

ELECTRICAL AND ELECTRONIC COMPONENTS IN THE AUTOMOTIVE SECTOR: LCA AND LCC STUDIES

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Abstract:

Automotive electrical and electronic systems (EES) comprise an area that has grown steadily in importance in the past decades and will continue to gain relevance in the foreseeable future. For this reason, the SEES (Sustainable Electrical & Electronic System for the Automotive Sector) project aims to contribute to a cost and eco-effective EES by defining sustainable scenarios for the recovery of automotive EES by taking into consideration the required improvements in EES design and the development and implementation of new recovery technologies. The research project SEES is funded by the European Commission (Contract n° TST3-CT-2003-506075) within the Sixth Framework Programme, priority 6.2. In order to analyse the influence of all life cycle steps Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) case studies are applied within the SEES project. These case studies are conducted for two different EES components. Results of the LCA and LCC case studies for analysed EES components are presented in this paper. An engine wire harness (WH) and a passenger smart junction box (PSJB) produced by LEAR and assembled in an existing Ford car model are chosen as representative EES components. Firstly, the basic assumptions for a status quo scenario as well as LCA and LCC results for the analysed status quo scenario will be presented. Additionally, new design scenarios as well as different End of Life (EOL) scenarios for the wire harness and the smart junction box are analysed and evaluated. Their influence on the LCA and LCC results will also be shown.

1. Introduction

The SEES project aims at development of sustainable, clean, cost- and eco-effective EES prototypes and dismantling/ recycling processes to increase the vehicle recovery/ reuse rate. Within the SEES project LCA and LCC studies have been employed to guarantee the life-cycle perspective and to help define the optimum recycling and design scenario for two analyzed EES components.

2. Goal and Scope of the Studies

The goal of the studies is to determine and compare the potential environmental and economic impacts of alternative product system scenarios and assess the significance of improvement potentials in design and recycling. The components under study are an engine wire harness (WH) including a wired junction box for power and signal distribution in the engine compartment and a smart junction box (PSJB) located in the passenger compartment for electronically controlling and switching functions. One WH, respectively one PSJB assembled in a middle-class Ford car model with an assumed use phase of 150.000 km in 12 years

is defined as the functional unit. For the fuel consumption during the use phase a European average mix between diesel (44 %) and gasoline (56 %) engines has been assumed [1]. Allocation of fuel consumption from the whole car to the single car component has been based on an incremental approach (see [2]).

2.1 Alternative Design Scenarios

The analysed alternative design scenarios are based on EES designer's recommendations from the status quo scenario results. The design scenarios for the WH/ PSJB include material based changes as well as fasteners related alternatives to facilitate disassembly and recycling. In Table 1 the different Design Scenarios for the Wire Harness are shown. In Design II.1 the conventional round cables are partly substituted by flat flexible cable (FFC) to reduce total weight and copper content. Design II.2 employs hook-and-loop tapes, thereby reducing the needed channels, clips and adhesive tapes for routing and fixation of the WH and reducing assembly and disassembly times.

Table 1: Material Composition of WH in relation to analysed Design Scenarios

	Design I		Design II.1		Design II.2	
	Original Design	(Flat Flexible Cable)	(Hook & Loop Tapes)	Mass [g]	Mass [%]	Mass [g]
Copper	3539,7	48,2	2293,7	39,9	3539,7	49,2
Ferrous metals	149,5	2,0	149,5	2,5	149,5	2,1
Other metals	21,5	0,3	21,5	0,4	21,5	0,3
Thermoplastics	2339,3	31,9	2138,2	35,6	2186,1	30,4
Other materials	1293,3	17,6	1298,9	21,6	1292,1	18,0
Total [g]	7343,4		6001,8		7189,0	

The design scenarios for the PSJB contain the use of lead-free solder alloys (Design II.1) and easy-to-dismantle fasteners of the housing of the PSJB (Design II.2) to facilitate second level disassembly of the printed circuit boards (PCB) from the box.

2.2 Alternative End of Life Scenarios

EOL 0/0a: Status Quo – Car Shredder and Metal Recycling

After pre-treatment and depollution the car is shredded with the WH/ PSJB remaining in the car. Using standard separation techniques the following fractions are obtained: ferrous metal fraction (mainly steel), non-ferrous metal fraction and shredding residues (ASR). The ferrous fraction and non-ferrous metals are recycled and the remaining ASR is sent to a landfill (EOL0) respectively is incinerated (EOL0a). The assumed separation rates are:

- 98 % of the ferrous metal input goes to the ferrous fraction for steel recycling
- 80 % of the copper input ends up in copper recycling (after further separation of the mixed non-ferrous fraction for specific recycling)
- 100 % of the plastics and other materials end up in the ASR

EOL 1: Disassembly of the WH/ PSJB and Advanced Mechanical and Chemical recycling

The disassembly from the car will take place manually. After disassembly, the components will then be mechanically recycled in various steps of size reduction and material separation (for details on the mentioned recycling technologies

see [3]). For the recycling of scrap PCBs from the PSJB hydrometallurgical approaches developed by Rohm & Haas and Imperial College London have shown viability to recover metals such as gold, silver, palladium, tin and lead [4].

EOL 2: Car Shredder and Advanced Post-Shredder Recycling

The whole car undergoes the shredder process without prior dismantling of the WH/ PSJB (as in EOL 0/0a). Besides the usual recycling of the ferrous and non-ferrous metal fraction the ASR will be sorted and mechanically recycled using innovative technologies to be analyzed within the SEES project. This reduces the amount of ASR that has to be disposed of and increases recycling and recovery of metals and plastics from ASR.

3. Impact Assessment

In Figure 1 normalised impact category indicator results are shown for the analysed design scenarios and status quo recycling/ disposal of the WH.

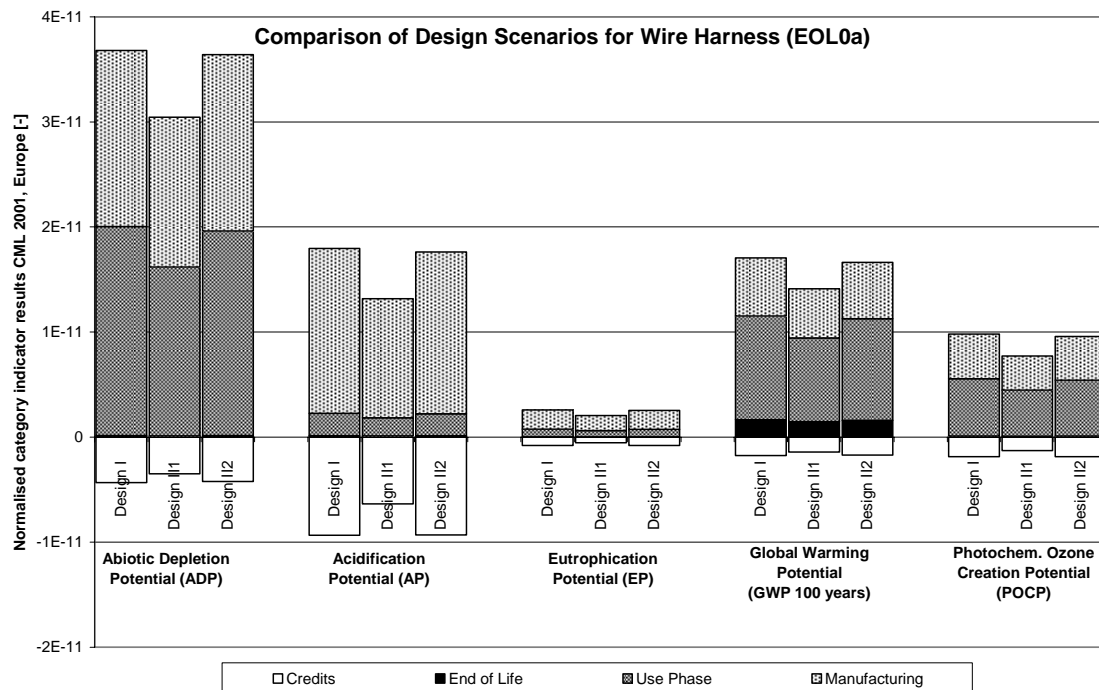


Figure 1: LCA results for the WH in relation to the Design Scenarios

The alternative Design II.1 has considerably lower potential environmental impacts in all analysed categories compared to the Design I. This is due to the reduced weight (ca. -18 %) which positively influences the impacts allocated during the use phase and due to the reduced material production for manufacturing of the WH. Because of the reduced relative copper content of the Design II.1 the strongest relative reduction occurs in the impact category AP which is dominated by the copper production. Design II.2 has no significant effect on the LCA results, only the slightly reduced weight of Design II.2 still results in an improvement of about -2 % of the impacts during the use phase.

Looking on the life cycle costs they are dominated by the raw materials and manufacturing cost (more than 90 % of the total life cycle costs). The costs of the use phase again correlate to the different weights of the alternative designs. During the manufacturing phase the Design II.1 has increased costs of about 3

% (higher costs of FFC compared to round cables) which exceeds the savings during the use phase. The revenues from the obtained fractions for recycling consequently are also lower for Design II.1 (reduced copper content) than for the other two. Design II.2 results in slightly reduced end of life costs because of faster disassembly.

Comparing the EOL scenarios the results show that EOL 1 and EOL 2 are both superior to EOL0/0a from an environmental point of view due to the credits given for the obtained additional recyclable fractions which exceed additional impacts of the recycling processes. For the WH EOL 2 is better than EOL 1 because the WH can only be partly disassembled and the rest is remaining in the car going the shredder way. On the other hand, for the PSJB EOL 1 would be preferable because more material can be recycled than in EOL 2 leading to higher credits for recycling.

The analysed design scenarios of the PSJB showed that a shift to lead-free solder alloys in this case slightly increases the potential environmental impact during manufacturing in the categories ADP, AP, GWP and POCP. Generally, the LCA results of the PSJB are even more driven by the manufacturing phase than for the WH, especially material production and production of electronic components are important.

4. Conclusions

The analysed design scenarios showed that the alternative with the highest weight reduction and reduced copper content shows the highest environmental improvement potential. Generally, the end of life processes contribute to less than 10 % of the life cycle impacts but determine the credits given for the recycled fractions. Therefore, advanced recycling technologies for EES could reduce the overall potential environmental impacts and increase the revenues of the recyclers.

5. Acknowledgement

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6. References

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