## LCA Case Studies

# Life Cycle Assessment Study on Resilient Floor Coverings

**Albrecht Günther, Horst-Christian Langowski**

Fraunhofer Institut für Lebensmitteltechnologie und Verpackung, Giggenhauserstr. 35, D-85354 Freising, Germany

Abstract

Fourteen European producers of resilient floor coverings examined thirty-two objects of their products in a Life Cycle Assessment Study. The product groups were PVC, cushioned PVC, polyolefin, rubber and linoleum, with one reference example from textile and parquet.

Important results include the following:

- There is no material specific ranking for 'best' or 'worst' environmental performance. Differences within the material groups – depending on the individual formula – are larger than between the groups.
- The introduction of material-specific recycling for used floorings as well as the use of recycled material in the flooring production could reduce environmental loads significantly.
- The premature change of a flooring by the user may induce a major influence on the environmental performance of a flooring.

Keywords: Life Cycle Assessment; LCA case studies; resilient floor coverings

## 1 Introduction

This article is a summary of the study „Life Cycle Inventory with Impact Analysis for Resilient Flooring Systems" performed by the Fraunhofer-Institute ILV for the individual member companies of ERFMI, the European Resilient Flooring Manufacturers Institute[1]. The examined object was a cross section of their product range, selected for the study in collaboration with a Technical Project Group of ERFMI. It was subjected to a critical review by a panel consisting of three external experts according to ISO 14040.

Its purposes are:

- To provide an overview of the whole number of 32 flooring systems investigated, with the two reference non-resilient products parquet and textile as comparison, also produced by ERFMI member companies,
- to focus on the different functional classes (traffic bearing capabilities) and the different material groups of the floorings investigated,
- to concentrate on quantifiable, non-locally relevant environmental impact potentials, for which accepted transformation rules from the Life Cycle Inventory stage into an Impact Assessment stage exist.

Especially the concentration on quantifiable parameters for the Impact Assessment has a noticeable consequence: **Toxicological and ecotoxicological issues** are still very open in the LCA community with respect to their treatment in an Impact Assessment ISO 14042. Also with respect to the floorings investigated, not even the bare facts – which are already necessary for the Inventory stage – for emissions of possibly (eco)toxicologically relevant substances were available in sufficient quality. **The consideration of these issues has therefore been excluded from the scope of this study.**

The structure of the study and the related results should allow for recommendations (within the framework of the environmental parameters assessed)

- to end users of floorings, with respect to a proper choice for a given application and
- to the individual companies with respect to improvements of their own products with the help of results documented in the individual reports.

It must be emphasised that a detailed documentation of all environmentally relevant factors of the different floorings cannot be made without violation of the principles of confidentiality.

The following general results can be deduced **for an end-user orientated recommendation:**

- The major factor influencing the environmental performance of a flooring is **its actually achieved lifetime**, directly connected with decisions of the end user:
  - The individual's choice of the right product for the given technical application, and
  - their possible decision for an earlier removal than really necessary on a purely functional basis.
- Among floorings for similar applications, individual differences caused by different product formulas dominate over the differences found between basic materials.
- The differences between product groups for different traffic bearing capabilities, as described in their EN classification, are also small compared to the overall band width related to the individual products.

From an expert's point of view, the very simple, but not always obvious recommendation which can be given to the end user for product selection is *not material specific*, but related *to*

[1] The full report will be published this year in the book series "LCA Documents".

*the required function*:
The end user should select the product best suitable to fulfil its required function for the required lifetime.

For the group of companies as a whole, the following general recommendations can be given:

- New formulas and technologies exist which allow an overall reduction of environmental impacts.
- The use of recycled material is a true environmental benefit. The introduction of take-back and recycling/recovery schemes for used floorings would also create great benefits, although with different preferred recovery schemes for different materials.

Some companies provided formulas concerning new technologies or an input of recycling material, but – due to reasons of confidentiality – no specific results can be shown here. Also, more specific recommendations again touch confidentiality questions and are therefore limited to bilateral activities between the Fraunhofer Institute and the individual companies.

## 2 Goal Definition and Scope

In the beginning of the study, the objectives of the investigation for ERFMI were the following:

- To acquire an overview of the environmental performance of a selected range of products with respect to those environmental impact criteria for which – at least in relative terms – quantifiable transformation rules from the Life Cycle Inventory were available,
- i.e. with a focus on globally and regionally relevant material flows and impacts,
- without a non-quantitative treatment of other, especially toxicological and ecotoxicological issues and
- without a further aggregation in a formalised valuation step, e.g. in the form of a single score ranking.

The background intentions of the participating companies were:

- To detect whether certain flooring systems would show significant deviations from the gross product range,
- to also detect improvement options in the own production sequence of the companies,
  - either by improvement of the production equipment
  - or by changes of the formulas of the individual flooring products
- and to gain an insight into the methods of raising environmentally relevant data which would also be required for the performance of an *Eco - Audit* according to directive 1836/93 EEC.

The conflict between the necessary confidentiality for company specific data on the one hand and the presentation of the results at least inside the group of ERFMI on the other is obvious in such a study.
The solution for this problem was:

- To provide all participating companies with individual reports on their submitted products
- and to prepare an overall report for the whole ERFMI group.

Therefore, no *comparative assertion* of the products in the sense of ISO DIS 14040 had been intended.

### 2.1 The Products under Study

A selection of 32 different floorings was studied, 30 resilient floorings, with parquet and textile as a reference, produced by 14 ERFMI member companies. The floorings mainly cover the EN classes 3x and 4x, i.e. the commercial and light industrial applications.

Table 1 shows an overview of the 30 resilient floorings studied, grouped by materials. Table 2 displays the typical shares of the composition, without disclosing actual product formulas. It can be seen that the mineral filler and not the quoted material (e.g. polyolefin) frequently represents the main component by weight.

### 2.2 The Functional Unit

In all product LCA's, the description of the functional unit is the key step. It is necessary to make a definition as accurately as possible in order to compare different product life cycles, options or scenarios. In an ideal case, all products investigated in a study should fulfil the same technical function exactly during their – quantifiable – service lifetime. This becomes increasingly difficult for products in which the following influential factors are relevant:

- The lifetime of the products is subject to non-systematic variations
- Different and widespread consumer habits exist which influence the product performance and its lifetime
- A broad variety of products is to be examined which reveal features not directly related to quantitative performance indicators.

In addition, the life cycle for our products not only comprises the production and waste management of a flooring, but also the actions (namely the cleaning) during its use. After a thorough discussion, the Technical Project Group described the functional unit as:

**"The typical use of 20m² flooring over a period of twenty years"**

It is obvious that this definition does not include every aspect of the quality of a flooring. The following two parameters therefore have to be given more thorough consideration.

#### 2.2.1 Traffic bearing capability (EN class)

A main parameter of the functional unit which should be considered is the type of application where the flooring is used or rather for which it is designed.

Table 1: Overview of the objects under study and their EN class

| Material | Number of samples investigated | Thickness of samples investigated | EN classes represented | European market share represented by ERFMI member companies |
|---|---|---|---|---|
| PVC and<br>cushioned PVC | 13<br>6 | 2.0 - 2.5 mm<br>1.7 - 3.0 mm | 3x - 4x &<br>2x - 4x | 90 % |
| Polyolefins | 3 | 2.0 mm | 3x - 4x | 100 % |
| Linoleum | 4 | 2,0 - 2,5 mm | 2x - 4x | 100 % |
| Synthetic and natural rubber | 4 | 2.0 - 3.2 mm | 4x | 90 % |

In this study, the functionality of the floorings is characterised by their EN classes. Note that the conditions relevant for the different EN classes do not simply cover the different action of one single type of mechanical load. The different applications represent several types of loads in different ratios of relevance, ranging from several types of abrasive loads up to indentation effects. Moreover, different application fields are characterised by different requirements for the visual appearance of the products. Therefore, the requirements of a certain EN class are not simply achieved by an adjustment of the thickness of a flooring, for example, and a higher class does not simply mean a higher environmental load due to more input of basic material.

Table 2: Typical formulas for the floorings under study. Note that the individual differences are large

| | | | |
|---|---|---|---|
| **PVC** | | **Linoleum** | |
| PVC | 40 % | Wood powder | 30 % |
| Limestone | 35 % | Linseed oil | 25 % |
| Plasticiser: DEHP | 20 % | Limestone | 20 % |
| Pigments | 5 % | Jute | 10 % |
| | | Colophony | 5 % |
| **PVC cushioned** | | Cork | 5 % |
| PVC | 45 % | Pigments | 5 % |
| Limestone | 30 % | | |
| Plasticiser | 20 % | **Rubber** | |
| Foaming agent | 5 % | Clay | 35 % |
| | | Kaolin | 25 % |
| **Polyolefins** | | SB-rubber | 20 % |
| Limestone | 55 % | Natural rubber | 15 % |
| Polyolefins | 40 % | Pigments | 5 % |
| Pigments | 5 % | | |
| | | ***Textile*** | |
| ***Parquet*** | | *Minerals* | *40 %* |
| *Wood (3 layers)* | *95%* | *Polyamide* | *35 %* |
| *Rag felt, adhesives* | *5 %* | *Polypropylene* | *15 %* |
| | | *SB-rubber* | *10 %* |

In reality, different formulas exist for the different EN classes which of course are the very specific and confidential know-how of the producers.

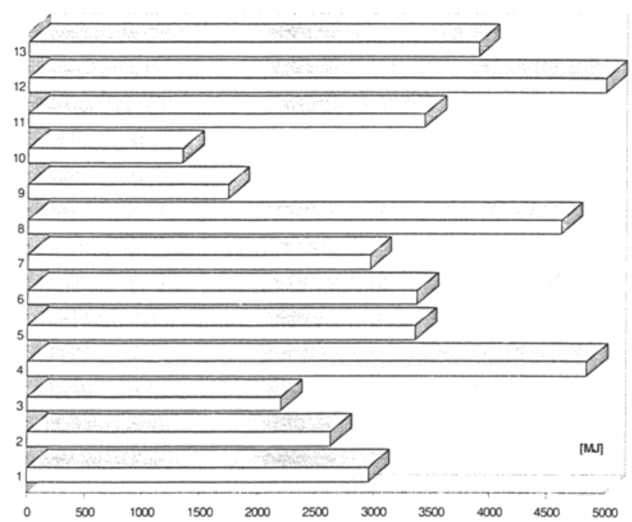


Fig. 1: Gross energy value for production and disposal of some PVC floorings per functional unit. Use phase excluded

Therefore, the consequence is to show the results of the floorings grouped according to the materials used as main polymeric component (PVC, CV, PO, linoleum, rubber, parquet, textile). Nevertheless, this manner of presentation also bears some limitations:

- A material group may comprise different substances, like natural and synthetic rubber.
- A material group usually comprises a large variation in the results for the individual floorings. This is best documented in the study for the range of the gross energy value in the PVC group which shows a factor of more than three (→ *Fig. 1*).

The reasons for this large spread are a combination of many individual differences between the formulas, the choice of input materials, and also the actual application case:

- Where functionally appropriate, a high fraction of mineral fillers may reduce the gross energy uptake,
- whereas, on the other hand, the use of roll material – accompanied by higher losses in laying especially in the case of ornaments – requires more resources than the use of tiles.

### 2.2.2 Lifetime of floorings

One of the most important parameters which influence the overall result of the life cycle inventory is the lifetime of flooring. As for most long-life products, this is very difficult to be quantified on a sound basis. Different values derived from the long-term experience of the participating companies may be used as reference values:

- If properly chosen, a flooring in a given application should survive 10 - 20 years of service.
- Observed and reported lifetimes vary between 7 and 40 years for resilient floorings.
- For textile floorings, lifetime values are generally lower, i.e. down to about 5 years, whereas values for parquet are generally higher (up to 50 years and more).

The question, as to whether the lifetime of a flooring should be seen as its maximum lifetime (limited by the technical performance under given conditions) or as an average lifetime (also including cases when a flooring is removed because of changes in consumer taste), could not be solved within the Technical Project Group for the following reasons:

- Reported average lifetimes are clearly of the same uncertainty as other rules-of-thumb,
- and, in addition, very much dependent on the respective countries, local habits, etc.

The consensus was therefore to choose **one reference lifetime of 20 years for all floorings** and to build up additional scenarios about different assumed lifetimes (in the following chapters the expression "lifetime" means the actual lifetime).

Therefore, life cycles of floorings which belong to the domestic group (EN class 21 -23) have additionally been calculated for lifetimes of 5 and 10 years, the floorings which belong to higher classes have been calculated for lifetimes of 10 and 20 years. However, the results of these individual lifetimes are listed in the individual reports and cannot be shown here because of reasons of confidentiality.

*In the aggregated* **impact assessment** *results presented in chapter 4, the reference time is twenty years per full life cycle. The question about the applicable lifetime, however, becomes relevant only*

- *in a comparison between floorings for the same purpose with different actual lifetimes*
- *and in a comparison between the cleaning effort during the use phase and the environmental loads generated by the production and disposal sequence.*

All these differences, however, are practically not normalisable in the description of the functional unit, as is *theoretically* required according to usual LCA methodology. This shows the inherent problem in the comparison of different long-living products for which – in addition – different, non-quantifiable characteristics exist which are nevertheless relevant for the individual application case. One major conclusion of the study is already to be seen from the results shown in these introductory remarks:

**The decision of the end user for a premature change may imply much higher environmental effects than any material orientated choice.**

This is very important since the manufacturers' statistics indicate that the end of the lifetime of a flooring is not caused by technical reasons in most cases.

## 2.3 System Boundaries

In order to get the tool "Life Cycle Assessment" (LCA) into a manageable frame, system boundaries have to be defined to reduce the complexity of the total economic system acting as background to all systems usually studied. According to today's state-of-art ISO 14040, we used the following general guidelines in our study:

- The Life Cycles of all system components (in our case the components of the floor covering systems) were investigated from the extraction of raw materials up to incineration/final disposal or recycling.
- Energy supply processes are to be described with all their emissions and wastes from the extraction of energetically usable resources over refinement processes up to the supply of the energy into the different processes of the process network.
- Secondary raw materials may appear as **an input or output**. For a secondary raw material to appear as an input or output, it has to be in a usable form.
- The Input/Output flows of the full production processes for ancillary components/agents were generally not taken into account. In all cases, however, the gross energy values of their production pre-chains were estimated and included into the total energy figure. In this study, ancillary components are characterised either by the fact that they do not enter into the system components (such as lubricants) or that they do not fulfil a primary function in the final product or that their mass fraction in the final component is below 3 % (a value set by experience). Note that the "3%-rule" was applied as an option; its application was cross-checked in view of the final results. This 3%-cut off criterion would not have to be applied **in the inventory stage** for substances generally known to be toxic and persistent like heavy metal stabilisers.
- If – due to lack of data – no production processes or further treatment processes could be modelled for a certain material, the life cycle was cut off at that point. Relevant materials/substances are noted in the result protocols of the individual reports under „previous modules are missing“ or „following modules are missing“. In all cases, it was checked that the fact of missing data had no significant effect on the results.

As far as the production sequence and the conditions of the waste management system are concerned, the time frame valid for this study was chosen as the years from 1994-1995.

## 2.4 The Use Phase

### 1. Separation of the use phase

For the flooring systems under study, there are several reasons why the use phase is to be treated separately from the rest of the whole life cycle:

- The range of possible input data varies a lot more than the input data given by the manufacturers for the main production sequence or the data for the pre-chains.
- In establishing the use phase, many assumptions have to be made which strongly affect the end result.
- The actions during the use phase (e.g. maintenance) are in a part of the life cycle which is hard to influence by the producers.

⇒ These figures, therefore, represent a data quality which is totally different from the data situation for the description of industrial processes.

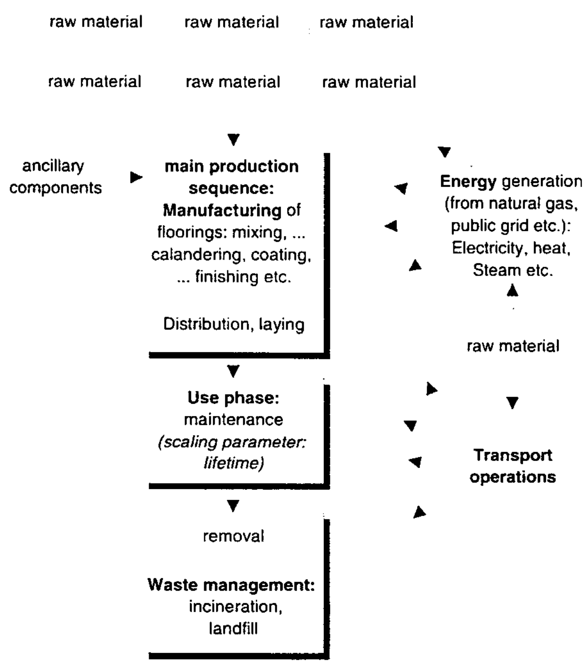


Fig. 2: Schematic flowchart of a typical flooring. The use phase is marked different to show clearly that the use phase is taken separately as an own small life cycle

**The Technical Project Group decided to separate the use phase and to build up an own small life cycle for the mainte-**nance in order to have a comparison of the environmental burdens caused – on the one hand – by the production & waste management and – on the other hand – by the use of the flooring (→ *Fig. 2*).

*Note: Please regard the given impact assessment results assigned to the use phase – as shown in* Figure 3 *and* Figure 4 *– only as a reference for the order of a magnitude of this influence on the overall result. Depending on the assumptions made, the results could vary quite a lot.*

### 2. Emissions during the use phase

Parallel to and after the study, some discussions were concerned with possible effects due to emissions during the use of a flooring and subsequent effects on human health (e.g. "Sick building syndrome"). The Technical Project Group discussed this problem widely seeking for opportunities to include this in the study. According to today's state of the art and in relation to the temporal and financial frame of the study, it was agreed that this aspect could not be tackled here. The reasons for this decision:

1. The available indoor emission data from the participating companies were largely different both in magnitude and quality for the same type of floorings.
2. The toxicity data of many emitted substances are not available.

For an extended explanation please refer to the full report in the "LCA Documents".

## 3 The Impact Assessment

According to a methodology developed by an interdisciplinary scientific working group initiated between the Fraunhofer-Gesellschaft and the GSF ("Münchner Kreis"), the impact-related aggregation of present Life Cycle Inventory data may lead to a set of eleven parameters (→ *Table 3*) [1]:

Table 3: List of impact criteria used for the study

| | |
|---|---|
| **Input parameters** | |
| 1.1 | Energy equivalent of non-renewable, energetically assessable resources |
| 1.2 | Energy equivalent of renewable, energetically assessable resources |
| 1.3 | Total mass of mineral resources |
| 1.4 | Total of water intake |
| **Output parameters** | |
| 2.1 | Mass of solid wastes of the type "municipal solid waste" |
| 2.2 | Mass of waste of type "hazardous waste" |
| | 2.2.1 chemical waste |
| | 2.2.2 radioactive waste |
| 2.3 | Material flows with eutrophication potential |
| 2.4 | Material flows with acidification potential |
| 2.5 | Contribution to anthropogenous global warning potential (GWP) |
| 2.6 | Contribution to catalytic stratospheric ozone depletion potential (ODP) |

## 4 The Results

In this section, only the aggregated results of the Life Cycle Impact Assessment are shown. To obtain these findings, the results of the Life Cycle Inventories for the 32 different floorings – as documented in the individual reports supplied to the participating companies – were first subjected to an impact related aggregation according to the parameters shown in *Chapter 3*. These results were then aggregated for the different groups of the individual floorings to simple mean values without considering any weighting, e.g. the market share. As indicated above, we finally decided to group the different floorings according to their **main polymeric components**.

All results presented in this chapter are referred to the reference lifetime of twenty years which means that the functional unit, with respect to production and waste management, is equivalent to one full life cycle for all floorings under study.

Figure 3 shows the **gross energy value** for production and disposal of the flooring groups. As a reference figure for the use phase, the gross energy value for dry cleaning is shown, caused by the energy demand of a vacuum cleaner which, although mainly used for textile flooring, exceeds all average values for the contract cleaning application of flooring products.

Parquet shows the lowest share of non renewable energy, but – due to the relatively high mass of wood – the highest fraction of renewable energy and also the highest total gross energy value. (Please note that the lifetime of parquet could be longer than twenty years, and that of textile somewhat shorter.)

**Water demand**
The typical water input for wet cleaning over 20 years of service exceeds the water needed for the production of all flooring groups by far (→ *Fig. 4, p. 79*).

**Municipal and chemical waste**
The biggest part of the municipal waste comes from the laying reject and the removal of the floorings after use. Therefore, rubber floorings (because of their weight) show the highest amount of municipal waste by mass (→ *Fig. 5, p. 79*).

With respect to the PVC and cushioned PVC floorings, the chemical waste primarily stems from the incineration plant processes (salts from flue gas scrubber) and in the pre-chain processes, where the PVC production is quite sensitive (→ *Fig. 6, p. 79*). Please note that the output of flue gas scrubber residues also depends on the incineration system. In this case, actual incineration plants in Germany are considered.

**Acidification potential**
Regarding the results of the different life cycles, the acidification potential is mainly caused by airborne emissions, namely by oxides of nitrogen oxides and sulphur (→ *Fig. 7, p. 80*). They are generated by energy supply processes and pre-chain processes (e.g. emission of sulphur due to the vulcanisation for rubber). In contrast to many other Life Cycle Assessment studies which we have thus far performed, transport operations are not important here due to the fact that only bulk transports are relevant for this production group.

**Global warming potential**
There are two substances in all life cycles which dominate a potential effect of the anthropogeneous global warming:

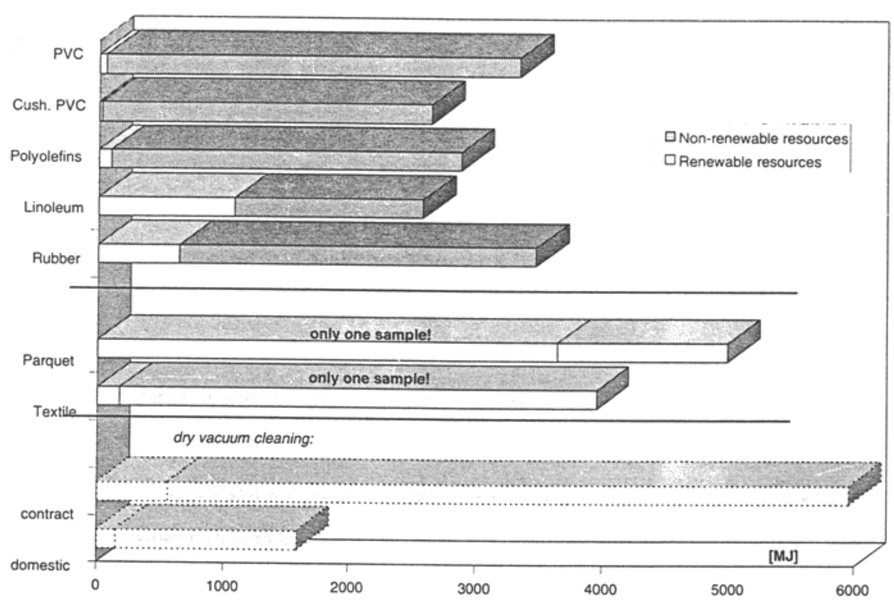


**Fig. 3:** Gross energy value for non-renewable and renewable resources. Reference: 20 m² of flooring, use over 20 years. Use phase shown separately, i.e. efforts for dry vacuum cleaning in domestic areas

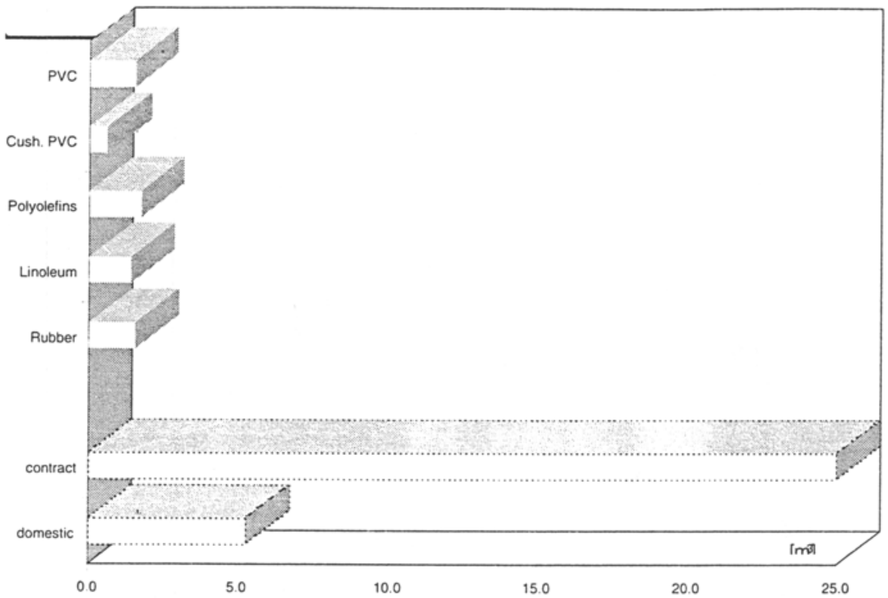


**Fig. 4:** Water demand. Reference: 20 m² of flooring, use over 20 years

Methane which is generated under anaerobic conditions by biodegradable substances at the dump site and carbon dioxide as a result of the burning of fossil carriers for energy supply (→ *Fig. 8, p. 80*).

Floorings with biodegradable compounds (parquet and linoleum) show the highest effect, followed by floorings with a high energy demand.

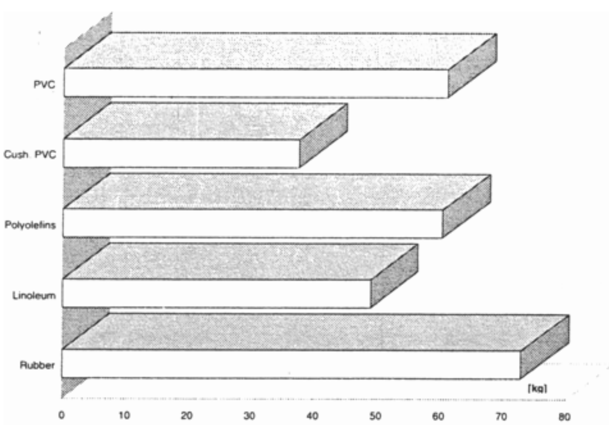


**Fig. 5:** Municipal waste. Reference: 20 m² of flooring, use phase excluded

## 5 Key Findings

It must once again be noted that the following conclusions have been made on the basis of the goal and the scope of this study. Explicitly, this means that

- in the presentation of the results, the confidentiality for company specific data and results had to be kept
- and that the study for good reason dedicatedly concentrated on those contributions to environmental loads which are at least quantifiable in relative terms.

As a consequence,

- direct comparisons of individual products had been excluded; the conclusions therefore have to be rather general in this overall study
- and aspects like ecotoxicological and toxicological issues could not be treated.

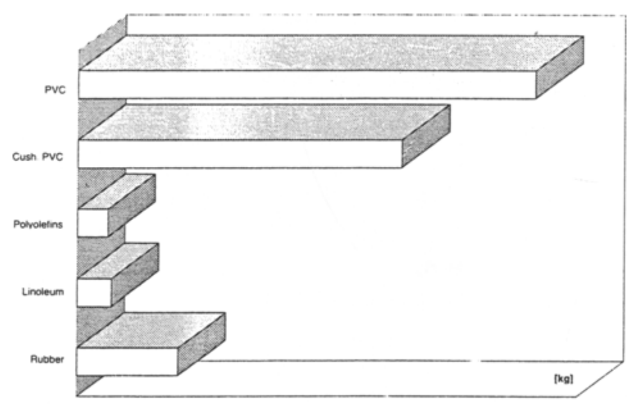


**Fig. 6:** Chemical waste. Reference: 20 m² of flooring, use phase excluded

Especially for the last aspect, ongoing research activities on a European level have to provide more facts about the different substances which are presently under discussion.

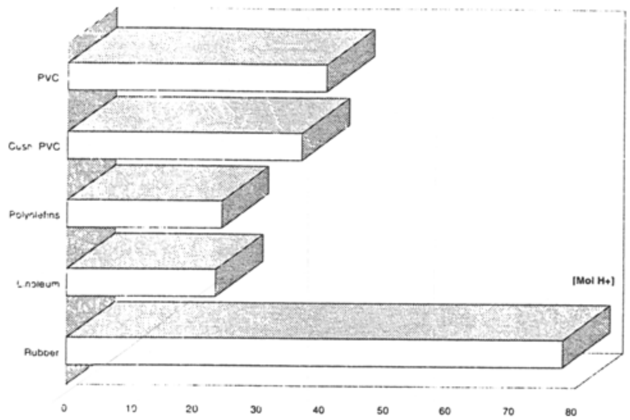


Fig. 7: Acidification potential. Reference: 20 m² of flooring. Use phase excluded

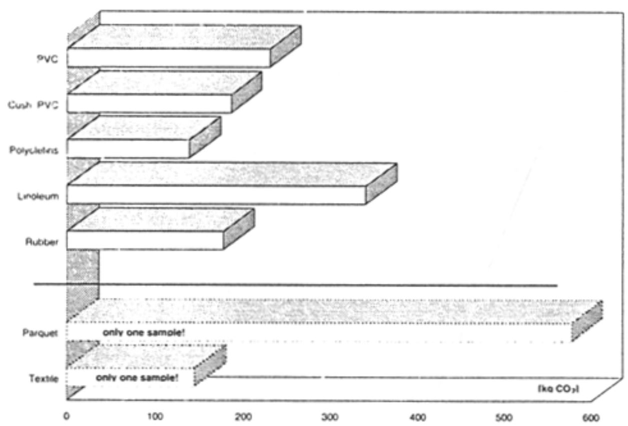


Fig. 8: Global warming potential. Reference: 20 m² of flooring, use over 20 years

1. **Findings of general interest**

⇒ Concerning the **different basic materials**, there is **no material specific** ranking for 'best' or 'worst' environmental performance, whereas relative advantages concerning specific categories are to be found.

⇒ Significant improvement options are to be found for all floorings and in all parts of the life cycles.

⇒ The results within one material group may differ, largely depending on the individual formula of a given product. **This individual formula therefore dominates over the selection of the basic polymeric material.**

⇒ Contract dry cleaning may require more energy over the lifetime of a typical flooring (6 GJ) than the production of all floorings investigated; similarly, the water input for contract wet cleaning (26 m³) may exceed the water demand in the production of all floor coverings by far.

⇒ The influence of transport operations is weak because only bulk material is carried.

2. **Findings relevant to the end user**

⇒ **The effects of a premature change** of a flooring, either because of an inappropriate selection of a product for a given application or a decision driven by habit or taste, may have a **higher influence on the environmental performance of the product system "flooring" than most other options for improvement.**

3. **Findings relevant to the producers**

⇒ Improvements in energy demand may be achieved – where technically appropriate – by:

- Formulas using a higher share of minerals,
- renewable materials
- or recycled materials.

⇒ As most of the municipal waste comes from the flooring after removal and most of the chemical waste is generated in municipal waste incineration plants, efficient recovery/ecycling schemes will have a great effect on the reduction of both types of wastes.

⇒ Recovery schemes, however, must be very material specific: As PVC, if incinerated, is responsible for the largest contribution to chemical waste, it is essential that PVC floorings be recovered by material recycling, whereas the especially native materials may be used in energy recovery.

⇒ As energy supply processes show the largest influence to eutrophication and acidification by associated $NO_x$ emissions, improvements in energy supply efficiency are a viable option in this area for those companies which do not use electricity – heat co-generation.

⇒ The Global warming potential is dominated by carbon dioxide emissions (energy supply) and methane emissions, the latter predominantly for native materials (landfill of organic, biodegradable substances). Also here, the huge improvement opportunities due to efficient recovery schemes are to be emphasised in which, however, energy recovery leads only to a reduction in the Global warming potential if natural substances are to be treated. In the case of fossil raw materials, energy recovery does not reduce the Global warming loads in comparison to landfilling.

## 6 References

[1] A. Günther; W. Holley: Aggregierte Sachökobilanz-Ergebnisse für Frischmilch- und Bierverpackungen. Verpackungs-Rundschau, Technisch-wissenschaftliche Beilage, 46 (1995) No. 3, pp. 53-58 and Nr. 5, pp. 62-68, 1995