Assessment of the roofing membrane Rhepanol fk from an ecological perspective

Summary

on the

Life Cycle Assessment of the roofing membrane Rhepanol fk

Updated according to DIN EN ISO 14040 ff.

for

FDT FlachdachTechnologie GmbH & Co. KG

Mannheim

by

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1 INTRODUCTION AND OBJECTIVES

In 1989-1990 the working group for integrated chemical assessment of the chemical analysis department at the Battelle Institute e.V., Frankfurt am Main carried out an

Assessment of the synthetic roofing membrane Rhepanol fk from an ecological perspective.

In this study, which according to the former terminology was called "Produktlinienanalyse" (RIPPEN, G. & WIESERT, P., 1990), the synthetic roofing membrane Rhepanol fk (black) was assessed with regard to its ecological impact. The assessment included the life cycle periods

- raw materials production
- roofing membrane manufacturing
- roofing membrane usage
- roofing membrane disposal

The assessment of the ecological impact connected with the production of the roofing membrane started with the extraction of the raw materials. The reference quantity and functional unit was one ton of Rhepanol fk.

The project (C.A.U , 2002) outlined in this paper contains an update of this study carried out for the product Rhepanol fk grey. The update refers to both the data applied and the methodology. The methodology applied is based on the standards DIN EN ISO 14040 (DIN, 1997), DIN EN ISO 14041 (DIN, 1998), DIN EN ISO 14042 (DIN, 2000a) and DIN EN ISO 14043 (DIN, 2000b) for life cycle assessments and was carried out in the form of a screening.

The Life Cycle Assessment (LCA) follows a holistic approach by analysing and assessing every ecological aspect along the entire life cycle of a product or a service. This integral approach promotes strategies that lead away from end-of-pipe technologies and the transposition of environmental burdens into other media or life cycle periods.

To date it is the only international standardized method (ISO EN 14040-49) for comparative ecological analyses of products, processes and services. It is precisely this standardization combined with an internationally co-ordinated development of methodology that has significantly promoted the acceptance for and the role of life cycle assessments as a valuable means for making decisions in the field of ecological management and environmental policies. The objective of the life cycle assessment is not the decision itself, but a scientifically well-founded basis for making decisions by, for example, identifying ecological hot spots and optimization potentials.

2 METHODOLOGY OF LIFE CYCLE ASSESSMENT

2.1 Structure and standardisation

This methodology is based on the concept of recording, quantifying and assessing any relevant environmental impact of a product or service during its entire life cycle. A Life Cycle Assessment comprises the following components (see also fig. 2.1-1):

- Goal and scope definition
- Life cycle inventory analysis
- Life cycle impact assessment
- Life cycle interpretation

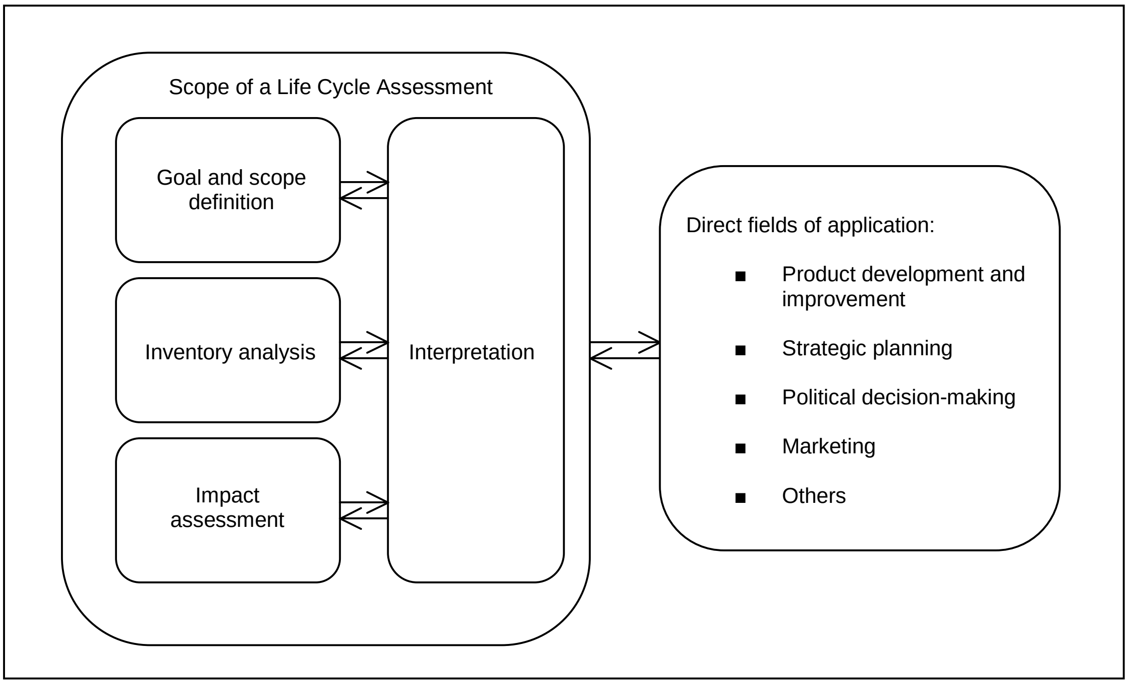

Fig. 2.1-1: Components of a life cycle assessment according to DIN 14040

2.2 Goal and scope definition

In addition to the goal definition itself for a specific Life Cycle Assessment the following provisions are determined:

- System boundaries (technical, spatial and temporal)
- Functional unit (reference unit for system comparison)
- Rules and assumptions (cut-off and allocation rules, aggregation)
- Data collection
- Type of impact assessment and valuation
- Target group(s) (internal, marketing, public, politics...)
- Expert verification

2.3 Inventory analysis

In the inventory analysis, based on a "product tree" consisting of so called modules, all inputs and outputs are registered according to their mass and energy values and applied to the functional unit. In principle, the entire life cycle is registered, although smaller branches without significant impact may be cut off.

Input:

- Operating supplies
- Energy
- Water
- Land use

Output:

- Products
- Waste materials
- Emissions into the atmosphere, water and soil

The necessary data is either collected directly or generic data is used. In most cases direct data is available for production and prefabricates, as well as for the disposal or recycling. Generic data are most commonly used for energy provision, transportation, widespread raw and basic materials (e. g. metals, synthetic materials, concrete etc.), as well as for standard disposal processes. The generic data are usually mean values for a certain economic area or representative individual values taken from existing data pools.

Based on the collected input and output data of the modules throughout the product life cycle and including the prechains (e. g. energy provision) and the downstream modules (e.g. waste disposal), the withdrawals from the environment (resources, land use) and emissions into the environment (into the atmosphere, water and soil) are calculated for the assessed system.

2.4 Impact assessment

An impact assessment is necessary for the aggregation and systematic interpretation of the inventory analysis results, with its numerous individual data. The list of categories according to SETAC-Europe (UDO DE HAES et al., 1999; UDO DE HAES, 1996) includes the following features, which cover most of the problematic environmental fields under discussion:

A Input related categories:

- Abiotic resources
- Biotic resources
- Land (land use)/use of natural space

B Output related categories:

- Global warming (climate changes)
- Depletion of stratospheric ozone
- Human toxicological impacts
- Ecotoxicological impacts
- Photo-oxidant formation/summer smog
- Acidification
- Eutrophication (including BOD (biological oxygen demand) and heat)
- (Odour)
- (Noise)
- (Radiation)

In order to transform the quantitative data of the inventory analysis into impact indicator results the following steps must be carried out:

- Selection of impact categories
- Classification
- Characterisation

Classification means the assigning of input and output data of the inventory analysis to the individual categories, e.g. CO_2, CH_4, N_2O to the category "Global Warming", the acids and acid-forming gases (e.g. NH_3, SO_2) to the category "Acidification", the smog-forming hydrocarbons (VOC) to the category "Photo-oxidant Formation" etc. Every impact category has its impact indicator, e.g. release of protons (H^+_{aq}) for the category "Acidification", from which the characterising factors for transforming the inventory analysis results into impact indicator results are derived.

The characterisation is the most important step for converting and aggregating the classified data into impact indicator results. This is relatively simple in the case of Global Warming, as the Intergovernmental Panel on Climate Change (IPCC) has proposed a suitable aggregation method, i.e. the „Global Warming Potential" (GWP) as well as up to date conversion factors. The GWP is given in kg CO_2.

Optional elements of the impact assessment are:

- Standardisation (Calculation of the ratio between the impact indicator results and one or more reference values)
- Sorting (Classification and possible ranking of impact categories)
- Weighting (Conversion and possible aggregation of indicator results beyond impact categories by using numeric factors based on value structures)
- Data quality analysis

2.5 Interpretation

The final phase of the Life Cycle Assessment aims towards a comprehensive review of all results, not only those of the impact assessment, in part with mathematic tools, and combines the Life Cycle Assessment with the applications. The interpretation includes the following components:

- Identifying the significant parameters based on the results of the inventory analysis and impact assessment phases of the Life Cycle Assessment
- Evaluation considering completeness, sensitivity and consistency checks
- Conclusions, recommendations and the report on significant parameters

The application of an iterative method is one of the principles of interpretation, both in the interpretation phase and in the other phases of a Life Cycle Assessment.

3 EXECUTION OF LIFE CYCLE ASSESSMENT

3.1 System definition

The points given in the methodological part (chapter 2) provided the guideline for the conducted operations. The methodology has been applied in a simplified way to the product Rhepanol fk grey manufactured by FDT FlachdachTechnologie GmbH & Co. KG . The main focus of this project has been the affirmation and updating of the predecessor study.

The functional unit(s) have been defined after clearance with the client. Time of use has also been considered.

The system comprises the entire life cycle of the roofing membrane Rhepanol fk, from the provision of raw materials with its prechains to the production in Hemsbach, the distribution, application, use and disposal. The functional unit is the waterproofing of a roof area of 800 m^2 for a period of 30 years.

With regards to the various possible application methods, mechanical fastening with Gripfix-system (velcro) strips was investigated. Product trees have been drawn up for the system under investigation. A general scheme is given in fig. 3.1-1.

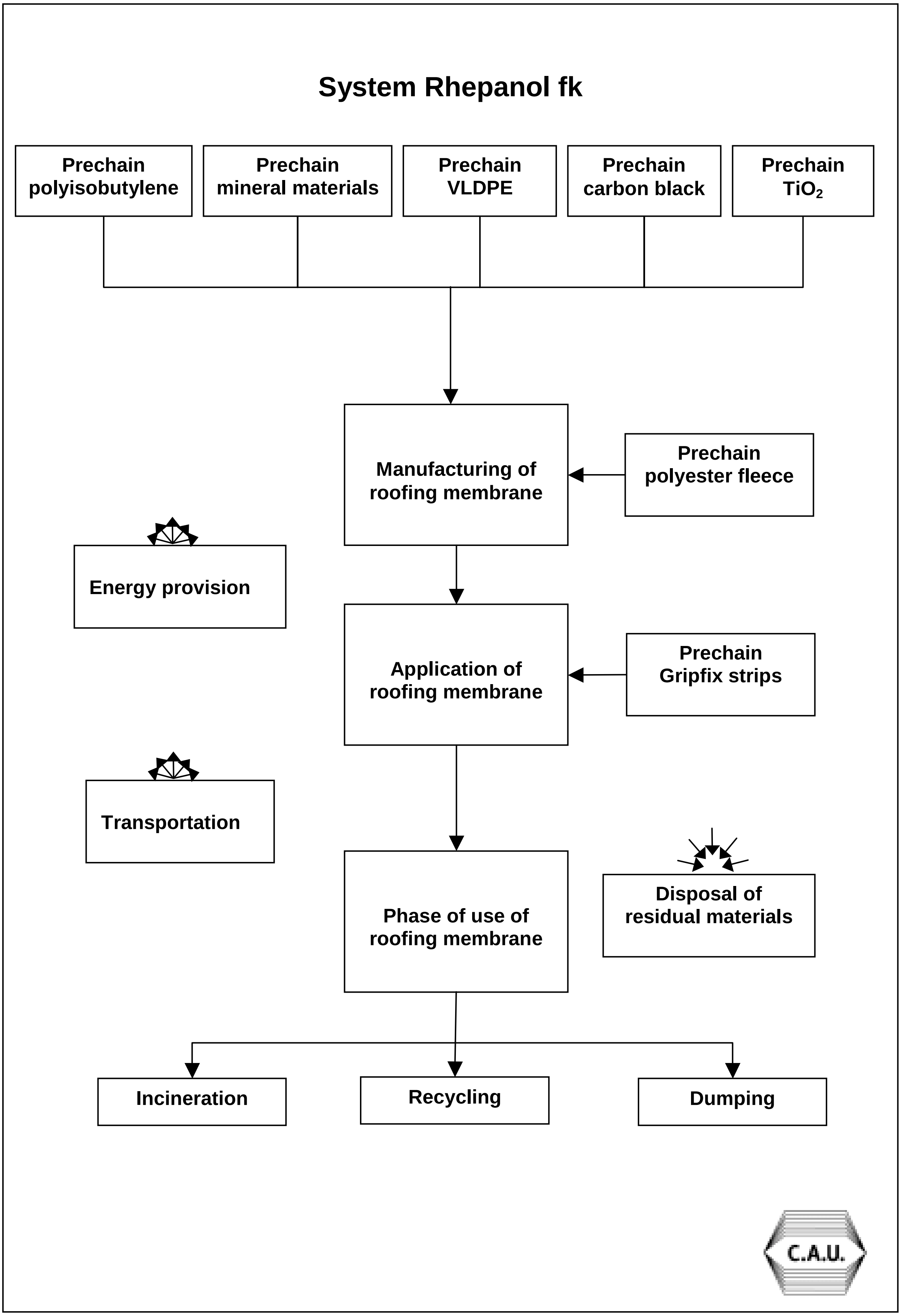

Fig. 3.1-1: General product tree for the roofing membrane system Rhepanol fk grey

3.2 Data sources and further provisions

In addition to the specific data provided by the client (the basic data for the product from the predecessor project and differing effective basic data; the C.A.U. GmbH has provided a questionnaire for this purpose), data on the prechains of raw materials for other modules such as power generation, transportation etc. is needed. The following generic data sets, *inter alia*, are available:

- Life cycle inventories of energy systems (ESU-ETH, 1996)
- Life cycle inventories of waste disposal processes (ESU-ETH, 1996)
- Life cycle inventories of packaging (BUWAL, 1998)
- Eco-profiles of the European plastics industry (e. g. BOUSTEAD, 1999).

Before using data sets in an inventory analysis they must be checked and, if necessary, adapted with regards to symmetry of system boundaries and parameter lists. This is based on the life cycle inventories of energy systems (ESU-ETH, 1996), which also include waste treatment and infrastructure.

Compared to the predecessor study the following new modules had to be considered:

- Prechain titanium dioxide
- Disposal on dumping grounds (domestic waste)
- Disposal by incineration with energy recovery

3.3 Inventory analysis

3.3.1 Prechains

The prechains of the raw materials

- polyisobutylene
- polyethylene
- mineral aggregate calcium carbonate (chalk)
- mineral aggregate silicate
- titanium dioxide
- carbon black
- other organic chemicals
- polyester fleece and fleece adhesive

which are processed in Hemsbach, have been calculated based on literature data, mainly from BOUSTEAD, 1999; BUWAL, 1995; ESU-ETH, 1996; WEIBEL & STRITZ, 1995, manufacturers' instructions and data of the predecessor project (RIPPEN & WIESERT, 1990).

The C.A.U. GmbH has the complete recipes of Rhepanol fk as well as all documents on the raw materials used in Rhepanol fk. An investigation has been carried out for all materials which are relevant to the Life Cycle Assessment; materials not specifically indicated have no significant impact on the assessment.

3.3.2 Production in Hemsbach

The manufacturing of the roofing membrane Rhepanol fk is based on the production data of the factory in Hemsbach. For this purpose operation data from the year 2000 was collected. As the roofing membrane is the main product, the collected data for the whole production could be used and assigned to the output amount without any further allocation. The following parameters are relevant

- Energy consumption

- Consumption of operating supplies
- Consumption of packaging materials
- Water consumption and waste water discharge
- Land use
- Quantity and disposal of waste materials
- Waste gas purification of biofilters

Raw material consumption has been calculated based on the recipe.

Any production waste of Rhepanol fk is collected, separately conditioned and recycled in the production process. The production line itself is equipped with special highly effective biofilters which allow the building of such production plants in mixed areas, i.e. areas with resident and commercial buildings.

3.3.3 Distribution

For distribution freight vehicle transport with an average distance of 300 km has been assumed.

3.3.4 Application

For the application of Rhepanol fk, according to the assessed application technique, washers, screws and Gripfix (velcro) strips are necessary. Packaging materials are classed as waste materials for recycling or disposal. There are no hazardous emissions, which is especially significant, because, for example, comparable roofing membranes of competitors do emit decomposition products or solvents at least when sealing seams with hot air or solvents. Due to the use of a self-sealing edge for seam sealing such emissions do not occur with Rhepanol fk.

3.3.5 Phase of use

A life span of more than 30 years for Rhepanol fk has been proven on several existing objects. There are also experts' reports on this. Therefore for the purpose of this Life Cycle Assessment a service life of 30 years is assumed.

During the phase of use, the biocide can be washed out of the roofing membrane by rain. For the Assessment complete release was assumed.

3.3.5.1 Behaviour in fire

Within the framework of a survey carried out in 1996 by the Bayreuth Institute for Ecological Research (ÖKOMETRIC, 1996) on several different synthetic roofing membranes a quantitative analysis of the release of pollutive substances in case of fire has been carried out. The overall results show that Rhepanol fk proved to have the best characteristics among all the synthetic roofing membranes that had been surveyed. For several relevant substances the survey results for Rhepanol fk were even lower than the analytical detection limit.

3.3.6 Disposal

It can be assumed that currently in 80 % of cases of roof refurbishment the old roofing membrane remains on the roof and serves as a substrate for the new cover. Therefore the disposal of the roofing membrane in most cases is carried out, temporally delayed, when the building is demolished and, due to its continued use, is thus not within the assessed system boundaries. For the remaining 20 % of waste materials, disposal was calculated as for municipal waste according to the current conditions (25 % incineration, 75 % dumping).

Based on life cycle inventories of waste disposal processes (ESU-ETH, 1996a), inventory analyses can be calculated for disposal modules for specific waste materials. To achieve this, the roofing membrane Rhepanol fk has been analysed on important parameters such as heavy metals and halogens (analysis carried out by C.A.U.), and the calculations were carried out based on these data. Content of heavy metals in Rhepanol fk was below the limit of quantification. With regard to halogens only traces from the mineral aggregates could be detected at the limit of quantification.

3.4 Impact assessment

3.4.1 Methodological provisions for characterisation and classification

The currently employed methodology for life cycle impact assessment is the impact category method, which was initially proposed by CML (Leiden) and later modified in some details (HEIJUNGS et al., 1992; KLÖPFFER & RENNER, 1995). The list of impact categories according to SETAC-Europe (UDO DE HAES, 1996) (see art. 2.4) can be narrowed down, as not all categories are relevant for every problem, considering the data situation.

As described in art. 2.4, for some selected impact categories a quantitative impact assessment has been carried out, where, in the first place, the method published by KLÖPFFER & RENNER (1995) has been employed, with modifications to the categories Consumption of resources and Eutrophication.

Resources are mainly considered to be fossil fuels and mineral materials in deposits. Renewable raw materials such as wood are not resources in the sense of an impact assessment, as agricultural and forestry products are produced within the system boundaries. In the category Consumption of resources weighting is done with the multiplicative inverse of the statistical reach of the respective resource (LINDFORS, 1995). The statistic reach of crude oil serves as reference parameter for standardisation.

The cumulated energy demand (CED) is defined in the VDI directive 4600 (VDI, 1997). This energy assessment does not include the input parameters Human labour and Metabolic energy (e.g. nutritional value of food) as well as passively used solar energy. The CED is normally calculated on the basis of the net calorific value (Hu) of the used energy sources.

For the calculation of the global warming potential (GWP) in the impact category Climate changes (global warming) the values published by IPCC (2001) for an assessment period of 100 years have been used.

The depletion of stratospheric ozone is quantified by the Ozone Depletion Potential (ODP) (in R11-equivalents).

The acidification of aquatic and terrestrial ecosystems is quantified by the Acidification Potential (AP) (in SO_2-equivalents).

Eutrophication here means the over-fertilisation of aquatic and terrestrial ecosystems, which are quantified separately because of the different limiting nutrients for water and soil and are divided into the terrestrial (NPT) and aquatic (NPA) eutrophication potential. For terrestrial eutrophication emissions into the atmosphere are registered as nitrate equivalents, whereas for aquatic eutrophication emissions into the atmosphere and water are weighted as phosphate equivalents. The weighting factors W(AP), W(NPT) and W(NPA) derive from stoichiometric calculations.

For the quantitative life cycle impact assessment of human and ecological toxicity the weighting factors of the Critical Surface Time methodology (CST 95) according to JOLLIET & CRETTAZ (1997) and JOLLIET et al. (1998) have been used. For the calculation of the weighting factors, distribution and degradation behaviour in the environment as well as toxicity data are considered. The human toxicity potential (HTP) is indicated in lead equivalents, the aquatic (AEP) and the terrestrial (TEP) ecotoxicity potential in zinc equivalents.

In the impact category Use of natural space, the land use recorded in the inventory analysis is categorised as regards its potential impact on the natural environment. There is no aggregation to a ratio as for the other quantitative impact categories.

The different uses of natural space by humans induce more or less severe interferences with the above-mentioned natural functions and potentials. The scale or level of anthropogenic interference is best characterised on the basis of the hemeroby grades or levels of naturalness.

According to the usage characteristics the land use (product of area and time of use) given in the inventory analysis can be assigned to the individual hemeroby grades (e.g. hemeroby grade 7 for sealed surfaces) and summed up within the grade.

3.4.2 Methodological provisions for standardisation and sorting

For these impact assessment measures an approach proposed by the Umweltbundesamt (Federal Environmental Agency) (SCHMITZ & PAULINI, 1999) has been implemented. It is orientated towards the higher-ranked protected goods of the environmental policy

- Human health
- Structure and function of ecosystems
- Natural resources

as well as towards both the existing and target health and environmental states. The following provision has been drawn up:

"Provision":

An impact category or a specific impact indicator result is considered all the more detrimental to the environment, i.e. it is assigned a higher priority,

1. the more severe the potential hazard to be considered for the ecological protected goods in this specific impact category is (independent from the current environmental state),
2. the further away the current state of the environment in this impact category is from either ecological sustainability or any other target environmental state,
3. the larger the impact indicator result is in relation to single reference values, e.g. the percentage of the respective total yearly emissions in Germany.

These aspects are taken into account by implementing the following criteria:

1. Ecological hazard
2. Distance-to-target
3. Specific contribution.

For the working steps Standardisation and Sorting, the indicator results of each impact category must be valuated with respect to all three criteria. The valuation produces a ranking at a five-grade ordinal scale ranging from

A (highest priority)

to

E (lowest priority):

It must be emphasized that this ranking is to be seen as a ratio between the impact categories or indicator results and not as a final conclusion.

The ranking for the criteria Ecological hazard and Distance-to-Target is independent from the existence of a concrete Life Cycle Assessment. Here the grading proposed by the Federal Environmental Agency (SCHMITZ & PAULINI, 1999) has been used.

Tab. 3.4.2-1: Proposals of the Federal Environmental Agency for the ranking of impact categories

Impact category	Ecological hazard	Distance-to-Target
Use of resources RES	C	B
Use of natural space at hemeroby level 3	D	B
Use of natural space at hemeroby level 7	A	B
Climate changes GWP	A	A
Depletion of stratospheric ozone ODP	A	D
Acidification AP	B	B
Terrestrial eutrophication NPT	B	B
Aquatic eutrophication NPA	B	C

4 RESULTS

The most significant contribution to the environmental load in almost every impact category derives from the provision of raw materials for the roofing membrane production. Within the prechains, supply of polyisobutylene plays the most significant role.

Taking the impact categories Use of resources and Climate changes as an example, the contribution of the individual life cycle periods are presented in the following figures.

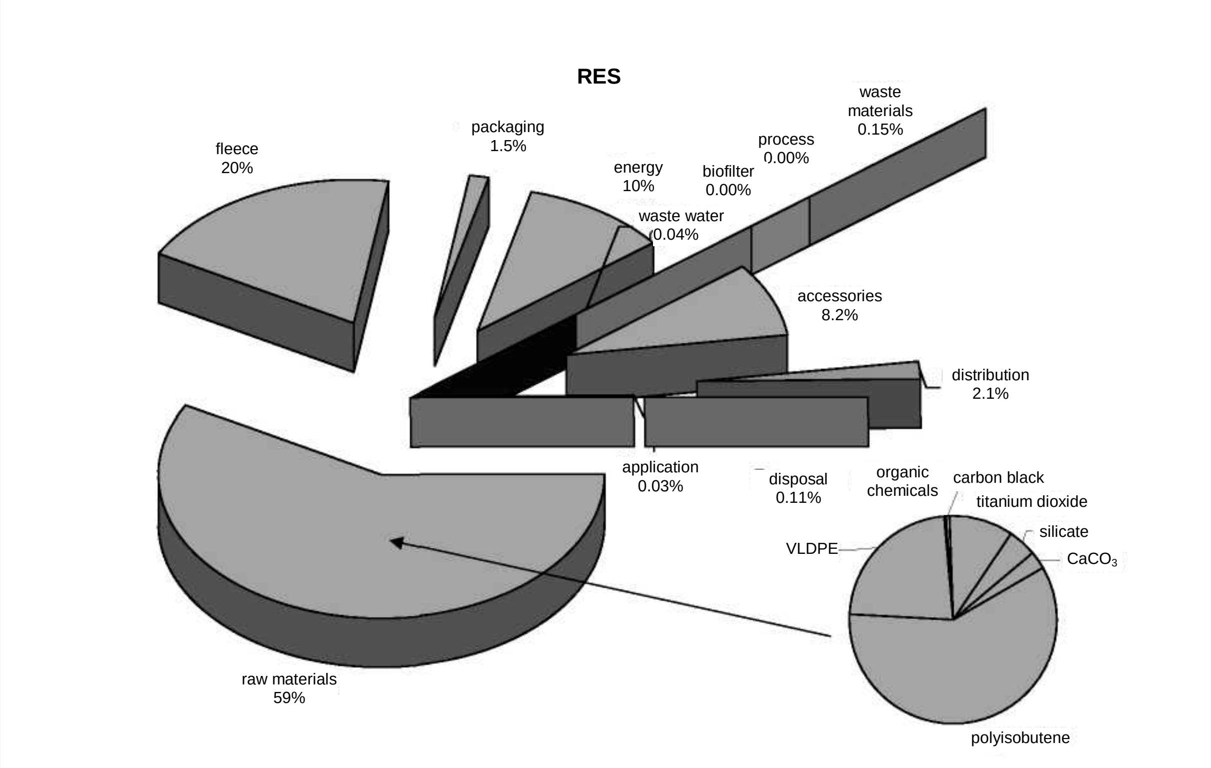

Fig. 3.4-1 Contribution of the individual life cycle periods or sections and modules to the impact category Use of resources RES

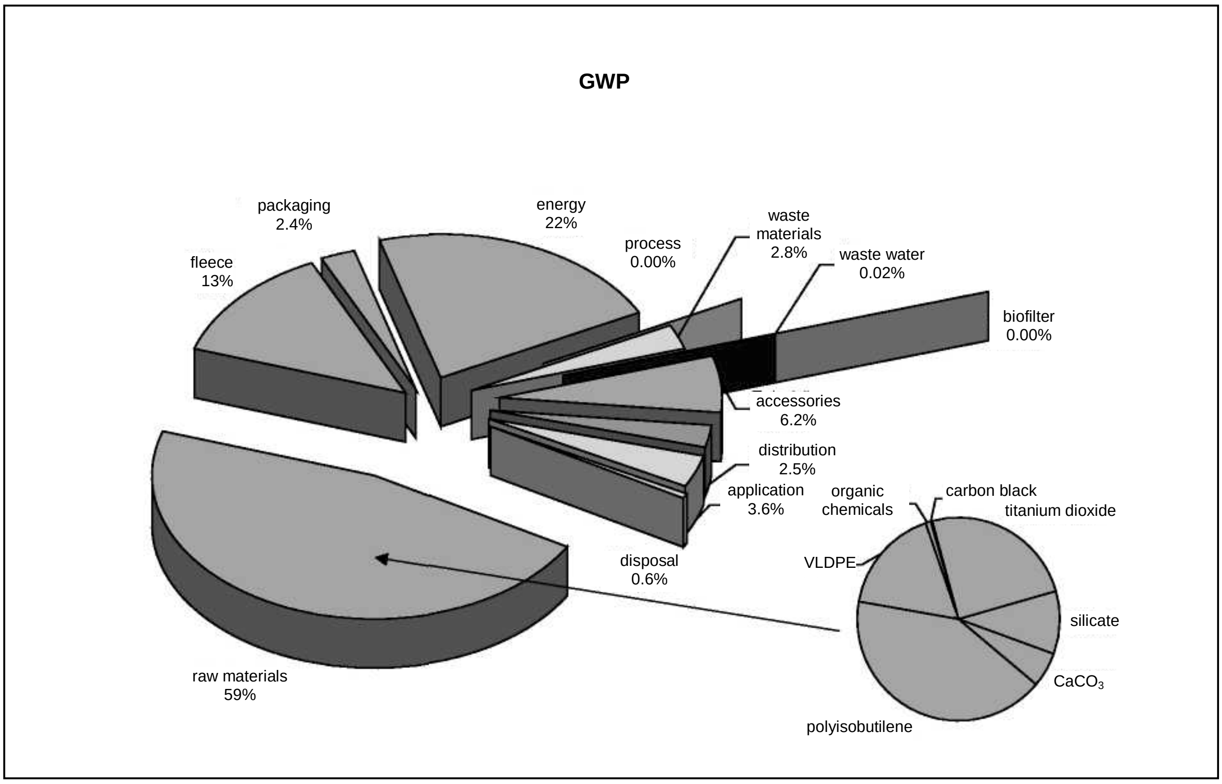

Fig. 3.4-2 Contribution of the individual life cycle periods or sections and modules to the impact category Climate changes GWP

For standardisation and ranking purposes the impact indicator results for the functional unit were referred to the national yearly emission or consumption values (from environmental data). The largest relative contribution was set at 100 %, the percentages were assigned to a five-grade scale. The established specific contribution, together with the criteria Ecological hazard and Distance-to-Target, show the Ecological Priority of the individual impact categories for the analysed roofing membrane system.

Tab. 3.4.2-1: Standardisation and sorting results for the ranking of impact categories

Impact category	Specific contribution	Ecological hazard	Distance-to-Target	Ecological priority
Use of resources RES	A	C	B	High
Use of natural space at hemeroby level 3	E	D	B	Low
Use of natural space at hemeroby level 7	E	A	B	Medium
Climate changes GWP	C	A	A	High
Acidification AP	A	B	B	High
Terrestrial eutrophication NPT	D	B	B	Medium
Aquatic eutrophication NPA	E	B	C	Medium

The raw material prechains have the most significant influence on the results of the impact assessment. The contribution of the modules which are part of the production in Hemsbach make for 10 % to 43 % of the overall load. The largest individual share is contributed by power consumption.

From Standardisation and Ranking a large relative Ecological priority can be derived for the impact categories Use of resources, Acidification and Climate changes. However, the specific contribution to climate changes is only medium, so that the high priority is largely independent from the system under investigation. The highest specific contribution comes from Use of resources and Acidification which are mainly determined by raw material prechains and energy consumption at the production. Thus an optimization potential can be reached by increasing the use of recycling materials at the production and decreasing power consumption.

The quality and the completeness of the used data is sufficient for the statements made. Data are missing for the inventory analysis as regards emissions of toxic substances. The missing data are, however, a result of missing data in the used generic data. The statements on the impact categories Human and Ecotoxicity therefore have a higher level of uncertainty. This is especially true because the completeness and data quality for the respective characterisation factors in the impact assessment are lower than in the other impact categories.

A result of the inventory analysis that has not been considered in the life cycle impact assessment is the biocide emission during the time of use of the roofing membrane. Referred to the surface and the service life, it is approximately at the same level as the distribution of herbicides on agricultural fields.

5 CONCLUSIONS

During the entire life cycle of the roofing membrane Rhepanol fk there are no significant environmental impacts. The high durability and the recycling characteristics must be highly appreciated.

Due to the high percentage of mineral raw materials such as natural calcium carbonate the cumulated energy demand (CED) for Rhepanol fk is by far lower than for purely synthetic materials.

The relative contribution of Rhepanol fk to the emission of greenhouse gases, which are regarded all over Europe as one of the most severe ecological problems of our times (see the Kyoto protocol), is within the average.

There are no hazardous health emissions to be expected during application of the membranes or in the case of fire. The disposal of the roofing membrane is unproblematic either at dumping grounds or by incineration

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