Excluded life cycle stages, cut-off and assumptions

No major step or component was totally omitted from the modules lifecycles. Nonetheless some substeps or subcomponents were neglected essentially due to industrial confidentiality reasons and availability in LCA databases. These omissions would be validated in the final comparative LCA at the end of iModBatt project.

According to the ISO 14 044 standard, some categories of operations may be excluded from the system with the condition that this is clearly stated. Following the categories not considered in the modelling:

- Consumption of packaging from raw materials or others inputs components (lack of data),
- Machinery manufacturing and production buildings because we considered that it is a stabilized operation of each system (impacts are amortised throughout their period of use).

2.1.4 Calculation method

According to ILCD guidelines, the LCA considers midpoint environmental indicators presented in the Table 2. The table lists indicators, associated methods, abbreviations, referential units and the classification according to their ranking in the ILCD. RESCOLL used the following LCA software from Thinkstep: “GaBi 5.0 Professional”.

Environmental indicators	Abbreviations	Units	Ranking
IPCC global warming, excl biogenic carbon	**GWP**	kg CO2 eq	I
Ozone depletion, WMO model, ReCiPe	**ODP**	kg CFC-11 eq	I
Photochemical ozone formation, LOTOS-EUROS model, ReCiPe	**POCP**	kg NMVOC	II
Acidification, accumulated exceedance	**AP**	Mole of H+ eq	I
Marine eutrophication, EUTREND model, ReCiPe	**EP**	kg N eq	II
Resource depletion, fossil and mineral, reserve based, CML2002	**ADP**	kg Sb eq	II

Table 2 - Environmental indicators considered in this study (I: recommended and satisfactory, II: recommended with improvements; according to the ILCD handbook).

2.2 Life Cycle Inventory Analysis (LCIA)

First exchanges allowed to define generic steps and a shared bill of materials was created to detail each part of the battery packs and modules with information about weight, nature of materials, manufacturing process. Wherever possible, industrial data (also called primary data) were collected from consortium members (REN, EGO, TYVA). When primary data weren't available, secondary data (data from literature and/or LCA software databases) have been used considering assumptions. Only generic available LCA databases from GaBi software (ELCD, PE international, ecoinvent…) were used for the modelling. Below the LCIs considered for each scenario (quantified inputs and outputs are not detailed for confidentiality reasons):

- Renault ZOE Q90 ZE 40 Battery pack: Information about the li-ion cells, module casing, upper and lower casing of the battery pack were shared. Assumptions from RESCOLL were necessary to model BMS. Information were also shared by REN for the HVAC but it was considered outside the boundaries for this deliverable. As far as possible, the majority of inputs/outputs were modelled considering ELCD databases.

- e.GO Life 60 Battery pack: Information about the li-ion cells, module casing, upper and lower casing of the battery pack were shared. Assumptions from RESCOLL were necessary to model BMS. As far as possible, the majority of inputs/outputs were modelled considering ELCD inventories.

- TYVA Moduloo A4+ module: Information about the li-ion cells, PCB, mechanical parts and fixations were shared. As far as possible, the majority of inputs/outputs were modelled considering ELCD inventories.

3 Results and discussion

3.1 Environmental footprint of Renault ZOE Q90 ZE 40 battery pack

The Table 3 shows the results of environmental impacts for one REN battery pack for each of the six selected indicators. The Figure 2 shows the repartition of environmental impacts and it appears that the modules have the highest impacts (70 to 90% according to indicators). Also battery pack casing shows not negligible environmental impact, especially for GWP, POCP and AP indicators and PCB for ADP indicator.

		Modules	BP casing	BMS	Total
GWP	kg CO2 eq	1,37E+03	4,65E+02	2,83E+01	1,86E+03
POCP	kg CFC-11 eq	5,94E+00	1,04E+00	1,41E-01	7,13E+00
ODP	kg NMVOC	1,07E-04	1,80E-07	2,64E-06	1,10E-04
AP	Mole of H+ eq	1,50E+01	2,24E+00	1,99E-01	1,74E+01
EP	kg N eq	4,30E-01	8,50E-03	7,77E-03	4,46E-01
ADP	kg Sb eq	3,17E-01	7,80E-03	4,06E-02	3,66E-01

Table 3 – Environmental impacts of REN battery pack (with details at module scale)

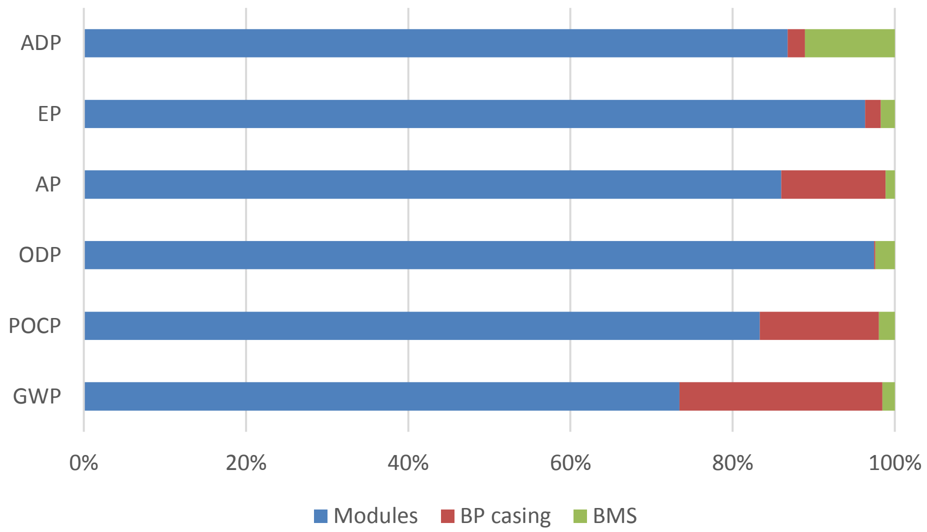


Figure 2 – Identification of environmental impacts origins for the REN battery pack

The Figure 3 shows the repartition of environmental impacts for one module. It appears that the majority of impacts are due to the li-ion cells (80 to 100%).

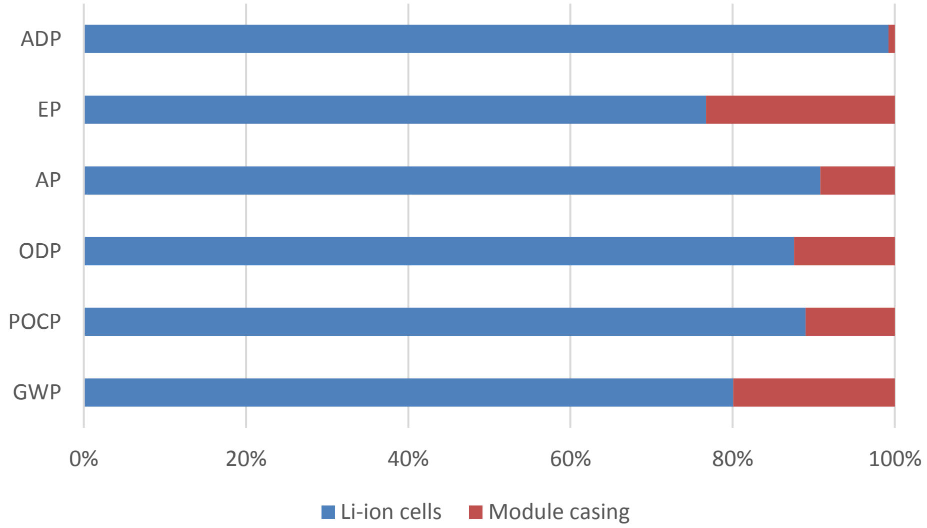


Figure 3 - Identification of environmental impacts origins for one REN module

3.2 Environmental footprint of e.GO Life 60 battery pack

The Table 4 shows the result of environmental impacts for one EGO battery pack for each of the six selected indicators. The Figure 4 shows the repartition of impacts and it appears that the modules have also the highest impacts (50 to 90% according to indicators). Also battery pack casing (especially lower casing) shows not negligible environmental impact, especially for GWP, POCP and AP indicators and PCB for ADP indicator.

		Modules	BP casing	BMS	Total
GWP	kg CO2 eq	7,81E+02	8,80E+02	2,83E+01	1,69E+03
POCP	kg CFC-11 eq	3,34E+00	1,94E+00	1,41E-01	5,42E+00
ODP	kg NMVOC	6,05E-05	3,60E-07	2,64E-06	6,35E-05
AP	Mole of H+ eq	8,40E+00	4,25E+00	1,99E-01	1,28E+01
EP	kg N eq	2,48E-01	1,61E-02	7,77E-03	2,72E-01
ADP	kg Sb eq	1,74E-01	1,10E-02	4,06E-02	2,26E-01

Table 4 - Environmental impacts of EGO battery pack (with details at module scale)

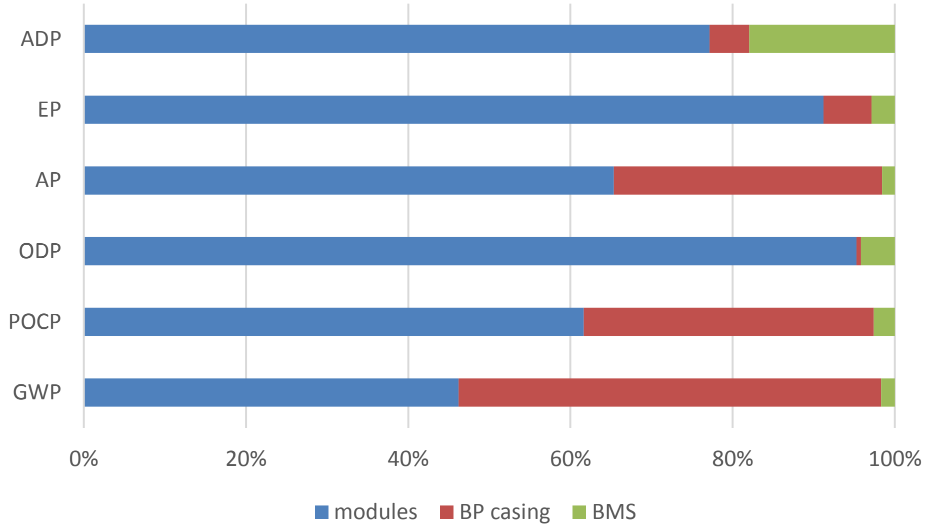


Figure 4 - Identification of environmental impacts origins for the EGO battery pack

The Figure 5 shows the repartition of impact for one module and it appears that the majority of impact are also due to the li-ion cells (70 to 99%).

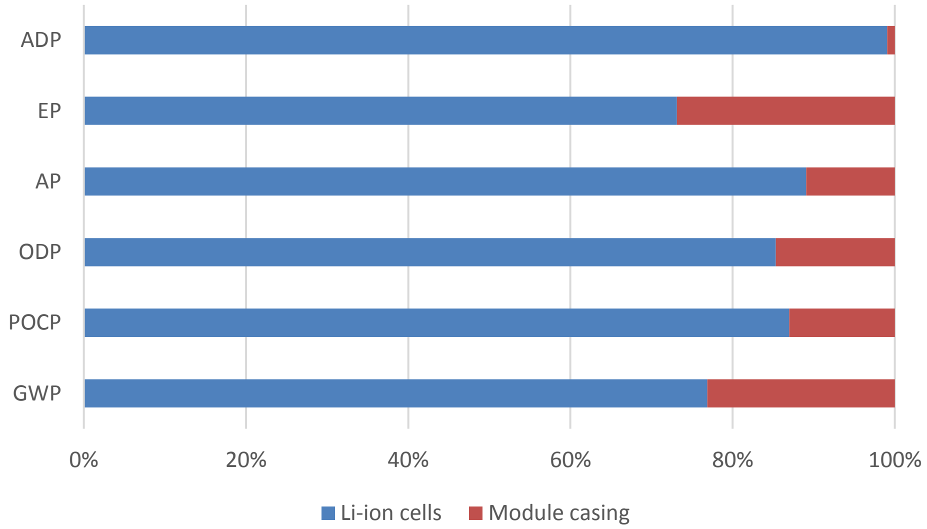


Figure 5 - Identification of environmental impacts origins for one EGO module

3.3 Environmental footprint of TYVA MODULOO A4+

The Table 5 shows the result of environmental impacts for one TYVA module for each of the six selected indicators. The Figure 6 shows the repartition of impacts and it appears that the li-ion cells have the highest impacts (70 to 90% according to indicators). Also battery PCB shows not negligible environmental impact for all of the indicators.

		Li-ion cells	PCB	Others components	Total
GWP	kg CO2 eq	3,51E+01	1,37E+01	1,31E+00	5,01E+01
POCP	kg CFC-11 eq	2,89E-06	1,17E-06	1,18E-08	4,07E-06
ODP	kg NMVOC	1,65E-01	3,45E-02	2,44E-03	2,02E-01
AP	Mole of H+ eq	4,64E-01	8,23E-02	4,67E-03	5,51E-01
EP	kg N eq	1,12E-02	3,29E-03	3,90E-04	1,49E-02
ADP	kg Sb eq	1,01E-02	1,34E-03	8,24E-06	1,14E-02

Table 5 - Environmental impacts of TYVA module (with details at components scale)

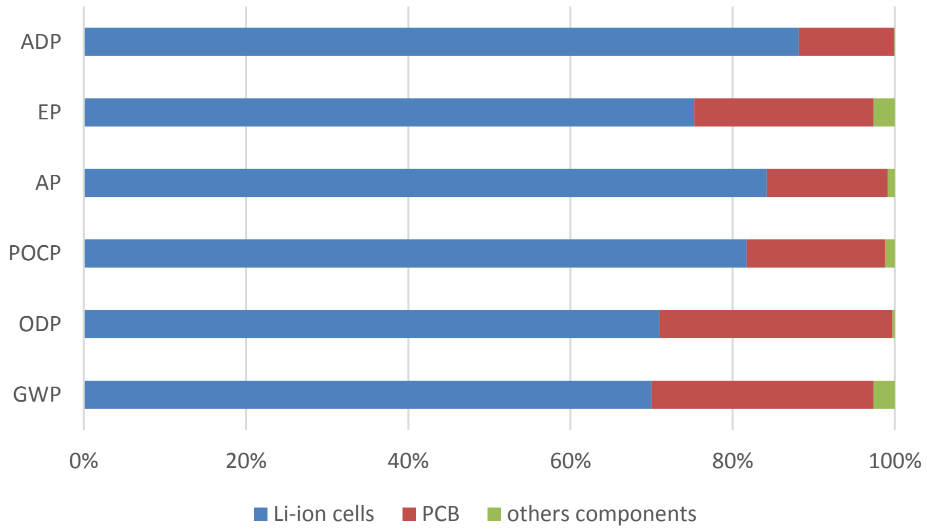


Figure 6 - Identification of environmental impacts origins for one TYVA module

4 Conclusions

This first LCA allowed to identify independently the different baseline modules and battery pack designs from end users consortium partners and to highlight the main environmental impacts origins in order to prioritize eco-design works in iModBatt project. As reminder no functional unit was defined for the baseline LCA and each module/battery pack has different functionalities. Environmental impacts were calculated for 6 indicators: GWP, POCP, ODP, AP, EP and ADP. Considering results, it appears that REN battery pack (without HVAC) has a higher environmental impact than EGO battery pack. For both it was identified that modules show the highest impacts at battery pack scale (60 to 80 % for REN battery pack and 40 to 80 % for EGO battery pack, depending of environmental indicators). It appears also that battery pack casing and BMS have a not negligible environmental impact (30 to 10%) depending of indicators (rather GWP, POCP and AP for the BP casing and ADP for the BMS). Concerning the environmental impact of the modules, REN module shows the highest impacts followed by EGO module and finally TYVA module with the lowest impacts. It was identified that li-ion cells have the majority of environmental impacts at module scale (and also at battery pack scale) for all the three scenarios. The significant environmental impacts (30 to 10%) of the PCB in TYVA module is also important to highlight considering eco-design works in the project.

In the literature it was identified that use and end of life steps could have highest impacts in comparison to the manufacturing step. Optimizing the battery energy density, battery efficiency (internal resistance), calendric and cycle life of battery have significant effects to decrease environmental impacts of the use step. In parallel increasing the weight ratio of recyclable materials and optimize disassembly have also a significant effect to decrease environmental impacts of the end of life step. Further works in collaboration with consortium partners will be necessary to well-defined the modelling assumptions for these steps in the global LCA.

Regarding milestone linked to this Deliverable:

MS	MS header	Related WPs	Est. Date (Month)	Description of executed activity
MS17	LCA of defined BP industrial handling process and means (preliminary)	WP7	M12	The baseline LCA focused on the manufacturing step of three modules/battery packs from REN, EGO and TYVA. Some partners involved in this task for the data collection (REN, EGO, TYVA and RSC). The assessment allowed to highlight the main environmental impacts origins in order to prioritize eco-design works in iModBatt project.

Table 6 – MS linked to this Deliverable