PRELIMINARY STUDY FOR A LIFE CYCLE ASSESSMENT OF A HYBRID ELECTRIC VEHICLE

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Abstract: PSA Peugeot Citroën is going to rebuild its know-how about LCAs. A study is undertaken to compare conventional and hybrid vehicles. As a preliminary study, a synthesis of the state-of-art in automotive industry on LCA has been done, which will lead us to put LCA into practice at PSA. Different choices can be made, e.g. choices of the Functional Unit. The characteristics of hybrid vehicles in relation to LCA must then be highlighted, which requires knowledge about hybrid vehicle. There are three hybridization levels; each one of them has different battery technologies. It appears that the most relevant items are the level of hybridization and the battery.

Key words: Life Cycle Assessment (LCA), automotive sector, state-of-art, hybrid electric vehicle (HEV)

1- Introduction
Governments and NGOs want industries to design eco-efficient products; currently, the best way to prove the eco-efficiency is to make Life Cycle Assessments (LCA). The LCA of a product is a method standardized by the ISO 14040/44. It consists of the evaluation of the potential environmental impacts of a product throughout its life cycle. Automotive industry is no exception to the rule and many manufacturers conduct such studies. PSA Peugeot Citroën is going to rebuild its know-how by comparing three vehicles: the current one, the successor, and the successor with an alternate drive train. To prepare this study, an introduction to LCA in automotive industry and its specificities related to the hybrid drive train are synthesized in this bibliography which is complemented with proposals for an implementation at PSA Peugeot Citroën.

2- LCA in the automobile field
The goal of this paragraph is to summarize the practices of the LCA in the automobile, the ways of working of the manufacturers included. The conclusions concerning our study are presented.

2.1 – The Functional Unit
The definition of the Functional Unit (FU) is given in ISO 14040 [A1]; it can be defined as follow: “Quantified performance of a product system for use as a reference unit in a life cycle assessment study” [JH1]. Most of the time, manufacturers do not choose the same FU. Volkswagen (VW) describes its Golf as a car which transports up to five people over a total distance of 150,000 km during 10 years [VW1] [SM1]. Ford’s Polo also covers a distance of 150,000 km but in 12 years [F1]. Mercedes-Benz (MB) [MB1] published some Environmental Certificates which define different FU:
- C-Class vehicles cover 200,000 km
- A-Class and B-Class vehicles cover 150,000 km
- E-Class vehicles cover 250,000 km
- GLK-Class vehicles cover 200,000 km
- S400 Hybrid vehicles cover 300,000 km
Nevertheless, it does not specify duration to cover these mileages, like Toyota [T1] whose Prius covers 150,000 km.

The International EPD System organization publishes Product-Category Rules (PCR) on its web site for Environmental Product Declarations. There is one PCR for “Passengers vehicles” which recommends the following FU: “a passenger vehicle, with a life-time of 150,000 km (15,000 km/year),[…].” [I1]. This PCR was valid until 2008.
According to the French publisher “Techniques de l’Ingénieur”, the FU for a passenger vehicle shall be: a mileage of 200,000 km in 12.5 years [BF1].

There are other studies e.g. in Australia where they chose a mileage of 150,000 km covered in 12 years [SS1]. In The Netherlands, Castro et al. [CR1] made a LCA for an average end-of-life vehicle which life-time was approximately 14 years and mileage was 200,000 km.

The French national institute of statistics and economic studies (INSEE) with the committee of the French manufacturers of cars (CCFA) carried out a study on the average mileage per year of French people [C1]. The results are that from 1990 to 2008, the average mileage decreased
from 13,600 to 12,800 km. Moreover, Diesel cars decreased from 22,200 to 15,800 km.

It seems that the FU depends a lot on the year of creation of the study and the geographical place. However, 150,000 km in 10 years seems to be the most common FU all the more so the statistic study shows that French drivers are covering about 15,000 km per year. In our study, we must pay attention to the FU because it is common to the three vehicles compared. As a first hypothesis, the chosen FU is 150,000 km covered in 10 years; it will depend on the characteristics of HEVs.

2.2 – The product system

As well as the FU, the boundaries depend on studies. Some proposals for an implementation at PSA are shown.

Manufacturing: The inventory of this stage is very complex because there are more than 3,500 parts in a vehicle. As 70% of parts are manufactured by suppliers, most of the data are not available because of the huge amount of suppliers. To solve this problem, we decided to use primary data for the parts manufactured by PSA such as the engine and secondary data for the parts from suppliers through mass/material balances and databases.

MB and VW include all stages of manufacture; this involves good communication between the manufacturers and their suppliers. Ford does not include everything but states some assumptions.

Distribution: The geographical area and the modes of transport are the most important items. No information is available from manufacturers.

Use: The scope is the well-to-wheels (WtW) analysis and the maintenance. This phase causes more impacts than the others. WtW depends on the amount of fuel used during the lifetime of the vehicle. To calculate the fuel consumption and the emissions for the WtW analysis, the car undergoes cycles of standardized tests. In Europe, the tests used are called UDC (Urban Drive Cycle), EUDC (Extra-Urban Drive Cycle) and NEDC (New European Drive Cycle). NEDC is the association of four UDC followed by one EUDC [I1].

Ford considers in its study “the additional fuel consumption of air-conditioning that is not covered by most published complete vehicle LCAs” [F1].

Concerning the maintenance, VW and MB do not take it into account because “maintenance and care for vehicle have no relevance for the result” [MB1].

Ford’s study includes maintenance in use phase: refrigerant and oil refilling [F1].

End of life: In the Environmental Commendation of the Golf, VW explains that “no environmental credits were awarded for the secondary raw material obtained from the recycling process” [VW1].

For Le Borgne and Feillard [BF1], only closed-loop recycling should be considered. It is also possible to do not count the recycling material in waste.

PCR [I1] does not include the end-of-life. Boundaries are different from a study to another. Sensitivity analyses help to interpret results.

The standards define open-loop and closed-loop recycling. Klöpfer [K1] proposes some allocation rules to apply recycling using loops. But the hypothesis we are going to make is to do not take into account the benefits due to recycling.

2.3 – Impact assessment

Looking at the following Figure 1, it appears that climate change, air (acidification, photo-oxydant formation) and water (eutrophication) pollutions are common to most of the studies. The abiotic resources depletion potential is also predominant.

![Figure 1: Synthesis of choices of impacts.](image)

This state-of-art is valid for conventional vehicles, but not for hybrid vehicles. Thus, the following chapter deals with the specificities related to the hybrid drive train.

3- Concerning hybrids vehicles

The goal of hybrid vehicles is to decrease the CO2 emissions during the use phase. It is not a global approach (the entire life cycle) and do not cover more environmental damages. Conducting a LCA will detect any pollution transfers. Thus, after reminding what hybridization is, their characteristics in relation to LCA are introduced.

3.1 – Reminders about HEVs

The hybridization of drive trains corresponds to the association of two or more energy sources. Currently, the most known combination is the association of an internal combustion engine (ICE) with one or more electric motors and a battery: hybrid electric vehicles (HEV). Three levels of hybridization, clarified hereafter, are on the market: Micro, Mild, and Full.

Micro hybrid vehicles have the start-stop system: the ICE is shut down when the car is stopped. It restarts the ICE when the car begins moving [P1].

Mild hybrid vehicles have also a start-stop system but employs regenerative brake. Moreover it increases the power of the vehicle to start.

Full hybrid vehicles can run only with the electric power, like an EV, for low speed and short distances. There are also plug-in hybrid electric vehicles (PHEV): the battery can be
charged from outside, e.g. by connecting to the electrical network.

3.2 – The characteristics of HEVs

3.2.1 – The Functional Unit

The current lifetime of batteries is shorter than the lifetime of the vehicle. Thus, during the use stage, and depending on the FU, the battery of the HEV may be substituted, which may modify the eco-profile.

3.1.2 – The product system

Manufacturing: New materials, which are not included in the composition of conventional vehicles, are used to manufacture the battery. The technology of the battery depends on the hybridization level (e.g. NiMH for Full hybrids, Li for PHEVs). In Rade’s thesis [R1], the availability of scarce metals is studied; she identifies a risk in terms of raw material resources.

Use: The fuel consumption is one of the most important data for a LCA. Hybrid vehicles have two energy sources: heat and electric energies, contrary to ICE vehicles which have only the heat energy. The fuel consumption and the battery state of charge must be measured. Concerning PHEVs, some pollution transfers may appear: if the battery is charged in France, nuclear waste is produced because it creates electricity from nuclear power, while if the battery is charged in China, there are CO₂ emissions caused by plant coals. As a battery has not the same life-time as the vehicle, the maintenance and the replacement of the battery play a more important part.

End of life: The end of life of new battery technologies is not really well-known. There are not many information about the recycling of the battery.

Conclusion

The manufacturers are carrying out more and more LCAs on complete vehicles. This kind of studies is complex. These LCAs make it possible to justify design decisions, and communicate on the potential environmental impacts of the vehicles.

The standards ISO 14040/44 give the framework of the study but do not explain methodology; there is thus a great freedom on the choice of the method. Thus, differences exist between the studies, e.g. the taking into account or not of maintenance during the use phase. But certain choices prove to be relatively common.

The PSA “Projet Environnement” department is going to make a comparative LCA of conventional and hybrid vehicles which raises the complexity and will check wether HEVs create less environmental impacts than conventional vehicles. It will help the French manufacturer to avoid pollution transfers.

5- References


