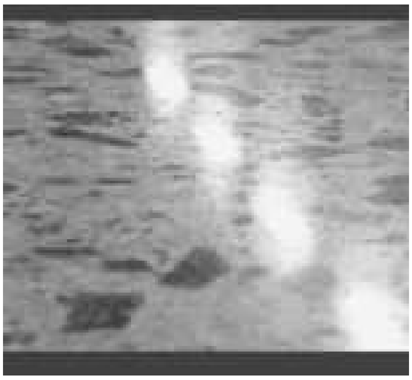
# Life Cycle Assessment of Industrial Floors

## A comparative study of HTC Superfloor™ and an epoxy floor



by

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# Summary

Sustainable development is a central concept for environmental activities and an essential element of these activities is the production and use of products and services with minimal impact on the environment. Environmentally compatible products are becoming increasingly important in product marketing.

This study has been commissioned by HTC Sweden AB to provide an overview of how its HTC Superfloor™ system compares to one type of epoxy flooring. A comparative life cycle assessment was conducted and three categories of environmental effects were studied: potential global warming, acidification and eutrophication. The results were then considered in relation to the floor as a whole, i.e. production of the concrete in the floor, the surface coating method and the waste management.

HTC Superfloor® is a system of diamond-ground, impregnated, polished concrete floors without surface coating. The floor withstands high pressure, is easy-to-clean and can be used in warehouses, workshops and public areas.

A life cycle assessment enables us to examine the environmental impact of a product from the raw material stage through to waste management. In a comparative life cycle assessment, the common areas in the life cycles of the products are excluded and the remaining areas are analysed.

Epoxy floors are very common in industrial premises and the floor used in this comparative study is a 3-mm, Peran SL, self-levelling epoxy floor.

The results of the comparative life cycle assessment of epoxy and HTC Superfloor show a huge difference between the floors. The epoxy floor's contribution to potential global warming is 189 times greater than that of HTC Superfloor™. Equivalency factors indicating the contribution to acidification and eutrophication are 548 and 758 respectively.

The environmental impact of the epoxy floor is also a major part of the floor as a whole. The epoxy coating's contribution to eutrophication and acidification is as much as 50% of the floor as a whole. Corresponding values for HTC Superfloor™ are 0.19% and 0.12% respectively.

# Abstract

The goal to achieve sustainable development is central to environmental activities. Using and producing environmentally-friendly products is an important part of this. Emphasising the low environmental impact of a product is becoming increasingly important in a company's marketing of its products.

This study was commissioned by HTC Sweden AB, who wants to compare the environmental impact of its HTC Superfloor™ system to that of an epoxy floor. A comparative life cycle assessment has been performed and three environmental impact categories have been studied: potential global warming, acidification and eutrophication. The results have then been compared to the environmental impact of the floor as a whole, which is the production of the concrete, the surface treatment and final disposal.

HTC Superfloor™ is a grinded, impregnated and polished concrete floor. It is very durable, easy to clean and suitable in stockrooms, workshops and other premises.

Life Cycle Assessment is a method of studying the environmental impacts of products from raw material to final disposal. A comparative LCA excludes any parts of the products' life cycles that are the same.

Epoxy floors are common in industrial premises. In this comparison, a 3-mm self-levelling epoxy floor, Peran SL was chosen to represent the epoxy floor.

The results of the LCA show there is a great difference between the floors. The contribution to potential global warming from the epoxy floor is 189 times greater than from HTC Superfloor™. The corresponding factors for acidification and eutrophication are 548 and 758.

The environmental impact of the epoxy floor is also a substantial part of the floor as a whole. The contribution to acidification and eutrophication is as much as 50 percent of the floor as a whole where the corresponding numbers for HTC Superfloor™ are 0.19, and 0.12 percent respectively.

# Preface

This study has been carried out as a thesis research project at Linköping University as the final phase of my MSc degree in Machine Engineering.

First and foremost, I would like to thank my supervisor at the university, Leif Thuresson.

I would also like to thank everyone at HTC for being so obliging and helpful. A particular thank-you is extended to Karl Thysell, Håkan Thysell, Henrik Rosencrantz, Kåre Kilgren and Sten Jeansson.

Thank you to Daniel, Elisabeth and Roland for giving me lifts and your wonderful company on our trips to and from Söderköping!

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Thanks to my mum, Karin, Thomas and Mattias for reading through my report and helping me make it readable. Thanks to Jostein, my opponent, for your excellent advice and suggestions.

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Josefine Hellström

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# 1 Introduction

## 1.1 Background

Sustainable development is a central concept for environmental activities as well as in other areas such as finance and social work. It's about thinking long-term and creating a rational society, both now and in the future. Agenda 21 is the United Nations' action programme for the environment and sustainable development. It is one of five documents agreed at the United Nations' Summit in Rio in 1992. Agenda 21 is founded on the three main areas of sustainability – social, economic and ecological sustainability. All three are equally important to the achievement of sustainable development.

It is necessary to produce low environmental impact products to achieve ecological sustainability. An essential part of this is to see the environmental impact of products from a life-cycle perspective. Environmental compatibility of products is becoming increasingly important, in product marketing as well, because of increasing pressure from the authorities and consumers.

## 1.2 Purpose & Objectives

This report has been commissioned by HTC Sweden AB who wants to know how its HTC Superfloor™ system compares, from an environmental point of view, to an epoxy-coated industrial floor. The purpose of this study is to describe the environmental impact of a square metre of these two industrial floor coverings over a twenty-year period. It is possible that the results will be used by HTC Sweden AB for marketing HTC Superfloor™.

A comparative life cycle assessment will be carried out to determine the environmental impact of these floor coverings. Three categories of environmental impacts will be examined: potential global warming, acidification and eutrophication. A comparison will be made with the environmental impacts of concrete so that the environmental impacts of the surface coating method can be evaluated in relation to the floor as a whole, i.e. production of the concrete in the floor, surface coating method and waste management.

# 2 HTC Sweden AB

HTC Sweden AB was founded in 1987 as a contractor company, working with the machinery and technology that was then available. In 1992, HTC developed its own first grinding system. This patented system was initially designed for grinding natural stone, but it soon proved to be just as effective on concrete. HTC Sweden AB is owned by Håkan and Gunn Thysell who both work in the company. Håkan is the originator of product and process ideas and his son, Karl, is Head of Product Development. HTC Sweden is based in Söderköping (illustration 1) and all divisions are housed in the same building: production, purchasing, sales and construction (information material, HTC).

Illustration 1: HTC in Söderköping (www.HTC-Sweden.se)

HTC develops and produces a full range of grinding machines, grinding tools and dust extractors. The grinders are used to scrub and polish concrete, natural-stone, terrazzo and wooden floors, together with HTC’s diamond tools for grinding. (Information material, HTC)

80% of HTC’s products are exported and its grinders are used globally. HTC has some 80 employees and is steadily expanding (Information material, HTC).

# 3 Theory

## 3.1 Industrial flooring

The three principal requirements for industrial flooring are that it should be dust-free, heavy-duty and easy-clean. Environmental impact requirements have also become more stringent in recent years. The appearance of the floor is less important in commercial premises where functionality takes precedence over aesthetics. However, it is far better that the floor retains its original appearance for a longer period of time. Virtually all industrial flooring is made of concrete and is treated in different ways to obtain the desired properties (Johansson, 2006).

Of all the surface coating methods, the most common are various kinds of epoxy coatings. Some examples of epoxy coatings: epoxy painting, coating flakes, thin layer coating, self-levelling and antistatic (Flowcrete.se). Epoxy-flooring manufacturers include Flowcrete, Eradur, Epirex, Marcopox and Armeca.

Hard concrete is another type of surface coating. Hard concrete is made up of granulated quartz which is trowelled into the surface of the concrete base while it is still damp. The result is a smooth, glossy and extremely durable floor. The only drawback with this is that the hard concrete material can only be applied to newly-laid bases. Research is being carried out to develop methods of making the quartz adhere to old floors. No such method is currently available on the market (Johansson, 2006).

In order to polish the surface, and thereby a great amount of additional material, the concrete floor can be polished and impregnated to obtain a durable, hard-wearing floor that is easy to clean. HTC Superfloor™ is just such a floor. Details of how HTC Superfloor™ is made are provided later on in this report.

## 3.2 Concrete

### 3.2.1 General

Concrete is a mixture of aggregate (crushed stone) of varying coarseness, cement and water (Elfgren 2006). Cement is crushed limestone, blended with shale or sand. During the cement-production process, calcium oxide reacts with silicon oxide to form calcium silicate, the predominant component that gives concrete its strength and hardness (Hillerborg, 2006).

Various additives can be mixed in to improve the concrete’s qualities. The resultant mouldable composition has to be mixed. The calcium silicates in the cement react with the water and harden the paste by binding the aggregate particles together. It usually takes about a month at normal temperature for the cement to fully dry and harden. To ensure maximum strength, the cement must be kept damp until it is completely set.

Porous concrete (without additives) has a density of about 2400 kg/m$^3$. The compressive strength of porous concrete varies between 25 and 80 Mpa, depending largely on the water ratio. The compressive strength can be improved by adding silicon powder and a wetting agent. Concrete has low tensile strength and is therefore usually reinforced with steel bars or mesh (Elfgren, 2006).

### 3.2.2 The environmental impact of concrete

Limestone and aggregate are quarried. This creates vibrations and noise and scars the landscape. This report does not closely examine the effects of quarrying.

A great amount of energy is required to produce cement for concrete. The impact this has on the environment depends on the type of energy used. During the process, nitric oxides, carbon dioxide and particles are emitted into the atmosphere. If the cement contains sulphur, sulphur dioxide is also formed. Purification plant filters remove particles, 90% of the sulphur dioxide and 80% of the nitrogen dioxides (Cementa, 2006).

A life cycle assessment of concrete showed that transportation during the production process is the greatest contributor to emissions. Emissions from production processes and waste management of concrete are presented in Appendix 1 (Sjunnesson, 2005).

## *3.3 Plastics*

Plastic comprises one or more polymers and one or more additives. There are two main types of plastic – thermoplastics and thermosets. Thermoplastics can be melted and reshaped and thus recycled.  Thermosets consist of polymers that undergo a chemical cross-linking change during manufacture. This occurs either in the final stage of polymerisation or through the addition of hardeners. Due to the chemical cross-links (which are many more than in rubber), the thermosets cannot be melted down again or dissolved in any solvent. Thermosets are rigid but brittle.

Thermosets have a wide range of uses and are commonly used in the boat-building and automobile industries. They are also frequently used as various types of floor coverings (Terselius, 2006).

## 3.4 *Epoxy plastic*

Thermoset floors are mainly manufactured using epoxy plastic. It consists of epoxy resin which is cured through the addition of a hardener. An epoxy resin is a molecule that has several epoxy groups, also known as a glycide group (illustration 2).

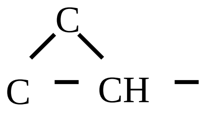

Illustration 2: Epoxy group

Epoxy plastic is the reaction product of bisphenol A and epichlorhydrin. Bisphenol A is formed through the reaction of propane and chlorine, and epichlorhydrin is made from acetone and phenol. When bisphenol A and epichlorhydrin react, diglycidyl ether of bisphenol A (DGEBA) is produced. DGEBA has different molecular weights depending on the ratio of bisphenol to epichlorhydrin. The average molecular weight is often specified since the resin contains epoxy molecules of different lengths. The lowest molecular weight is 340. If the average molecular weight of the epoxy resin is between 340 and 700, it is called low-molecular. If it has a higher average molecular weight, it is called high-molecular. Epoxy resins can sometimes cause allergic reactions and it is the molecular weight that determines how great a risk of an allergic reaction there is. The lower the molecular weight, the greater the risk of an allergic reaction. The molecular weight also determines what the epoxy resin can be used for, as the different resins have different properties. A low-molecular epoxy resin is liquid at room temperature, while a high-molecular resin is hard.

Epoxy resin reacts with a hardener to form epoxy plastic. Different compound groups can be used as hardeners, such as amides, amines, acid anhydrides, phenols and metal oxides (Augustsson, 2004).

### 3.4.1 Epoxy plastic in industrial flooring

There are many reasons for using epoxy plastic in floor coatings. The plastic has excellent adhesiveness, high mechanical strength, good chemical resistance, good electrical insulation properties, minimal shrinkage, good heat resistance and is diffusion-proof and waterproof.

This is common in coverings made of self-levelling floor screeds. These are applied at a thickness of between 1.5 and 5 mm. Self-levelling floor screeds produce smooth, seamless and non-porous floors. However, one problem is that when exposed to heavy traffic, the concrete underneath the floor covering gets worn and broken, causing it to become loose and dislodged. To ensure that it is sufficiently durable, the covering has to be thick enough to disperse the weight over a larger area. The floor should be coated with a thickness of at least 3 mm to ensure sufficient dispersal (Augustsson, 2004).

## *3.5 The environmental impact of epoxy plastic*

Epoxy plastic has the greatest impact on the environment before it cures. After it has cured, it is not considered environmentally-hazardous. In Section 21 of the regulations on thermosetting plastics issued by the National Board of Occupational Safety and Health, it says:
“An epoxy plastic component may not be used at a temporary worksite unless an investigation is carried out and shows the use to be necessary in order to meet the necessary technical requirement of the end product. A low-molecular epoxy plastic component may not be used at a temporary worksite as moisture barrier, alkali barrier or other such emission barrier if there are alternative products, methods or constructions which yield equivalent results.”

The term “temporary worksite” refers to “a workplace outside of a permanent operating point or a workplace for alteration, repair or enlargement of equipment at a permanent operating point”. This means that if another product can be used instead of epoxy, then the alternative product must be used.

The contents of epoxy resin before it cures are environmentally hazardous, first and foremost, to water organisms (Safety Data Sheet, Peran SL).

Epoxy, like all plastics, is made from oil, which is a natural resource of finite quantity.

## *3.6 HTC Superfloor™*

HTC Superfloor® is a system of diamond-ground, impregnated concrete floors without a surface coating. The floor withstands high pressure, is easy-to-clean and can be used in warehouses, workshops and public areas. It is not advisable to place leaking machines on the concrete floor because it cannot withstand large oil or chemical spills. The final appearance of the floor depends on the concrete. The colour and appearance of a new floor can be modified through the choice of aggregate in the concrete (Thysell, 2005).

### 3.6.1 Manufacture

HTC Superfloor™ is manufactured by grinding the concrete in several steps. On new installations, the surface paste is first ground away. On old concrete floors, previous coatings and uneven surfaces are removed. Coarse grinding is performed in two steps using metal-bonded diamond tools and the floor is then treated with HTC Cure to provide protection from water penetration. HTC Cure is water glass impregnation that strengthens concrete and lowers the pH and the relative moisture content in the concrete (Information material, HTC Superfloor™). HTC Cure may be irritating to the skin and eyes, but it contains no known substances categorised as hazardous to the environment (Safety Data Sheet, HTC Cure).

After the impregnation stage, the floor is polished in five steps. The first using a metal-bonded diamond tool and the subsequent four using plastic-bonded diamond tools. In the final step of the HTC Superfloor™ process, HTC Sealer is polished into the floor (Information material, HTC Superfloor™). The product contains no ingredients for which mandatory declaration is required. The recipe for Sealer is a trade secret, but the safety data sheet states that no evidence of negative environmental effects from the product has been found (Safety Data Sheet, HTC Sealer).

#### 3.6.1.1 Grinding machines and dust extractors

The grinding machine used in the comparative study is the HTC 800 (illustration 3).
The HTC 800 has a power output of 11 kW and it takes one hour to complete all the grinding steps on a $^2$ finished floor surface (Thysell, 2005).

Illustration 3: HTC 800 grinding machine (www.HTC-Sweden.se)

The machine weighs 570 kg and is made of 85% steel, 10% aluminium, 5% polymers, copper and other material (Andersson, 2006).

A machine has a 10-year life, but bearings and belts are replaced after about 400 operating hours. About 15-20 kg of steel bearings are replaced each time (Johansson, 2006).

A dust extractor is used with the grinding machine and it collects the fine dust in plastic bags which are then sent for landfill disposal. The dust extractor used in the comparative study is the HTC 55D (illustration 4). It has a power output of 5.5 kW (Thysell, 2005).

Illustration 4: HTC 55D dust extractor (www.HTC-Sweden.se)

The extractor weighs 199 kg and is made of 60% steel, 35% aluminium, 5% polymers, copper and other material (Andersson, 2006).

### 3.6.1.2 Tools

The three grinding discs under the grinding machine each have three or six tools. Two types of tool are used – metal-bonded (illustration 5) and plastic-bonded (illustration 6). Both have grinding segments with synthetic diamonds. The metal-bonded tool is made of steel alloy with welded grinding segment and the plastic-bonded tool is polyamide (Nilsson, 2005).

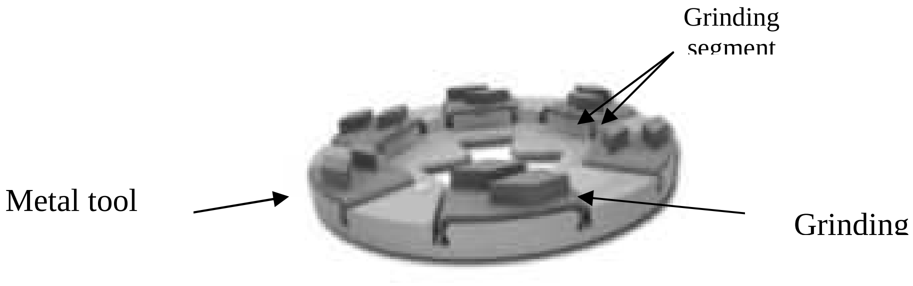

Illustration 5: Grinding disc with six metal-bonded tools, used when grinding HTC Superfloor™. Shown here with six tools (www.HTC-Sweden.se)

Illustration 6: Plastic-bonded tools used when grinding HTC Superfloor™ (www.HTC-Sweden.se)

### 3.6.2 Cleaning

The floor is cleaned using a mop or a floor scrubbing machine together with HTC Cleaner. HTC Cleaner is a soap used with water (0.5 – 1 part Cleaner to 100 parts water). Just like HTC Sealer, the recipe is a trade secret. HTC Cleaner contains no ingredients for which mandatory declaration is required. It is not categorised as hazardous to the environment and human health, or as a fire hazard (Safety Data Sheet, HTC Cleaner). Information from interviews with companies that have HTC Superfloor™ indicates that the floors are normally cleaned 2 to 5 times a week and all those interviewed said they use scrubbing machines (User Interview, Appendix 2).

## *3.7 Peran SL*

There is an extensive range of different epoxy resin floor finishes available from a number of different manufacturers. As it is a normal industrial floor, a self-levelling, two-component epoxy floor coating with an application thickness of 3 mm has been chosen for the purpose of comparison. The study uses Peran SL from Flowcrete Sweden AB to represent this type of floor. Peran SL has a clear environmental product declaration for its floors. This was also a determining factor in the choice of manufacturer.

Flowcrete Sweden AB is based in Perstorp in southern Sweden. The company was set up in 1968 as part of the Perstorp Group of Companies. Flowcrete manufactures a range of seamless, thermoset-based industrial floors and wall systems. Until 2005, the company's name was Peran AB. In 1997 it launched Peran. In 2005, the company was taken over by the British Flowcrete Group plc and changed its name to Flowcrete Sweden. It markets epoxy, vinyl ester, acrylic and polyurethane floor finishes. Flowcrete Sweden has been awarded ISO 9001 and 14001 management system certification (www.flowcrete.se).

Peran SL is a solvent-free, self-smoothing resin floor finish available in a range of colours (Product Data Sheet, Peran SL, Appendix 10).

### 3.7.1 Manufacture

On new installations, the surface paste is ground away. On old concrete floors, the surface is washed if necessary and then ground down to a pure concrete surface.

A two-component primer (Peran LVS) is applied. Then the Peran SL epoxy compound is mixed and spread over the floor. The compound consists of components A and B and quartz sand filler. The total amount of material required for Peran SL is 5.88 kg/m$^2$, 0.3 kg/m$^2$ of which is primer (Product Data Sheet, Peran SL, Appendix 10).

### 3.7.2 Maintenance

Cleaning is normally carried out using a scrubbing machine and detergent. A whole range of detergents can be used, provided their pH is between 3 and 14. Strong solvents should not be used (Product Data Sheet, Peran SL, Appendix 10). ISS Services (a cleaning company that cleans BT in Mjölby) uses Jontec Forward Free to clean this type of floor (Widberg, 2006). According to the safety data sheet, the detergent is irritating to the respiratory organs and skin. There is also a risk that it may cause serious damage to the eyes. However, the detergent is considered not harmful to the environment (Safety Data Sheet, Jontec Forward Free, Appendix 5).

## *3.8 Concrete recycling*

Every year, 960 000 tonnes of waste concrete are generated from construction and demolition activities. 20% of this is recycled, about 5% is dumped and 75% is dumped in landfill sites. No research is conducted in this area partly because of the low cost of depositing waste products and the ready availability of natural gravel and rock (Grönholm, 1999).

The reason why only a small amount is recycled is that the properties and quality of the concrete vary considerably. It is primarily used as a filling material on roads or as aggregate in new concrete. In the Netherlands, the concrete is heated to a temperature of more than 300 degrees so that the cement paste falls off and the aggregate can be recovered. This reduces the problem of variable quality in the aggregate (Gram, 2005)

Since this study is comparing an epoxy floor and HTC Superfloor™ it is interesting to know if the coating has any impact on the potential for recycling. According to Jan-Olof Sundqvist at IVL, an epoxy coating has no effect on what happens to the floor, since the epoxy is not considered harmful to the environment after it is cured and does not otherwise prevent recycling (Sundqvist, 2005).

# 4 Method – Life Cycle Assessment

A comparative life cycle assessment will be carried out on HTC Superfloor™ and the thermoset floor to compare their environmental impacts. LCA stands for Life Cycle Assessment. An LCA examines the impact a product has on the environment and its use of resources throughout the entire life of the product – from extraction of raw materials to its end disposal, reuse and recycling (Baumann & Tillman, 2004).

These components are included in an LCA and are examined in more detail in this chapter:

| | |
|---|---|
| Objectives and scope | Objectives and system boundaries for the study are defined |
| Inventory | Data is collected for all the stages included in the life cycle |
| Environmental impact assessment | The collected data is converted into different environmental impact categories |
| Interpretation | The results of the environmental impact assessment are interpreted |

## *4.1 The ISO 14040 series*

ISO 14000 is an international standard for environmental management systems. Like the other ISO standards, it has been developed by the International Organisation for Standardisation (ISO).
The ISO 14000 Series of standards provide guidelines for environmental management systems and audits, environmental performance and LCAs. ISO 14040-49 covers life cycle assessment (Rydh et.al., 2002). Table 1 presents a summary of ISO standards.

Table 1: ISO 14040 Standards (SIS 2006)

| | | | |
|---|---|---|---|
| ISO 14040 | Life Cycle Assessment – Principles and Framework | Completed 1997 | Review of the four documents 14040-43 began in 2004, rewritten as two new documents, now FDIS 14040 and FDIS 14044 (FDIS - Final Draft International Standard) |
| ISO 14041 | Objective and scope definition and life cycle inventory analysis | Completed 1999 | |
| ISO 14042 | Environmental impact assessment | Completed 2000 | |
| ISO 14043 | Life cycle interpretation | Completed 2000 | |
| ISO/TR 14047 | Illustrative Examples on How to Apply ISO 14042 | Completed 2002 | |
| ISO/TR 14048 | LCA Data Documentation Format | Completed 2002 | |
| ISO/TR 14049 | Illustrative Examples on How to Apply ISO 14041 | Completed 2000 | |

## *4.2 Objectives and scope*

This section of the LCA defines the product being studied and the objectives of the assessment. ISO 14040 requires a report to be included here on why the study is being undertaken and who the target groups are. The target group is often rather general and unclear when the assessment begins but becomes more specific as the study progresses (Baumann & Tillman, 2004).

### 4.2.1 Functional unit

In order to compare the environmental impact of the different systems, it is necessary to define a common denominator. This is called a functional unit and describes the function and performance of the system. There are often many different ways to meet a need. Take the storage of liquid as an illustration. The functional unit can then be a “one-litre package of liquid” and thus serves for all kinds of packages. For the comparison to be correct, three different levels of characteristics must be specified for the functional unit: quantity, sustainability and quality.

The quantitative part of the functional unit is used to allow inputs and outputs of material and energy for the system to be measured. As an example, this could be tonne-kilometres if looking at transportation of goods, or a unit of some item if looking at products.

It is also important to define sustainability, especially if the greatest environmental impact occurs during the usage phase of the life cycle. It is also vital to consider the technical life and the actual life of the product. Even if a product can last a certain number of years, there is no guarantee that it will remain interesting for that long – it might be considered old-fashioned or technologically outdated.

It is sometimes important to define quality too. One example might be the lighting in a room – light bulbs, fluorescent tubes, candles, etc. It might then be necessary to have a quality requirement for luminance, for example (Rydh et.al., 2002).

### 4.2.2 System boundaries

When carrying out an LCA, it is essential to decide which parts of the system will be studied and which will be omitted. Boundaries have to be drawn against other systems such as natural systems or other products. This might mean leaving production and maintenance of roads and lorries out of the system, even if transport energy consumption is included (Norrblom, 2000).

It may be necessary to set geographical boundaries because the LCA can look different depending on whereabouts in the world it is. Infrastructure, transport, energy production and waste management can vary considerably in different regions. Different kinds of environments also have different levels of tolerance to adverse environmental conditions. For example, in areas with lots of limestone in the bedrock, acidification is not as great a problem as in granite bedrock areas. Wind and weather conditions also affect emissions to the atmosphere (Rydh et.al., 2002).

## *4.3 Inventory*

The next stage of the LCA is an inventory. This is called Life Cycle Inventory or LCI and involves presenting the materials and energy flows for every phase of the system's life cycle. This includes materials, chemicals and energy that enter the system and emissions to the atmosphere and water, and waste leaving the system (Norrblom, 2000).

The system is presented as a flow chart according to the chosen system boundaries. Data about all the activities in the system is then collected and documented. This data is then converted so that it corresponds to the functional unit. The flow chart is not complete because only relevant flows and flows with environmental impacts of one kind or another are included. During the inventory process, more information is gathered about the system and it can sometimes be necessary to go back and adjust the objectives or modify the system boundaries (Rydh et.al., 2002).

Normally, a product has more than just one single input and one output. The raw materials are converted into other products and the life cycle often includes some kind of recycling or reuse of materials. The consumption of resources and the impacts on the environment sometimes have to be spread across several products to ensure they are correct for one product. There is no problem if recycled material is channelled straight back to the same process. It reduces the amount of new material in the process. However, the material is often recycled in new products. The consumption of resources for the product must then also apply to the new product, to a certain extent, and the consumption of resources must be spread across several products. This is called allocation (Rydh et.al., 2002).

## *4.4 Environmental impact assessment*

The next stage of the life cycle assessment is to use the information from the inventory and produce a Life Cycle Impact Assessment or LCIA. The aim of the environmental impact assessment is to try and describe the consequences on the environment. This is done by aggregating and translating the environmental data from the inventory into environmental problem categories, such as acidification, ozone depletion, effects on biological diversity and so on.

Aggregation is performed for a number of reasons, the main one being to make the information from the inventory more readily accessible. It might be easier to relate the environmental impact to the concept of acidification than to $SO_2$ emission figures. It makes the information more environmentally relevant and intelligible. Another reason is to make the information more manageable. The results of the inventory can be extensive and difficult to visualise or understand. This also facilitates the comparison between the environmental impacts of different products (Rydh et.al., 2002, Baumann & Tillman, 2004).

### 4.4.1 Environmental impact categories

The initial stage in an environmental impact assessment is to define the environmental impact categories that will be used. The decision for this is sometimes based on the objectives set in the beginning of the assessment and sometimes on the information obtained from the inventory.

The environmental impact categories can be divided into three main groups:

- Use of natural resources, e.g. water and land
- Health effects, e.g. toxic effects inside and outside the work environment
- Ecologic effects, e.g. global warming and acidification.

A category for "other flows" is often added. This includes the flows for which no data is available or which have not been followed from the cradle to the grave because of system boundaries. This is done to ensure that no flow is omitted (Rydh et.al., 2002, Baumann & Tillman, 2004).

### 4.4.2 Classification

The next stage of the environmental impact assessment is to make a classification. Classification involves sorting the parameters obtained from the inventory into the chosen environmental impact categories, i.e. saying which environmental problems they contribute to. Tables showing the environmental impacts of the various substances facilitate this stage (Rydh et.al., 2002, Baumann & Tillman, 2004).

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### 4.4.3 Categorisation

Once all the substances have been sorted into environmental impact categories, an index is created for each category. This is done by multiplying the contribution of each substance by an equivalence factor and then adding them up to create an indicator, e.g. one for acidification, one for global warming and so on. The equivalence factors are specific to substances and categories and are based on the potential environmental impact of the substance. The acidifying effect of substances is affected by their capacity to release hydrogen ions, $H^+$. One molecule of HCl can release one hydrogen ion, while one $SO_2$ molecule can release two hydrogen ions. Their molar equivalence factors are thus 1 and 2. However, the tables show the factor according to weight and there the equivalence factor for $SO_2$ is defined as 1 and the factor is given the unit "g $SO_2$-eq/g". Thus the equivalence factor for HCL is 0.88 g $SO_2$ eq/g. The calculations are performed using science-based models for cause-effect relations in natural systems. However, these models are often highly simplified (Rydh et.al., 2002, Baumann & Tillman, 2004).

Some environmental impact categories and equivalence factors are listed below (Table 2).

Table 2: Environmental impact categories (Rydh et.al. 2002)

| **Environmental impact category** | **Abbreviation** | **Equivalence factor and unit** |
|---|---|---|
| Global warming potential | GWP | kg $CO_2$(carbon dioxide) equivalents/kg |
| Stratospheric ozone depletion potential | ODP | kg CFC11(freon) equivalents/kg |
| Acidification potential | AP | kg $SO_2$ (sulphur dioxide) equivalents/kg |
| Eutrophication potential | EP | kg $PO_4^{3-}$ (phosphate) equivalents/kg |

### 4.4.4 Weighting

The final stage of the environmental impact assessment is the weighting. This is when all categories are added up to give one single environmental impact figure. The weighting can be qualitative or quantitative, with the various environmental impact categories weighted against one another. Each environmental impact category is multiplied by a weighting index that reflects the relative weight for that category. There are different methods of establishing a weighting index and they are based on various social or individual values. For example, political goals or economic and natural conditions. A weighting index is based on distances to goals, monetary values or panel methods and can be found in weighting index tables for the various methods.

Some examples of weighting methods are listed below.

Table 3: Examples of weighting methods (Rydh et.al. 2002)

| **Method** | **Environmental goal or reference** | **Weighting principle** |
|---|---|---|
| Eco-indicator 99 | Current state | Panel weighting |
| Ecological scarcity | National emissions | Relative reduction of distance to goal |
| EPS 2000 | Current state | Willingness to pay |
| Tellus | Zero emissions | Willingness to pay for purification equipment |

The weighting can never be entirely objective since it is based on values. It is therefore advisable to use several evaluation methods when comparing the results.

A life cycle impact assessment (LCIA) is thus a gradual aggregation of data identified during the life cycle inventory stage. ISO 14042 2000 states that classification and characterisation are mandatory steps in an LCA, while weighting is optional. The ISO Standard states that the weighting may not be published if two products are compared, as no internationally approved method of weighting exists. If the study comprises an inventory but no LCIA, it is termed an LCI (life cycle inventory) (Rydh et.al., 2002, Baumann & Tillman, 2004).

## *4.5 Interpretation*

When the results of the environmental impact assessment are ready, it is time for what is perhaps the most important phase of the LCA – the interpretation of the results in order to reach conclusions and provide recommendations based on the findings of the study. If only an LCI has been conducted, the results of the inventory are interpreted. The interpretation can result in changes to production processes or materials.

One of the greatest difficulties with the interpretation is that there is usually a considerable number of parameters. Conclusions drawn from the interpretation and analysis of the data should be presented clearly and comprehensively. The environmental impact assessment aggregates inventory data and makes the information more manageable. These values can be analysed to identify which phase of the product’s life cycle has the greatest impact on the environment.

The quality of the final data determines which conclusions can be drawn from the study and the sensitivity of the system when different parameters are changed. In a comparison of two different systems, it can be difficult to see if any significant difference exists between the two. There may be some uncertainty such as missing data or variations in the measurement data. Since reality is constantly changing, some of the inventory data may not correspond well to the actual conditions.

An uncertainty and sensitivity analysis can be conducted on the life cycle. An uncertainty analysis is performed to determine how great the difference is in the results due to the various uncertainties in the inventory data. A sensitivity analysis is performed to determine how the results are effected if different key parameters in the life cycle are varied, for example, the system boundary (Rydh et.al., 2002, Baumann & Tillman, 2004).

## 4.6 Methodology review

Just as with all methods, it is important to be aware of the positive and negative features of the method used. The LCA method naturally has its advantages and disadvantages.

Table 4. Advantages and disadvantages of LCA (Rydh et.al. 2002).

| **Advantages**<br>(Luftropp, 1997) | **Disadvantages**<br>(Lave et al., 1995, Portney, 1994, Fiksel, 1996, Hendrickson et. al., 1997) |
|---|---|
| Reveals upstream and downstream material and energy flows that might otherwise have remained hidden | Data is often missing and the method has to be based on theoretical estimates or short measurement series |
| Provides information for decision-making in order to generate new ideas that deliver the same functionality with less impact on the environment | The collection of data for a life cycle assessment is a very time and resource consuming process, making it difficult to use in the product development process |
| The results can shed light on environmental disputes | Requires extensive training in order to use it correctly |
| The results can provide the information required for producing guidelines on the environmentally compatible development of products | It is difficult to conduct a life cycle assessment for a new product/process and relatively costly in relation to the results obtained. |
| Greater knowledge about the company's own product/production process during discussions with clients and other stakeholders | The quality of the available data is not always satisfactory, which means that a small change of input data can give rise to considerable variations in the results |
| | There is a lack of reliable and comparable LCA/LCI-data |
| | There is no internationally approved method of weighting |

# 5 A comparative life cycle assessment of HTC Superfloor™ and Peran SL

As a comparative life cycle assessment is to be conducted, all common areas in the life cycle are excluded. However, the results will then be evaluated in relation to the environmental impact of the concrete floor. A worse case scenario will be used in the event of uncertain parameters.

## *5.1 Objectives and scope*

The objective of the life cycle assessment is to show how great a difference there is in the impact on the environment between the floors and which stage of the life cycle has the greatest impact. The LCA has been commissioned by HTC Sweden AB with potential application of the results in the marketing of HTC Superfloor™.

### 5.1.1 Functional unit

Unit areas are a suitable functional unit for floors and surface coatings. The functional unit for this study was therefore identified as one $m^2$ of floor. A time unit was also used and, after discussions with HTC, it was decided a floor could reasonably be expected to have a 20-year service life.

The functional unit used in the study is therefore: 1 $m^2$ of floor over a 20-year period.

### 5.1.2 System boundaries

The production of concrete will not be included in the comparative analysis of each floor separately, but will be included in the comparison with the concrete floor as a whole. This also includes the waste management of the floor as there are currently no differences between the floors with respect to recycling. The term “floor as a whole” refers here to the production of concrete, surface coating and waste management.

Since it is necessary to remove the surface paste or previous coating from both of the floors, this will not be included in the analysis of each floor separately either, but will be included in the comparison with the floor as a whole.

The amount of energy used in grinding the floor and manufacturing grinding tools will be calculated for HTC Superfloor™. The environmental impact from the manufacture of grinding machines will not be taken into account. It has been determined that each machine grinds so many square meters of floor that they will have no major impact on the environment per functional unit.

The assessment includes emissions from the production of epoxy components.

Scrubbing machines are used to clean both the floors. The frequency of cleaning depends mainly on the activities carried out in the building. The assessment will therefore not include production, maintenance and energy consumption for machinery. Both the floors can be cleaned using detergents that are not considered as harmful to the environment. Cleaning is therefore not included in the assessment.

Maintenance such as regrinding operations and floor replacement will be included in the assessment.

It is assumed that the floor is in Sweden and that Swedish electricity is used during grinding operations. The comparative assessment does not include the transportation of materials and grinding machines as there is no significant difference between the two floors in this respect.

It is assumed that the premises in which the floor is used is suitable for both the floors. As these are industrial floors, they are exposed to heavy traffic (mainly forklift trucks) but the emission of chemicals from operations in the premises is low. This is due to HTC Superfloor’s limited resistance to chemicals.

As mentioned above, three environmental aspects will be studied: potential global warming, acidification and eutrophication. These have been chosen because data about the contribution of both these floors to these environmental problems was available.
Toxicity would also have been an interesting aspect to study because of the toxicity of epoxy before it cures. However, there is no relevant data available that would allow a comparison to be made and toxicity is therefore not included in this study.

## *5.2 Inventory – HTC Superfloor™*

First, a process tree is created for the floor (illustration 7).

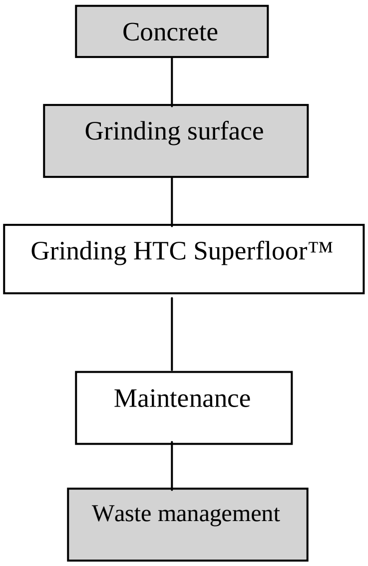

Illustration 7: Process tree for HTC Superfloor™. This also shows areas that will be included in the comparison with the floor as a whole, but they are shaded grey.

### 5.2.1 Manufacture

An HTC 800 grinding machine is used. This has a power output of 11 kW, 380 V. It grinds the 10m$^2$ of finished HTC Superfloor™ in 1 hour. This includes all steps and the same grinding machine is used (Thysell, 2005)

An HTC 55D dust extractor is used with the grinding machine. This removes practically all the dust created when grinding and has a power output of 5.5 kW. (Thysell, 2005)

Electrical energy for grinding is thus 5.94 MJ per m$^2$ floor.

About 2 kg of dust is produced per square metre when grinding. The dust is collected in plastic bags and sent for landfill disposal.

#### 5.2.1.1 Metal-bonded tools

Metal-bonded tools are used in the first three grinding steps. They comprise a metal plate made of 14-gram steel alloy (Thysell, 2005).

Amount of steel alloy per tool: 14 g
Energy consumption for steel production: approx. 30 kJ/g
Energy consumption per tool: 420 kJ
(Reference: Gotland University College, 2005)

A robot solders the two metal grinding segments onto the plate.
Power output of robot: 8 kW
Soldering time per tool: 30 seconds
Energy consumption per tool: 240 kJ
(Lindén, 2005)

The metal-bonded tool is then air blasted.
Power output of the compressed air compressor: 7.5 kW
Time per tool : 30 seconds
Energy consumption per tool: 225 kJ
(Lindén, 2005)

Nine tools are used per step
Total energy consumption per tool: 885 kJ
Total no. of tools: 27
No. sq. metres before the tools need changing: 2000
Energy consumption per $m^2$: 11.9 kJ
(Thysell, 2005)

### 5.2.1.2 Plastic-bonded tools

Plastic-bonded tools are used in the final four grinding steps and are made of polyamide (Nilsson, 2005).
Amount of polyamide per tool: 14 g
Energy consumption for polyamide production: 95 kJ/g
Energy consumption per tool: 1330 kJ
(Gotland University College, 2005)

The grinding segment on the tool is made of a composite material with a matrix of phenol plastic (Nilsson, 2005).
Amount of phenol plastic per tool: 14 g
Energy consumption for phenol plastic production: approx. 95 kJ/g
Energy consumption per tool: 1330 kJ
It is assumed here that the energy consumption for the production of phenol plastic is about the same as for the production of polyamide.

The grinding segment is made in a machine with a total power output of 5.5 kW and which manufactures grinding segments at a rate of 1000 tools per hour. The energy consumption is thus 19.8 kJ per tool.

The tools are dried in a drying cabinet at a temperature of 80 degrees for four hours.
Power output, drying cabinet: 2 kW
Time in drying cabinet: 4 hrs
No. tools at a time: 1512
Energy consumption per tool: 19 kJ

Nine tools are used per step
Total energy consumption per tool: 1370 kJ
Total no. of tools: 36
No. sq. metres before the tools need changing: 500
Energy consumption per $m^2$: 194 kJ
(Thysell, 2005)

Other materials:
The particles in the composite are 1 gram of synthetic diamonds and 4 grams of silicon carbide. The amount of emissions per $m^2$ for these substances will be so minimal that it will not affect the results of the assessment.

#### 5.2.1.3 Total

Energy for grinding: 5940 kJ
Energy for metal-bonded tools: 11.9 kJ
Energy for plastic-bonded tools: 194 kJ
Energy consumption per $m^2$: 6150 kJ

#### 5.2.1.4 Health risks associated with grinding

Fine stone dust is produced when grinding concrete floors and exposure to respirable silica dust increases the risk of contracting the lung disease known as silicosis. Tests have shown, however, that the correct usage of HTC dust extractors eliminates all problems with silica dust when grinding HTC Superfloor™. The values are within the specified range for silica dust emissions (Norén, 2005).

### 5.2.2 Maintenance

The last 5 grinding steps are repeated if the floor in high forklift truck traffic areas needs regrinding. The process is carried out faster than the initial grinding process (25-30 $m^2$/hr) and is only performed on worn areas. At BT in Mjölby, worn areas represent about 5% of the total floor surface. This is done about every 5 or 6 years (Johansson, 2006).

| | |
|---|---|
| Number of $m^2$ ground per hour: | 25 |
| Power output for grinding machine and dust extractor | 16.5 kW |
| Number of regrinds per functional unit (20 yrs): | 3 |
| % of total area that is reground : | 5% |
| Energy consumption per functional unit: | 0.356 kJ |

### 5.2.3 Total energy consumption, HTC Superfloor™

A total of 6.50 MJ electrical energy is used for grinding and regrinding. The energy comes from electricity. In Sweden, 49% of the electricity is produced by hydroelectric facilities, 45% by nuclear power facilities and 6% by the combustion of fossil fuels. This electrical energy gives the following inflows and emissions per MJ and total per functional unit (FU):

Table 5: Swedish average electricity, HTC Superfloor™, (Rydh et.al. 2002)

| Inflow | Swedish average electricity | HTC Superfloor™ |
|---|---|---|
| Natural resources | g/MJ | g/FU |
| Biomass | 2.66 | 17.3 |
| Coal | - | - |
| Crude oil | 10.4 | 67.6 |
| Natural gas | 0.23 | 1.50 |
| Uranium | 0.0039 | 0.0254 |
| Emissions | g/MJ | |
| $CO_2$ | 13 | 84.5 |
| CO | 0.0036 | 0.0234 |
| $NO_x$ | 0.021 | 0.137 |
| $SO_2$ | 0.014 | 0.0910 |
| $CH_4$ | 0.019 | 0.124 |

## 5.3 *Inventory - Peran SL*

A process tree for Peran SL is presented below (illustration 8).

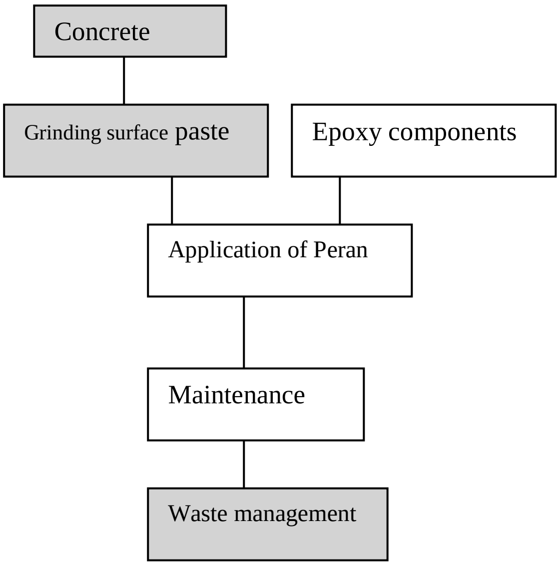

Illustration 8: Process tree for Peran SL. This also shows areas that will be included in the comparison with the floor as a whole, but they are shaded grey.

### 5.3.1 Manufacture

The energy used for raw material production of epoxy resin and hardeners is approximately 32 MJ/kg. A total of 0.3 kg Peran LVS is used per $m^2$ and a total of 5.4 kg Peran SL per $m^2$ (Product Data Sheet, Peran SL, Appendix 10). The total weight per square metre of floor surface is thus 5.7 kg and the energy used for raw material production is 185 MJ/$m^2$ (Environmental Product Declaration, Peran SL). Emissions from the production of Peran LVS and Peran SL are reported in Section 5.3.3. where total use of epoxy components is calculated.

Primers and epoxy compounds are manually applied so energy consumption is zero.

### 5.3.2 Maintenance

After about 10 years, the floor is re-ground, removing 0.5 mm of coating with a grinding machine. The grinding machine has a power output of 11 kW and in 1 hour it grinds 100 $m^2$ of floor. It therefore uses 0.4 MJ/FU (Overmar, 2006).

Table 6: Swedish average electricity, Peran SL, (Rydh et.al. 2002)

| Inflow | Swedish average electricity | Peran SL |
|---|---|---|
| Natural resources | g/MJ | g/FU |
| Biomass | 2.66 | 1.06 |
| Coal | - | - |
| Crude oil | 10.4 | 4.16 |
| Natural gas | 0.23 | 0.092 |
| Uranium | 0.0039 | 0.404 |
| Emissions | g/MJ | |
| $CO_2$ | 13 | 5,2 |
| CO | 0.0036 | $1.44 \cdot 10^{-4}$ |
| $NO_x$ | 0.021 | 0.0084 |
| $SO_2$ | 0.014 | 0.0056 |
| $CH_4$ | 0.019 | 0.0076 |

About 1 mm of new epoxy is applied, which is the equivalent of 1.8 kg of epoxy compound (Overmar, 2006)

### 5.3.3 Total

5.7 + 1.8 = 7.5 kg is the total amount of coating used per functional unit (FU).

Table 7: Emissions from the production of epoxy compound and quartz for Peran SL, plus conversion to emissions per functional unit (Environmental Product Declaration, Peran SL)

| Emissions to the atmosphere | g/kg epoxy compound | g/FU |
|---|---|---|
| $CO_2$ | 1900 | 14300 |
| Organic pollutants | 12 | 90.0 |
| $NO_X$ | 11 | 82.5 |
| $SO_X$ | 6 | 45 |
| Particles | 5 | 37.5 |
| Emissions to water | g/kg epoxy compound | g/FU |
| COD | 17 | 128 |
| Suspended particulates | 27 | 203 |
| $BOD_7$ | 11 | 82.5 |
| Organic pollutants | 2 | 15.0 |
| Salts | 450 | 3380 |
| Landfill disposal | g/kg epoxy compound | g/FU |
| Minerals | 96 | 720 |
| Slag and ash | 11 | 82.5 |
| Other solid waste | 31 | 233 |

Since nothing else has been specified, it has been assumed that the emission of organic pollutants corresponds to methane. A comparison with the environmental declaration of another epoxy floor (Eradur Massiv) has also been conducted and methane emissions seem to correspond to the emissions of organic pollutants (Environmental Product Declaration), Eradur Massiv, Appendix 14).

## *5.4 Environmental impact assessment*

### 5.4.1 Environmental impact categories

The environmental impact categories that have been studied are global warming, acidification and eutrophication. Each emission is classified according to its environmental impact.

### 5.4.2 Classification

Table 8: Emission classification (Rydh et.al. 2002, Baumann & Tillman 2004)

| Substance | Global warming | Acidification | Eutrophication |
|---|---|---|---|
| $CO_2$ | X | | |
| CO | X | | |
| $NO_x$ | X | X | X |
| $SO_2$ | | X | |
| $CH_4$ | X | | |
| COD | | | X |
| Particles | | | |

### 5.4.3 Categorisation

According to the objective of the study, three environmental impact categories are to be investigated: global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP). Once classification has been completed, the different characterisation factors will be derived. The equivalence factors of the various substances are listed in Appendix 17.

### 5.4.4 HTC Superfloor™

Potential greenhouse effect is converted to carbon dioxide equivalents per functional unit.

84.5 [g $CO_2$/FU] · 1 [$CO_2$ eq/$CO_2$] = 84.5 [g $CO_2$ eq/FU]
0.0234 [g CO/FU]· 3 [$CO_2$ eq/CO] = 0.0702 [g $CO_2$ eq/FU]
0.137 [g $NO_x$/FU] · 7 [$CO_2$ eq/$NO_x$] = 0.959 [g $CO_2$ eq/FU]
0.124 [g $CH_4$/FU] · 21 [$CO_2$ eq/$CH_4$]= 2.60 [g $CO_2$ eq/FU]

Total GWP-100: 88.2 [g $CO_2$ eq/FU]

Potential acidification converted to sulphur dioxide equivalents.
0.0910 [g $SO_2$/FU] · 1 [$SO_2$ eq/$SO_2$] = 0.0910 [g $SO_2$ eq/FU]
0.137 [g $NO_x$/FU] · 0.696 [$SO_2$ eq/$NO_x$] = 0.0954 [g $SO_2$ eq/FU]

Total AP: 0.186 [g $SO_2$ eq/FU]

Potential eutrophication is converted to sulphate equivalents.
0.137 [g $NO_x$/FU] · 0.13 [$PO_4^{3-}$eq/ $NO_x$] = 0.0178 [g $PO_4^{3-}$ eq/FU]

Total EP: 0.0178 [g $PO_4^{3-}$ eq/FU]

## 5.5 Peran SL

Global warming potential, GWP-100:
14300 [g $CO_2$/FU] · 1 [$CO_2$ eq/$CO_2$] = 14,300 [g $CO_2$ eq/FU]
82.5 [g $NO_x$/FU] · 7 [$CO_2$ eq/$NO_x$] = 578 [g $CO_2$ eq/FU]
90.0 [g $CH_4$/FU] · 21 [$CO_2$ eq/$CH_4$] = 1890 [g $CO_2$ eq/FU]

Total GWP-100: 16,700 [g $CO_2$ eq/FU]

Acidification, AP:
45.0 [g $SO_x$/FU] · 1 [$SO_2$ eq/$SO_x$] = 45.0 [g $CO_2$ eq/FU]
82.5 [g $NO_x$/FU] · 0.696 [$SO_2$ eq/$NO_x$] = 57.4 [g $SO_2$ eq/FU]

Total AP: 102 [g $SO_2$ eq/FU]

Eutrophication, EP:
82.5 [g $NO_x$/FU] · 0.13 [$PO_4^{3-}$eq/$NO_x$] = 10.7 [g $PO_4^{3-}$ eq/FU]
128 [g COD/FU] · 0.022 [$PO_4^{3-}$eq/COD] = 2.82 [g $PO_4^{3-}$ eq/FU]

Total EP: 13.5 [g $PO_4^{3-}$ eq/FU]

# 6 Results

Table 9 shows the results of the environmental impact assessment.

Table 9: Comparison of GWP, AP and EP for HTC Superfloor™ and Peran SL

| | Peran SL | HTC Superfloor ™ | Factor (Peran/HTC Superfloor) |
|---|---|---|---|
| GWP (g $CO_2$ eq/FU) | 16700 | 88.2 | 189 |
| AP (g $SO_2$ eq/FU) | 102 | 0.186 | 548 |
| EP (g $PO_4^{3-}$ eq/FU) | 13.5 | 0.0178 | 758 |

The coating is just one part of a floor. Table 10 shows the results if the environmental impact of the surface coating method is evaluated in relation to the total environmental impact of a 15-cm thick concrete floor, including surface coating. The calculations for the concrete floor are based on emissions from concrete that are presented in Appendix 1. Since the removal of surface paste or previous coatings was eliminated from the assessment of HTC Superfloor™ and Peran SL, the environmental impact of this is transferred to the concrete floor. An HTC 800 has been used in the calculations for grinding and it is assumed that the machine grinds 20 $m^2$ per hour.

Table 10: Comparison of GWP, AP and EP between the concrete floor as a whole and the surface coating method

| | The concrete floor, excluding surface coating | HTC Superfloor™ as % of the floor as a whole | Peran SL as % of the floor as a whole |
|---|---|---|---|
| GWP (g $CO_2$ eq/FU): | 42000 | 0.210 | 28.4 |
| AP (g SO2 eq/FU) | 95.2 | 0.195 | 51.7 |
| EP (g $PO_4^{3-}$ eq/FU) | 14.1 | 0.126 | 48.9 |

## *6.1 Uncertainty analysis*

### 6.1.1.1 HTC Superfloor™

It is obvious that the production of the floor has the greatest environmental impact for HTC Superfloor™. The analysis studies how the results of the environmental impact assessment are affected by different uncertainties in the inventory data.

The following manipulations were performed:
GWP: Results from the environmental impact assessment
GWP1: Results when the grinding machine grinds 8 m$^2$ per hour instead of 10.
GWP2s: Results when the number of m$^2$ for the metal tool is halved from 2000 to 1000
GWP3: Results when the number of m$^2$ for the plastic tool is halved from 500 to 250
GWP4: Results when the number of m$^2$ of regrinding is doubled from 5% to 10%
GWP5: Results when 4 regrindings are performed instead of 3 in a 20-year period

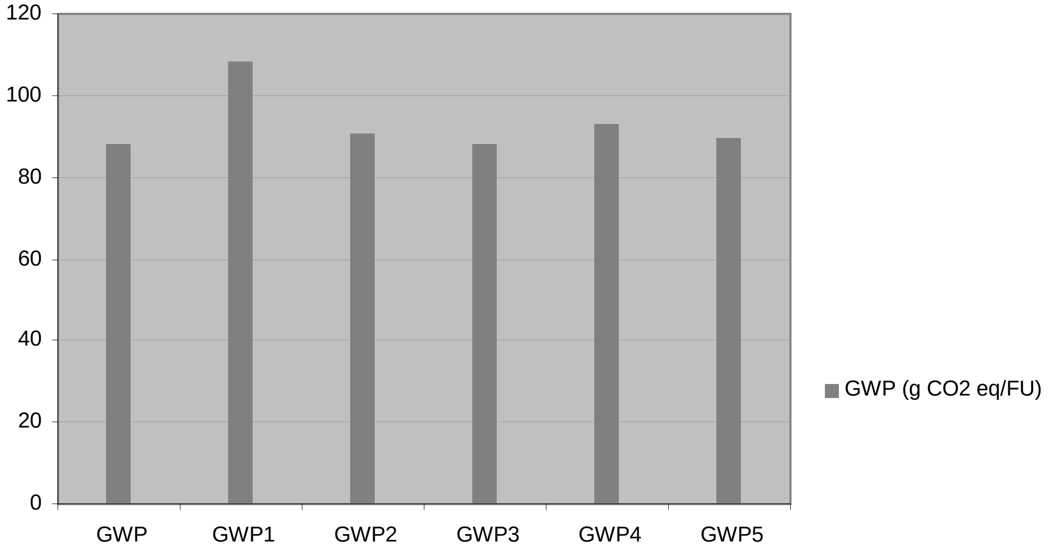

Illustration 9: Uncertainty analysis of the results for HTC Superfloor™

This clearly shows that it is the number of square metres for the grinding process that has the greatest impact. This is not so strange as this is the greatest contributor to energy consumption. The difference between the results is about 23%. If the results from GWP1 are compared with the results from Peran SL, the quotient is 155 instead of 189. In other words, there is still a notable difference.

Calculated on GWP1, the HTC Superfloor™ coating method is now 0.26% instead of 0.21%. The surface coating method is still a tiny fraction of the floor as a whole.

### 6.1.1.2 Peran SL

It is possible to change the number of floor regrinding operations in the calculations of the environmental impact of Peran SL. 1.8 kg of new epoxy compound is applied each time. This shows the figures for when the floor is reground two or three times instead of once.
GWP: Reground once
GWP1: Reground twice
GWP2: Reground three times

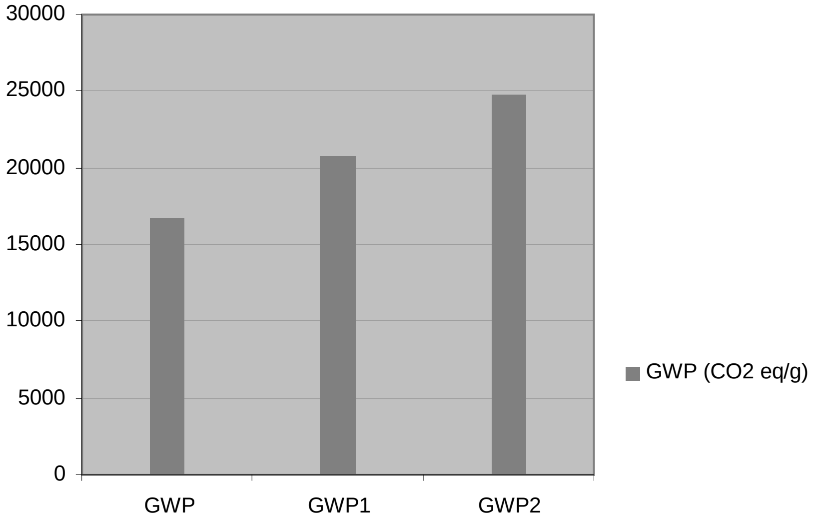

Illustration 10: Uncertainty analysis of the results for Peran SL

The GWP here increases by about 25% every time the floor is reground. If the normal values for HTC Superfloor™ and GWP2 are compared, the quotient is 235 instead of 189. After two regrindings, the epoxy coating becomes 33% of the floor as a whole, compared with 28% after one regrinding. This is a 5% difference. This is significant difference considering how large the environmental impact from the whole floor is.

## 6.2 Sensitivity analysis

The calculations were performed using values for Swedish average electricity, which produces relatively low emissions of carbon dioxide. To change the geographical boundaries, calculations are performed using European average electricity values to see what effect this has. The results for HTC Superfloor™ show a large difference, while the difference for the epoxy floor is not so large. This is because the consumption of electricity during the grinding operation represents a small fraction of the epoxy floor production process. Emissions for European average electricity are shown in Appendix 18.

Thus the results after calculations are:

Table 12: Results of environmental impact assessment when using European electricity.

| | Peran SL | HTC Superfloor™ | Factor (Peran/HTC Superfloor™) |
|---|---|---|---|
| GWP (g $CO_2$ eq/FU) | 16 700 | 929 | 18.0 |
| AP (g $SO_2$ eq/FU) | 102 | 8.52 | 12.0 |
| EP (g $PO_4^{3-}$ eq/FU) | 13.5 | 0.317 | 42.6 |

The difference between the floors is not at all as great as when using Swedish average electricity. The global warming factor has decreased from 190 to 18 and eutrophication potential from 800 to 43. The acidification factor has decreased to 12. The bedrock in many parts of Europe is rich in limestone, which means acidification is not as great a problem there as in Sweden.

# 7 Epoxy painting

The intention of this study was to make a comparison with an epoxy floor. However, it can be interesting to make a quick comparison with a painted epoxy floor too. This type of floor coating is much cheaper than both HTC Superfloor™ and Peran SL. As environmental product declaration data was readily available from Eradur, Eradur WB was chosen for the purpose of comparison. 0.1 kg of epoxy compound was used for each square metre of this floor (compared to 5.88 for Peran SL). According to the environmental product declaration for Eradur WB, each square meter of floor emits the following:

Table 13: Epoxy painting emissions according to Eradur WB's environmental product declaration

| Emissions | g/FU |
|---|---|
| $CO_2$ | 590 |
| $CH_4$ | 4 |
| $NO_X$ | 4 |
| $H_2$ | 2 |
| $SO_X$ | 2 |
| Particles | 2 |

The effects of these on global warming, acidification and eutrophication are shown below.

Table 14: comparison of HTC Superfloor and Eradur WB

| | Eradur WB | HTC Superfloor™ | Factor (Eradur/ HTC Superfloor™) |
|---|---|---|---|
| GWP (g $CO_2$ eq/FU) | 704 | 88.2 | 7.98 |
| AP (g $SO_2$ eq/FU) | 4.78 | 0.186 | 25.7 |
| EP (g $PO_4^{3-}$ eq/FU) | 0.63 | 0.0178 | 35.4 |

These figures do not take maintenance into account. As the floor will probably be repainted several times over a period of 20 years, these figures will multiply many times. This means that even with such a tiny amount of epoxy, about 1.7% of Peran SL, the potential global warming effect of a thin-layer epoxy floor in Sweden will be at least 10 times as much as that of HTC Superfloor™.