Ecodesign **Me**thodology for recyclable **Tex**tile coverings used in the European construction and transport industry

Final summary report

1. Executive summary

The overall aim of EcoMeTex was to develop a tailored ecodesign methodology for optimising the design of textile coverings with regard to eco-efficiency and cost-effectiveness.

This comprises an analysis of the entire life cycle, identification significant environmental and economic impacts and hence potential for improvements, guaranteeing high product quality, as well as high product safety.

Life Cycle Assessment (LCA) allows to identify the crucial weak points in the life cycle and to assess improvement strategies to achieve an environmentally sensitive product design. LCA informs designers and developers concerning the implications of their choices on the environmental impacts and is therefore a decision-making tool.

The innovative methodology faces the challenge to solve the paradox of textiles coverings:

- On the one hand the bonding of the multi layers has to be solid and high-quality raw materials are used in different combinations to ensure long lasting products.
- On the other hand the multi layers have to be easy to dismantle for recycling, but dismantling procedures to facilitate material recycling are not yet part of the product design processes. Concepts focussing on technologies to recycle 'state of the art' textile coverings failed due to complex mechanical or chemical separation procedures and consequently due to their high cost- and low eco-effectiveness.

Re-design comprises not only optimisation of currently used material sets or manufacturing and distribution processes but also product and process innovations: It covers the development of innovative material adaptations as well as new approaches within the manufacturing process, recovery and reuse stage itself.

The focus of the EcoMeTex project is the design of a closed loop system of resources and raw materials enabling and facilitating full material recycling (see Figure 1).

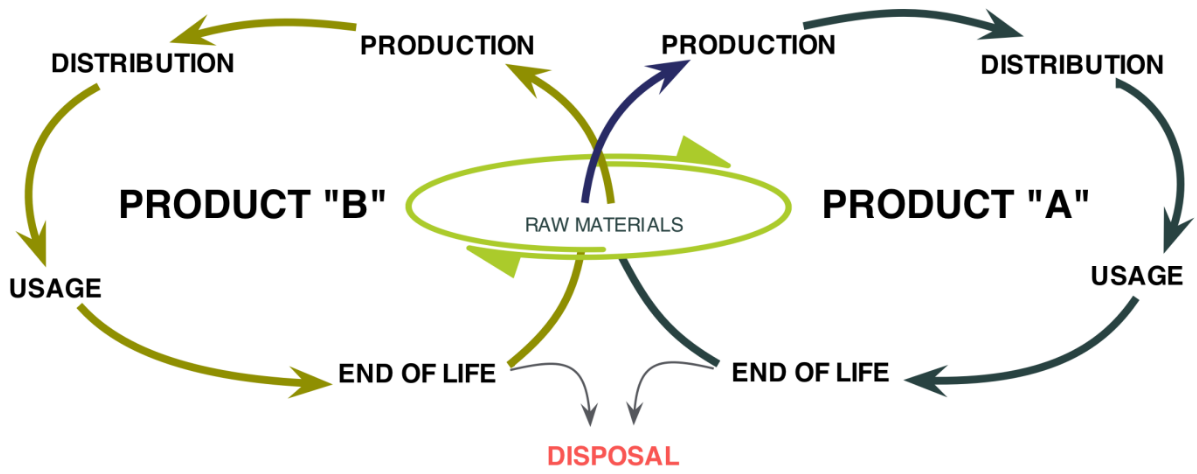

Figure 1: Principle of raw material pools

The feasibility of the re-design concepts will be proven by producing prototypes of eco-designed textile floor coverings. The work will be completed by describing the methodology in a Code of Practice which will be implemented in a customised, practical and intuitive software tool. The environmental communication of the received results is based on LCA results in the EN 15804 format. These Environmental Product Declarations (EPDs) are already widely used in the EU construction sector and provide data for architects and planers in a standardized format. The transferability of the ecodesign methodology for textile floor coverings to other sectors will be analysed using the example of luggage coverings for automotive applications representing the transport sector.

To achieve these goals three basic strategies where selected:

- Momomaterial approach
- Separation layer approach
- Material reduction

The following report gives an overview on the basic findings within the project EcoMeTex.

2. Summary description of project context and objectives

Basically the project was divided into three parts:

- The first part was the development and implementation of an ecodesign methodology.
- The second part was the transfer of the developed methodology to the textile sector and the realisation and evaluation of an eco-designed floor covering.
- The third and last part was the transfer of the developed ecodesign method into another industry sector.

2.1. Development, implementation and evaluation of ecodesign methodology for textile floor coverings

Work package 2 "Development, implementation and evaluation of Ecodesign methodology for textile floor coverings" aimed at developing and implementing a systematic approach, the ecodesign methodology, for textile floor covering products. The applied methodology should have a strong whole life cycle approach, but also consider the different stakeholders (especially participating enterprises) together with their production processes and involved technologies. On the other hand the methodology had to be flexible enough to be applied to different textile products and industry sectors.

The chosen system is therefore divided into 8 Steps as shown in Figure 2.

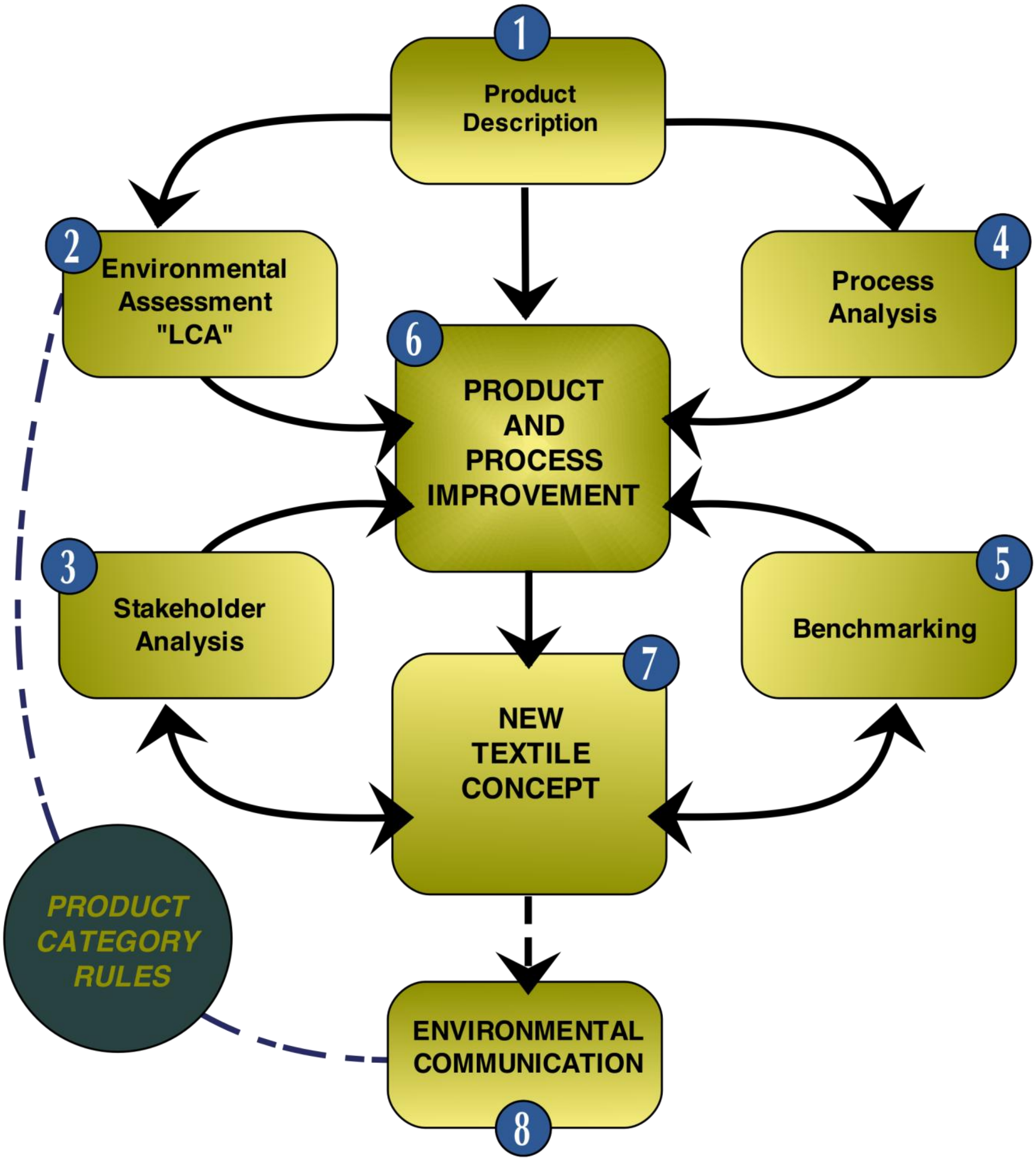

Figure 2: Eight steps of the ecodesign methodology for textile floor coverings developed for the EcoMeTex project

The organization of different research teams has been identified as an important factor especially in the early phase of the work. The objective was to establish the basis for collaboration and exchange of information and data on the products to be assessed. The selection and description of the products and the understanding of the motivations and expectations of all project partners in the consortium were important joint objectives of EcoMeTex. In addition, the structure of the ecodesign methodology in eight steps had to be customized with the active participation and inputs of the partners involved in the project. The objective was to develop the general framework and the specific data collection instruments for each step, namely, for the product description, environmental assessment, stakeholder analysis, process analysis, benchmarking analysis, product and process improvement, new textile concept and environmental communication. The developed templates should contain all the important product, process data, and environmental information for the assessment, and as such, the templates should become the instruments for the real data collection with the companies in the project. Therefore, a balanced approach was needed, for the depth and level of details, and the effort required for data collection.

The expected results from the assessment should include for example, the technical description of the products, their environmental assessments, the process description and their environmental assessments, the list of stakeholder and their requirements, the results from prioritization discussions, the lists of considerations for product improvements, the decision- making tools for new product design, the environmental communication templates, and other associated documents to each step.

Finally these results shall allow project partners to identify and describe concepts for (new) eco-designed products. The concepts shall not only be based on results of the method itself, but also include the inputs from the realization and testing of the eco-designed product concept at laboratory and pilot scales.

The selection of compatible materials for separation, and the use of appropriate technologies to produce textile coverings are to be combined in such a way, that recycling of the products is possible and feasible and will allow new input stream into raw material pools (see Figure 1).

The environmental assessments for these new product concepts should be completed to compare the outcomes of applying the ecodesign methodology at the product level, i.e. before and after. Furthermore one objective is the evaluation of the ecodesign methodology to confirm its applicability to different sectors and products.

2.2. Realisation of eco-designed textile floor covering

The first evaluation step was realized in WP3 “Realisation of eco-designed textile floor covering”. Goal of this work package was the development of concepts and prototypes of recyclable carpets on the basis of PA 6.

In order to show that a circulation of the carpets raw materials (in this case basically PA 6) would be possible in future, the recyclability of the new designed carpet has been demonstrated. To achieve this, different aspects of the process chain have been considered.

- Yarn production,
- Production of woven and tufted carpet,
- Development of possible recycling and logistic concepts.

Knowing the complex structure of textile floor coverings in combination with the different production methods is crucial for the understanding of the multiple individual tasks within the realisation phase.

Concerning carpets, a principal difference is made between tufted carpets on the one side (see Figure 3 left) and woven carpets (see Figure 3 right) on the other side.

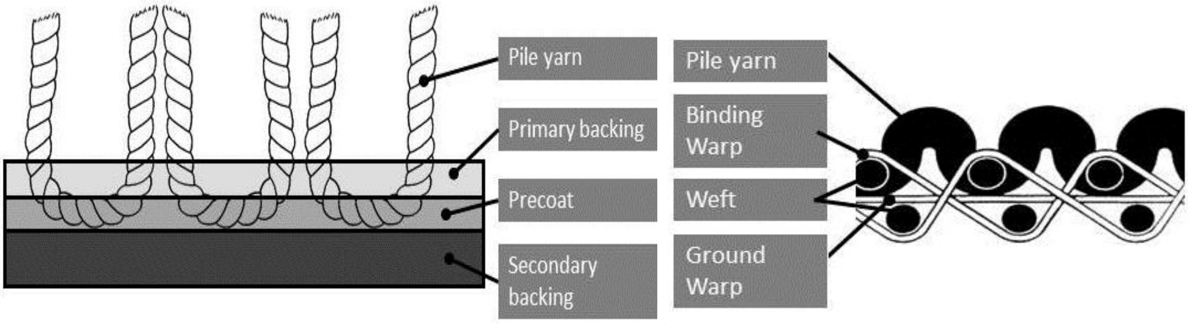

Figure 3: Schematic sketch of tufted carpets (left) and woven carpets (right)

Tufting is a widely-used technology for producing textile coverings. More than 60% of all textile floor coverings are produced by using this technology. During the tufting process, a pile yarn is tufted into the primary backing.

Afterwards, the tuft backing is coated in order to fix the pile and to provide it with a stable backing. The carpet used as benchmark for the area of the tufted carpets is the carpet tile Heuga 727 SD produced by Interface European Manufacturing BV, Scherpenzeel, Netherlands (INT). The particular aspect of those carpet tiles is that they can be produced in 50x50 cm pieces and can be laid loosely.

For this reason, carpet tiles have to have a good dimensional stability (+/- 0.2% deviation). This aspect is very important for the relocation and the usage (e.g. cleaning) of the carpet tiles. It can be realised due to a heavy and stable backing from bitumen and glass.

The idea is to have a separation between the polymer part (pile, primary backing and coating) and the bitumen part. Thus, only the upper area of the carpet has to meet the requirements of a chemical recycling process.

In contrast to the tufted carpet, a woven carpet (see Figure 3 right) does not get a backing. The textile structure of the fabric has a sufficient dimensional stability with the help of a thin coating and therefore meets all the requirements.

For this reason, it is the idea to implement the woven carpet in a form of a monomaterial carpet. Benchmark for the woven carpets is Taurus Rips Color SD of the company Anker-Teppichboden Gebr. Schoeller GmbH + Co.KG, Düren, Germany (ANK).

2.3. Evaluation of eco-designed textile floor covering

After that the new concepts were evaluated within WP4 “Evaluation of eco-designed textile floor covering”, which itself is divided into two parts.

In the first part, semi-finished products will be analysed to give a continuous feedback to the development processes of the new carpet structures.

The main objective of the second part is the evaluation of the final innovative (eco-designed) products, which should meet the quality requirements of the production chain and the demands of the health and safety regulations according to european and international standards.

Furthermore the results will be needed to compare the new concepts with the two benchmark products. Additionally, it has to be found out if the laboratory tests used for existing commercially available products are suitable for classifying the eco-designed textile floor coverings developed within the project.

Being construction products, textile floor coverings are addressed in the EU-Construction Products Regulation (CPR) which lists seven essentional requirements (ER) for the products. These ER are specified in detail in harmonised standards which are valid Europe-wide. For resilient, laminate and textile floor coverings, the specific harmonised standard is EN 14041. The description of the product and its application properties follow the specific product standards in which the classification requirements and the according test methods are set. For textile floor coverings, this product standard is EN 1307.

Accordingly, a testing plan divided into four stages is designed in order to carry out the evaluation of the final products (see Figure 4). The idea of the four stages is to give a fast feedback to the carpet developers about the properties of possible new materials and processes in a descending order.

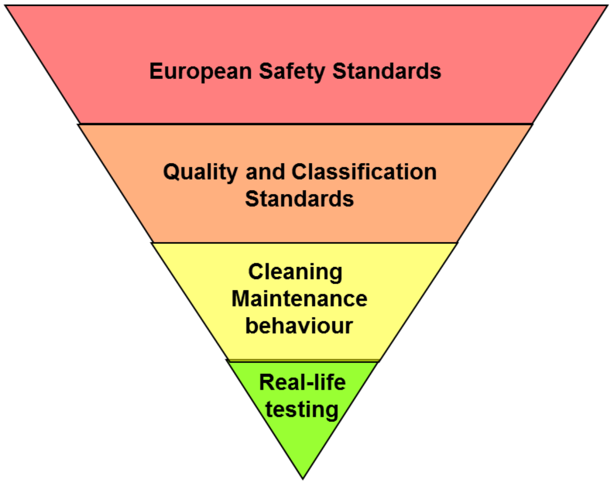

Figure 4: Stage system for testing and evaluation of textile floor coverings

For example, if the new eco-designed products do not meet health and safety requirements, they are not to be tested further or if they do not pass the quality tests, they are not installed in the framework of the Real-life testing (RLT). If a new product passes all four stages successfully, the goals of the eco-designed carpet are achieved.

2.4. Transfer of ecodesign methodology to other sector

Next to the construction sector the transport sector is used for the evaluation of the developed methodology. This is done in WP6 “Transfer of Ecodesign methodology to other sector/product”. The objective of this work package is to transfer the successfully applied ecodesign methodology for textile coverings in the construction sector to textiles in the transport sector, and to use it as the framework for a product innovation process.

As such, one of the overall goals of the EcoMeTex project is to develop and implement a versatile methodology which can be used for assessing various textile applications. At the end the project serves as a proof of concept, to understand the needs when adapting and using the methodology in another sector.

In this case the product selected as reference is a coated textile luggage cover for automotive.

The transfer to the second sector covers the full product innovation process, from the description and of the existing reference product, to the adaptation of all the templates for data collection, then the implementation of the steps of the methodology, leading to a new textile concept.

Likewise, the testing of this new concept, up to the production and evaluation of a prototype are part. Finally, the adapted ecodesign methodology will be evaluated.

3. Description of the main S&T results/foregrounds

3.1. Development of an ecodesign methodology for textile floor coverings

The ecodesign methodology for textile floor covering developed in the EcoMeTex project is structured in eight steps. The ecodesign methodology aims at improving the overall environmental performance of a reference product based on a comprehensive approach, as shown inFigure 2. Possible areas for improvement are derived from the results of the product environmental assessment (Step 2), the stakeholder analysis (Step 3), the process analysis (Step 4), and the benchmarking of products (Step 5). Ecodesign tasks and ideas are derived from the identified possible improvement areas (in Step 6). The ecodesign tasks are then translated into a new product concept (in Step 7). Lastly, an environmental communication instrument (Step 8) is developed for the new product concept.

Templates for each step were developed, as well as the concept for a tool (in WP5) and a “Code of Practice”. Especially the data collection instruments build the backbone of the methodology, and these shall be used in the planning and in the application of the methodology, and in the collection of the real data on product and processes. The following sub-sections describe each step, to show the use and results of the methodology.

The **Product description (Step 1)** is the framework that supports the following steps of the methodology, and contains relevant information on the product to be assessed. It is based on information from technical standards, descriptions of floor coverings, information from mandatory certifications and voluntary labelling schemes, economic, and environmental data. A template for the product description was developed, aiming at collecting the data in a structured manner, and with specific criteria and their corresponding connection (referencing) to technical data sources.

Two case studies were selected for the implementation of the ecodesign methodology. The first reference product is a woven broadloom carpet with 100% Polyamide 6.6 (PA 6.6) pile fiber, meeting the requirements for heavy contract rating. The product´s weight is approx. 1.5 kg/m^2. The yarn, weft, and warp account together for about 73% of the product´s weight, and the finish (backing) for 27% of the weight. The second reference product is a tufted tile of 100% Polyamide 6 (PA 6) pile fiber, also for the contract market, with an average total weight of roughly 4.2 kg/m^2. The yarn and primary backing account for 15%, the pre-coat for 20%, and the secondary backing for 65% of the product´s total weight per m^2.

The **Environmental assessment (Step 2)** deals with the description of the environmental aspects and impacts of the reference product over its entire life cycle. The goal of the environmental assessment in the ecodesign methodology was to calculate the Global Warming Potential impact (GWP) using the web application ECODESIGN+ of the ECODESIGN COMPANY ENGINEERING & MANAGEMENT CONSULTANCY GmbH, Vienna, Austria (ECO) for the assessment of the product carbon footprint in kilograms of Carbon Dioxide equivalents (kg CO_2-eq). This software tool allows identifying the environmental hot spots of a product, with a reasonable modelling time. The functional unit used for the environmental assessment of the reference product is one square meter, with a service life of 10 years. For both products, the largest impact (GWP contribution) is resulting from the materials in the pile yarn. The second largest contribution is due to the energy consumption for cleaning the products during their entire service live, and in third place are the contributions from the manufacturing processes.

The **Stakeholder analysis (Step 3)** aims at identifying important stakeholders and their concrete demands to be able to understand their requirements and further translate them into concrete technical parameters for product design. The different actors for textile floor coverings included the international bodies setting standards and labels, regulators, end customers, architects, contractors, carpet manufacturers, and post consumers (e.g., waste managing organizations). These stakeholders have a set of requirements which were identified and included for the analysis. The technical parameters influencing these requirements were also identified and displayed in a “relationship matrix” (Quality Function Deployment Matrix, or QFD). The QFD matrix shows the relationship between the most important technical design parameters and the important requirements form stakeholder.

In addition, a sub-set of stakeholders was well assessed in more detail, namely specific types of customers for textile floor coverings. These might be, for example, customers mainly interested in the performance, or customers interested in the aesthetics of the products. The results of the stakeholder analysis show that the most important technical parameters in the case of the woven reference product are:

- The pre-coat material
- The mechanical yarn construction
- The construction of the product.

For the reference tufted tile, the most important technical parameters are:

- The additive material in the pre-coat
- The pre-coat material itself
- The material of the secondary heavy backing.

Process analysis (Step 4) focuses on the systematic quantification of key parameters of manufacturing and auxiliary processes and activities, to understand their associated environmental aspects and impacts. The process analysis for the manufacturing of textile floor covering comprises an input-output assessment, focusing on material and energy flows in the production chain. First, each single manufacturing step, and how it is connected in the manufacturing sequence, is defined and described. Then, for each process, the input flows in terms of material (including the toxicity of materials) and energy inputs, as well as the output flows in terms of product, co-products, wastes, and emissions, are defined. The result from this process analysis is the identification of “hot-spots”, in other words, processes that need to be further investigated for improvement in terms of material efficiency, energy consumption, and/or toxicity issues.

The energy consumption during manufacturing is a relevant issue for both reference products, especially in the finishing step, namely the process involving heat for drying the backing compounds of the textile floor coverings.

The **Benchmarking of products (Step 5)** refers to the collection of information about “other” products such as competitor products, prototypes, and best available products. The objective is to assess how, and to which degree, these products fulfil specific stakeholder requirements when compared to the reference product. The benchmarking for the selected reference textile floor covering products show that most woven products are loop pile carpets containing Polyamide 6.6 (PA 6.6) yarn. The total weight and pile weight show differences according to the different luxury classes. The reference woven carpet is the lightest product in this comparison. For tufted tile products, most contain a loop pile of recycled PA 6 (e.g., Econyl®). Such products have a reduced (30% less) carbon footprint in the materials and production, when compared to products with virgin PA 6.

The **Product and process improvements (Step 6)** summarize all significant results of the previous five steps, to identify a range of product and process improvement actions. Improvement actions have been generated during "product improvement workshops" with project partners, where all results for each reference product were thoroughly discussed. The outcomes for the reference woven broadloom include a list of fourteen improvement measures, and for the reference tufted tile, ten measures. These measures range from new yarn compositions and new mechanical properties, to different pre-coat compositions, and alternatives for manufacturing using different technologies, for example those which allow pile fiber fixation without using additional components. In general the improvement measures fall into four categories or improvement strategies:

1. Improving the construction of the textile floor covering product
2. Improving the production processes
3. Prolonging the service life
4. Closing the loop of materials

The identified improvement actions need to be assessed in greater detail and prioritized for putting forward a **new textile concept (Step 7)**. The criteria for the evaluation are based, for example, on benefits, effort, and risk of the proposed improvement action. Ideally, the improvement actions with high benefit, low effort, and low risk will be taken into account. Next to the evaluation of the improvement actions, the possibility to combine different actions was an important objective when formulating the new product concept(s). The improvement measures were prioritized and combined for the description of new product concepts or variations for each of the reference products. These measures were also proposed and selected to support the recyclability goals of the project, primarily looking at the material compositions, which allow physical and chemical recycling of the layers in the carpet**.**

As part of the project´s demonstration work, the industry partners produced a set of prototypes as in the technical realization part, considering recommendations from the methodology on a monomaterial and a separation layer approach using a pile of PA6. In this way, the complete carpet is designed according to the requirements of the PA6 depolymerisation process, so that it can be sensibly conveyed in a chemical recycling plant. The new tufted tile concept for example also includes a non-woven primary backing based on PA6. A coating composition allows the use of a separation layer for the tile. This facilitates the separation of the pile thread with its tufting medium and the carpet backing.

The final step of the ecodesign methodology is to communicate the environmental performance derived from the implementation of prioritized measures for the product (and process) improvements to relevant stakeholders by means of the **Environmental communication (Step 8).** Textile floor covering manufacturers are already using environmental product declarations (EPD) for their environmental communications. EPDs according to ISO14025 and EN 15804 contain pertinent information to be communicated in the commercial sector. The EDP provides information on products and on its environmental performance by using predetermined parameters, which comprise, among others, a sufficiently comprehensive set of impact category indicators. The information provided is credible, transparent, and structured in a clear way. It is verified by a third party and leads to reproducible results. Therefore the EPD is the recommended instrument for external communication with the contract (B2B) market, concerning the environmental impact of the new eco-designed textile floor covering in the EcoMeTex project.

After finishing the development of the methodology a customized tool should be set up. The developed customized tool concept can be seen as the repository of all the ecodesign methodology information and knowledge created and developed with and for the industrial partners in the project. The tool is sequentially structured like the eight steps of the ecodesign methodology (product description, environmental assessment, stakeholder analysis, process analysis, benchmarking, product and process improvement, new textile concept, environmental communication). The tool is realized as an interlinked PPS-tool, and includes all templates of the methodology as downloads. These templates assist in the clear documentation of the relevant information, and in providing a comprehensive overview of the work.

Moreover the tool concept includes four specific ecodesign strategies for textile floor covering, in line with the ecodesign strategies in the software ECODESIGN PILOT, ECODESIGN COMPANY ENGINEERING & MANAGEMENT CONSULTANCY GmbH, Vienna, Austria. These strategies have been selected based on the results from the analysis steps, and based their relevance to support the product and process improvement step (Step 6) of the methodology. These four ecodesign strategies for textile floor coverings are:

- **Strategy 1:** Improving the construction of the textile floor covering product
- **Strategy 2:** Improving the production processes
- **Strategy 3:** Prolonging the service life
- **Strategy 4:** Closing the loop of materials

Following the structure of the ECODESIGN PILOT, each strategy contains a group of checklists. The idea is to use questions and examples to guide the user to think about alternatives for addressing the specific question and environmental issue. In this way, each checklist starts with an environmental assessment question, related to the priority of the topic addressed. The checklist then gives background information on the topic, as well as information on current research, specific knowledge, and examples from the EcoMeTex project.

The different strategies and their checklists have already been successfully tested during two in-house training workshops with the project partners ANK and INT. The checklists worked generated lively and creative discussions about additional product improvement ideas generated during the training.

At the end of the project the ecodesign methodology as a whole was evaluated. This evaluation showed that the structured approach to analyse products from an environmental perspective is robust and clear. For selected steps the data collection efforts are rather high, and identifying product improvements and new product concepts needs the strong involvement of experts, particularly from industry. The application of the ecodesign methodology in the EcoMeTex project has been completed for textile coverings in the construction sector, looking at woven broadloom and tufted tile carpets for contract use. The customized tool concept, together with the Code of Practice, is a compilation, in practical form, of the methodological approach and its specific results in the EcoMeTex project.

3.2. Realization of the eco-designed textile floor covering

As previously described there were three different approaches to develop a new textile floor covering structure:

1. Separation layer
2. Monomaterial
3. Material reduction

Within the project two different carpets were identified as reference products. The first one was a tufted carpet tile and the second one was woven broadloom carpet.

3.2.1 Tufted Carpet

A tufted carpet consists of several layers (see Figure 3). The top half layer (THL) is a nonwoven (primary backing) and the pile material. The bottom half layer (BHL) is the secondary backing and consists of different materials like bitumen and some other filler. Due to the fact that the tufted carpet consists out of several layers with different materials the use of the monomaterial approach was not feasible. Therefore the separation layer approach was chosen. The idea was to separate the top and the bottom half layer from each other. Furthermore it was the idea to use the monomaterial approach for the THL. This was due to the fact that a monomaterial THL can be better recycled after a possible separation process.

Current primary backings consist up to 100% out of Polyethylenterephthalat (PET), which would cause a disturbance in the recycling process. To realise a monomaterial THL a new high PA 6 containing bicomponent yarn and fleece was developed. The new backing, which was developed within the EcoMeTex contains only 60% PET and 40% PA 6.The main features were its very high strength after tufting and its dimensional stability at elevated temperatures. Another main feature of this particular nonwoven was its recyclability, especially in combination with PA 6 tuft yarns. In this way it did not disturb the recycling process.

For tufted carpets it is important to fix the yarns in the primary backing. Concerning tufted carpets there should also be a good bonding between the top and the bottom half layer. In the project, two different approaches for the coating were used.

One of the procedures was to melt off the yarns with the help of a calender roll. At the other procedure, the yarns were stuck with a polyolefin (PO) dispersion.

The novelty was that the layer for the fixation of the yarns could also be used to establish a separation layer between the THL and the BHL. At the calender technology, the separation layer was performed thermally reversible and at the coating with the polyolefin dispersion a thermally irreversible separation layer arises. In the following both techniques will be described more in detail.

Calender Technology

The individual process steps of the calender technology procedure are shown in Figure 5.

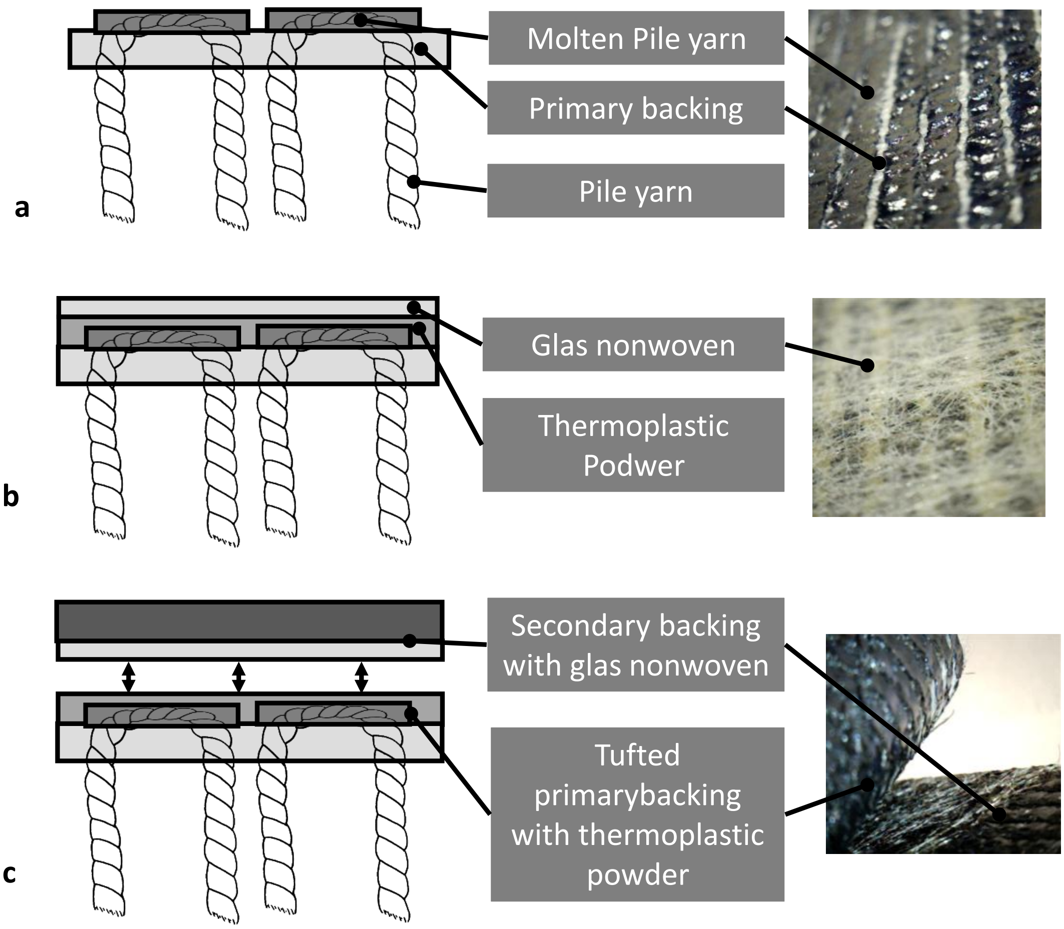

Figure 5: Process steps of the calender technology

For the separation, the used carpet had to be heated up to only 100°C. At this temperature only the separation layer softened, so that the bond between the top half layer and the secondary backing decreased and an easy separation was possible.

Next to the basic development of the separation layer, this technology was adapted to the special requirements of a carpet out of PA 6. This includes the reduction of the emission of caprolactam, which occurred due to the melting, the optimization of the dimensional stability due to the choice of thermoplastic binder and the equipment with permanent anti-static agents. Concerning the equipment with anti-static agents, the whole carpet had to be considered, because otherwise an isolation layer occurred due to the fused yarns and the thermoplastic powder. It appeared that by an insertion of anti-static agents in yarns, primary backing and separation layer, a sufficient anti-static behaviour could be achieved. In the area of flame retardant, this technology, furthermore, showed good properties.

Coating

The second separation technique was the thermally irreversible separation layer with a coating. The coating was done with a dispersion. However, the coating was based on a polyolefin dispersion, which did not disturb the recycling process. Thereby, the dispersion was applied on the tufted primary backing and afterwards dried in an oven.

The thermal irreversible separation layer was thereby realised through microspheres. It refers to small plastic beads which are filled with a propellant. At a heating point over a certain temperature, the gas expands and the beads extend to a multiple of their original size. Due to this expansion, cracks occur in the dried dispersion and the layers dissolve from another. The effect mechanism is shown in Figure 6.

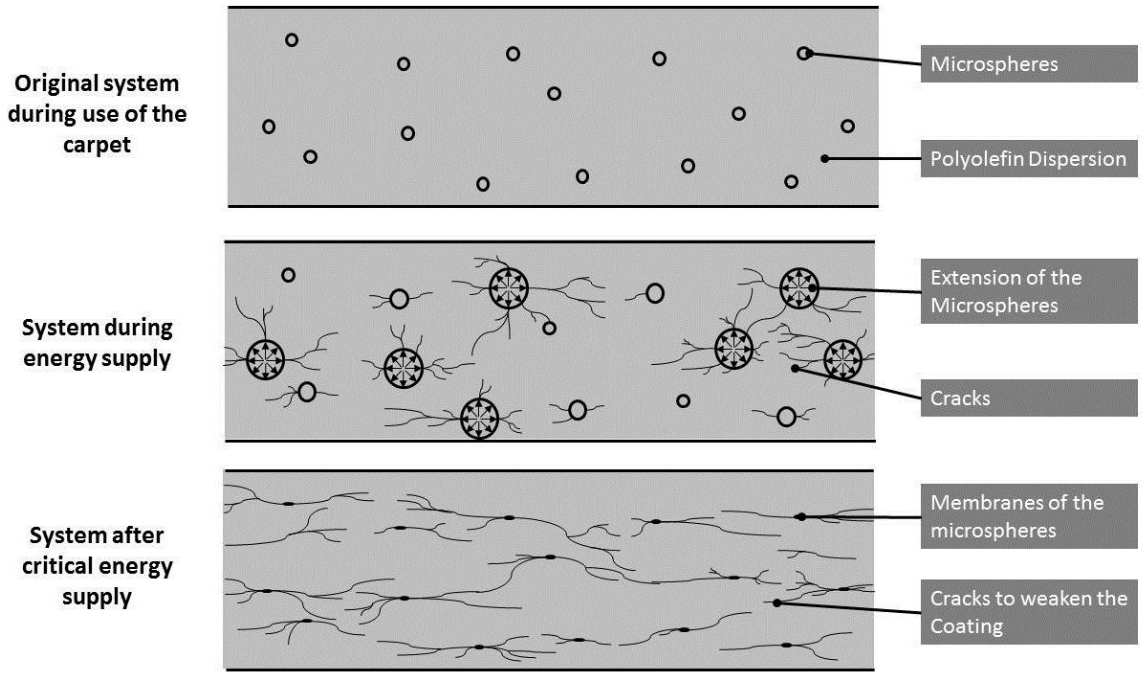

Figure 6: Effect mechanism of the microspheres

Next to this basic development of the separation layer the processing parameters of the microspheres in the production process of the carpet tiles were also examined. Thereby dependencies of the different separation concepts and the processing technology in the carpet production process were analysed.

After that the carpets were manufactured in industrial plants. In the area of tufted carpets, several industrial attempts have been performed at INT. A standard tufted primary backing was used and calendered at KLIEVERIK HELI BV, Oldenzaal, Netherlands (KLI), equipped with thermoplastic powder and combined with a glass fleece. Afterwards, the product was equipped with a bitumen backing at the production plants at INT. The resulting material showed good properties compared to the defined stakeholders. However, the binding to the secondary backing through the separation layer was not sufficient. This was repaired, in the following, due to material modifications concerning the thermoplastic powder.

After that some trials with a polyolefin coating with microspheres were done. As the source material, a standard tufted primary backing was used. This material was coated with a mixture of polyolefin dispersion and microspheres at the coating plants at INT. After that the material was dried and afterwards the secondary backing was applied.

Those attempts showed that the impact of the microspheres in the later separation process was dependent on the processing. Thus, laboratory tests were performed afterwards, which examined the connection between process control and damage of the microspheres and therefore enabled a better setting of the processes.

Meanwhile, an antistatic nonwoven solution for the production of the recyclable carpet tile was developed, which decreases the static discharge and loading significantly. At the end of the project three different carpet concepts were located in a real life test at the Institut für Textiltechnik der RWTH Aachen, Aachen, Germany (ITA).

3.2.2 Woven Carpet

The structure of a woven carpet can be seen in Figure 3. In contrast to the tufted carpet the woven carpet has only a one layer structure. Therefore in this case the monomaterial approach was chosen.

The main challenge for woven carpets, which are purely from PA 6, was the lacking dimensional stability of the PA6. This dimensional instability is reflected in the fact that in the final coatings and drying of the woven goods, a shrink happens and therefore the carpet shows shafts at a later point. For this reason, the combination of PA6 and PET is currently used. The amount of the PET is thereby so high, that the recycling process will be disturbed.

In order to anticipate this shrinkage of the woven goods, yarns were developed, which have a small shrinkage. For the production of such yarns, further process steps were necessary, which initiate the shrinkage already in the yarn. Those yarns were then interwoven at production plants and afterwards, the resulting woven goods were tested. The result of those attempts was that the shrinkage was, on the one hand, reduced, but on the other hand, the narrow requirements cannot be met. Based on those attempts, other material combinations were used, which promise a better dimensional stability. This was due to the recycling procedure of Polypropylen (PP). Therefore, different areas of the woven goods are superseded by PP. The use of PP was thereby so small that a disturbance of the recycling process did not happen. Nevertheless, the use of PP was sufficient in order to improve the dimensional stability. The processing of the woven goods and different trials during the project showed that this improved dimensional stability was also not sufficient.

3.2.3 Recycling

There are basically two different ways to recycle a polymer like PA 6:

- The first is the physical recycling process that proceeds through melting, filtering and extrusion.
- The second is the chemical recycling process that consists in the break down back to the raw monomers, which will be used to produce the original polymer once again.

Physical Recycling

The first approach within the project was to use the physical recycled process. The idea was to use waste PA6 yarns and raw materials within this process. The waste yarns were melt-filtered and pelletized. The physical recycled material could be processed on a melt spinning line but the resulting yarns were undefined black and not dyeable.

Thus, they were not suitable for carpets. One approach to solve this problem was to produce bi-component filaments (see Figure 7).

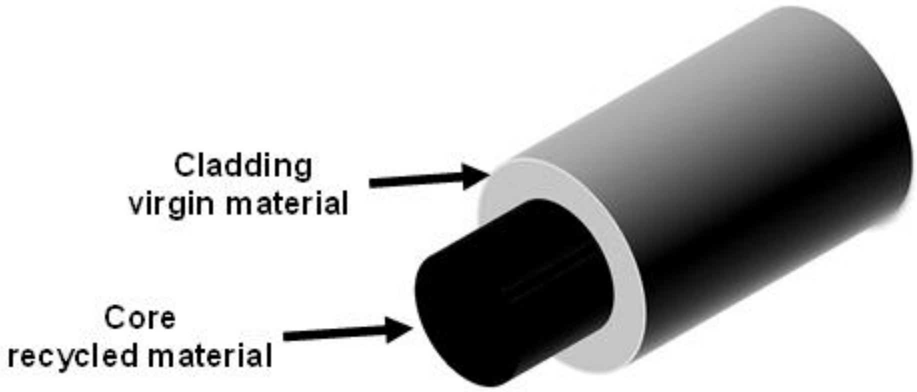

Figure 7: Concept of bi-component filaments

Recycled material was used for the core and virgin material was used for the sheath that covered the core material. But, the yarns were still grey-black, even with a core/sheath ratio of 25/75. Dyeing of the sheath material was not working either. Thus bi-component fibers were no solution to bring in physical recycled material into the pile yarn of carpets. Thus, physical recycled material was not suitable for carpets because of the missing dyeability (see Figure 8).

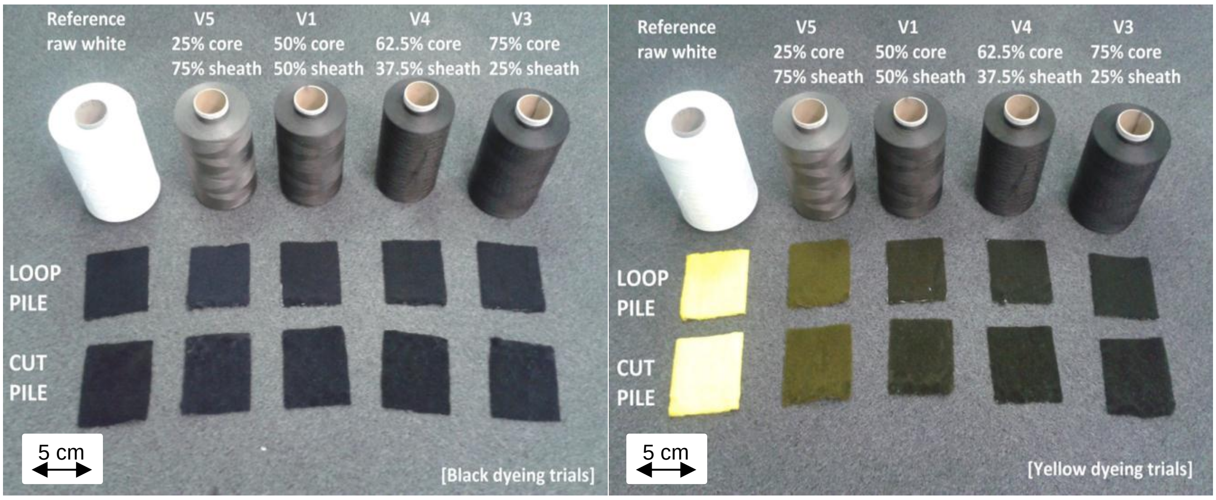

Figure 8: Black (left) and yellow (right) dyed physical recycled filaments

Another idea to use the possibilities of physical recycling was to remove PET and PA 6.6 from PA 6 via melt filtration and creating, a raw material out of old carpets which was useful for the chemical recycling. But even with a filter fineness of 16 µm, a removal of the impurities was not possible. The melting temperatures were too close together, so that all materials were molten and passed the filters. But, the fiber material from older carpets contains more than only impurities through other polymers. Thus, this material contains more than 10% limestone and latex. Those materials were removed with a single filtration with 250 µm filter fineness in a way that the material can be used for injection moulding.

Chemical Recycling

The aspired recycling procedure for the different carpets was the chemical preparation. With the help of this procedure, yarns could be produced which could meet the requirements like dyeability of the yarn.

Furthermore the advantage of this process was that the passage back to caprolactam (the monomer) allows a first separation of the components typically found in the carpets, like other polymers, pigments, soiling and so on.
This happens because the recycling process is divided into two steps:

- At first, there is the depolymerization of melted PA 6, that is converted back to caprolactam and stripped away with the water steam, while the biggest part of the impurities remain in the reactor and they are discharged as molten phase from the bottom;
- Secondly, there is further purification, where the impurities with a boiling point close to the one of caprolactam are removed by using a distillation column.

In order to be able to run the recycling economically with this procedure, some boundary conditions of the recycled material have to be fulfilled. Those conditions are:

- High content of PA 6 (as high as possible)
- No PET, Latex, PA 6.6 or inorganic salts
- Low content of PP

One goal of the project was the demonstration of the recyclability of the new carpet concepts. It was clear from the weaving trials that a 100% monomaterial PA 6 carpet was impossible to produce. Therefore one target of the recycling was to determine which polymeric material was suitable as impurity in a carpet. PP, PET and PA 6.6 were investigated; they were inserted all at once in the pilot plant, along with PA 6, and the caprolactam obtained was analyzed, it was analyzed after the depolymerization and after the purification.

From the combination of analytical results and management of the process, the conclusion was that the preferred polymer is PP. In fact, both PA 6.6 and PET undergo degradation in the process conditions and the output was a lower quality of caprolactam.

Next to those basic exclusions of materials, also concrete materials were tested and examined with regard to their recyclability within the recycling. For example, different kinds of hotmelts were investigated. The results confirmed that PO based hotmelts were more suitable for recycling than PA and PET-based hotmelts.

Next to the different materials also antistatic and flame retardants were investigated. Antistatic can be easily managed, if the carpets were both carbon fiber and steel based. Concerning flame retardant, the situation was more complex, since most of them were not inert during the depolymerization process. For example, graphite expanded at the production process temperature, while Alumina Trihydrate (ATH) was not suitable since the process requires acid pH to proceed.

Showing the recyclability, the individual components of the carpets were commingled, in order to simulate a real carpet structure (both for tufted carpet and for woven broadloom). The caprolactam obtained from the pilot plant can be judged as a good product, surely adequate for using. This material was used to obtain PA 6 and in all cases the result was a good polymer, with production time and process parameters that did not differ from the standard production. In conclusion, the trials gave an acceptable result. Therefore the recycling through depolymerization would be possible.

3.3 Evaluation of the eco-designed textile floor covering

The different recycled carpet concepts have to be tested in WP4 “Evaluation of eco-designed textile floor covering” to define the quality. This evalution can be divided into two different steps.The first step of the evaluation process is the testing of the semi-finished products. By differential scanning calorimetry it was observed that the molecular weight decreases with extrusion while recycling and that the heat setting process can be influenced positively.

The result of capillary rheometry is that viscosity of physically recycled material is lower than the viscosity of chemically recycled material.

The thermogravimetric analysis at air atmosphere shows that physically recycled material contains ingredients with lower molecular weight than chemically recycled material. These ingredients can be additives and/or macromolecules with a shorter molecular chain.

In tensile tests, shrinkage tests and crimping tests, physically recycled material shows slightly worse material properties than PA 6 virgin material but still within acceptable limits.

In tenacity and shrinkage tests on chemically recycled material of various heat-setting parameters it was found that by the discontinuous autoclave process the shrinkage reduction is doubled compared to the continuous superba process.

Beyond that, micro-chamber emission tests were conducted on different yarns, primary backings, tufted grey cloths, pre-coatings. With this qualitative method, no restricted substances emitting from the products were found. However, attention was turned to the emission of ε-caprolactam, which is the monomer for polyamide 6. Further analyses of this substance were carried out on the finished products.

The second part of the testingis the evaluation of the final products. These tests were divided in to the four different stages seen in Figure 4.

Stage 1: EU Construction Products Regulation and EN 14041

Three eco-designed prototypes emit more TVOC (Total Volatile Organic Compounds) than permitted in the Ausschuss zur gesundheitlichen

Bewertung von Bauprodukten (AgBB) scheme of Deutsches Institut für Bautechnik (DIBt). The reasons for this are high ε-caprolactam emissions from the yarns. In tests on semi-finished products it is shown that a reduction of these emissions is possible by washing at high temperatures, washing with detergents or an oven treatment at high temperatures.

The odour requirements set by GUT Gemeinschaft umwelt- freundlicher Teppich-boden e.V., Aachen, Germany are fulfilled by all the eco-designed prototypes tested.

All prototypes are flame resistant similar to the reference products.

For evaluating the electrical behaviour, a walking test and resistance measurements have been done. On all eco-designed prototypes, the body voltage measured in the walking test is below the critical limit of 2 kV. The vertical resistance is too high on the eco-designed prototypes produced with the fusing technology. The other prototypes are statically dissipative like the reference products.

Stage 2: Quality and Classification – EN 1307

With the fulfilment of the basic requirements, all eco-designed prototypes are generally suitable for classification into use classes.

All eco-designed prototypes are classified for moderate or heavy contract use. For the woven eco-designed prototypes, a change of the colour of the ground fabric would most likely lead to appearance retention similar to the reference product.

Another aspect that needs consideration is the resistance to fraying which is not given for the products backed with the fusing technology. For this production technology, process parameters have to be adapted further in order to reach the requirements. This applies also with regard to delamination of top and bottom layer in the castor chair test.

The tufted loop eco-designed products show severe curling and doming due to the various heat and water influences in the test. These characteristics are highly dependent on the properties of the primary backing. However, if the tiles are adhered permanently in installation, the requirements do not have to be fulfilled.

Stage 3: Cleaning and Maintenance

In soiling and cleaning, the eco-designed prototypes have similar characteristics as their corresponding references. Slight deviations in some results are attributed to different pile yarn colours.

The stain removal properties are comparable from reference to eco-designed prototype in the tufted products. On the woven eco-designed prototypes, some of the stains could not be removed as good as on the appendant reference product.

Stage 4: Real-life Test (RLT)

Two major questions have to be considered on the basis of the results of the RLT:

- Are the eco-designed prototypes suitable for real-life wear?
- Are the existing test methods suitable for testing the eco-designed prototypes?

In order to answer the first question, the median grades of the 9 assessors are shown in Figure 9.

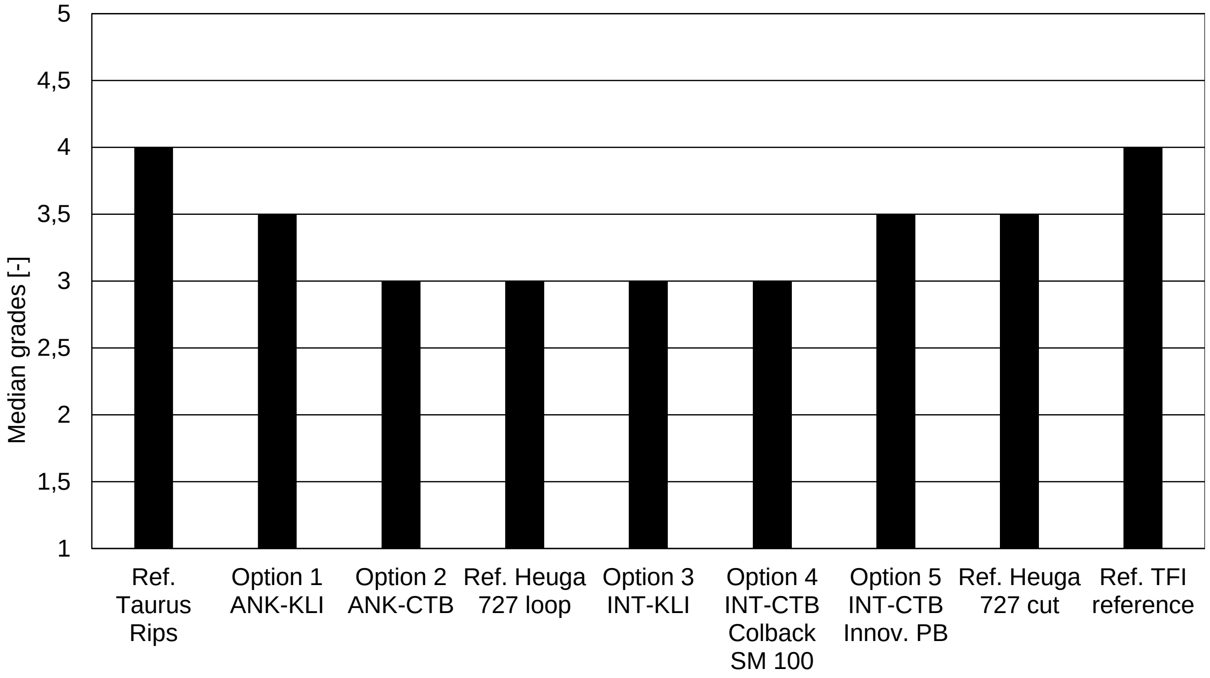

Figure 9: Median appearance change grades of 9 assessors after 6 months RLT

The slightly worse results of the woven prototypes result from the ground fabric's colour. A change from white to black would most likely improve the appearance retention in a real-life test. The appearance retention in real-life of the tufted prototypes is at least as good as of the appendant reference. Consequently, the eco-designed prototypes are suitable for real-life wear considering the topics addressed in the set-up.

In Figure 10 and Figure 11 the median assessment grades for the RLT and the Vetterman drum test (short term and long term) are plotted. The deviation from laboratory test result to RLT result is much higher in the industrial comparison products than in the eco-designed prototypes and their references. Therefore, the conclusion is that the existing test methods are suitable for testing the eco-designed prototypes.

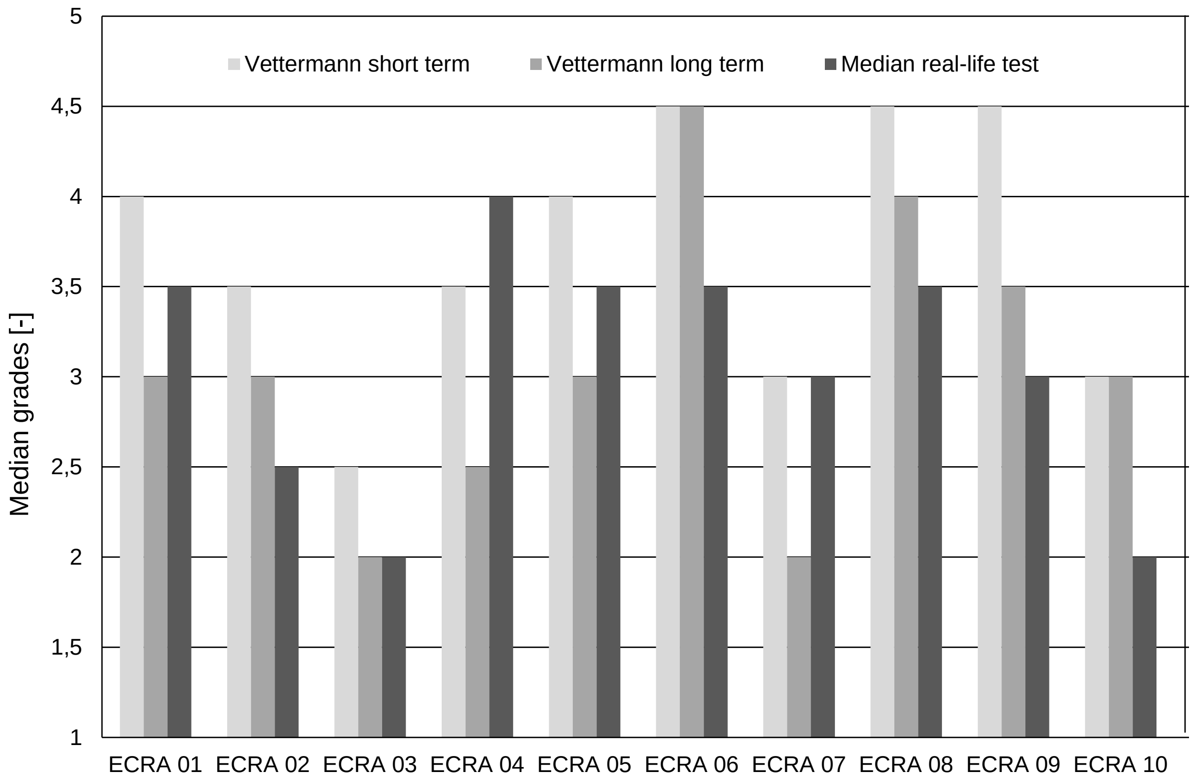

Figure 10: Appearance change grades Vettermann drum test and RLT (1)

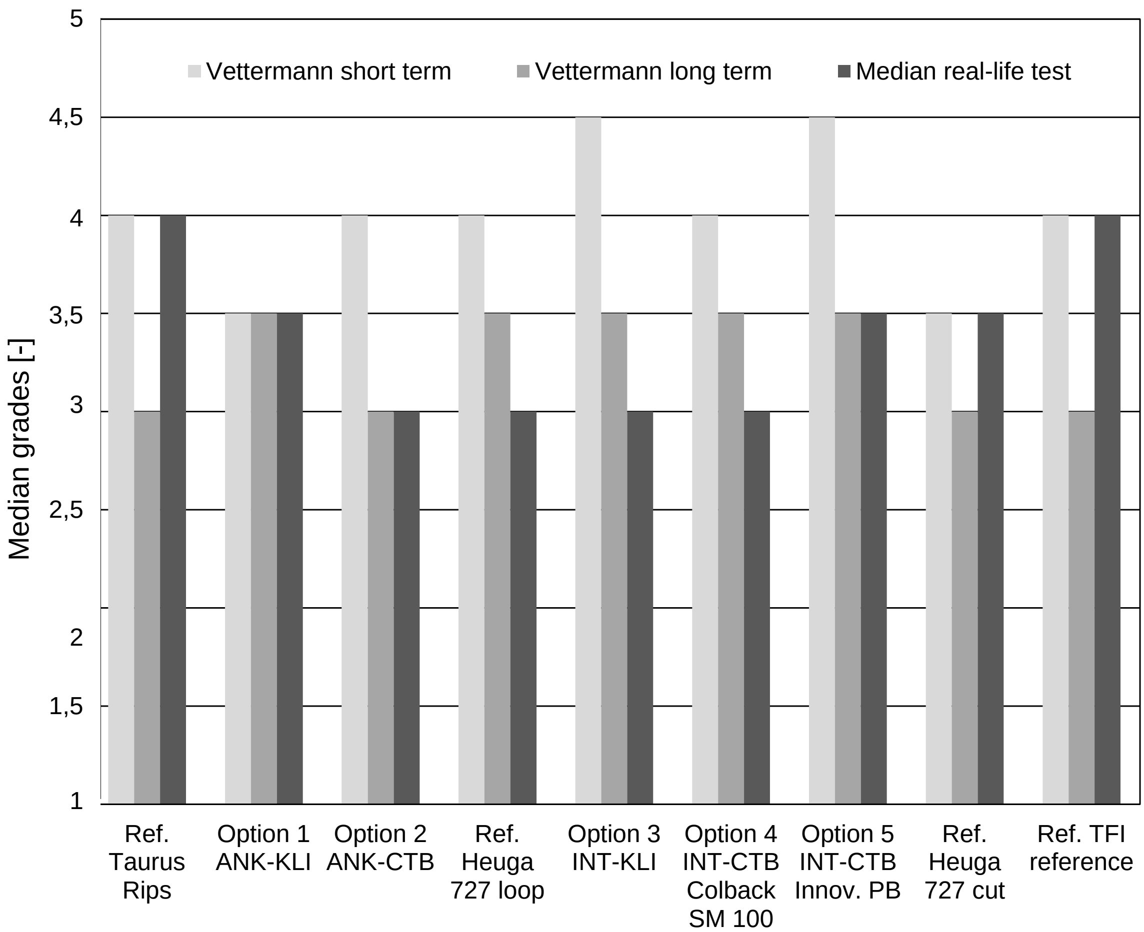

Figure 11: Appearance change grades Vettermann drum test and RLT (2)

Beyond this answer to the stage 4 questions, a closer look at the results has to be taken. The deviations of the laboratory results to the RLT results of the industrial reference products are highly inconsistent. Additionally, the grade of wear of all products after 6 months in RLT in a moderate contract use is more severe than expected. Thus, a prediction of the time of usage in the classified use class is not possible as it was by the time the test methods and classification scheme have been implemented. Future research has to solve this problem.

The eco-designed prototypes were manufactured until project month 27 for the stage system tests. Afterwards, on feedback of the test results, improvements on the eco-designed products have been made. On some of these products, special characteristics have been tested and a feedback to the manufacturing work packages has been given. Some properties of the products manufactured after month 27 are improved compared to those of the prototype products. Due to limited work package time and availability of material, these improved products have not been tested according to the complete stage system.

3.3.1 LCA-Analysis

At the end of the carpet realization part of the project a comparison was performed between the reference textile floor covering products and three eco-designed products, developed in laboratory and pilot scales during the project.

The aim was to assess the environmental aspects and impacts of these eco-designed textile floor coverings, and overall, to evaluate the results and benefits of the ecodesign methodology.

For this purpose, Life Cycle Assessments (LCAs) were carried out, covering the entire products life cycle "from cradle to grave". Two LCAs focused on the reference products, and three LCAs dealt with eco-designed product concepts.

The LCA studies included:

The two references product produced by Interface and Anker. Additionally two new designed products with different separation layer approaches based on the Interface product (coded ECO 1 and ECO 2), as well one new designed woven product based on Anker's reference product (coded ECO 3). Data for manufacturing and for the laboratory scale separation technology of these concepts were obtained from project partners. Different logistic scenarios have been modelled and analysed.

For all of these products and scenarios complete EPDs have been created including full background reports in the requested EN 15804 format.

A critical review process with external LCA experts was conducted to ensure consistency between the LCAs, following the requirements of the international standards ISO 14040 and 14044.

According to the review statement, the LCAs were correctly conducted, with appropriate data and calculations. The LCA reports were evaluated as transparent and consistent.

The following Figure 12 shows some of the results of the LCA study. GWP potential calculated for the tufted carpet is used as an example.

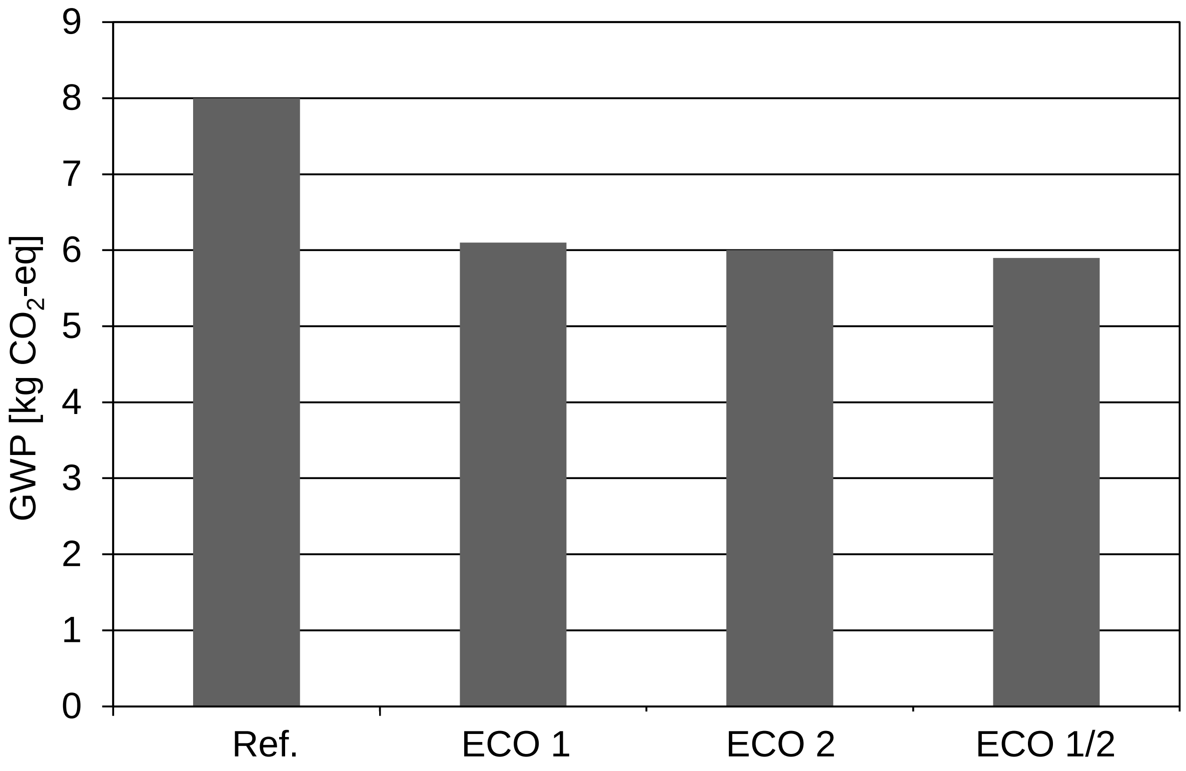

Figure 12: Global Warming Potential; Cradle to Gate results for the reference tufted tile and the eco-designed products

Figure 13 and Figure 14 show the basic reduction of the GWP that can be achieved when chemically recycled PA 6 fibers are used for the production of the new designed carpet. As shown in Figure 12 the overall difference in the GWP for ECO 1 and ECO 2 are small and can be neglected for principle discussion. In all further comparisons therefore the average values (ECO ½) have been used.

Figure 13 shows that the use recycled PA 6 fibres reduces the GWP already by 29%.

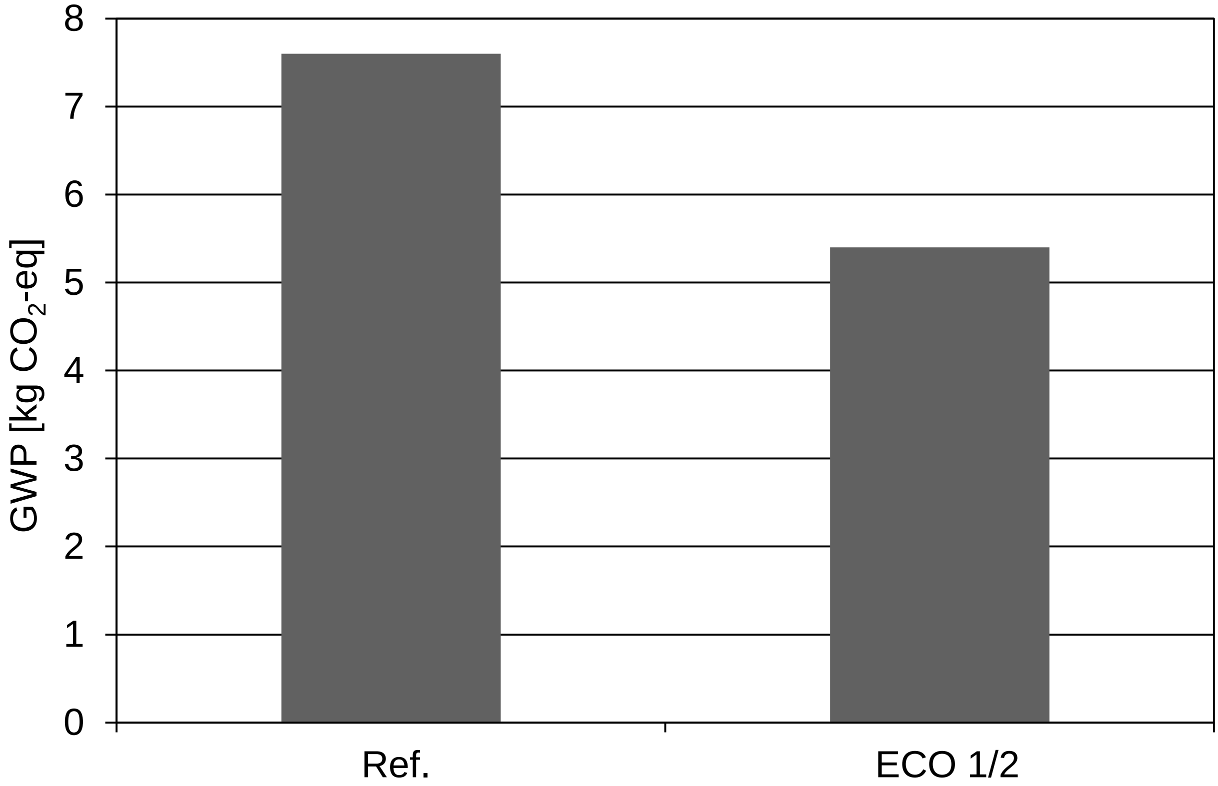

Figure 13: Reduction of GWP due to the use of recycled PA 6 fibers

Reference product and EcoMeTex designed carpets are fully comparable with respect to their use specification. Consequently no differences in the energy and water and detergent consumption are to be expected.

Based on an average life time of 10 years Figure 14 shows the results of the cradle to end of use comparison. Environmental impacts of transport to the construction site as well as the installation of the carpets are identical.

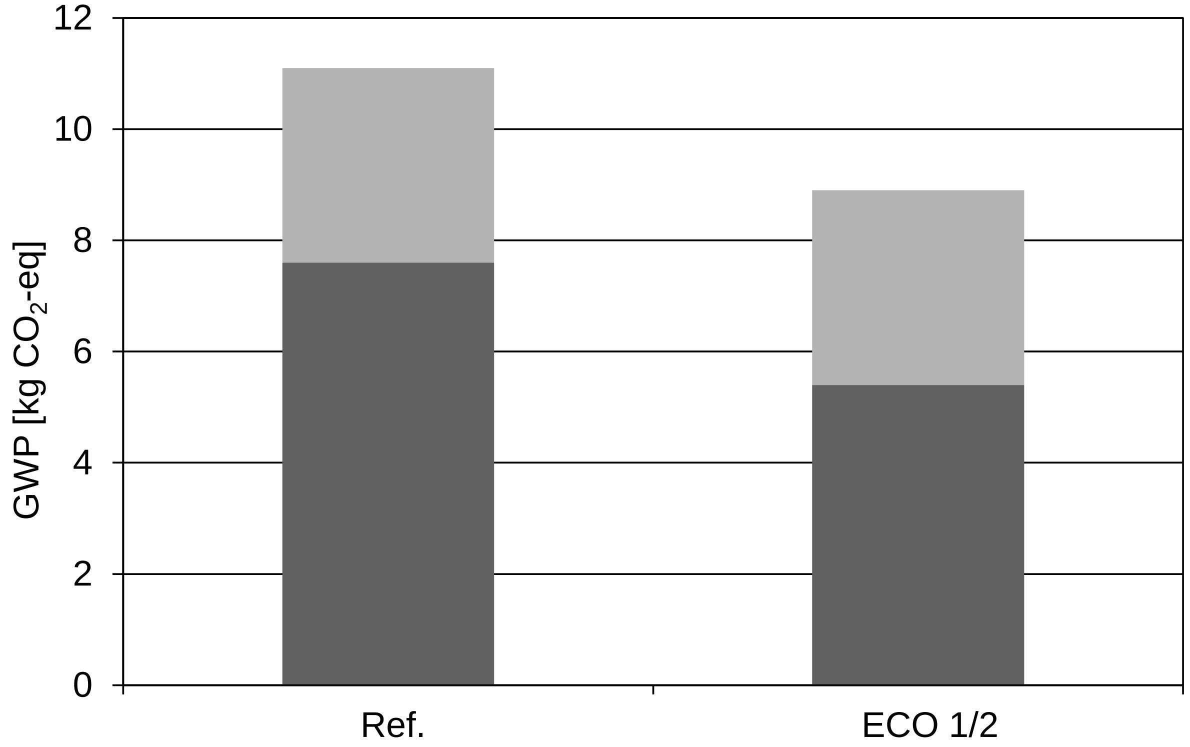

Figure 14: Comparison including a use phase of 10 years for carpets

The End-of-life EOL logistic scenarios differ significantly. **Figure 15** shows that the environmental impact caused by the transport of the EcoMeTex carpets to the recycling locations is five times higher.

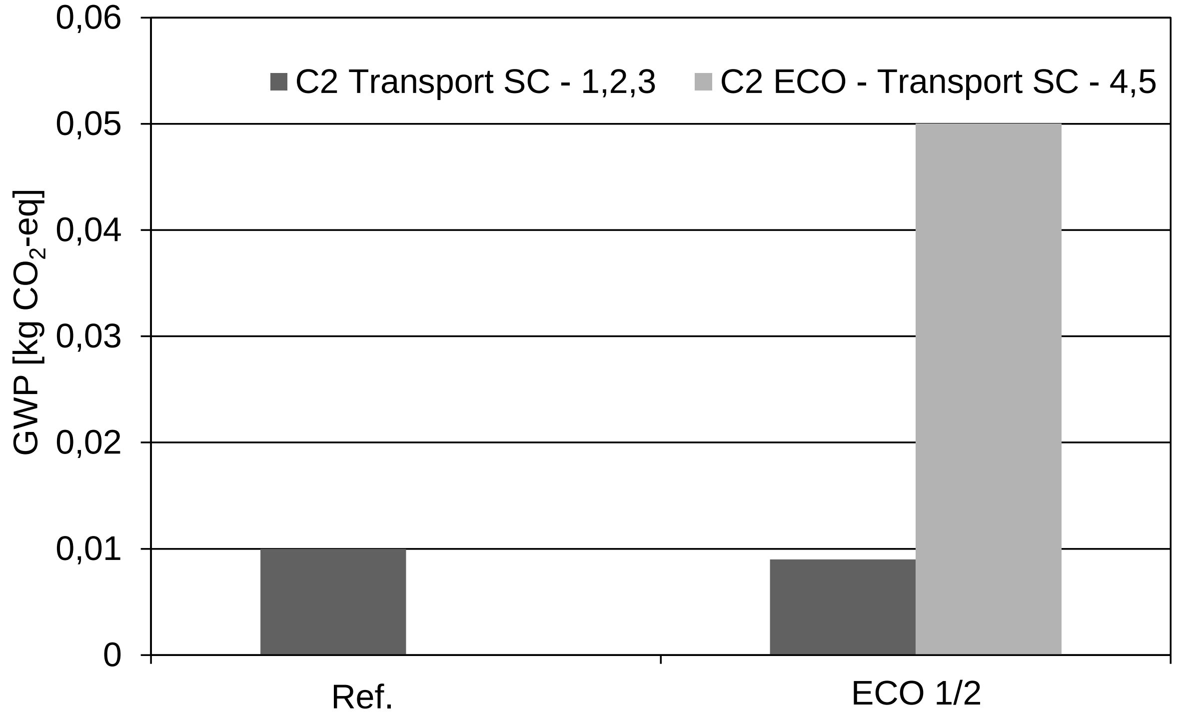

Figure 15: Comparison of EOL transport scenarios

But compared to the absolute figures and to the benefits obtained in the case of recycling these additional burdens can be neglected.

Finally Figure 16 shows the possible improvements that can be achieved when using the new design approach.

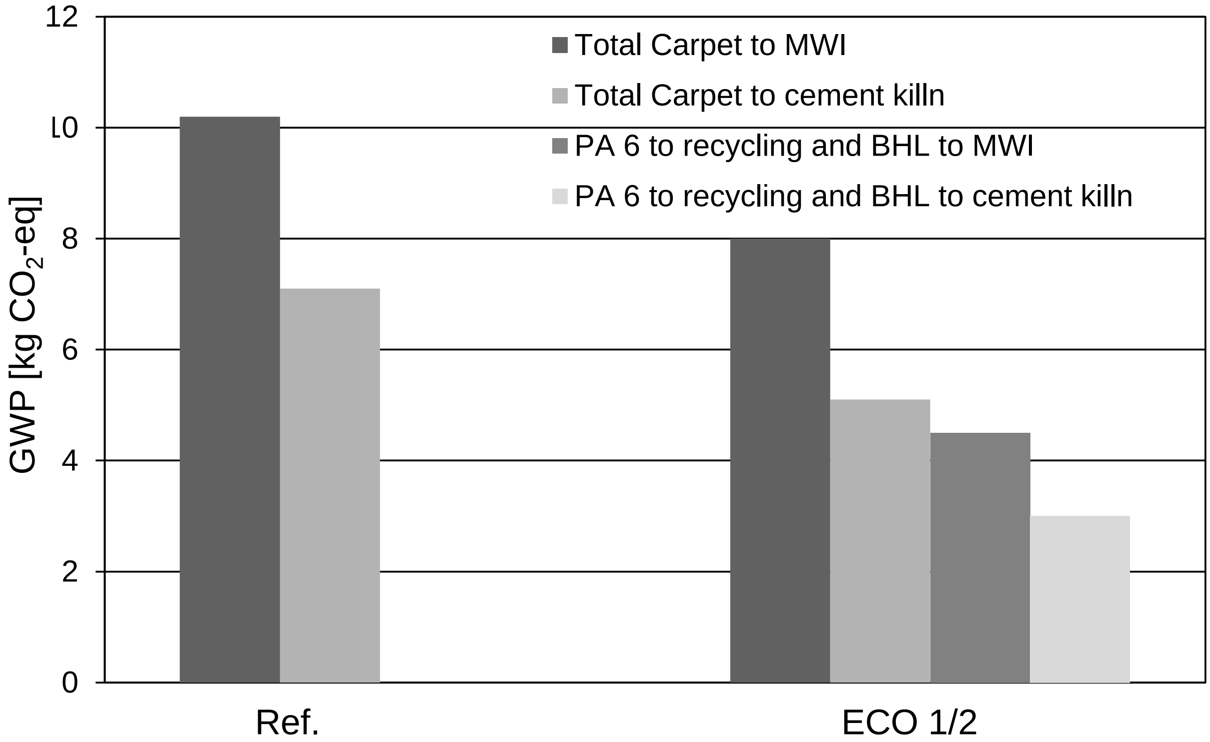

Figure 16: Final comparison of EcoMeTex designed carpets with reference products and state of the art EOL scenarios

The reduction of the GWP compared to the reference is:

- 22% if recycled fibers are used in the production of the new designed carpets
- 50% if the new designed carpets are used as secondary fuel during the transition phase, when recycling option are not fully installed.
- 56%-70% if the recycled fibers used in the pile are recycled a second time and made available as resource in the PA 6 raw-material pool.

It has to be kept in mind that these figures will vary based upon the final calculation model used:

a) In the case of carpet waste used as secondary fuel in the cement industry most of the loads are allocated to the cement by current conventions.
b) %-values will vary if the whole lifecycle impact is taken into account. In the current examples and the models used for impact analysis in the discussion

with the external validators, all identical impacts during the use-phase have not been taken into account. This, basically as the final use time might vary between 5 and 20 years.

E.g. the environmental burden caused by cleaning and maintenance in a time frame of 10 years (mainly electricity consumption) is responsible for 46% of the overall GWP in the case of the reference product and for 64% in the case of the new designed product.

Thus the shown maximum reduction potentials for the GWP of 56% - 70% will change based on the calculation model, to 29% - 35%.

Nevertheless the order of improvement steps shown in Figure 16 will not be affected. In all cases, in which polymer materials are used as a feedstock for the raw-material pool, shows the highest environmental improvements.

3.4. Logistic Concept

Next to the realization and evaluation of new recyclable carpet concepts, it was also a goal of EcoMeTex to set up a logistic concept. In this case one of the biggest challenges for a recyclable carpet is to put in place a logistics proposition that will allow to:

1. Close the loop
2. Keep the loop closed

Aim of this task is the formulation of a logistical concept which is believed to have the potential to close the EcoMeTex carpet loop. Prerequisite for this logistic concept is that certain economic assumptions are met and that the EcoMeTex technology is used by the broader contract industry.

The approach taken to ensure a feasible logistics concept started with the analysis of past failed logistics approaches to understand what did not work. Once the failure root causes of past efforts was understood the logistics advantages that an EcoMeTex product would bring where analysed and, based on that, two logistics scenario, “centralised” and “de-centralised”, was formulated. This logistics scenario took for the four main contract carpet markets in Europe into consideration:

- Predicted raw material revenue
- Predicted fixed costs
- Predicted variable costs
- Transportation costs

The scenario figures are based on INT experience/know how in the recycling of carpet tiles adapted to the EcoMeTex product. In the logistics scenario we attempt to extrapolate such figures such as revenues costs and consequent financial breakeven quantities. An LCA of the proposed logistics concept was carried out by Institut für Bodensysteme an der RWTH Aachen University e.V. Aachen, Germany (TFI) and European Carpet and Rug Association, Brussels, Belgium (ECRA) to understand environmental implications and allow for a more informed decision as to which option is best.

Failed recycling efforts analysis:

This effort was part of our “due diligence” i.e. understanding why most of past carpet recycling efforts in Europe failed (most notorious ones being the Polyamid 2000 and the RECAM-Project (Recycling of Carpet Materials) efforts). Discussions with both Interface associates and with EcoMeTex consortium members were extremely valuable in identifying the key contributors to past carpet recycling logistics concepts and allowed us to identify the advantages that an EcoMeTex product brings. Key topics taken into consideration were:

- Cost of separation
- Purity of separated material
- Cost of purification
- Flawed average face weight estimations
- Flawed estimations on yarn type and its detection technologies
- Low amount of high value material in carpets
- Energy involved in recycling carpets and its LCA implications.

EcoMeTex Carpet advantages:

Figure 17 below is critical to understand the approach and the advantages that the EcoMeTex product brings. The carpet is made of two parts that crucially are separated by a non-contaminating layer that can be triggered using low running and capital cost, high throughput. Furthermore, the high value material in the top layer can be accessed by recycling partners Aquafil Spa, Arco, Italy (AQU) without further purification steps required.

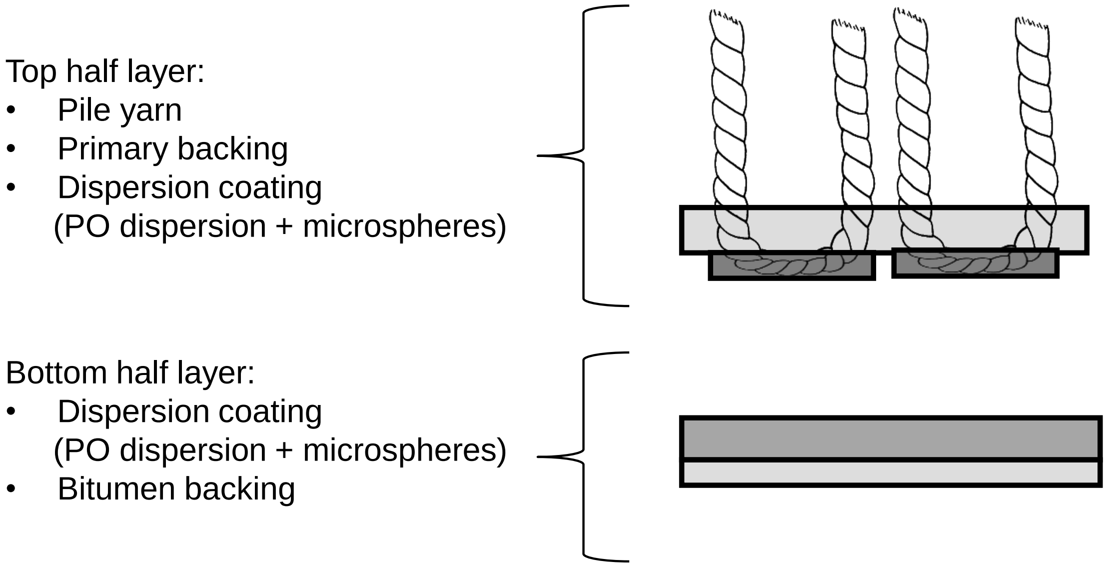

Figure 17: Schematic Representation of one of the EcoMeTex products

Past industry attempts had to utilize high technology, low throughput and high maintenance equipment to separate carpets and gain some value from the output streams but the EcoMeTex carpet is designed to be recycled/disassembled and, thus, the separation and purification costs are drastically lower (> 50% lower based on INT experience). But as the separation technology of the EcoMeTex product was proven only at lab level and not in larger scale, assumptions had to be made on cost of separation (both carpet and running costs i.e. energy and labour wise) Installation type is also believed to be a key influencing factor as carpet installation removal (removal time/m²) and contamination percentage is unwanted and affects recycling costs.

The logistical concepts take two possibilities into consideration. Either a “centralised” hub taking EcoMeTex tiles from the main carpet markets in Europe and carrying out the separation process in one spot only. Or a “de-centralised” process where the top and bottom separation (See Figure 17) process is carried out in small hubs in each country and then separated material is sent for recycling (depolymerisation at Aquafil, Slovenia) or for other end of life applications (Waste to Energy or Cement Kiln). The two concepts show difference in transportation costs and variable cost but are in theory both feasible. LCA values for transportation have shown to be similar so this is not an influencing decision making factor. Both concepts could be taken into consideration due to the modularity and low cost of the separation technology expected to be required for the EcoMeTex products. This is a key factor as high capital costs and throughputs required to recycle “standard” carpet is only possible/likely with a centralised proposition.

Both the “centralised” and “de-centralised” propositions were analysed under the point of view of fixed cost, variable cost, transportation costs and revenue. Assumptions where made for the separation technology costs as this could not be defined during the EcoMeTex project. But a number of potential technologies were taken into consideration and, based on Interface’s general recycling and reclaiming experience, figures were generated. Key financial influencing factors were identified and taken into consideration.

Such factors such as variable costs of temporary labour in high or low labour cost countries, transportation costs, fixed costs where considered. Furthermore INT explored the effect of the total amount of PA6 polymer in one m^2 carpet on financial break even quantities (as shown in Table 1 below). The logistics concept, especially at its initial stages, relies on a “recycling fee” per m^2 to be charged to the client and that is dedicated to the recycling costs. In Interface’s experience and, in the business to business (B2B) market, clients have sustainability/end of life stakeholder commitments which make extra “recycling fees” acceptable. This said it is hoped that the separation technology is adopted by the broader carpet tile industry and, as a consequence, that the recycling would be made possible with lower “recycling fees” or no fees at all. Pan industry discussions on this topic have been suggested by ECRA and are likely to occur in 2015.

Table 1: Examples of financial influencing factors

Influencing Factors	Comment
Face weight	Halving weight → ~ x1.5 - 2 break even m^2/year
Separation location	Variable costs variance +/- ~20-30% (high vs. low labor location cost
Separation cost (hypothetical)	EcoMeTex <~50% Traditional/Standard scenario

Analysis of the financial figures for the different logistics concept scenarios allowed for an estimation of the “break-even” quantity where the number of square meters required to be processed in order to achieve financial parity are calculated. The findings have shown that the (hypothetical) break even numbers are within the realm of feasibility especially if the separation technology is used by a number of industry players rather than a sole one.

Other factors such as improvements in revenues from the separated materials and improved efficiency in separation (expected with experience) would contribute in lowering the separation cost. Considering that the average life of carpet tiles is between 7 and 10 years a retroactive approach would need to be taken into consideration and planned.

To conclude the EcoMeTex product lends itself to a logistical concept aimed at closing the loop of its high value materials and keep loop closed considerably more than standard products thanks, in most part, to the way this is designed and the separation technology.

3.5. Transfer of the methodology to a different sector

As last part of the EcoMeTex project the developed method was transferred to the transport sector in the WP6 “Transfer of Ecodesign methodology to the transport sector“. The existing ecodesign methodology developed for the textile floor coverings was taken as the basis for its adaptation. Concretely, this meant the detailed review of the set of templates used for the implementation of the eight steps of the methodology, to enable its implementation for the reference textile luggage cover. SIOEN Industries NV, Ardooie, Belgium (SIOEN) is the manufacturer of the luggage cover, and has extensive expertise on coated textiles for numerous applications beyond those for the transport sector. This facilitates the adaptation and implementation of the ecodesign methodology.

ECO conducted the research, data collection, and review of the technical, product, and environmental information for the coated textile cover, as well as the complete review and adaptation of ecodesign methodology adopted, including the following eight steps:

1. Product description
2. Environmental assessment
3. Stakeholder analysis
4. Process analysis
5. Benchmarking of products
6. Product improvement, and
7. New textile concept
8. Environmental communication

The templates which support the gathering of relevant data on the product and associated processes, as well as information on other life cycle stages of the luggage cover, were adapted for each step as described below.

The **Product description (Step 1)** and its associated template are based on the analysis performed for the reference product selected by SIOEN. The luggage cover was selected according to the interest of this industry partner, also considering the potential for product improvements. The adapted data collection template describes the textile luggage cover, according to criteria and requirements set by the OEMs and its suppliers for this semi-finished product (The customers of SIOEN incorporate the reference coated textile into a cartridge, which is later on installed in the luggage compartment of the estate vehicles).

For the **Environmental assessment (step 2)**, a separate template has been developed for collecting data along the life cycle stages of the luggage cover. As a component within the larger system (i.e., vehicle), this assessment provides a comprehensible picture of the environmental aspects and impacts of this semi-finished product. The aim is to identify the most relevant environmental impacts, for a subsequent analysis of the potential product improvements. Results showed that the contribution of the luggage cover´s weight to the car´s fuel consumption is the most relevant issue. In other words, the use phase of the luggage cover (as a component in the vehicle) is responsible for 85% of the Global warming potential (GWP) of the product over its entire life cycle.

The third step of the methodology is the **Stakeholder analysis (Step 3)**, namely, the description of the product considering the specific requirements from various stakeholders. These needs and expectations on the reference product are be analysed by means of the Quality Function Deployment (QFD) approach. The corresponding template or “QFD Matrix” shows the relationship between selected technical parameters of the product, and the expectations and/or requirements from its stakeholders (e.g., the B2B customers in the automotive industry). Understanding and prioritizing this relationship will support the product improvement and new product development processes later on.

A separate data collection instrument for the assessment of the manufacturing processes of the reference product has also been adapted in **Step 4, Process analysis**. This step is based on an input-output analysis, and includes the material and energy flows for the manufacturing of the luggage cover, according to the technology and practices used by SIOEN.

The **Benchmarking of products (Step 5)** includes the description and comparison of other different products (market competitors, prototypes, best-available technology, etc.) with the reference luggage cover. The idea is to identify the product features which allow them to better fulfil specific stakeholder requirements. In this case, the features considered were those included in the technical parameters and the stakeholder requirements from Step 3. For the market and the customer perspective, the QFD and the subsequent benchmarking with other products showed that the reference product is over dimensioned regarding specific customer requirements (e.g., tensile strength). Therefore, changes in specific in performance features would still be possible without negatively compromising the product use as luggage cover.

The **product and process improvement (Step 6)** summarizes key results of each of the previous four analysis steps of the ecodesign methodology. The results are recorded in the corresponding template. In addition, the concrete actions for product and process improvements can be derived and clearly documented. This summary helped identify possible product and process improvement opportunities, to be translated into concrete actions for the new product development process.

These concrete actions were prioritized by consortium experts according to technical feasibility (risk), effort, and benefits, and subsequently documented in the template of the **new product concepts (Step 7)**.

After finishing the 8 steps the work package focused on the production and evaluation of each of the proposed new concepts. The evaluation considered the feasibility for manufacturing, selection of materials, and the evaluation of the production costs. Five concepts or “tracks” for new luggage cover coated textiles were proposed, showing variations in the manufacturing processes and the material choices. After the evaluation of each concept and the prototyping at a laboratory scale, one track appeared to be more promising than the other four. This is a textile cover manufactured by the calendering of a thin Polyvinyl chloride (PVC) layer over a light weight non-woven of recycled Polyethylene (PET).

The improvements achieved for the coated luggage cover, and also the results for the environmental assessment of the new product concept are to be communicated to interested stakeholders in the automotive sector. In the case of SIOEN, this **Environmental communication (Step 8)** is based on the data from own testing of prototypes, and from the technologies already in use. The strategy of SIOEN is to present directly to B2B customers the cost-structure, the technical properties of the new product, and the environmental assessment results. This new concept shows significant reduction of the greenhouse gas emissions during the use phase when installed in the vehicle. These changes in the materials compared to the reference product are inducing performance changes and production cost variations. In addition to a significant reduction of the environmental impact of the new concept (50% lower GWP), its production cost is about 20% lower than for the manufacturing of reference product.

Following the results from the steps of the ecodesign methodology two tracks have been identified for the development of eco-designed luggage cover products.

1. Calendering on lightweight and open textile fabric
   The calendering process, based on molten polymer coating, allows the use of open and flat textile substrates, which are lighter than the current substrate in the reference product. Plasticized PVC offers the best performance and price balance compared to other material for this application. The use of non-woven glass requires more coating material than for PET based non-wovens. A flat substrate allows the reduction of the weight of the calendered foil. Therefore,

flat PET non-wovens are good candidates for reducing the weight of the luggage cover.

2. Lamination of a pre-embossed calendered foil on a non-woven
   Using pre-embossed calendered foil as front coating would allow reducing its thickness, and increasing the production speed. Such foils are later on laminated onto a light weight textile substrate. Nevertheless, the temperature range for the adhesive processing and the required temperature stability for the material is small and brings challenges in the processing.

The lab-scale development, prototyping and evaluation revealed that calendering is the most suitable process for reducing the coating weight of the automotive luggage cover. Regarding cost considerations, plasticized PVC remains the material with the best performances to price balance.At the end of the project part the ecodesign methodology was evaluated, to assess its robustness and flexibility to deal with textile coverings in the transport sector. This evaluation included a comparison against international standards for ecodesign, but also considered aspects of its application to luggage covers by the manufacturer SIOEN.

The evaluation shows that the ecodesign methodology follows the recommendations on early integration of environmental aspects into product design and development. The selection of the tools provided in the eight methodological steps also follow the recommendations given in international standards. The worksheets provided in the several steps of the methodology facilitate the documentation of relevant results and the subsequent synthesis for each step in an exemplary manner. The general approach of the ecodesign methodology was evaluated by the manufacturer of the luggage cover as understandable and logically structured. The effort for applying the methodology, compared with the benefits obtained, was assessed as appropriate. The level of detail is evaluated as reasonable and the manufacturer could imagine applying the methodology also to other products in the near future.

The evaluation also provided insights on how the use of free accessible Life Cycle Inventory data (e.g. from the European reference Life Cycle Database provided by the Joint Research Centre) could support the manufacturer to run the environmental assessment of the products on their own. Also for the collection of information for benchmarking with products from other companies, a simplified approach could be based on Product Category Rules (PCRs) for automotive parts. These are though not yet available but theoretically would are establish rules and requirements for conducting comparative Life Cycle Assessment (LCA) studies with a focus on weight differences between design options.

The implementation of the ecodesign methodology meet the expectations and motivations of the industry partner, as it helped SIOEN identifying ecologically advanced alternatives for manufacturing the automotive luggage cover, within the technical and economic constraints associated to this product and its market.

4. The potential impact

Within the project EcoMeTex the focus was on two different important sectors. The first sector was the construction sector and the second sector was the transport sector

Construction sector:

Textile floor coverings in the European construction sector cover products for residential and commercial use, and represent about 38% of all floor coverings of the western EU market, with 660 million m^2 (in 2012). Expectations are that textile floor coverings for the commercial sector will continue to grow in the near future. For Western Europe alone the production of tufted carpets increased to 373 million m^2 in 2012. This implies consumption of resources and energy, and the generation of wastes which needs to be managed properly, but also, in times of materials and energy constrains, environmental consciousness and knowledge needs to be applied to product development as part of a larger sustainability strategy.

In light of the growing importance of environmental requirements for textile floor coverings, the goal of the EcoMeTex project was to develop and implement an ecodesign methodology for textile floor coverings. The main idea is also to take advantage of technical and design opportunities, to reduce the environmental impacts of the textile floor coverings in Europe. Ecodesign focuses on optimizing the products performance, so that reduced environmental impacts are present over its entire life cycle, including raw materials, manufacturing, distribution, use, and end of life.

The ecodesign methodology provides a solid framework to analyse products in a systematic way, and supports product developers, technical experts, marketing and top managers in understanding their products, in finding improvement ideas, and in communicating those improvements to various stakeholders. Innovative products, with lower environmental impacts, as well as lower life cycle costs can be developed in this way. A good understanding of the relevant life cycle stages, especially at the beginning of the product development process, is important because most of the relevant decisions and planning activities are set at the early development stages. With this in mind, the implementation of ecodesign has to be seen as a part of a broader organizational strategy. This strategy includes various levels, from product and production to the market, corporate, and management levels.

In the EcoMeTex project the implementation of the methodology has been successfully completed for selected woven and tufted carpets for the commercial market.

Transport sector:

In 2011, estate cars represented about 12% of the European car market, corresponding to about 15 million cars produced every year. For these vehicles, the average luggage compartment is about 1.3 m^2. From these figures, a conservative estimate of the European demand in luggage cover material is approximately 2 Mio. m^2 per year. Other estimates even reach 6 Mio. m^2 of coated textile material. These enormous quantities show that every improvement in the environmental performance of the coated textiles can make a significant impact at the European level.

The ecodesign methodology developed in the EcoMeTex project offers a possibility to tap into this potential. It provides a solid framework to analyse products in a systematic way, and supports product developers, technical experts, marketing and top managers in understanding their products, in finding improvement ideas, and in communicating those improvements to various stakeholders.

In the EcoMeTex project the implementation of the ecodesign methodology has been successfully completed for selected woven and tufted carpets for the commercial market. The ecodesign methodology has been evaluated and further transferred to the transport sector, looking at the luggage cover textile. The resulting product improvements concentrated on the reduction of the weight of the product, because weight reduction of the vehicle´s components contributes to a lighter vehicle that requires less fuel over its entire service life.

The automotive industry is in a phase of transition, with new revolutionary car concepts increasingly becoming available. The perception of how a car looks (e.g., changes in the exterior of the vehicle) is already changing, so these might be potential for changing the appearance of the interior of the vehicle too. This would open possibilities for incorporating lighter textile covers in the luggage compartments.

As million vehicles are sold, the reduction of emissions from their operation is an important aspect in achieving the sustainability goals of the EU and the rest of the world.

The methodology in EcoMeTex was successfully implemented to significantly different products in two different sectors during EcoMeTex, and in this way it was demonstrated that the ecodesign methodology can be transferred to many other different products.

All attempts gave conclusions on the processes, which are usually not representable in the laboratory scale. For example, the dimensional stability could only be measured precisely if the carpet tiles are produced in the industrial process and not in laboratories during the hand laminating process. Thereby, the industrial attempts helped on the development, even though, afterwards, the attempts have again been performed in laboratory scale. The next steps of the development in the companies can therefore take place in a faster and more determined way.

At the end of the project the methodology was integrated into a concept tool. This tool together with the Code of Practice can be used by product developers and/or product managers to set up an ecodesign project leading to new products ideas. Through the analysis steps especially the environmental analysis the product will be looked at from a completely different perspective than usual. As a result a list of ideas are derived which have lower environmental impact but can also be very innovative. The realisation of such innovative ideas can support the marked share or opens the door for new markets.

The tool is intuitively structured along the eight steps of the methodology, and allows to downloading the templates for data collection. The Code of Practice supports the user with clear explanations of the methodological approach in each step, and gives additional hints on the procedure to complete them.

Moreover, such a customized tool is a suitable asset for conducting ecodesign training sections in companies. The usability and practicability has been tested during two training workshops with employees of the project partners ANK and INT, with good feedback. Such a tool could also be used as an "e-Learning" resource.