

Life Cycle Environmental Performance of an Electric Van with Operating Plastic Rack. A Vehicle Technology Comparison

Javier Sanfélix¹, Maarten Messagie¹, Anthony Aalves², Joeri Van Mierlo¹

¹*Vrije Universiteit Brussel, Faculty of Engineering, Mobility and Automotive Technology Research Group (MOBI),
Pleinlaan 2, 1050 Brussels, Belgium. jsanfeli@vub.ac.be*

²*Mecaplast, Group Centre Technique de Lens, PA La Croisette, Rue des Poissonniers, 62300 Lens, France*

Summary

This paper documents the Life Cycle Assessment performed in the FP7 project Opera4FEV, which compares the environmental performance of the Opera4FEV battery rack in an electric van with other van technologies: diesel, gasoline, LPG and CNG. The results show that the content of metals contributes significantly to the environmental impacts. The Opera4FEV rack improves the environmental performance of the electric van, since it is manufactured with thermoplastic materials, which prove to contribute less to the environmental impacts when comparing with the metals. Charging the vehicle in countries with a low share of coal power plants in the supply mix, reduces the overall environmental impacts of the electric van.

Keywords: LCA, environmental impact, battery pack, LMO

1 Introduction

Electric vehicles have the potential to reduce the climate change effect and improve air quality when compared with conventional vehicles [1]. However, impacts related to the production of electricity and the additional electric components for the electric powertrain of the vehicle need to be considered. For these reasons, Life Cycle Assessment (LCA) is widely used for assessing and comparing the environmental impacts of battery electric vehicles (BEV) and its components. The methodology takes into account the processes involved in all the life stages of the vehicle or component, from raw material extraction, production of components, assembly, transport, use and end of life treatment.

In vehicle LCA studies the use stage is normally modelled using so called “well-to-wheel” (WTW) approach, which covers the life cycle of the energy carrier (i.e. fuels or electricity) used to drive the vehicles. The WTW life cycle can be subdivided into the “well-to-tank” (WTT) stage that focuses on the fuel supply chain, and the “tank-to-wheel” (TTW) stage, which denotes the energy conversion at the vehicle.

A literature review on LCA studies of Battery EV and battery packs has been performed, to provide an overview of the state of the art. Many LCA studies exist where the BEV is compared with other vehicle technologies, e.g. CNG, FCEV, hybrid electric, etc. Different results and interpretations are observed in literature when the environmental performance of different vehicle technologies is compared, influenced by the lack of comprehensive goal and scope definition of the studies [2].

Some studies promote the usage of EVs to reduce environmental impacts and emphasize the importance of the selection of the energy source for electricity production [3]. Other studies focus on points to improve the

environmental benefits of BEVs [4], concluding that this improvement requires engagement around reducing vehicle production supply chain impacts and promoting clean electricity sources. Frischknecht and Karin [5], present the main drivers of the environmental performance of BEVs, obtained from the 43rd LCA forum held in Zurich in 2011, where they list as the most important drivers: the weight of the car, the battery production, the electricity mix, the technological progress and the societal dynamics. There are studies that focus primarily on energy related issues, which often limit the scope of the assessment to a WTW analysis, discarding effects during the production of the vehicle and the End-of-Life treatment, e.g. [6]. Through the literature collected, the results are expressed in different units and based on different assumptions. Comparison of the results from different studies is not straightforward and should be interpreted with care. All the assumptions taken are not always described in the studies. The selection of the individual vehicles, the energy source to produce the electricity and the lifetime of the battery pack and vehicle influence in the final result. The GWP of a BEV in the reviewed literature has a range of 0.04 – 0.31 kg CO₂eq/km.

Very few published studies focus on the environmental performance of producing traction batteries compared to the number of publications on the life cycle of EVs. One of the first studies about the life cycle of batteries for EVs is the one published in 1980 from Sullivan et al [7]. In their study, they analyse different batteries with the objective of examining the total energy demanded during manufacturing, use and recycling, without considering other potential environmental impacts. Later on, Gaines and Singh [8] compare the environmental performance of four types of batteries (advanced lead-acid, sodium-sulphur, nickel-cadmium and nickel-metal hydride), showing that, even when there seem to be similarities in a battery chemistry, like nickel-cadmium and nickel-metal hydride, the results might show big differences due to the production of components like the electrodes. Another study worth to mention is from Rantik [9] in 1999, where he analyses different scenarios according to the charging mode of the batteries, normal or fast. These are some of the most relevant studies that during the 90s were published about LCA comparing different chemistries, each of them with different objectives, which brings to different functional unit definitions according to their goal and scope. An important European project, SUBAT [10], conducted by the Vrije Universiteit Brussel (VUB), performed an LCA study comparing different battery cells chemistries. Matheys et al [11] published their work about the influence of the functional unit definition in LCA of traction batteries, where they state the importance of defining an appropriate functional unit that considers all the relevant parameters of an EV battery. Based on Matheys et al, Table 1 shows the parameters of the battery pack to be considered in the definition of the functional unit and the relation they keep for each functional unit among the different chemistries. For example, when choosing a constant mass in a comparative LCA study of battery chemistries, the energy content, number of cycles and driving range will be different and battery mass and energy consumption will remain constant.

Table1: Parameters to consider when defining the functional unit and the relation when comparing different chemistries [11].

Functional unit	Battery mass	Energy content battery	Cycles / day	Energy consumption (Wh/km)	Car range
Constant mass	=	≠	≠	=	≠
Constant energy content	≠	=	≠	≠	≠
Constant range	≠	≠	=	≠	=

One of the first studies assessing lithium ion batteries is from Van den Bossche et al. in 2005 [12]. At that time, the technology of li-ion chemistry was under development and their study did not include any data about the production stage neither inventory. A few years later, in 2009, Notter et al. [13] published one of the most detailed LCA studies about batteries for EVs up to then, which was then included in the Ecoinvent database [14]. Their study is focused on (LMO) battery cells, and thanks to the level of detail reached in the inventory, their results allow identifying environmental hotspots in the manufacturing process and therefore suggest improvements at component and material level. The manufacturing inventory of the battery cells of the present study is based on this inventory from Notter. Majeau-Bettez et al. [15] publish in 2011 the manufacturing inventory of three types of battery cells including lithium iron phosphate (LFP) among them. Together with these two publications, other authors also studied the environmental performance of li-ion batteries [16], [17] and [18]. Most of the published studies reckon on the manufacturing stage of the batteries

excluding the influence of the use and recycling. Only Notter et al. [13] includes a full life cycle approach, but the information about the recycling stage is vague. In general, the results obtained in the different studies analyzed stress the use stage of the battery as the main contributor to the emissions during the life cycle. They all propose as a measure to reduce the impact of the use stage to move towards cleaner electricity mixes, as electricity generation is the main cause of the emissions in the use stage of the battery cells.

Due to the fact that batteries are composed of valuable materials (cobalt, metal hydrides and others) an interest in battery recycling has also developed [19]. However, as mentioned above, very few studies consider the EoL of the battery cells. Even though some studies show the benefits in resources saving thanks to recycling of li-ion batteries [20], the debate about the economic viability of this type of batteries recycling has brought an interest in analyzing other EoL scenarios, as it can be a second life or remanufacturing [21]. Nevertheless, even if the lifetime of the battery is extended with a second life use, it will have to be recycled after the second usage, in order to achieve the legislation from the European Commission on End-of-Life vehicles and batteries [22].

The methods perceived as the most appropriate for li-ion battery recycling are pyrometallurgical and hydrometallurgical processes [23]. The pyrometallurgical recycling process uses high temperatures to transform the metals. This method does not follow a generic process to recycle batteries and each of the existing methods is unique, which complicates the data collection for the LCI. This process does not recover the lithium content of the battery cells. On the other hand, the hydrometallurgical recycling process follows a series of mechanical and chemical steps, based on an aqueous processing of metals. This process recovers the lithium and cobalt and it is the recycling method applied in this LCA study.

2 Goal and scope

The overall purpose of the present study is to estimate the potential environmental impacts of the battery pack developed in the Opera4FEV project during its life cycle, as well as during its use in an electric van and its comparison with other van technologies.

The life cycle of the studied system has been modeled following the ISO standards 14040 and 14044 on LCA methodology [24], [25] and with an attributional approach. The defined functional unit is one km driven with a vehicle (van), and the total lifetime of the vehicles is 180.000 km for all the technologies. The life cycle stages included in the study are manufacturing, use and recycling. Figure 1 describes in a flow diagram the life cycle stages and system boundaries for the case of the BEV. The upstream processes of the manufacturing stage (e.g. mining, material processing, etc.) are also included in the system. The recovered materials substitute the use of raw materials, this substitution is further explained in the description of the recycling.

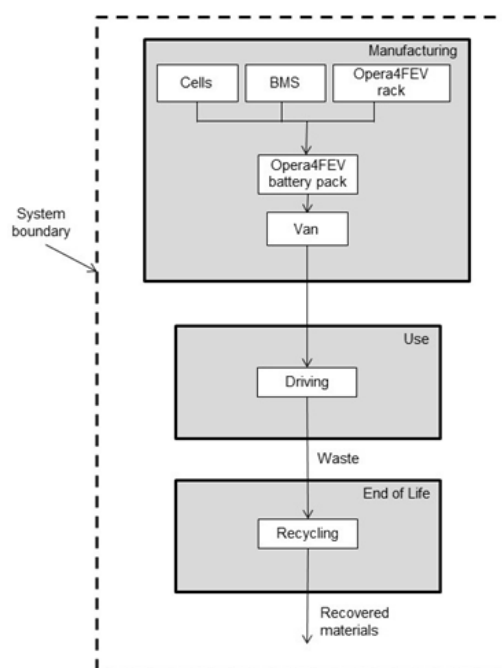


Figure 1: System boundaries of the LCA study

3 Life Cycle Inventory

This section describes the inventory collected for the LCA study, it includes the description of the manufacturing inventory of the Opera4FEV rack, the use stage and the EoL. For the other van technologies the data sources to collect the inventory are cited. The manufacturing stage is divided in manufacturing of the Opera4FEV rack and manufacturing of the van. The use stage comprises the electricity consumption, where the vehicle and battery parameters influencing it are considered in the model. The EoL scenario chosen is a hydrometallurgical recycling process that recovers a high percentage of the metals contented in the battery cells. The inventories presented contain all the material and energy input flows as well as the emissions output flows that occur during the different life cycle stages.

Most of the data of the manufacturing process of the Opera4FEV rack was provided by project partners. When data could not be provided by project partners literature and public inventories were used to implement it. The software used to perform the study is GaBi 6 with Ecoinvent v2.2 and GaBi 6 databases.

3.1 Manufacturing of the Opera4FEV rack

The general concept of the Opera4FEV rack consists in a thermoplastic battery rack that integrates electrical connections and that it is adaptable to any BEV, with special attention on the thermal management system, safety issues and the dismantling. Table 2 includes the main components of the manufacturing inventory of 1 kg of the Opera4FEV rack, based on data provided by project partners. For 1 kg of battery rack, 0,68 kg of battery cells are needed and 10 kWh of electricity is consumed. The subcomponents included in each of the items are listed in the flow chart described in Figure 2. Further details of the manufacturing inventory of the rack cannot be provided at the time of preparing this work, due to confidential agreement with research partners. The total weight of the analysed battery pack is 228 kg, with an energy content of 18 kWh and an expected lifetime of 90000 km. The manufacturing inventory of the LMO battery cells has been obtained from literature [13], the chosen inventory is also included in the Ecoinvent database used in the study.

Table2: Components list of 1 kg of Opera4FEV rack

Component	Input	Unit
Pack pan	9.9E-02	kg
Module	8.6E-02	kg
Pack cover	6.7E-02	kg
UCSB panel	6.2E-03	kg
BMS cover	3.2E-03	kg
Others / screws	3.4E-03	kg
Module electronic boards and UCSB	5.6E-02	kg
LMO cells	6.8E-01	kg
Energy and processes	Input	Unit
Electricity for assembly	1.0E+01	kWh

3.2 Manufacturing of the van

In the present study five vehicle (van) technologies are compared. The manufacturing inventory of the van has been obtained from Ecoinvent database, selected as the most closely matching to the van used in Opera4FEV. It is assumed that the manufacturing stage of the ICE vans assessed is common for all of them, regardless the specific technology (diesel, gasoline, CNG or LPG), being this the common approach in LCA comparison of ICE vehicles.

In the case of the electric van, the reference manufacturing inventory of the van used for the other technologies has been adapted. To do so the materials that correspond to the engine in the inventory are extracted and replaced by an electric motor and the Opera4FEV pack previously described. The inventory of the electric motor has been modeled with data from Ecoinvent [14].

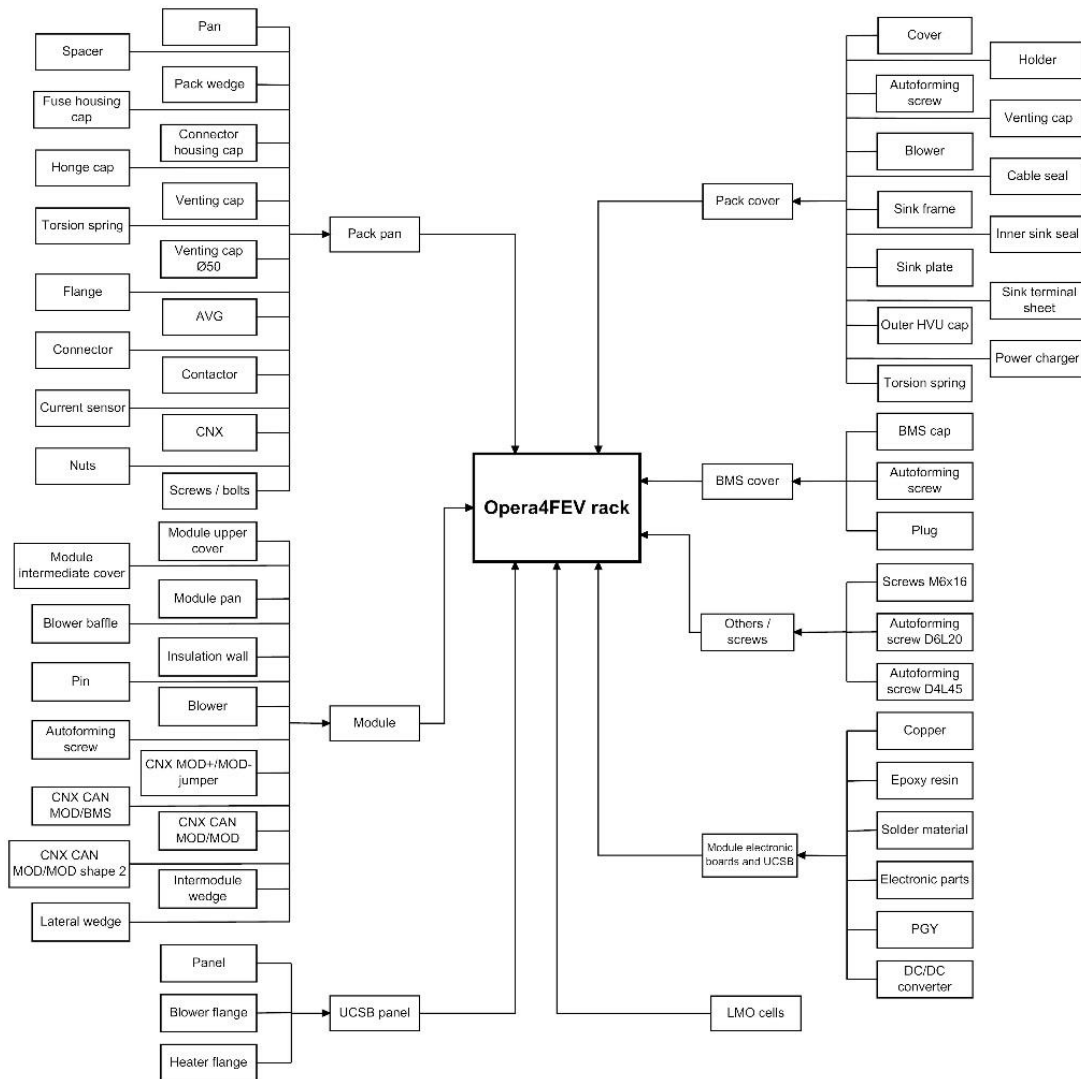


Figure2: Manufacturing flow chart of the Opera4FEV battery pack

3.3 Use stage

The use stage covers all the emissions that take place during the use of the van. In this study the use stage is modelled with the Well-To-Wheel approach. Therefore Well-To-Tank covers all the emissions that occur during the production and distribution of the electricity, diesel, gasoline, LPG and CNG. The Tank-To-Wheel covers the emissions that take place during the driving of the vehicle, in this study only the tailpipe emissions have been considered in the TTW.

3.3.1 Electric

The use stage of the electric van is modelled with a driving cycle simulation that estimates the power demand of a van with the Opera4FEV pack. This model represents, in the most detailed level possible, the performance of the battery pack inside the electric van. For the simulation the New European Driving Cycle (NEDC) was modelled. Figure 3 represents the main elements and power flow of an electric vehicle drivetrain that are part of the simulation model, where η_{battery} , $\eta_{\text{converter}}$, η_{motor} and η_{trans} are the efficiency of the battery, the converter, the motor and the transmission respectively. P_B , P_{conv} , P_{shaft} and P_{wheels} are the battery power, converter power, motor power and the mechanical wheels power. Further info about the model used can be find in [44]. The parameters of the battery pack are based on data provided by the Opera4FEV partners. The

calculated energy supply to the battery is 0,20 kWh/km. The total driving distance during the use stage is 180.000 km, hence the total energy consumed in the use stage is 35.308,67 kWh.

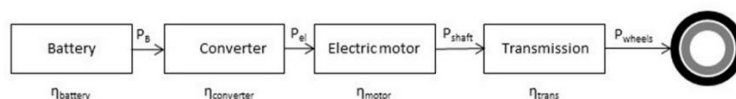


Figure3: Main elements and power inside an electric vehicle

The use stage is assumed to take place under European average conditions, therefore the Well-To-Tank emissions of the electric van have been modelled with a European electricity mix. The mix has been created with data from Eurostat [26]. The electricity mix selected is from the year 2011, this year has been selected because at the time of performing the study the latest emissions inventory data for electricity production was from 2011. The emissions inventory data corresponds to European average conditions in 2011, based on Ecoinvent datasets and updated with data from VUB. The electricity mix selected has an average impact of 0,51 kg CO_{2eq}/kWh, according to the results from the GaBi model.

Table3: Share percentage of the European electricity mix for 2011. Source Eurostat [26]

Power plant	%	Power plant	%
Coal	31	Wind	6
Nuclear	28	Oil	4
Natural gas	19	Solar	1
Hydro	11		

3.3.2 Internal combustion engine

The Tank-To-Wheel emissions of the ICE vans (diesel, gasoline, LPG and CNG) have been modeled considering the tailpipe emissions. The Ecoscore database [27] has been selected as reference database for direct emissions and consumption in this study. Ecoscore¹ makes use of the emissions measured during the homologation test procedures that the cars have to undergo before they can be offered on the European market, e.g. NEDC as described in Regulation No. 83 [28]. For the present study, the regulated emissions have been complemented with non-regulated emissions from the Ecoinvent database, therefore ammonia, benzene and NMVOC (non-methane volatile organic compounds) among other pollutants are also considered in the study. The total lifetime of the ICE vans in the use stage model is 180.000 km, to be in line with the total lifetime of the electric van.

Regarding the Well-To-Tank emissions - emissions during the production and supply of the different fuels (diesel, gasoline, LPG and CNG) - Ecoinvent and GaBi databases have been used, selecting the datasets available for European average conditions.

3.4 Recycling

The recycling stage has been modelled with a substitution approach and an open loop recycling scheme. That is to say that the materials recovered at the EoL stage go to another product system and they substitute primary raw materials. Due to this modelling approach of the EoL the environmental impacts of that life cycle stage have a negative value; the negative sign represents the credit that the studied system receives from the avoided impacts of the manufacturing of the recovered products. In the model it is assumed that the quality of the recovered material is not degraded during the recycling process, that assumption has been taken after consultation with experts in battery recycling. Therefore, in the substitution approach 1 kg of recovered material substitutes 1 kg of “virgin” material.

¹ More info about the Ecoscore database can be found in their website (www.ecoscore.be/info).

The battery pack is dismantled from the van and recycled separately in a hydrometallurgical recycling plant. The inventory for the recycling of the van is based on data from VUB [29], and adapted to the composition of the van assessed in this study. The inventory of the hydrometallurgical process is obtained from an LCA report on battery waste management from the “Department for Environment, Food & Rural Affairs” (DEFRA) of the UK [23], which has been adapted to fit with the Opera4FEV battery pack.

4 Life Cycle Impact Assessment

The results of the LCA study presented in this section include the environmental impacts of 6 impact categories: Global Warming Potential (GWP), Particulate Matter (PM), Photochemical Ozone Formation (POF), Human Toxicity Cancer Effects (HTC), Human Toxicity Non-Cancer Effects (HTNC) and Acidification (ACD). The impact methods implemented are those recommended by the European Commission [30]. It focuses not only in the comparison of the environmental performance of the electric van versus other vehicle technology, but also analyzing the manufacturing of the Opera4FEV battery pack developed in the project. The results are presented in the first place for these three life cycle stages comparing the different vehicle technologies included in the study, afterwards the environmental performance of the Opera4FEV pack is analysed separately, for a better understanding of the processes and materials contributing to the impacts. The results are all included in Figure 5 and presented per functional unit (km).

Global Warming Potential

Figure 5 shows the impact of GWP on the top left. As it appears, the electric van has the lowest impact with 0,11 kgCO_{2eq}/km. The highest impact is generated by the gasoline van with a total of 0,32 kgCO_{2eq}/km, followed by the LPG and CNG. The figure shows that the Tank-To-Wheel stage has an important contribution in the total GWP impact of diesel, gasoline, LPG and CNG vans, mainly due to the CO₂ emitted during driving. The electric van has no contribution to GWP in the Tank-To-Wheel stage since it does not have tailpipe emissions, but it has a significant impact during the Well-To-Tank stage, which represents a 73% of the total emitted in the life cycle of the EV. This is due to the emissions during the electricity production needed in the use of the electric van. That impact is mainly generated by burning fossil fuels in the coal and natural gas power plants. Which represents a 32% and 19% respectively in the electricity mix used in the study, as showed in Figure 4.

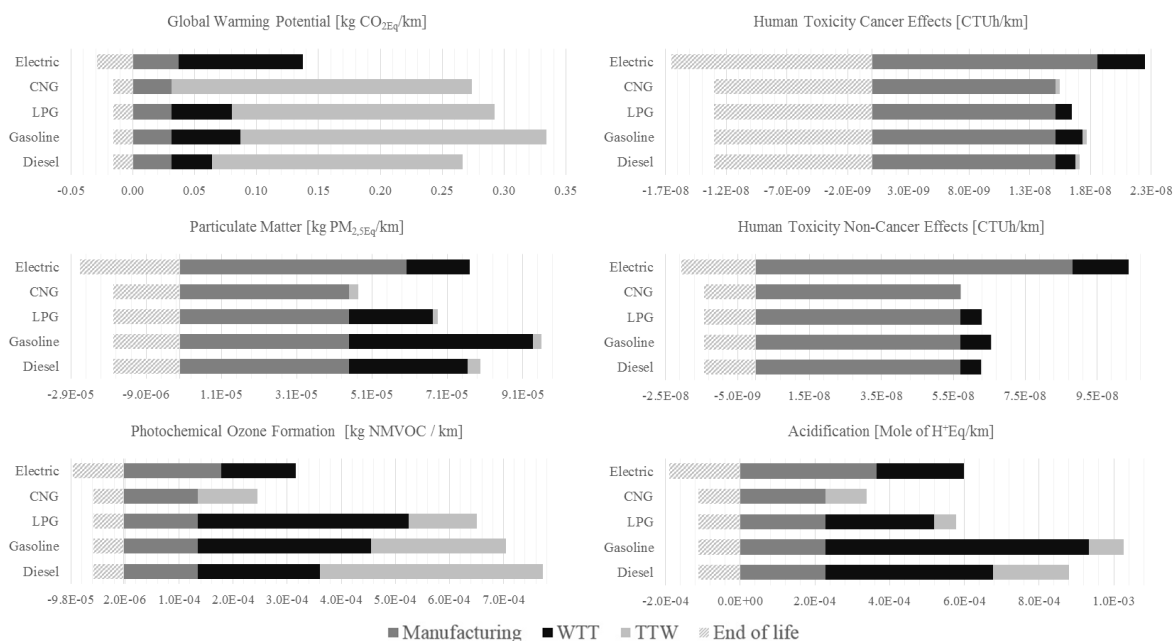


Figure4: Environmental impact of the different van technologies

Particulate Matter

For PM, manufacturing is the main life cycle stage generating the impact as it appears in Figure 4, especially for the electric van due to the impact induced when manufacturing the battery cells. The WTT stage also

plays an important, particularly in the case of the gasoline van, as it requires extra refinement operations to obtain the gasoline, compared to the diesel. The impact generated in the WTT stage of the electric van is generated by the electricity production, being the hard coal and the oil power plants the main contributors to the impact. These emissions are generated through the entire life cycle of the electricity production, being the mining operations to extract the fuels one on the principal sources. These operations are located outside Europe and so are the emissions. The hard coal and oil power plants represent the 65% and 28% respectively of the total impact generated during the WTT stage of the EV. The impact generated during the TTW stage represents only a 4% of the total emitted in the case of the diesel van, and 2% for the gasoline, this value is influenced by the fact that homologated emission values have been used in the study. These results would have been much higher for these two fuel vans if real world emissions would have been used, as pointed by Hooftman and colleagues [31].

Photochemical Oxidation Formation

From Figure 4, it appears that the electric van has a total impact of $2,2\text{E-}4$ kg NMVOC/km during its life cycle, being the second lowest result after the CNG van with $1,9\text{E-}4$ kg NMVOC/km. Conventional vans have the largest impact. The diesel van emits more NO_x, and therefore it has the highest result in the TTW stage. Results from studies on passenger vehicles show that, NO_x emissions can be seven times higher than the emission limit when using real world data [32], therefore the calculated POF impact for the ICE vans can be much higher when using real emissions data.

Human Toxicity Cancer and Non-Cancer Effects

Figure 4 shows that the main life cycle stage contributing to human toxicity impact is the manufacturing of the vans, for all the vehicle technologies assessed. With the highest impact for the electric van with a total of $1,9\text{E-}8$ and $8,8\text{E-}8$ CTUh/km for HTC and HTNC respectively. Regarding the cancer effects impact of the electric van, the manufacturing of the van represents about 82% of the total, the Opera4FEV rack only 5% and the battery cells 17%. The main material generating the impact is the steel alloy used in the van, where the disposal of the slag created during the manufacturing of the steel is one of the main sources of the HTC impact. The results of the HTNC during the manufacturing stage show that, the main contributor to the emissions is the copper for all the components: van, rack and battery cells. The emissions generated with the disposal of the mine dumps are the main source of that impact.

Acidification

As it appears from the results the CNG van has the best performance with $2,3\text{E-}4$ mole H⁺_{eq}/km, followed by the electric van with $4,1$ mole H⁺_{eq}/km. It can be appreciated from the figure, that the impact of the WTT stage of the gasoline and diesel van is much higher than the rest of technologies, due to the refinery operations to obtain the fuels. In the case of the electric van WTT impact, the main contributors are the hard coal and oil power plants when producing the electricity needed for the use stage.

Figures 5 and 6 show the contribution of the components that form part of the Opera4FEV rack and cells to the impact categories, during the manufacturing stage.

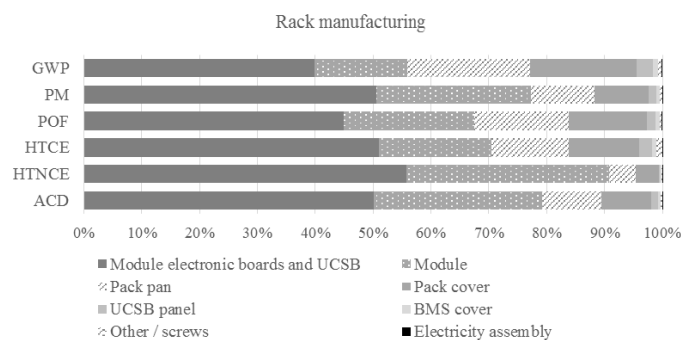


Figure5: Contribution to the impact categories during manufacturing of the rack components

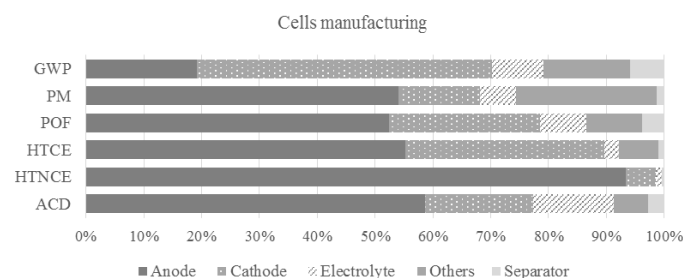


Figure6: Contribution to the impact categories during manufacturing of the battery cells

Looking at the results from the Opera4FEV rack in Figure 5, it appears that the main contributor to GWP are the module electronic boards and UCSB, being the connectors and DC/DC converter the main components generating the impact. The pack pan and pack cover represent a 21% and 18% respectively, being the connectors, polypropylene and aluminium the main materials / components contributing to the GWP impact. Regarding the battery cells contribution to GWP in Figure 6, the main component generating the impact is the cathode with 51% of the total, principally due to the aluminium content and the lithium manganese oxide used as active material in the electrode paste, which have high level of emissions during their processing.

The contribution of the Opera4FEV components to the PM impact, included in Figure 5, show that the main contributors are the module electronic boards and UCSB with a 51%, followed by the module with a 27%. In both cases is the mining and processing of copper are the sources of the impact. In the case of the battery cells manufacturing, it is the anode the main component generating the impact, due to the copper contented in the substrate.

Regarding the POF impact of the rack, Figure 5, the module electronic boards and UCSB generate a 45% of the total impact due to the copper, DC/DC converter and connectors. The module contributes with a 23% to the impact, mainly due to the copper. Looking now at the results from the cells manufacturing in Figure 6, the biggest contributor to the POF impact is the anode, due to the copper used as substrate and the graphite used as electrode paste. The cathode contributes with a 26% of the total impact due to the aluminium used in the substrate and the lithium manganese oxide used in the active material.

In the case of HTCE in Figure 5 **Error! Reference source not found.**, the module electronic boards and UCSB are the main contributors with a 50% of the total, due to the copper, connectors and DC/DC converter. The mine dumps from copper, leftovers from the separation of the copper from the uneconomic fraction of the ore, are the source of the impacts. Regarding the results for the battery cells in Figure 6, the main contributors are the anode and cathode with 55% and 34% respectively, being the copper the main contributor to the impact in the anode, and the aluminium in the case of the cathode. In the case of the aluminium the source of the impact is the red mud generated during the mining operations. Indeed, red mud is one of the most important disposal problems of the mining industry.

For HTNCE impact category the manufacturing of the van represents 72% of the emissions, the Opera4FEV rack 7% and the battery cells 21%. As it appears in Figure 5, the module electronic boards and UCSB are the main contributors among the components of the Opera4FEV rack, with a 56%. In the case of the battery cells the main contributor is the anode with a 92% of the total emissions, due to the copper contented as previously mentioned in the comparison of the vehicles technologies.

Looking at the results of ACD, the module boards and UCSB are the main contributors during the manufacturing of the Opera4FEV rack, with a 50% of the total impact. The processing of the copper included in the boards and the DC/DC converter are the principal contributors to the acidification impact. Regarding the manufacturing of the battery cells, the anode contributes with a 59% of the total impact as it can be appreciated in Figure 6, the main contributor is as well the processing of the copper contented in the substrate of the anode.

5 Sensitivity analysis

The results from the impact assessment show that, the electricity mix has an important relevance in the impacts generated during the Well-To-Tank stage of the electric van. In this study a European electricity mix has been selected to represent European average conditions. To see how the impacts are influenced with the use of other electricity mixes during the use stage of the electric van, this section compares the total impact

during the life cycle of the battery pack calculated in this study, with the impacts obtained with the Belgian and French electricity mixes, the datasets used for the electricity production are representative of the year 2011. Table 4 includes the electricity mix used in the sensitivity analysis as well as the EU27 mix used in the study. It can be appreciated from the table that the percentage share of nuclear power plants is much higher in the case of Belgium and France than the EU27 mix, 63% and 84% respectively, and also the percentage share of coal power plants is decreased considerably for both countries when compared to the EU27 mix. Figure 8 shows the results of the comparison in percentage.

The results from Figure 7 show that, the total life cycle impact of the electric van is reduced when producing the electricity, during the use stage (Well-To-Tank), with the Belgian or French electricity mix. In the case of GWP the total impact can be reduced up to 67% when using the French electricity mix, meaning that the electric van is driven within the French boundaries. These results show that environmental performance of the electric van is highly influenced by the electricity mix selected in the use stage. Therefore, driving the electric van in one country or another will vary significantly the total environmental impact. For example, with the results obtained with the Belgian or French electricity mix, the electric van with the Opera4FEV rack will be the best performing in half of the impact categories assessed GWP, POF and ACD, obtaining one of the best environmental performances from the technologies assessed.

Table4: Share percentage of the electricity mix in 2011. Source Eurostat [26]

	Belgium (%)	France (%)	EU27 mix (%)
Oil	0.3	1.1	4.4
Coal	5.9	2.7	31.2
Natural Gas	20.1	5.7	18.7
Biofuel	9.7	2.7	-
Geothermal	-	0.1	-
Solar	-	0.0	1.5
Wind	1.5	0.9	5.7
Hydro	0.1	2.8	10.6
Nuclear	62.4	83.9	27.6

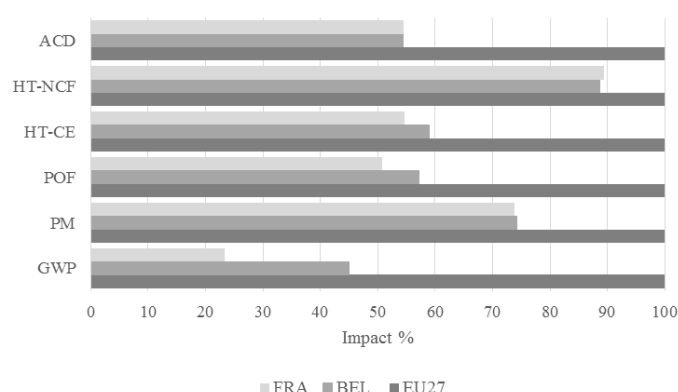


Figure7: Influence in the life cycle of the electric van for the impact categories: Global Warming Potential, Particulate Matter, Photochemical Ozone Formation, Human Toxicity Cancer Effect, Human Toxicity Non-cancer Effects and Acidification

6 Conclusions

In the present study the environmental performance of five technologies for the drivetrain of a van are analysed by applying the LCA methodology, being one of the technologies an electric van operating with the Opera4FEV pack developed in the FP7 project. The results show that the manufacturing and the Well-To-Tank stage play an important role in the environmental impacts. During the manufacturing stage, it has been identified that the content of metals contributes significantly to the impacts, due to the emissions generated when extracting and processing metals, especially copper and steel. In that sense, the Opera4FEV rack improves the environmental performance of the electric van, since the rack is manufactured with thermoplastic materials instead of aluminium. As it appears in the results showed, the contribution of the thermoplastics used in the Opera4FEV rack to the impacts assessed is minor compared to the one of the metals. The fact of using plastic also reduces the weight of the electric van, which reduces the amount of energy required to move the van and hence less electricity is demanded in the use stage. On the other hand, the content of metals in a battery pack is inevitable, due to their electrical properties.

Regarding the use stage the environmental impact generated in the WTT of the electric van, which includes the production and distribution of the electricity, is highly influenced by the electricity mix used. In this study a European mix has been implemented to represent European average conditions, making the impacts from the WTT stage of the electric van an important contribution during the life cycle, especially in the impact categories GWP, POF and ACD. The sensitivity analysis shows that this can be improved by “charging” the van with electricity mixes with a low share of coal power plants. As it is the case of Belgium and France, with a 5,9% and 2,7% of electricity produced by coal power plants respectively. With such scenarios, the overall environmental performance of the electric van with the Opera4FEV rack will be the best in a considerable range of impact categories. Looking at the impacts generated during the TTW, the electric van has no impact since it does not generate tailpipe emissions and non-exhaust emissions are not considered in this study. In this case is the diesel van the principal contributor, mainly due to the high level of NOx emissions.

The results of the EoL stage, show that the materials recovered in the recycling plants avoid part of the environmental impacts generated during the manufacturing and use, due to the open loop and substitution approach taken in the LCA study. The avoided impacts is higher in the electric van, thanks to the recovery of the materials from the Opera4FEV rack.

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Authors



Javier Sanfelix obtained his PhD in Engineering Sciences at VUB in January 2016. His PhD thesis is entitled Multiregional Input-Output Life Cycle Analysis of a Battery Pack for Electric Vehicle Applications. His current research is focused on the environmental impact of the manufacturing of components for electric vehicles applying LCA. Previously he has worked at Joint Research Centre of the European Commission, developing content for the European Platform of Life Cycle Assessment.



Maarten Messagie is an engineer specialized in industrial development. He obtained a Master degree in sustainable development (VUB) and specialized himself in environmental assessment methodologies as trainee in an environmental consultancy agency and as PhD student in Aalborg University and the University of Trondheim (NTNU). Currently he is an environmental researcher for the MOBI team working on environmental assessments (Well -to - Wheel and Life Cycle Assessment) of the transport and energy sector in various national and international projects. His main focus is on conventional and alternative vehicles, with a special interest for electric and hybrid cars. His research interests are alternative vehicle technologies, Life Cycle Assessment methodology, Eco - design and sustainable energy systems.



Mr Alves joined Mecaplast's Technical Center in 1999 as an engineer in charge of design of engine components such as air induction and cooling systems. For the past eight years, his primary focus has been technically developing Mecaplast's engine product line at the advanced phases. His efforts to meet the continuous challenges for increased vehicle performances such as Electrical Vehicle efficiency continues to bring the advanced solutions of the Mecaplast Innovation team to market, fulfilling the needs of the OEM. Anthony holds a degree in Mechanical engineering from ISAT Automotive Institute, France. He spends his spare time restoring vintage cars and coaching basketball matches for his three sons, who aspire to be the next Tony Parker.



Prof. Dr. ir. Joeri Van Mierlo obtained his Ph.D. in electromechanical Engineering Sciences from the Vrije Universiteit Brussel in 2000. He is now a full -time professor at this university, where he leads the MOBI - Mobility and automotive technology research centre (<http://mobi.vub.ac.be>). Prof. Van Mierlo is visiting professor at Chalmers University of Technology, Sweden (2012). He is expert in the field of electric and hybrid propulsion systems (power converters, energy storage, energy management, etc.) as well as to the environmental comparison of vehicles with different kinds of drive trains and fuels (LCA, WTW). Prof. Van Mierlo is Vice - president of AVERE (www.aver.org), is the secretary of the board of the Belgian section of AVERE (ASBE) (www.asbe.be). He chairs the EPE chapter "Hybrid and electric vehicles" (www.epe-association.org). He is member of ERTRAC's Energy & Environment Working Group (European Research Transport Advisory Council). He is an active member of EARPA - the European Automotive Research Partner Association and IEEE senior member as well.