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SEES

Sustainable Electrical & Electronic System for the Automotive Sector

Specific Targeted Research or Innovation Project
(STREP)

Priority 6.2: Sustainable surface transport

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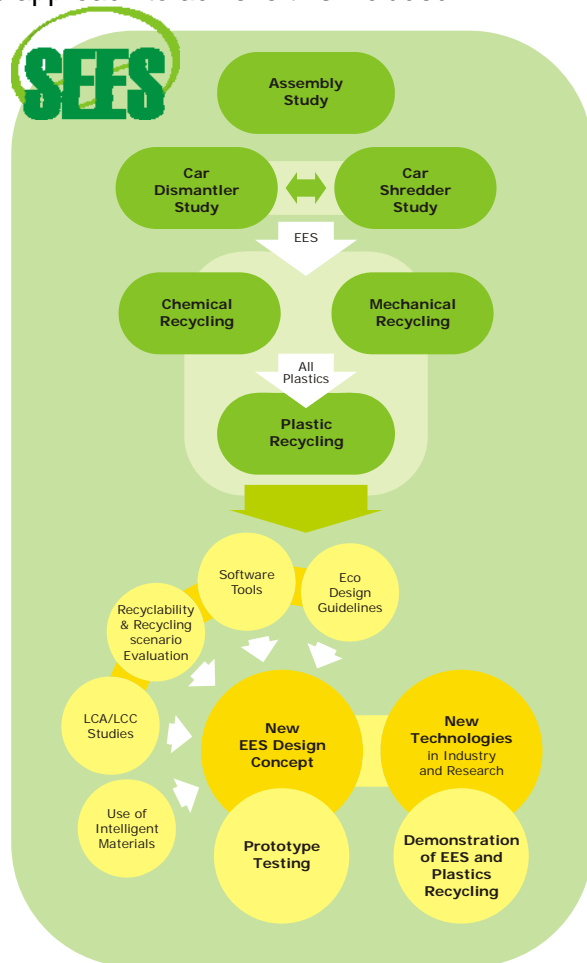
1 Introduction

1.1 The SEES project

SEES is the acronym of Sustainable Electrical & Electronic System for the Automotive Sector. The project is developed under the EU Sixth Framework Programme, started in February 2004 and finished in January 2007 (contract no. TST3-CT-2003-506075).

The main goal of the SEES project was the development of prototypes and dismantling/ recycling processes for a sustainable, clean, cost- and eco-effective automotive electrical & electronic system (EES) to increase the recovery and reuse rate of vehicles where appropriate. This will facilitate the achievement of the recycling/recovery targets laid down in the Directive 2000/53/EC on end-of-life vehicles. The approach to achieve this included:

- Life-cycle perspective, covering all the life steps of the product (manufacturing, assembly, use, disassembly, shredding and materials recycling)
- Investigation of the optimal collection, dismantling and shredding procedures for the automotive EES through real tests
- Development/demonstration of new metal and plastic recycling technologies and identification of product applications
- Environmental and economic assessment of all the life cycle steps using LCA and LCC methodologies
- Development of eco-design guidelines to improve future EES designs and contribute to sustainability
- New Electrical & Electronic System Concept and specific parts/functions prototyping and testing
- Development of methodologies and software tools to assess end-of-life scenarios and recycling options of the EES



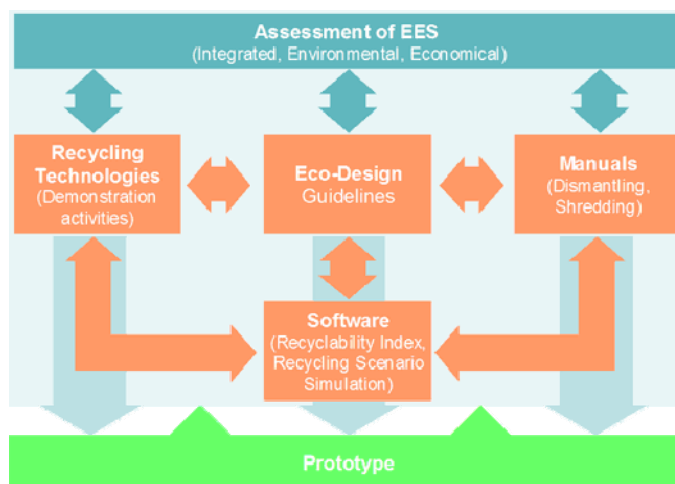
1.2 The SEES partner organizations

The skills of the 10 SEES partner organizations cover the complete life-cycle of EES, from design and manufacturing (LEAR), assembly and use (Ford), dismantling (Mügu1, Ford), electronics recycling (RHEMEL, IRSA) and shredding (Mügu 2). These partners are supported by environmental experts (TUB, URV and CIMA), a waste and plastic expert (GAIKER) and a software developer (CIMA). The country distribution guarantees the different point of view and technologies existing around Europe.

Profile	Organization Name	Country	Acronym
Coordinator / Research Institute	Technical University Berlin	Germany	TUB
Car EES Designer & Manufacturer	Lear Automotive (EEDS) Spain S.L.	Spain	LEAR
Car manufacturer	Ford Forschungszentrum Aachen GmbH	Germany	Ford
Electrical & electronic products chemical recycler	Rohm and Haas Electronic Materials Europe Limited (participation finished 30 April 2006)	United Kingdom	RHEMEL
Electrical & electronic products mechanical recycler	Indumetal Recycling SA	Spain	IRSA
Car Dismantler	Metall Recycling GmbH	Austria	Mügu1
Technological Center (Recycling and Recovery)	GAIKER Centro Tecnológico	Spain	GAIKER
Exploitation manager, Software developer	CIMA Kereskedelmi, Szolgáltató és Innovációs KFT	Hungary	CIMA
Research Institute	Universitat Rovira i Virgili	Spain	URV
Car Shredder	Mü-Gu Kft	Hungary	Mügu2

1.3 Expected achievements/ impacts

- Improve sustainability of EES products and processes
- Favour metal and plastic recycling processes for automotive EES to increase recovery and reuse rate
- Reduce resource consumption and quantity of auto shredding residue (ASR) that goes to landfill
- Reduce the costs associated to end-of-life processes of automotive EES
- Increase the competitiveness of European automotive EES designers, producers, dismantlers and recyclers
- Contribution to standards (dismantling procedure for EES, Design for Environment Guidelines for EES, Life Cycle Costing Methodology)



The main outputs and relations together with the expected achievements and impacts are shown in the graph above.

1.4 Summary of the work performed and major achievements

An *integrated assessment of automotive EES* supported the definition of the scope of the subsequent studies. Automotive EES devices have been classified and assessed. The classification of EES devices resulted in 14 different component groups. An assessment scheme for qualitative and semi-quantitative evaluation of legal, environmental and economic end-of-life aspects incl. dismantling, recycling and future trends for automotive electrical & electronic devices has been developed and applied to identify most relevant and representative components among the car EES. Available information on state-of-the-art end-of-life processes for vehicles and the contained metal and plastic materials of the EES have been collected and integrated. The selected components and collected information were the basis for the further workpackages in the SEES project.

The *assembly study* revealed critical parameters for cost, time and quality targets of the EES assembly process. Furthermore, future EES trends and their influence on the assembly process have been studied and possible synergies between assembly and disassembly investigated. This was used as a basis to study design parameters that could influence disassembly times later on in the project.

Within the *disassembly study*, destructive and non-destructive disassembly tests on cars of different type and age have been performed to identify influences on the disassembly time and cost and look for improvement potentials. The studies showed that only a small portion of the dismantling time can be addressed by product design. Times for direct disassembly work are in practice influenced to almost equal shares by inter-personal differences (e.g. experience, motivation, training level, work organisation) and design features. The strongest link between design and dismantling times is the number of previous parts to be disassembled.

The *shredding study* is based on the quantification and characterisation of the fractions obtained in the car shredding process (vehicles including the electrical & electronic systems as well as vehicles where these systems are dismantled) and the definition of the quantity of the material from the EES that goes to each shredder fraction. Shredding tests have been conducted and evaluated to analyse recycling options for the shredder output fractions and compare possible shredding and dismantling scenarios for EES. It was shown that disassembly of copper containing EES parts before the vehicle enters the shredder is not necessary to ensure the quality of the steel fraction but it would significantly increase costs in comparison with handpicking of copper parts after the shredder.

To improve the recycling of EES components, the project has undertaken *EES and plastic recycling studies*. New and emerging mechanical and chemical recycling technologies for the treatment of selected EES components, e.g. wire harnesses, junction boxes and other printed circuit boards (PCB) containing devices, have been identified and tested. Mechanical treatment aims at separation of valuable fractions for separate recycling. The chemical recycling approach targets precious metal recovery, mainly from PCBs. The developed mechanical and chemical recycling approaches have been applied successfully on different EES materials.

Furthermore, recycling of plastics from dismantled EES components as well as from shredding residues was studied in order to obtain recycled plastics of high quality and look for value-added applications. Using mechanical separation technologies main plastic fractions

could be separated from the tested samples, including polyolefins and polyamides. Plastics recycled from production rejection materials have good properties that allow to use them in the same application again. On the other hand, plastics recycled from end-of-life junction boxes required additivation to enhance their material properties and could not be reused in technical applications in the end. The heterogeneity of the plastics recycled from shredding residues made it difficult to find suitable additives and their material properties were not sufficient to reuse the recycled material in technical applications.

Environmental and economic studies have been carried out to analyse the potential environmental impacts and costs of different design and end-of-life scenarios of EES. Two representative components have been analysed in Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) studies, an engine wire harness and a smart junction box. It has been shown that the use and production phase (incl. material production) have a much higher impact over the whole life cycle than the end-of-life phase. Considerable environmental improvement potential could be identified for a design option of the wire harness with a reduced weight.

A prototype of a *SEES software* was developed, implementing two methodologies developed within SEES. The first methodology is for assessing recycling potential and evaluating disassembly effort for EES products from the perspective of the designer. This supports EES designers in comparing different designs for EES products. The second methodology for simulation of end-of-life scenarios allows to simulate process inputs/outputs and costs of combinations of recycling processes depending on the quality of the input material. This second part is to be used to support recyclers in their processing decisions.

Based on the results of the previous workpackages, *eco-design guidelines* for automotive EES have been developed considering improvement potentials along the whole life cycle. This includes a method for qualitative evaluation of product characteristics to identify priority life cycle phases for improvement and to check positive/negative effects of possible redesign options. A list of guidelines to address main issues in each life cycle steps has been provided together with other recommended actions to be taken by other life cycle stakeholders (e.g. car manufacturer, user, recycler, etc.). The basic framework of the guidelines could also be applied – after modification – to other types of electrical and electronic equipment.

The eco-design guidelines and previous SEES findings have been applied for *development of a new EES concept* with prototyping of specific parts and functions. The new EES concept included improvements on component and system level, e.g. substitution of glass fillers in plastics by natural fibres, alternative wiring technologies, fuel-efficient navigation system and an integrated energy management system. Tests with intelligent materials for automatic disassembly showed that the currently available functional materials are not able to fulfil the strict temperature and mechanical requirements to be applied in automotive EES. The new EES concept options have been tested and assessed with regard to benefits or drawbacks on assembly, disassembly, environmental & economic profile and recyclability potential.

Please find more information, presentations, papers and project reports on the SEES project homepage: <http://www.sees-project.net>

2 Project execution and main conclusions

2.1 Project background

This report summarises the main conclusions of the European research project “SEES - Sustainable Electrical & Electronic System for the Automotive Sector” which aimed at the development of guidelines, prototypes and processes striving for sustainable, clean, cost- and eco-efficient automotive electrical and electronic systems (EES). The SEES project has been developed within the 6th Framework Programme of the European Commission (contract no. TST3-CT-2003-506075) by a consortium of 10 European partners during February 2004 until January 2007.

The SEES project has followed a life cycle approach covering the whole life cycle of automotive electrical & electronic systems (EES), including design, assembly, use, disassembly, recycling and recovery. During the course of the project the focus of the research has been opened to cover a more holistic life cycle view instead of concentrating on end-of-life issues only. This shift of focus was based on interim findings which indicated low environmental and economic relevance of and limited actual design influence on the end-of-life phase in comparison with other life cycle phases.

2.2 Overview on SEES Approach and Main Results

The main products of the SEES project are:

- Investigation of the optimal transport, dismantling and shredding procedures for the automotive EES through real tests
- Demonstrated metal and plastic recycling technologies for automotive EES incl. value-added applications of the recycled materials
- Environmental and economic assessment of the EES life cycle steps using Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methodologies
- Specific methodologies and a software tool to assess end-of-life scenarios and recyclability/recoverability of EES products
- Eco-design guidelines to improve future EES designs towards sustainability
- New EES concepts and specific parts/functions prototypes to improve sustainability of EES

In the following sections, the main conclusions from the research activities on the above listed topics are summarised. The involved SEES partners are mentioned, using abbreviations for the organisations listed in section 1.2.

2.3 Disassembly of EES prior to recycling/recovery

Disassembly studies included EES disassembly tests on end-of-life and new vehicles using destructive and non-destructive approaches with different tools. These tests were carried out at Ford (new cars), Mügu1 (end-of-life vehicles) and LEAR (focussing on disassembly of junction boxes from different car models). The following has been found:

- Most of dismantling time cannot be addressed by Eco Design / Design for Dismantling (DfD) at all. For the rest mainly weak potential impacts of DfD could be identified;
- The strongest link between design and dismantling time is the number of previous parts, as well as the chosen dismantling tool;
- The selection of dismantling tools is mainly influenced by personal preferences and work organisation rather than eco-design;
- There is no significant correlation identified between further design features and an increase/decrease of dismantling times based on current vehicles. The effect of future trends that can influence the vehicle structure, like X-by-wire, has not been included in the disassembly trials and should be investigated in more detail in future research.
- Dismantling infrastructure-related aspects (available tools, experience, involved individuals etc.) are underestimated so far and should be investigated in more detail in future research.
- Redesign avoiding the need for dismantling at End-of-Life (due to the presence of substances legally required to be dismantled) should be analysed case by case if it could make sense along the life cycle.
- Disassembly of parts with high reuse value only makes sense if there is a clear demand.
- In general, component disassembly for material recycling is found not to be profitable due to the high disassembly costs.
- Hand picking of copper after shredding (e.g. of the wire harness) is much cheaper and almost equally effective in comparison with dismantling.

More information can be found in the public deliverable D3 which is available for download from the SEES website (www.sees-project.net).

2.4 Shredding and recycling of EES

It has been demonstrated that there are viable approaches to recover additional materials from EES by mechanical and chemical approaches. This includes mechanical separation of major material streams (e.g. copper, plastics), further purification and separation as in the case of the mixed plastics and specific chemical treatment for recovery of precious metals from PCB. These activities and main findings are shortly described in the next sections.

More information can be found in the public deliverables D4 (mechanical and chemical recycling), D5 (plastic recycling) and D6 (car shredding) which are available for download from the SEES website (www.sees-project.net).

2.4.1 Mechanical and Chemical Recycling

Within the mechanical and chemical recycling studies of the SEES project recycling schemes for different EES materials and components have been developed. Mechanical recycling approaches developed at IRSA have been shown to be able to recover valuable metal fractions and recyclable plastics from scrapped and end-of-life EES components such as junction boxes (printed circuit board containing devices) and wire harnesses. Also streams of mixed EES materials from the shredder have been recycled mechanically. The mechanical

recycling tests of disassembled starter motors and alternators revealed that it makes no sense to recycle these components separate from the car in mechanical treatment – it is rather recommended to leave them in the car for metal recycling through the shredder.

A chemical recycling approach has been developed by RHEMEL with its subcontractor Imperial College in the SEES project that is able to recover most of the precious metals which are present particularly in printed circuit boards of different EES devices. The developed leach and electrowinning process uses a feed of shredded circuit boards, dissolves practically all precious metals of the boards and then allows for selective electrowinning of metals such as gold, copper, silver, palladium, etc.

2.4.2 Plastic Recycling

Different plastic recycling tests have been carried out by GAIKER to demonstrate the possibility of recovering the plastic fraction from the Automotive Electrical and Electronic Systems. On the fact that plastic fractions from previously disassembled EES (polyamides and polypropylene from automotive junction boxes) have been recycled and these recycled plastic fractions have demonstrated good mechanical properties and surface quality comparing with virgin materials, furthermore different additives have been tested to improve the compatibility of the plastic matrix.

On the other hand different separation and recycling tests have been carried out to recycle the polypropylene from the Automotive Shredding Residue's (ASR) plastic fraction. ASR samples were produced and a plastic rich fraction obtained at Mügu1 for further treatment at GAIKER. The main problem in the separation and recycling of this input material is the heterogeneity of the sample. In spite of the fact that in some cases the polymer matrix is the same the heterogeneity of the fillers used for each application make difficult a homogeneity in the output recycled polypropylene material. In this case, different additivation tests have been carried out to improve the compatibility between polymer matrix and fillers included in the sample. In some cases the properties have been improved after adding the additives but the heterogeneity of some of the samples have not make possible the improvement of these properties. The separation of the plastic fraction from the automotive shredding residue is the main step to get the recycling of the plastic fraction from the ASR.

In the next paragraphs the main conclusions obtained in the Plastic Recycling Study are summarised:

Separation conclusions:

- The separation of ASR materials to obtain a very pure plastic fraction was very difficult – especially the separation of rubber from plastics was the primary problem and required handpicking support. Because of that only small quantities of plastic fractions could be obtained for further plastic separation tests.
- The main plastic matrix is different in each material input, the percentages of the materials are described in the tables (1-4). The polyolefins fraction was the main fraction in the material input from the production rejection junction boxes but the main plastic fraction in the junction boxes from the end of life vehicles is polyamide fraction. Separation tests have been focused in order to separate the main plastic fraction on each

input material. The ASR plastics are very heterogeneous samples (different materials within one sample and variations between different samples)

Processing conclusions:

- The processability of recycled materials was in appearance good. It is necessary to dry the polyamide (PA) and polypropylene (PP) materials before the extrusion and the injection process, especially in the case of PA which is more hygroscopic than PP. This is very important to obtain a better material which can be process easier and faster and to reduce the possible de-lamination effects.
- The pellets and the specimens of recycled plastics obtained present excellent surface finishing.

Recycling conclusions:

- Materials originating from production rejection are mostly achieving good recycled materials properties. The material has not suffered degradation in the use phase so the quality of the recycled material is better than other recycled materials from end-of-life vehicle components.
- The general material properties obtained for the recycled plastic materials from end-of-life samples are of lower quality than the range of values for the virgin materials used in production of automotive EES. The different input materials of the studied polyamides from end-of-life junction boxes hamper the compatibility between different plastic matrices and between plastic and the fillers.
- The heterogeneity in the plastic fractions from ASR are the main conclusion of the ASR recycling tests. After comparing the properties of the recycled polypropylene from different ASR samples versus the properties of the virgin materials used to manufacture automotive junction boxes, it was found that
 - The recycled materials have a higher density (probably from filler content or minor impurities),
 - The tensile and flexural properties values are inside the range of the property of the virgin materials,
 - In spite of the fact that the Charpy impact value is inside or near the range of values of the virgin materials, the value is quite low. The heterogeneity in the input materials makes the compatibility between the different plastics matrix and the fillers difficult.

Additivation/material upgrading conclusions:

- After searching available commercial additives and selecting the more suitable ones, different formulations have been developed taking into account the different input ma-

materials and the degradation in the properties that the materials have. The following results were obtained in the additivition tests of the recycled plastic samples:

- Polypropylene from production rejection: additivition improves material properties a little. The tested compatibilizers act in the same way, the plastic improves in tensile properties but the flexural properties decrease (because of decrease of compression properties).
- Polyamide from end of life vehicles: among the tested additives Booster PO improves the material quality more than the tested Elvaloy. The tensile properties are higher in the additived materials.
- Polypropylene from ASR: The additivition does not result in a clear improvement of the properties of the recycled materials but the tendency is similar to the properties improvement of the PP from production rejection. It has been observed that the heterogeneity of the recycled material after additivition has become lower than the heterogeneity of the original sample.

Conclusions on possible applications of the recycled material:

- The properties of the polyolefins from the production rejection junction boxes show good properties comparing with the properties of the virgin material. In this case the application of this kind of material can be the same as its original application. The best option to ensure quality of the material is to mix this material with virgin material to the same application.
- The polyamides from ELV present heterogeneity in their mechanical properties. In this case the properties have to be improved using additives to raise the value of the Charpy impact and the tensile and flexural strength. In these cases the application of the recycled polyamides in technical applications is not possible because relevant properties have been damaged.
- The properties of the polyolefins from automotive shredding residue are very heterogeneous and the mechanical properties are not good enough to apply this material in technical applications. As the process and injection of this material are possible and surface quality of this material is good, application of this material in exterior application is possible.

The economics of the developed recycling approaches have been studied for selected EES sample products which gave the following results:

- Manual extraction of EES components followed by manual disassembly processes imply high labour costs which cannot be compensated by revenues from recycled materials sales - with high purity -. When manual disassembly processes are substituted by mechanical recycling processes, labour costs are reduced substantially and could be compensated by materials sales – depending on the required effort (time) in extraction and on the quantity and quality of recovered materials. This second scenario is still economically unviable for a passive junction box (without electronic com-

ponents), but it could be viable for a smart junction box (with electronics/precious metals) if required effort (time) in extraction is low. In this alternative scenario, quantity and quality of recovered materials would be lower than in a full manual disassembly scenario but with a very limited economical influence in the overall balance.

- Shredding processes for cars containing EES imply very low processing costs for automotive EES. In this scenario it would be difficult to improve the quality of the obtained plastic fraction and to get a good market price for this fraction, but low processing costs are easily compensated by recovery and salery of printed circuit boards (PCB) – even considering significant material losses in PCB recovery.

2.5 Environmental and economic evaluation of EES life cycle

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) case studies have been conducted by TUB with support of URV, CIMA and RHEMEL to define optimum design options and end-of-life (EOL) scenarios for EES, taking into account all life cycle steps. These methodologies have been applied to two selected components: an engine wire harness (WH) and a passenger smart junction box (PSJB). For each component, two design alternatives have been compared with the original design, based on designers' recommendations from the status quo scenario results.

The LCA/LCC studies gave the following main results:

- The most dominant life cycle phases for the LCA results are manufacturing (including raw material extraction and production of materials and components) and the use phase. Similarly, manufacturing was even more the predominant phase in the LCC results.
- Among the analysed design alternatives, the highest environmental improvement potential were gained from the use of alternative wiring systems with reduced weight and copper content, but with slightly increased life cycle costs. Smaller differences of the results were determined for the different end-of-life scenarios.
- Disassembly costs were shown to be significant during the EOL phase. The LCA results of the EOL scenario depend on the component in question. Among the analysed EOL scenarios the post-shredder recycling was the preferable scenario for the WH from an environmental point of view. There was no significant difference in the LCA results of the SJB between disassembly and post-shredder-recycling scenario.

Besides LCA/LCC studies also specific methodologies to evaluate recyclability/recoverability potential of EES designs and simulate different recycling scenarios have been developed and applied to the same products. These applications gave the following results:

- The WH has an estimated recycling potential of 100%, excluding the wired junction box, with an estimated economical recycling benefit lower than the estimated cost of extracting manually the WH from the vehicle.
- The PSJB has an estimated recycling potential of 96% with an estimated economical recycling benefit lower than the estimated cost of extracting manually the PSJB from the vehicle and disassembling manually the box into its component parts. The following alternative end-of-life scenario for a PSJB: manual extraction of the box from the vehicle followed by mechanical recycling of the box, chemical recycling of PCBs and recycling of

PP - instead of disassembling manually the PSJB -, has a total estimated cost lower than the previous scenario without considering transport.

The potential environmental impacts during the life cycle of the analysed products are generally most strongly influenced by material production and the use phase of the products. In comparison, improvements during the EOL phase have only a very limited potential to reduce environmental impacts. The studied design changes displayed clear environmental advantages for (lighter) flat flexible cables (FFC) in the case of the WH whereas, the lead-free solder design alternatives showed a slight increase in some environmental impact categories during material production (but end-of-life effects of lead-free solders could not be sufficiently modelled). The application of these design changes has been limited in some cases by technical issues.

Focussing only on EOL improvements cannot be recommended for automotive EES products. A life-cycle perspective should be utilised for assessing improvements in individual life cycle stages of a product.

More information can be found in the public deliverable D7 (environmental and economic evaluation, incl. development of methodologies for recyclability assessment and simulation of recycling scenarios) which is available for download from the SEES website (www.sees-project.net).

2.6 SEES Software Tool

A prototype of a software tool has been developed by CIMA with support of URV and TUB to apply methodologies to assess end-of-life scenarios and recyclability/ recoverability of EES products. The software is intended to be a support tool for decision making for EES designers and recyclers.

The SEES software helps to analyse the requirements of the European legislation, especially the End-of-Life Vehicle Directive, the requirements on the end-of-life practices for automobiles, including quotas for recycling, reuse and recovery. It can be used to evaluate the situation for automotive EES and to provide concrete analysis as a basis for concepts, technologies, design guidelines, procedures to work towards the goal of sustainability in the automotive sector.

Further development of the SEES software for exploitation is currently ongoing at CIMA.

2.7 Redesign of EES

Based on the findings of the previous SEES studies, new concepts for redesign of automotive EES have been analysed which should contribute to a more sustainable EES.

2.7.1 Eco-design methodology and guidelines

Eco-design guidelines for automotive EES have been developed by LEAR with support of TUB and Ford, including a qualitative methodology for identification of priority life cycle phases based on product characteristics. The developed methodology supports in defining the right high priority areas and preventing sub-optimisation on a single life cycle phase, but:

- Validation on more products would be desirable

- The methodology is purely qualitative and does not provide a quantified evaluation. In cases without clear result additional quantitative tools are needed.

Implementation of the guidelines is to be focused on component level to enable direct implementation by an EES component engineer: i.e. only provide those guidelines to the component engineer, that apply to the component he is developing. But impact of redesign options on component level is often limited due to many functional and business restrictions that do not allow more impacting options. Options with higher impact often cross component boundaries.

Other actions to be taken by other life cycle stakeholders (e.g. the car user) are very relevant to improve the environmental performance of EES.

2.7.2 Relation between CO₂-emissions, fuel consumption, vehicle mass and electric energy consumption

As shown in the preceded work in SEES, fuel consumption is a major factor of the overall environmental impact in the life cycle of a vehicle. Fuel consumption is, amongst other aspects, influenced by vehicle mass and electric energy consumption. In the developed comparison method the relation between vehicle mass, electric power consumption and fuel consumption has been quantified. Questions like "what makes more sense, a certain reduction of the vehicle mass or reduction of electrical energy consumption?" can be more easily answered. This approach is not meant to substitute LCA, but as a means to support the discussion on implementation aspects of different improvement options.

2.7.3 Intelligent Materials to facilitate Disassembly

The possible application of intelligent materials to facilitate automatic component disassembly has been studied at GAIKER with support of LEAR and IRSA. Available intelligent materials show important limitations for automotive application:

- Activation temperature is very close to maximum use temperature of vehicle interior
- Adhesion between intelligent material and housing plastics is very weak
- High costs of the material

Furthermore it has to be considered that disassembly of the component from the vehicle is required prior dismantling. The activation energy for the studied intelligent materials is quite high, process efficiency should be improved. Research in other areas is expected to deliver new materials that can meet automotive requirements.

2.7.4 Study on new EES Concepts

From the results of the exploration on improvements options on component level at Ford it appears that it is very difficult to identify high potential improvement opportunities:

- The components are in most cases already highly optimised to fulfil their functional requirements at acceptable costs and within their technical framework
- Restricted substances have already been eliminated or reduced wherever possible

The new trends analysis identifies that new technologies could have a positive effect on product environmental profile. However, the analysis of real application of these technologies in the car are out of the scope of this project. Improvements mainly affect the use phase and the production phase. The end-of-life phase can only be affected to a very limited extend.

2.7.5 Improvement options resulting from the concept study

Based on the application of the guidelines several potential improvement options have been identified. For the highest potential options a detailed technical, economical and environmental evaluation has been done and in some cases prototypes have been developed:

- Substitution of mineral fillers, e.g. glass fibres, in EES plastic covers by natural fibres: this type of material shows a clear improvement potential on both environmental impact as on costs (cost reduction potential is estimated at ca. 15%). Two injection tests have been done to produce prototypes of a cover with simple geometry (seat mechatronics) and a very complex geometry (passenger fuse box). Performance tests have been done with the passenger fuse box. The part did not pass all required tests, but based on the results it is expected that with some design changes the requirements can be met.

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Figure 1: Seat mechatronics cover made of PP-30% hemp

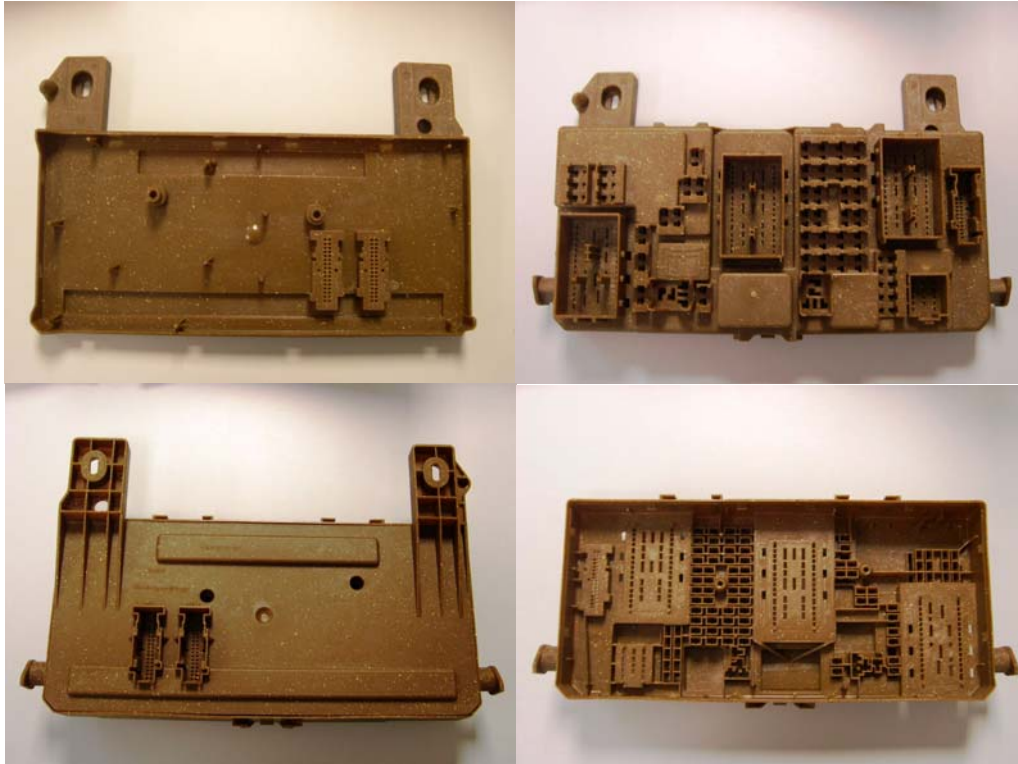


Figure 2: Ford C-Max Passenger Fuse Box made of PP-30% hemp

- Alternative wire harness technologies like Flat Flexible Cables, Flexible Printed Circuit boards, Plastic Optical Fibres, Aluminium wiring harness / Copper Clad Aluminium: Although there is an environmental improvement potential for most of the technologies, implementation of these technologies is much further ahead than is the case for the natural fibre reinforced plastics. The main reason for this is the high initial cost that makes one to one substitution not feasible. In addition there still are many technological aspects that should be improved. On the longer term alternative wire harness technologies will be gradually implemented in vehicles. The exception to this is the substitution of copper wiring by aluminium wiring. Aluminium has on the one side a significant cost and weight reduction potential, but on the other side a very high production impact. Based on the environmental analysis it has become clear that the gain in the use phase will be almost completely diminished in the production phase even when credits for recycled materials are taken into account.
- Substitution of Hg-containing lighting systems (HID headlights and backlights for colour LCD-screens) by LEDs: elimination of Hg-containing lights by LEDs for both head lights and back lights is not feasible yet because of several reasons. For head lighting LEDs are not homologated in the EU yet, which means that vehicles with this type of lighting will not be admitted on the road, also the price of LED-lighting systems is still quite high and performance levels have not yet reached the desired levels. For back lighting applications the requirements for in-vehicle screens are very high and cannot be met with LEDs yet. In addition power consumption is currently comparable or even slightly higher than the conventional systems. Developments are going very fast in this field and it is expected that both costs and energy consumption will further decrease beneath the level of conventional systems.

- Fuel efficient navigation: Based on this electronic feature a fuel consumption reduction of 3-30% can be achieved, depending on the type of routes a driver has to cover. Main critical point for implementation will be consumer acceptance, since in most cases the route with the lowest fuel consumption is not the fastest route.

2.7.6 Energy Management System

An energy management system has been developed (software simulation and hardware test bench) by LEAR to reduce the overall energy consumption of the EES and thereby reduce fuel consumption and driving emissions of the vehicle. The following has been concluded:

- Based on the simulation results it can be seen that the Energy Management Concept is able to reduce the fuel consumption (test bench based measurements) around 5% for short driving cycles.
- There is need to go further in the development and tunings of the solution.
- The battery life time (extrapolation to a long term drive cycle) seems to be around 10% increasing so the warranties and the effect on the customer could be relevant.
- The reduction on weight is driven at this time of development by the battery and is around a downsizing of 7-8% depending of the target car and use of it.
- More tests are needed with the test bench to look into the mild hybrid performance, and to have a clearer picture of the effects in the first step of hybrid application.

3 Final conclusions

The SEES project aimed at the development of guidelines, prototypes and processes striving for sustainable, clean, cost- and eco-efficient automotive electrical and electronic systems (EES). Within this project the partners provided an analysis of disassembly and shredding processes, developed recycling processes for EES materials, evaluated the environmental and economic life cycle of EES products, developed eco-design guidelines and concepts for a new EES. It has been shown that design changes can contribute to improving the production and use phase, but have no significant influence on improving disassembly. It also has been shown that disassembly of the studied parts prior to shredding is not reasonable for material recycling. However, innovative end-of-life processes are capable of recovering additional materials from EES where markets are available. Furthermore, concepts for an optimised EES which consider the whole EES life cycle are currently developed for which also technical and economical feasibility is analysed.

In particular improved EES designs and concepts and – to a significant lesser extent – the optimised end-of-life processes help to realise a more sustainable automotive EES scenario for the future.

4 Contact Information

Please find more information, presentations, papers and project reports on the SEES project homepage: <http://www.sees-project.net>

The SEES project has been coordinated by the Technische Universität Berlin (Technical University Berlin, TUB) at the Department of Systems Environmental Engineering.

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