

EUROPEAN ECOLABEL

BED MATTRESSES

LCA and criteria proposals

final report for the EC

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INTRODUCTIONINTRODUCTIONINTRODUCTIONINTRODUCTIO N

2.1 The history of the present projectThe history of the present projectThe history of the present project

The current report was drafted by Tauw Milieu on behalf of the Greek organisation ASAOS and the Greek Ministry of Environment, Physical Planning & Public Works in co-operation with the French Ministry of Environment within the framework of a project aimed at the establishment of European Ecolabel criteria for the product group "bed mattresses".

The above-mentioned project, entitled "Establishment of ecological criteria for the product group Bed Mattresses", comes forth from the Council Regulation 92/880 EEC, regarding the establishment of a European Ecolabelling scheme. The relevant study started in May 1994 when the Greek Expert Group presented a preliminary draft on the same subject during the Greek presidency meeting on ecolabels in May of the same year.

Next in May 1995, at the first Ad Hoc Working Group (AHWG) meeting held in Athens, the Greek experts presented the first draft on the feasibility phase of the relevant study. In September 1995 the complete report on the feasibility phase of the study comprising a market study as well was presented in Brussels. On the basis of this report the E.U. Commission decided to proceed with the project.

In May 1996 the Greek Ministry of the Environment asked all the consultant experts on LCA who had already won a contract with the E.U. Commission (DG XI, Ecolabelling Unit) to make proposals and send their tenders for assisting the Greek Expert Group, mainly on the LCA phase of the study. Tauw Milieu was selected among these consultancies for this job.

In December 1996 the first meeting of the representatives of ASAOS, the Greek Ministry of Environment, the Greek Expert Group, the representative of France and the experts appointed by Tauw Milieu was held in Athens with the purpose of clarifying the terms of their mutual co-operation. The first AHWG meeting to discuss the market study was held in March 1997. The second meeting, during which the draft report "Life Cycle Assessment" was discussed, was in June 1997.

The last AHWG meeting has been held in November 1997. At this meeting the LCA results and in particular the proposals for criteria for the Ecolabel were discussed by the Greek Expert Group, the consultant and representatives of the national Competent Bodies and European industry. Based upon this discussion and upon comment received from AHWG members, this final report was written.

2.2 The purpose of the EcolabelThe purpose of the EcolabelThe purpose of the Ecolabel

It should be noted that the main purpose of the ecolabel is to stimulate consumers to buy environmentally sound products. As a consequence, producers are stimulated to produce in an environmentally friendly manner.

An environmental LCA is used in order to determine the key issues regarding the environment impact of the products in question. The current project is carried out

according to the guidelines of the Group des Sages for ecolabelling studies [1]. According to these guidelines an ecolabelling study must contain six phases:

1. Feasibility study;
2. Market study;
3. Life cycle inventory;
4. Environmental impact assessment;
5. Setting of criteria;
6. Presentation of draft proposal for a commissions decision.

2.3 The content of this report

The current report contains the results of the Life Cycle Assessment (LCA) study for four representative mattresses, viz. polyether foam, latex foam, spring interior and a "scandinavian mattress". Also proposals for Ecolabel criteria are included in the report.

The LCA was performed according to the SETAC guidelines and the draft ISO standards on LCA (ISO 14040 series). These guidelines emphasize the importance of transparency and consistency of the study; underlying data and assumptions should be available to the reader.

The aim of the LCA is twofold:

- to give an overview of all environmental aspects related to the life cycle of mattresses;
- to identify the most important processes and emissions from an environmental point of view (the key issues).

Based on the LCA results and on other relevant information proposals for criteria for the ecolabel have been defined, reported and discussed by the Ad Hoc Working Group. The proposals included in this report are based on the proposals reported in report 'European Ecolabel for Bed Mattresses, LCA and criteria proposals, second draft, (Ref. R3535924.C04.EJD) and on the comment by the Ad Hoc Working Group.

3 PRODUCT GROUP DESCRIPTION PRODUCT GROUP DESCRIPTION PRODUCT GROUP DESCRIPTION

3.1 Definition of the product group Definition of the product group Definition of the product group

3.1.1 Beds and bed mattresses Beds and bed mattresses Beds and bed mattresses

In order to define the product group "bed mattresses", we first differentiate "**mattresses**" from "**beds**".

In this context, a bed is defined as a supporting structure for a mattress (a type of cushion designed to rest or sleep upon). The "cushion" normally consists of a replaceable mattress, but sometimes the supporting structure is integrated in or adjusted to the soft surface (e.g. a sofa/bed combination or a waterbed). The supporting structure of a bed can last a lifetime or even longer, whereas mattresses are normally replaced every 10 to 15 years. We therefore consider beds and bed mattresses as two different products.

As the present ecolabel is concerned with bed mattresses only, products sold as beds, such as water beds, box springs, bed/sofa combinations and mattress/bed combinations are not included in the product group.

However, an exception has to be made for the beds and mattresses which are being used in Scandinavia. A great part of beds used in the Nordic countries contains a wooden frame integrated with a spring system (box spring). Upon this a mattress (normally with spring interior) is fixed. This means that the box spring and mattress can not be separated and are always sold as one piece. Finally the whole is covered with a thin, replaceable mattress pad [2] (annexe 2).

3.1.2 Mattresses for private consumers and for institutional consumers Mattresses for private consumers and for institutional consumers Mattresses for private consumers and for institutional consumers

Introduction

Article five of the EU regulation 880/92 on the establishment of a community Ecolabelling award scheme states that the product group should be established in such a way that **all competing products serving similar purposes and having equivalence of use** are included in one group.

Generally speaking the function of a mattress is to provide a comfortable surface to rest or sleep upon. This function can basically be fulfilled by different products, ranging from straw beach mats to very soft mattresses. Also, some people might find a bed of nails comfortable. In order to define the product group, we therefore have to define a common denominator and find out what competing products the consumer can choose from. There are differences between the functional requirements of private consumers on the one hand and institutional consumers (e.g. hospitals) on the other. EU regulation 880/92 makes no distinction between private and institutional consumers.

Private consumers buy their mattresses mainly in shops (e.g. department stores, furniture shops, special bedroom shops and sometimes also in large do-it-yourself shops).

Institutional consumers, such as hospitals, army institutions, recreational institutions etc. on the contrary are not very likely to buy their mattresses in shops; they usually get them from wholesalers or directly from the producers.

The mattresses bought by institutional consumers often serve specific purposes. These special purpose products are not fully competing with mattresses for private consumers.

So there seem to be two relevant differences between private and institutional consumers that have their effect on what can be considered competing products:

- functional requirements;
- distribution system/availability;

Referring to article five of the above-mentioned EU regulation, the product group will include only those mattresses for institutional use for which the functional requirements are comparable to those of mattresses for private use.

3.1.3 Definition of mattresses

In the Longman's Dictionary of contemporary English the word 'mattress' is described as follows: *top part of a bed consisting of a strong cloth cover filled with solid soft material.*

There are several standards on mattresses, but most of these were found to contain no definition as to what a mattress is. An exception is the German RAL-GZ 441/1 (polyether foam mattresses, quality requirements) and the RAL-GZ 441/2 (spring mattresses, quality requirements). In the RAL-GZ 441/1 Polyether foam mattresses are defined as: *removable cushions for resting- and sleeping furniture, of which the cushion performance is caused by the core of polyether foam.* In the RAL-GZ 441/2 spring mattresses are defined as: *removable cushions for resting- and sleeping furniture, of which the performance on support and elasticity is principally caused by the core of the spring core.*

These definitions resemble the Longman's definition, but are fixed on a given material.

Please note that both the Longman's definition and the RAL definition define a mattress as something that is part of, or can be placed on, a bed structure. In the RAL standard this is complemented by the statement that a mattress should be **removable**, i.e. be replaceable after its lifetime. Apart from the element of replaceability, the function that a mattress has to fulfil (resting and sleeping upon) also has to be included in the definition. According to articles in consumer magazines [3,4,5], it may in general be stated that the consumer expects a mattress to be **fit for use** (to rest or sleep upon) and to **last at least several years**. According to the consumer tests and standards, a mattress is fit for use if it fulfils certain physical criteria (such as softness; durability; damp permeability etc). These will be elaborated upon in section 6.3.

Accordingly, the following three elements are included in the definition:

- it can be placed on a bed (removable/replaceable)
- it is fit for resting and sleeping upon
- it has a lifetime of several years

In line with these elements, the product group 'mattresses' is defined as follows:

"Products providing a surface to sleep or rest upon, that are fit for use by human beings for a long period of time, consisting of a strong cloth cover filled with materials, and that can be placed on an existing supporting bed structure."

The following competing products found in shops will fit this definition:

- spring mattresses; (with spring interior or with pocket springs)
- polyether mattresses (also called polyurethane or cellular plastics mattresses);
- latex mattresses (also called rubber foam or cellular rubber mattresses)
- other mattresses (among others combinations of the above-mentioned types and so called water-mattresses⁵).

The "Scandinavian mattresses/beds" as described in 2.1.1 will be included in the study, because they can be considered to be a mattress with attached frame.

Normally speaking, inflatable air beds are not meant to sleep upon for a long period of time. Due to this fact, they will probably not meet the criteria "fitness for use" which will be established within the framework of the Ecolabel⁶.

3.2 Product categories

The product group bed mattresses consists of a variety of mattress types. Therefore, it is not possible to identify one 'typical' mattress that covers the entire product group. Due to the diversity, the product group has to be divided into various categories. The LCA study includes a sample of each category.

As for the determination of the categories, the following requirements apply:

- Together, the resulting categories should cover the entire product group as defined in section 2.1.3.
- For each category it should be possible to collect market data and the data necessary for the LCA study. This means that preferably, the categorization chosen should also be used by producers, trade and consumers.
- Each category should consist of products that are comparable⁷ for the most relevant aspects, so that one 'typical' product can be identified that would be more or less representative for the entire category. This 'example product' will be used in the LCA study. A category consisting of spring mattresses and water mattresses e.g. would not meet this requirement, as an example product to represent both types can not be defined.

Based upon the above-mentioned requirements the mattress have been categorized according to the core material:

- **latex mattresses** (also called latex foam or cellular rubber);
- **polyether mattresses** (also called PUR foam or cellular plastics);
- **spring interior mattresses** (includes Bonnell, pocket spring, LFK, etc.);
- **"Scandinavian" mattresses/beds;**
- **mattresses of other materials** (e.g. cotton or coconut fibre core).

1 Water mattresses are "waterbeds" with a minimized amount of water and an internal supporting structure of plastic- or rubber foam. Due to their reduced weight, they can be placed on existing beds.

2 The exception to this rule was found in a furniture chain shop; it sells a mattress that can be rolled up to handleable size and that is said to be suitable for use over a longer period of time. Whether this product has a long life time and meets tough fitness for use criteria is not known.

3 i.e. differences between the categories should be bigger than differences within one category.

This categorization complies with the above-mentioned three requirements and is already in common use.

These categories do not fully coincide with the categories identified in the feasibility study [6]. In the feasibility study it was suggested to use two basic categories, one based on the method of construction, and the other one based on the use of the product. For these categories further subdivisions were suggested on the basis of size.

The subdivision on the basis of size or use is helpful for the market study, but is not necessary for the LCA study, because the composition of mattresses is hardly dependent on their size. Therefore a subdivision according to the core material is being used to differentiate the product group.

For mattresses for institutional use extra requirements often apply as compared to mattresses for household use. In order to meet these requirements the composition of these mattresses might also differ:

- Mattresses used in hospitals:

According to German DIN standards [7] the polyether foam or latex foam core of the mattress must be permeable for air and must be resistant to sweat and urine. If glue is used, this glue must be able to withstand boiling water. The cotton ticking must consist of one piece and must be replaceable. The core and ticking are to be sterilized and cleaned separately, either by steam or chemically.

Information from mattress manufacturers indicates that for hospital mattresses sometimes PVC tickings are being used.

As far as known, the requirement regarding resistance to sweat and urine also applies in other EU countries. In some countries an additional requirement for these mattresses is fire resistance.

Prevention of bedsores (decubitus) can also be a requirement for hospital mattresses.

- Mattresses used in hotels:

According to information from several mattress manufacturers the composition of these mattresses does not differ significantly from that of mattresses for ordinary use. In general the price of hotel mattresses is lower.

- Mattresses for prison, army, etc.:

The main additional requirements are about flame retardancy and resistance to cleaning and sterilizing methods.

According to a large manufacturer of mattresses, mattresses for institutional use, especially hospital and military mattresses, are often manufactured by specialized companies.

Those of the above-mentioned special purpose mattresses for which additional requirements apply are not really competing with mattresses for ordinary use. The other special purpose mattresses can be included in the appropriate product categories as defined in section 2.2.

The number of mattresses used within the European Union (EU) for hospitals and institutions is small compared to the number of mattresses for private households and hotels. The feasibility study [6] mentions the following estimations for the number of mattresses in use within the EU:

Private households:	345 million (95%)
Hotels:	11 million (3%)
Hospitals:	3.5 million (1%)
Army, prison, train, etc.	5 million (1%)

In this study only mattresses for private households and hotel use are taken into account, because of the additional requirements and the low sales numbers of mattresses for hospitals, army, prison, train etc.

Assuming that water beds constitute less than 3% of the bed types for private households and hotels [8], this means that the product group as defined above represents at least 95% of all the mattresses in use for private households, hotels and institutions within the EU.

4 COMPOSITION OF MATTRESSES COMPOSITION OF MATTRESSES COMPOSITION OF MATTRESSES COMPOSITION OF MATTRESSES

4.1 GeneralGeneralGeneralGeneral

In general a mattress consists of the following parts:

- **Core**

The core provides for the support of the mattress.

The composition and production of the core will be discussed below (chapter 3.2) for the five categories of mattresses. The main materials which are being used are steel springs, polyether foam and latex foam. According to a mattress test [9] horse hair and coconut fibre are also used as core materials, e.g. for baby mattresses.

- **Shell (padding)**

The shell or padding consists of a layer around the core. The purpose of this shell is to equalize the pressure on the human body. All mattresses with a spring interior and some of the mattresses with other core materials contain a shell.

Often mattress shells are composite structures. The materials mainly used are:

- Polyether foam (polyurethane or PUR foam)
- Latex foam
- Horse hair and camel hair (both sometimes rubberized)
- Coconut fibres (sometimes rubberized)
- Polyester (PET or Poly-ethylene-terephthalate)
- Cotton
- Wool
- Linen
- Felt
- Jute
- Cisal

The production method of the shell depends of course on the materials used. In general the materials used are glued and/or sewed to each other and on the core. Also staples are being used to fix the materials together.

- **Tick**

The outer cover of the mattress is called the tick or ticking. It provides a comfortable top layer. The main woven materials used for the tick of mattresses are:

- Cotton
- Polyester (PET or Poly-ethylene-terephthalate)
- Silk
- Polypropylene
- Nylon (polyamide)
- Wool
- Viscose

According to a tick manufacturer, ticks based on polyester are mainly used in the Southern European countries, whereas in the Northern European countries cotton-based ticks are preferred.

The tick can be fixed to the mattress by means of stitching or by tapes running through the mattress (tufting). Sometimes the tick is not fixed, but can be removed from the mattress by the customer.

4.2 Composition and production of core materials

In annexe 2 cross-sections of the different types of mattresses are given.

4.2.1 Latex foam

For latex foam natural latex (also called natural rubber, NR) as well as synthetic latex is being used. As far as known, the amount of natural latex in the foams used for mattresses ranges from 0% to 100%. The actual amount being used depends on aspects like the price of natural latex, the production process, the desired properties of the foam and consumer wishes (e.g. "green" mattresses with a high amount of natural latex).

The produced latex foam for mattresses may contain cavities or holes. These holes cause a lower overall density and areas with different hardness of the foam core.

Natural latex originates from the liquid (latex) of the rubber tree, which grows in regions around the equator, such as South-Asia, Africa and South-America. The latex liquid consists basically of minute rubber (polyisoprene) particles (35 w%) dispersed in water. Part of the latex is concentrated to about 60 w% rubber and exported as such [10].

According to latex foam manufactures the synthetic latex foam used for mattresses is mainly SBR, Styrene Butadiene Rubber. SBR is produced by polymerization of styrene (appr. 23%) and butadiene (appr. 77%) [10].

Latex foam production is based on the Dunlop (also called NSF) or Talalay process [10]. For both processes the concentrated latex is compounded with among others sulphur, activators, accelerators, antioxidants and soap, see section 8.3. Next the compound is foamed by mechanical mixing with air to 8 - 12 times of its original volume.

In the Dunlop process gelation of the foam is induced by chemical agents. A gelation time of 6 - 10 minutes allows the liquid foam to be poured into moulds. After gelation the foam is vulcanized by heating the moulds (appr. 100°C). The vulcanization, *i.e.* the formation of sulphur bridges between the polymer chains, yields an elastic latex foam. Normally the latex foam is washed with water to remove remains of additives.

In the Talalay process the gelation is carried out by deep-freezing the foam and subsequent introduction of carbon dioxide and air as a foaming agent. The other process steps do not differ significantly from those in the Dunlop process.

4.2.2 Polyether (PUR) foam

Mattresses containing polyurethane foam based on hydroxy-polyether (polyol) are often referred to as polyether mattresses.

The density of the foam for ordinary mattresses ranges from 25 to 35 kg/m³ (product information manufacturers). For a small quantity of high quality mattresses densities up to 60 kg/m³ are being used.

The PUR foam is manufactured by a reaction between precursors, mostly toluenediisocyanate (TDI) and a hydroxy-polyether. A small portion of polyether mattresses is based on diphenylmethane diisocyanate (MDI) instead of TDI.

Starting with crude oil, natural gas, sulphur, coke and sodium chloride, TDI or MDI are prepared in a number of process steps [11].

Hydroxy-polyethers are produced by three different process routes. The raw materials used are crude oil, natural gas, sodium chloride, animal fat, sugar and other organics [11].

During the reaction of the two precursors, the produced PUR is foamed at the same time.

Carbon dioxide, which acts as a blowing agent, is produced by the reaction of diisocyanate with water. The two basic reactions for PUR foam manufacturing are:

1. urea reaction: water + diisocyanate \rightarrow urea + carbon dioxide
2. urethane reaction: polyol + diisocyanate \rightarrow (poly)urethane

Additives like catalysts, emulsifiers, foam stabilizers and blowing agents are often used [12]. These will be discussed in more detail in section 8.3.

Sometimes volatile organic compounds are used as an additional, physical blowing agent.

PUR foam for mattresses is mostly produced on large scale with the so called slabstock process. In this process the reacting mixture of isocyanate, polyether and additives is dosed into a kind of gutter. During the reaction the mixture is moved through the gutter. When the reaction has proceeded so far that the foam can be handled, it is cut into large slabs. Next the reaction is completed (curing) at an elevated temperature. Because of the exothermic reactions taking place during curing, no external heat is necessary.

During the slabstock foam production TDI or MDI emissions to air may occur [54]. For environmental reasons nowadays venting with subsequent active coal filtering is sometimes applied.

4.2.3 Steel spring interiors

The core of these mattresses consists of springs. Many types of steel springs are being used, e.g.:

- Individually wrapped spring coils (pocket-springs)
- Individually placed spring-coils (Bonell springs)
- LFK (LeichtFederKern) springs (cylindrical springs)
- Springs embedded in rubberized foam
- A core of endless-wire springs

The springs are made from steel. Often a heat treatment is applied in order to improve the properties of the spring. The kind and number of springs, the diameter of the steel wire, and the height and diameter of each spring determine together the supporting properties of the mattress.

Iron is the main component of steel. Iron ore is extracted from ore-mines, which are located in e.g. Sweden, France and the former Soviet Union.

The amount of carbon in steel used for springs is normally 0.4 - 0.7%. Small amounts of other elements may be added, e.g. manganese for improved elasticity or magnesium.

In Europe about 25% of the steel is produced with the help of the electrosteel process, which uses nearly only scrap from e.g. car dumps as base material instead of ore. Besides scrap, the following components are added for quality improvement and/or change of properties [13]:

- ore;
- metals like chromium (Cr), manganese (Mn), vanadium (V), molybdenum (Mo);
- lime and some other additives.

The melting process in the furnace takes place with help of electrodes or a coil. After the melting process the steel is poured in moulds. The resulting steel blocks are reduced in size to so-called sticks with help of rolls. The sticks can be rolled to wire with several diameters. The wire-diameters range from 5mm to 30mm.

Several processes can be executed afterwards like surface treatment, wire drawing and/or hardening.

The other 75% of the steel in Europe is produced with help of the blast-furnace oxysteel process. Instead of scrap, ore is the main material used in the blast-furnaces.

Before the ore is put into the blast-furnace, the ore has to be treated to improve its quality. Two processes - pelletizing or cindering - can be executed.

To improve the quality of the steel, specified amounts of coke, lime, scrap, water and bentonite are added during these processes. Coke, which is manufactured out of coal, acts as reducing agent in the melting process.

In contrast with the electrosteel process, the furnace blast process is a continuous process.

The basic chemical reaction in the blast-furnace is $\text{Fe}_2\text{O}_3 + 3\text{CO (from coke)} \rightarrow 3\text{CO}_2 + 2\text{Fe}$.

After the melting process, the molten iron is transported to the oxysteel-plant. In this plant the amount of carbon in the melt is reduced with help of oxygen from 3 - 4% to 1.5% or less, in order to attain the desired properties regarding strength and elasticity.

The thick wire coming from the steel mills, with a diameter ranging from 5,5 - 30 mm, is drawn with a drawnbench to the desired diameter (for mattress springs 1.6 to 2.4 mm). To eliminate friction during drawing as much as possible, lubricants like mineral oils, synthetic and organic grease, graphite, molybdenesulphide or soaps are being applied [14].

Steel wire used in mattress springs, is often hardened by exposure to a high temperature before the coiling process. Thermic hardening as well as electric hardening is being used.

Before the hardening, the surface of the wire has to be cleaned and degreased. The most common degreasing methods are alkalic cleaning (NaOH, KOH in water), organic solvent cleaning or ultrasonic cleaning.

After the hardening processes, the hardened wire is glowed (720 - 900 °C) to eliminate the mechanical forces resulting from rolling and drawing.

Springs are formed out of steel wire with help of a coiling machine. During the coil forming process oil is put on the surface of the wire for lubrication.

The use of oil can be prevented by treatment of the wire with a fluororesin coating or with organic compounds like oxalic acid, glycine, tartaric acid or a amino acid compound. In how far these substances are being used on large scale in practice, is not known to the authors.

Pocket springs are steel springs which are individually wrapped with polyester or polypropylene fleece. The pockets are glued together.

4.2.4 Materials used in Scandinavian mattresses/beds

In Sweden, Norway, Finland and to a lesser extent Denmark a specific bed/mattress combination is commonly used. In Sweden such beds with a wooden frame account for about 50 % of the total production value of beds and mattresses [2].

This type of bed consists in general of a wooden frame integrated with a spring system. On top of that a mattress (normally with spring interior) is fixed. Finally the whole is covered with a thin, replaceable mattress pad. This pad consists of a polyether or latex core covered with a tick. In annexe 2 a cross section is presented.

4.2.5 Other materials

The core of these mattresses consists mainly of one or more of the following materials:

- Natural fibres, e.g. coconut fibres or kapok [37].

Especially in Southern-Europe coconut fibres are sometimes used as core material. This fibre material (also called coir fibre) is produced from the so called husk, the outer shell of the complete coconut. The husks are soaked in water, followed by defibring or milling. After sifting, the fibres which are to be used for mattresses are dried in the sun, baled or mechanically twisted and shipped. For the production of mattresses layers of the coconut fibre material are formed and put together. These layers may be sprayed with natural latex. If so, the layers are pressed together and vulcanised in an autoclave. The resulting material has a density of about 60 to 80 kg/m³.

- Cotton

So called black or white cotton is sometimes used as core material. It has to be stressed that this material has not to be cotton, but can consist of a manifold of textiles! The materials originate from second selection cotton (white cotton only) and from mechanical recycling of textile waste from textile factories. The textiles are first cut, shredded and carded to loose fibres. Next this material is processed to a layer, the wadding [55].

- Wool

- Horse hair

All of the above-mentioned materials might be combined with each other or with latex or PUR foam.

Finally water mattresses need to be mentioned. A water mattress consists of a plastic sac which contains an internal supporting structure and is filled with water. As compared to a waterbed, the water mattress is much lighter, due to the minimized amount of water contained in it. It can therefore be used on existing beds.

5 MARKET SITUATION FOR MATTRESSES MARKET SITUATION FOR MATTRESSES MARKET SITUATION FOR MATTRESSES MARKET SITUATION FOR MATTRESSES

5.1 IntroductionIntroductionIntroductionIntroduction

In order to establish the proper criteria for an ecolabel for mattresses, some knowledge of the market situation is needed.

Based on the number of mattresses sold in each category, representative mattresses can be defined and studied. In this respect national and cultural preferences for certain mattress categories are also relevant.

Information about the import and export of mattresses is needed among others to assess whether the market is dominated by large producers. It can also be useful in estimating the influence transportation has on the total environmental impact of mattresses.

This chapter describes the market situation of bed mattresses in the European Union. Statistical data on production, import and export of mattresses have been collected from Eurostat [15], several national statistical overviews [16,17,18,19] and the feasibility study [6]. Based on literature [21,22] and on information provided by national associations of manufacturers of furniture/sleeping products and by several mattress manufacturers, some market trends are described.

Information was also obtained from a visit to the furniture fair "Interzum" in Cologne.

5.2 Production and tradeProduction and tradeProduction and tradeProduction and trade

Table 1 presents an overview of the number of mattresses produced annually in the different EU member states.

The Eurostat import and export data for EU countries in 1995 are given in tables 2 and 3.

TABLE 1: PRODUCTION

Country	Rubber		Plastics		Spring-interior		Others	
	Number ¹	Value ²	Number ¹	Value ²	Number ¹	Value ²	Number ¹	Value ²
France (1994)	468,000		2,071,000		1,841,100			
Belgium & Lux. (1994)	Total value of production 207,000 (x 1000 ECU)							
Netherlands (1995)		29,721	325,000	19,767	spring + others: 31,162 (x 1000 ECU)			
Germany (1995)	510,000	87,539	863,000	43,421	5,174,000	398,919	398.000 ⁴	22,669
Italy								
United Kingdom (1993)		29,862		4,147		248,848		9,539
Ireland (1991)	Total value of production 15,300 (x 1000 ECU)							
Denmark (1st half 1996)	26,132	522	50,502	1,795	229,707	20,370	11,642	785
Greece	100,000				spring + others: 600,000 (mainly springs)			
Portugal (1995)			100,000		350,000		50,000 (incl. rubber)	
Spain (1995)	Approx. 2.000.000 mattresses produced. Value: 397,470 (x 1000 ECU)							
Sweden (1994)		1,821		10,124	spring + others: 9,605 (x 1000 ECU)			
Finland								
Austria (1994)					99,000		353,000 ⁵	

Table 1, Production of mattresses, continued

1: number of mattresses.

2: value at 1000 ECU.

3: not specified according to type of mattress.

4: contains production of 78.000 wool mattresses.

5: incl. rubber and plastic mattresses

Sources for production data:

France: Report "Ecolabel criteria development for bed mattresses", Athens, September 1995

Belgium & Lux.: Report "Ecolabel criteria development for bed mattresses", Athens, September 1995

Netherlands: CBS Mndstat industrie (96/12)

Germany: Statistisches Bundesamt, Produzierendes Gewerbe, Fachserie 4, Reihe 3.1, 1995

United Kingdom: Report "Ecolabel criteria development for bed mattresses", Athens, September 1995

Ireland: Report "Ecolabel criteria development for bed mattresses", Athens, September 1995

Denmark: Denmark Statistik, serie C, 1996:2

Greece: Greek mattress manufacturers

Portugal: Portugese Ministry of Economy, DG Industry

Spain: BfAI L nder und M rkte, 1995

Sweden: Sveriges Officiella Statistik, Industri Del 2, Varndata, 1995

Austria: Report "Ecolabel criteria development for bed mattresses", Athens, September 1995

TABLE 2: IMPORT (Value at 1000 ECU)

Country	Rubber mattresses		Mattresses of cellular plastics		Mattresses of spring interior		Mattresses excl. spring interior	
	Intra-EC	Extra-EC	Intra-EC	Extra-EC	Intra-EC	Extra-EC	Intra-EC	Extra-EC
France	9865	3391	9059	807	5015	1771	9692	1510
Belgium & Luxembourg	8222	558	8814	225	4766	5	2199	178
Netherlands	9515	1084	33249	555	4226	92	3778	1156
Germany	36101	4169	15636	2149	30159	7045	9989	7794
Italy	8264	61	1304	812	859	31	1549	745
United Kingdom	37	108	903	132	167	421	602	407
Ireland	2337	0	191	3	386	0	775	1
Denmark	575	272	932	304	5193	1983	1053	3986
Greece	1	27	727	12	119	72	273	65
Portugal	47	4	40	18	1425	2	251	75
Spain	1162	45	755	489	3671	15	3619	1039
Sweden	842	268	4043	5060	335	336	1559	2773
Finland	176	37	318	186	2726	1387	325	607
Austria	--	2869 ¹	--	1012 ¹	--	259 ¹	--	1364 ¹
<u>Eur-15</u>	77147	12.893	75971	11464	59047	13419	35691	21700

¹: Data based on the period January - September 1995.
Source: Eurostat Intra and Extra European Union Statistics (95-96)

TABLE 3: EXPORT
(Value at 1000 ECU)

Country	Rubber mattresses		Mattresses of cellular plastics		Mattresses of spring interior		Mattresses excl. spring interior	
	Intra-EC	Extra-EC	Intra-EC	Extra-EC	Intra-EC	Extra-EC	Intra-EC	Extra-EC
France	37789	3992	2473	12522	10922	3285	2879	4412
Belgium & Luxembourg	76024	6978	63432	654	33382	462	2795	697
Netherlands	4169	125	22479	3705	888	189	427	77
Germany	6764	532	10247	1337	10561	3999	5112	5051
Italy	5918	816	1081	456	8448	3917	9614	10409
United Kingdom	350	209	2338	1082	4855	833	7758	997
Ireland	275	130	2561	259	0	0	36	39
Denmark	250	249	1941	320	7534	1301	11964	11957
Greece	0	3	0	29	0	123	285	404
Portugal	42	56	0	65	5086	843	1912	418
Spain	77	489	99	111	2312	3394	816	1957
Sweden	272	166	825	1153	211	329	2000	2280
Finland	0	41	71	401	34	509	3	155
Austria		3132 ¹		160 ¹		849 ¹		717 ¹
Eur-15	131930	16918	107520	22254	84233	39005	45601	40108

1: Data based on the period January - September 1995.
Source: Eurostat Intra and Extra European Union Statistics (95-96)

In very general terms the market in Europe is about 64% spring interior, 22% polyether and 14 % latex mattresses. The spring interior mattresses amount to about 90 % by unit volume in the UK, 85% in Greece, at least 80% in Italy, 75 - 80% in Germany, around 50% in France and 37% in The Netherlands [22, 47]. In Denmark, Portugal and Spain spring interior mattresses are also by far the best-selling type. Polyether mattress share about 35% in France, 27% in The Netherlands, 10% in Greece and only 5% in Italy [22]. In The Netherlands latex mattresses constitute 18% of the sales [8], in Germany about 10% [5]. As mentioned in par. 2.1.1 in Finland, Sweden and to a lesser extent Denmark special bed/mattress combinations are being used.

Evaluation of the production, import and export data indicates that within the EU, a large part of the mattresses is produced and sold within the same country. This applies especially to mattresses with a spring interior. These observations are confirmed by several mattress manufacturers. For one reason this is due to the national preferences as to the type of mattress, see above.

The second reason lies in the fact that transporting mattresses is cumbersome and expensive, due to the large volume and weight of the mattresses. This is especially true for the mattresses with a spring interior. The expensive transport also explains why imports mainly originate from neighbouring countries.

The number of manufacturers of mattresses and their market share varies widely per country. In France for example about 65% of the bedding market is controlled by five large financial groups, while the rest is run by smaller family-owned companies. In Greece five or six large manufacturers share about 20% of the market, with the other 80% divided between a large number (more than thousand) of small manufacturers [48]. Italy has about 2200 mattress manufacturers, with 2000 of them making less than 30 mattresses per day [22].

5.3 TrendsTrendsTrendsTrends

As pointed out earlier, there are national preferences as to the mattress categories. In some cases, these preferences change in the course of time. In several countries for example, the number of Bonnel spring mattresses sold is decreasing in favour of pocket spring mattresses [22]. According to manufacturers this is due to the fact that pocket spring mattresses offer a increasingly good comfort/price ratio.

In several countries (e.g. Belgium, UK, The Netherlands) mattress manufacturers and retailers are promoting a more frequent replacement of mattresses. In the UK this lead in the last 12 years to a reduction of the mean replacement time by one-half year every year [22].

Other trends have to do with construction changes. Over the last years, several new types of construction have been developed, based mainly on combining existing constructions, e.g. spring mattresses containing zones with different spring types, or mattresses with springs embedded in foam materials.

5.4 European standards for mattressesEuropean standards for mattressesEuropean standards for mattresses

Available European standards with regard to mattresses provide information on among others the definition of the fitness for use and corresponding test methods. They are also indicative for the degree of standardization in the field of mattresses.

There are many European standards (annexe 1), which cover the following topics:

- requirements for mattresses and/or materials used in mattresses;
- test methods for mattresses and/or materials used in mattresses;
- directives for the application and treatment of mattresses;

- requirements for product information on mattresses.

A short description of some relevant standards is given below:

prEN 1957: Test methods to determine functional requirements.

NEN EN 1959: Beds and mattresses - Product Information. This standard specifies the product information that shall be given for all types of domestic adult beds and its components.

BS 1877, part 10: Domestic bedding, specification for mattresses and bumpers for children's cots, perambulators and similar domestic articles.

BS 3173: Specification for spring units for mattresses. Requirements include the number of springs, diameter of spring wire and durability of the springs.

RAL-GZ 441/1: Quality assurance of polyether mattresses. Requirements are given for the dimensions of the mattress, as well as for the thickness, density and elastic properties of the polyether core. Also requirements for the fabrics used in the tick.

RAL-GZ 441/2: Quality assurance of spring interior mattresses. Contains requirements for the spring core, shell and tick.

5.5 Existing ecolabels Existing ecolabels Existing ecolabels Existing ecolabels

Up to now there exist no national ecolabels for bed mattresses in the European Union. However, for latex mattresses and for some materials used in mattresses, several ecolabels have been defined by other organizations:

- Φkocontrol Label for latex mattresses, by Bundesverband økologischer Einrichtungshøuser. This is a German association of about 60 retailers of furniture. Maximum amounts are defined for volatile organic substances, formaldehyde, pesticides, heavy metals and azo dyes. Also fitness for use is being tested. In the near future the solvent CS₂ might be tested as well [23].
- QUL Label. QUL is the abbreviation of Qualitätsverband Umweltvertrøgliche Latexmatratze. (Quality Association of Environmentally Friendly Latex Mattresses). The members of this association are suppliers of raw materials and manufacturers and retailers of latex mattresses from different countries., The requirements are equal to those of the Φkocontrol Label [23].
- euroLATEX Eco Standard. euroLATEX is an association of European latex foam manufacturers. The standard contains requirements regarding the amount of pentachlorophenol, formaldehyde, pesticides, butadiene, vinylchloride, heavy metals and volatile organic substances.
- Φko-Tex Standard 100, with requirements regarding toxic substances for textiles. Textiles and other materials used in mattresses which comply with the requirements may be labelled [9].
- EU ecolabel for T-shirts and bed linens (March 1996). For this ecolabel ecological criteria have been defined for the raw materials (cotton and polyester) and for weaving and wet processing. Also fitness for use criteria have been defined. -Nordic Swan ecolabel for textiles (December 1994). Criteria are defined for cotton, wool, flax, polyester, polyamide (nylon), and regenerated cellulose fibres (a.o. viscose).

6 INTRODUCTION TO THE LCA INTRODUCTION TO THE LCA INTRODUCTION TO THE LCA

An environmental life cycle assessment (LCA) evaluates the various environmental impacts of the materials used for the products concerned.

During an environment-oriented LCA, a product is subjected to an integral environmental assessment. This means that its entire life cycle (from the extraction of the raw materials up to the waste phase) and all its environmental effects are taken into consideration and, if possible, quantified.

On behalf of the Dutch Ministries of the Environment and Economic Affairs, the Leiden Centre for Environmental Sciences has drafted a manual for the execution of an environment-oriented LCA [24]. This manual contains guidelines regarding the contents of an LCA and presents arithmetic methods for the quantification of environmental impact categories. These guidelines have for a large part been used for the formulation of international guidelines regarding LCA, as drafted by the ISO (International Standardisation Organisation), [25]. Also the manual is in accordance with the SETAC Code-of-practice [26] and the guidelines of the Groupe des Sages [1]. The environmental life cycle assessment (LCA) for bed mattresses has been carried out according to these guidelines and standards.

An important ISO rule is that the study has to be transparent, i.e. all used data, assumptions and calculations should be available and retraceable to the reader.

Environmental impact categories

According to SETAC (Society of Environmental Toxicology and Chemistry) the following environmental impact categories should be quantified in LCA [26]:

- abiotic resource depletion
- global warming (greenhouse effect)
- human toxicity
- acidification
- ozone depletion
- eutrophication
- photochemical oxidation (smog)
- ecotoxicity
- landscape demolition (not yet quantifiable)

Besides these SETAC environmental impact categories there are other environmental impact categories which are also often used in LCA. These impact categories are:

- use of energy (renewable and fossil energy)
- recyclability
- nuisance aspects (noise and smell)
- waste

Relevant environmental effects related to these additional impact categories have been included in the current study.

The structure of the LCA is based on the above-mentioned list of environmental impact categories, which forms the guideline for the description of the environmental LCA.

7 GOAL AND SCOPE DEFINITION GOAL AND SCOPE DEFINITION GOAL AND SCOPE DEFINITION

7.1 Goal definitionGoal definitionGoal definitionGoal definition

In the LCA the environmental aspects related to bed mattresses are elaborated. The goal is to identify the most important environmental impacts. The results of this LCA are used to formulate the proposals for the Ecolabel criteria for bed mattresses.

In order to achieve this goal the processes playing part in the life cycle of bed mattresses have to be identified and for a selected number of materials the environmental impacts have to be quantified in order to give insight into the importance of these impacts, the responsible materials, and the proportions of the contributing processes.

7.2 Product system and system boundariesProduct system and system boundariesProduct system and system boundariesProduct system and system boundaries

The life cycle of bed mattresses comprises many processes. Generally speaking the life cycle of a product consists of the following five life stages:

- 1) extraction of raw materials (cradle)
- 2) production of materials
- 3) production of consumer products
- 4) use of the product
- 5) disposal of the product (grave)

From an environmental point of view the extraction and production processes and the disposal of the product are usually the main points of interest. These concern mainly the extraction and refining of oil, gas and coal, rubber plantations, chemical industry, steel industry, mattress manufacturing industry and finally and landfill facilities.

Bed mattresses consist of a variety of materials. In the manufacturing processes of the mattresses besides the basic materials also machines and other goods are used, which also originate from production processes in which other goods are used. The process tree, i.e. the overview of all processes concerned in the life cycle of a product can therefore in principle be infinite.

According to studies [27], the total of contributions due to the production of capital goods and due to the personnel-related processes is often less than 5% of the overall environmental impact. For this reason and in order to avoid too much complexity, in LCA practice the following processes are usually not taken into consideration:

- production of capital goods, like shovels, trucks, machines, buildings etc.
- personnel-related processes, e.g. factory canteens, commuting etc.
- production of materials representing less than 5% of the mass of the product, e.g. glue or additives.

Based on the above-mentioned considerations, production of capital goods and personnel-related processes have been excluded from the current study.

However, the materials representing less than 5 w% of a mattress have not been neglected at forehand. Otherwise a material which is being used in small amounts in mattresses, but which has a high environmental impact, might be neglected unjustly.

Figure 1 present a schematic, generic overview of relevant process trees and the system boundaries for mattresses.

Figure 1: Product system of LCA for mattresses

7.3 Functional Unit

The functional unit is a quantitative description of the function of the product group. The primary purpose of the functional unit is to ensure compatibility of LCA results and to provide a reference to which the input and output data can be standardized.

The functional unit should be based on the standard use of the product. If such a standard use can not be defined (such as e.g. in the case of cosmetics), the functional unit might be based on actual consumer behaviour.

According to the Groupe des Sages [1,62], the focus in dealing with products having complex functions must be on the primary function, i.e. the main reason for which the product is bought. Defining representative products and the functional unit may lead to a refinement of the definition of the product group, which is done in consultation with the AHWG.

This statement by the Groupe des Sages is highly relevant to establishing a functional unit for a product group as diverse as mattresses. Mattresses do have a clear primary function: providing a sleeping/resting surface.

The secondary functions of special purpose mattresses vary. It will have to be discussed if these specific functions justify the formulation of more than one functional unit. In the same way, the fitness for use can be subdivided into different categories. Here also it is possible to formulate more than one functional unit. In this chapter we will clarify the aspects that play a role in this discussion and come up with suggestions as to the functional unit.

The two purposes of the functional unit

The purpose of functional units in ecolabelling projects is twofold:

- a) the functional unit serves as the quantification basis in the environmental Life Cycle Assessment (LCA);
- b) the functional unit can be used to base criteria upon.

Re. a).

Life cycle assessments usually serve to compare various products that have the same function. For the purpose of this comparison, one needs a unit that reflects this function. All data are calculated in relation to this unit. For the product copying paper, e.g. one A4 size sheet or one square meter of copying paper is a good functional unit. For transport systems, the transportation of one kg of goods over one km is often used. A small truck may emit less exhaust gas per km than a large truck, to the effect that it may be regarded as "better for the environment"; the large truck, however, can carry more goods, to the effect that per kg of transported goods, it may well be 'better for the environment'.

Re. b).

Ecolabel criteria often are qualitative requirements, but they may consist of quantitative requirements as well. In that case, the functional unit can be used as quantification basis. Up until now, this has not been very common, as there often are objections of a practical nature.

Using the functional unit in the criteria improves the fairness of the criteria.

In the Dutch ecolabel for copying paper for example, a quantitative criterion was established for the use of energy. The requirement stipulated that per square meter of paper, no more than 1,48 MJ of energy be used in the course of producing the

paper. Copying paper is usually made of paper weighing 70 to 90 grammes per square meter. The formulated energy criterion is difficult to achieve for the heavy-weight copying paper (90 g/m²) and relatively easy to achieve for light-weight copying paper (70 g/m²). Setting this requirement thus stimulates the use of light-weight copying paper, reducing the total consumption of paper, which leads to environmental benefits.

Dealing with diversity

The examples given above relate to relatively simple product groups.

The characteristic of a simple product group is that one function is dominating and that this function is easy to measure. For the copying paper, the function (copying) can be measured with a standardized test method that is commonly used. With this test method, fitness for use can be guaranteed to the consumer, even if the paper is of a relatively light weight. So for copying paper, the functional unit was: 1m² of copying paper, fit for use (i.e. complying with the quality standard).

Mattresses also have one dominating function. This function, however, cannot be measured easily. The primary function, *i.e.* "to provide a replaceable surface for sleeping or resting upon that is fit for use for a period of several years" primarily is a subjective rather than an objective criterion.

Specific consumer demands have resulted in different types of mattresses that are available in the shops. Such specific consumer demands may include for example:

- size
- price
- conformity (sufficient and overall support of all parts of the body)
- durability (expected life time)
- damp permeability
- firmness/softness
- insulation value of the mattress (some people like a warm mattress or a mattress with a winter and summer side)
- adjustability (suitable for an adjustable bed)
- fire resistance
- absence of odour (some mattresses smell, even after having been used for some time)

Some of these criteria are purely subjective (e.g. softness), whereas others are more objective and can be used to define the meaning of "fitness for use."

In two consumer tests [3,4] the hardness, the durability (related to cyclic loading of the mattress) and the damp permeability were tested and used to determine the overall functionality of the mattresses. Mattresses that provide good and overall support (conformity), a good damp permeability and make it through the durability test undamaged may be regarded as mattresses fit for use. The durability can be tested according to an official standard (prEN 1957:1995) and is related to the expected life span of a mattress. To our knowledge, there are no conformity and damp permeability test methods described in official standards. Test methods for these aspects are only described in test programmes of test institutes, e.g. the Dutch consumers organisation [45] and are often based on specific measuring equipment. For this reason damp permeability as well as conformity will not be included in the fitness for use criteria.

Accordingly, the following functional unit for mattresses is defined as follows:

" 1 m² of mattress, fit for use (i.e with a durability exceeding X)"

Durability and quality of mattresses

The "fitness for use" is not a black and white story. There is a certain gradation in the fitness for use, which may be related to the quality of the products or to the

requirements of the consumers. In the United States for example, a life time of 20 or sometimes even 30 years is required by consumers and guaranteed by producers. American mattresses therefore need to be very durable. In Europe the guarantee period is often much shorter (3 years or more).

Basically, the functional unit could be further differentiated according to quality class. For basic quality mattresses for example, Xb could be used, for standard quality mattresses Xs, and for premium quality mattresses Xp. It must be stressed, however, that consumer magazines do not distinguish quality or durability classes, nor are there any well-defined categories or classes used in shops. A German publication [4] notes that there are significant differences in price, which is not reflected in the quality/durability performance of the mattresses. In both [3] and [4], most of the mattresses tested are of good or sufficient quality and durability, according to the standards of the consumer organisations. In [3] 35 mattresses ranging in price from 200 to 500 ECU were tested. Of these mattresses, 21 were classified as 'good', 11 were classified as 'fair' and 2 were classified as 'moderate'. In [2], 21 mattresses ranging in price from 350 to 500 ECU were tested. Of these, 18 were qualified as 'good' and 3 as 'sufficient'. Also in [2], mention is made of a similar test performed in 1995 on 10 spring mattresses costing between 200 and 275 ECU, which were all classified as 'good'.

The defined functional unit is suitable to compare a selected number of different standard quality mattresses in an LCA. It is also suitable to base Ecolabel criteria upon. As was the case with copying paper, mattresses made from less material per square meter may be favourable from an environmental point of view. They may be less favourable from a durability point of view. Therefore, the functional requirement should guarantee good durability.

Lifetime

Talking about lifetime of mattresses, it is necessary to first differentiate between the technical and real lifetime. The technical lifetime ends when the mattress can no longer fulfil the functional requirements. The real lifetime ends with the disposal of the mattress by the owner. This real lifetime might as well be longer or shorter than the technical lifetime. In the first case the mattress is still being used, for whatever reason, after it no longer fulfils the functional requirements. In the second case the mattress is disposed of for reasons other than malfunctioning, e.g. hygienic reasons, purchase of a new bed, changing of family situation, etc.

The technical lifetime is determined by the composition of the mattress, its functional requirements and the way in which the mattress is used. The real lifetime depends of course on the technical lifetime, but also on consumer considerations on hygiene, comfort, etc.

Although the lifetime of different types and brands might vary considerably, it appears that there are no reliable data available on the average technical and real lifetime of the different types of mattresses in the EU countries.

One mattress manufacturer estimates the technical lifetime to be 10 years for spring interior, 5 to 7 years for polyether (depending on foam quality) and 8 years for latex mattresses. Another mattress manufacturer stated that in Greece spring interior mattress for ordinary use have an average real lifetime of 5 to 8 years. For hotel mattresses the lifetime would be 3 to 4 years.

The French 'Chambre Syndicale Nationale de la Literie' mentions an average lifetime of 15 years for polyether and latex foam mattresses in France.

According to recent market research, 50 % of polyether mattresses in The Netherlands has a real lifetime of more than 10 years. A real lifetime of 10 years or more is realised for 62% of the spring interior mattresses and for 44% of latex mattresses [8].

In several countries (e.g. Belgium, UK, The Netherlands) mattress manufacturers and retailers are promoting a more frequent replacement of mattresses. In the UK this leads to a reduction of the mean replacement time, see section 4.3.

The period during which the mattress is guaranteed by the manufacturer can not be used as an indication for the (technical) lifetime. Guarantee periods in the EU range from 3 to 15 years, with no direct relation with the lifetime. Principally the guarantee is meant for construction faults of a mattress.

Scientifically spoken the technical lifetime should be included in the functional unit, e.g. by looking at the environmental impact of a mattress **per year of use**. This would justify the following functional unit:

1 m² of mattress, fit for use
 ▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲
 average technical lifetime of mattress (year)

From a practical point of view, the real lifetime instead of the technical lifetime should be included in the functional unit. Because at present no reliable data or test methods on technical or real lifetime are available, it is assumed that the lifetime is equal for all considered products. Therefore lifetime is not included in the functional unit:

functional unit = 1 m² of mattress, fit for use

7.4 Example products Example products Example products Example products

For each product category as defined in section 2.2. an example product has been defined. For this product, being representative for its category, an LCA has been executed.

We decided to include in an example product as much as possible all the materials which are being used in products of the corresponding category. If e.g. cotton or wool is being used, an averaged amount of both will be included in the example product. This way a good insight is gained in the contribution of each material to the overall environmental impact of a mattress. Based on the available data regarding mattress compositions [28,29,46] four example products have been defined, see table 4.

For the beds/mattresses used in Scandinavia it has been assumed that such a product consists of a wooden frame with an integrated spring interior mattress, a mattress pad and additionally a spring interior mattress.

For the product category "other materials" it is not possible to define one representative example product because of the diversity of this group. However, according to the available market data this category is very small as compared to the other four product categories.

Table 4, Example products

	Spring interior	Polyether	Latex	"Scandinavian"*
Material	kg/m ² mattress			
Steel	4.0			2.5
PUR foam	1.3	4.8		1.0
Latex foam	0.2		9.0	1.5
Cotton, woven	0.6	0.6	0.6	0.5
Cotton, non-wov.	2.0	0.2	0.2	
Wool	0.4	0.2	0.2	

Polyester, non-woven	0.5			
Coconut fibre	1.0			
Felt	1.0			
Wood				10
Total weight:	11.0	5.8	10.0	15.5
Packaging : Polyethylene	0.23	0.23	0.23	0.4

* Figures relate to lower frame part and mattress pad only. These have to be combined with a spring interior mattress.

According to the draft ISO 14040 series standards the inventory is: *the phase of life cycle assessment involving compilation, and quantification of inputs and outputs, for a given product system throughout its life cycle.*

The inputs are economic inputs of all sorts (e.g chemicals or fuels). Outputs are the (semi)processed product or material and all emissions of substances to the environment. Such input /output data will be referred to as LCI data in this report.

Data Sources

The origins of the used environmental data are an important issue in LCA.

In the table below the main data sources are presented. For reasons of confidentiality the names of specific manufacturers have not been mentioned. A comprehensive literature overview is given in chapter 13.

Apart from the sources mentioned in table 5, information has been obtained from other parties as well;

- Manufacturers of latex and PUR foam, spring interiors, tickings, glues, coconut fibre, felt and mattress manufacturing equipment have been contacted during a visit to the furniture fair in Cologne, May 5, 1997. Those manufactures are from Belgium, Brazil, Germany, Great Britain, Italy, the Netherlands, Spain, Sri Lanka and Switzerland.
- Manufacturers associations:
 - The bedding and/or furniture manufacturing associations of the European Union, Belgium, France, Great Britain, Italy, the Netherlands, Portugal, Spain, Sweden and Switzerland were contacted.
 - euroLATEX, the latex foam manufacturers association has been contacted about data regarding latex foam.
 - Members from Europur and ISOPA, associations of European PUR (polyether) and isocyanate manufacturers attended the Ad Hoc Working Group meeting on 20 June 1997 and gave (preliminary) comment.
- Ecolabel institutes:
 - The German Eco-Umweltinstitut has been contacted in order to obtain insight in the existing labels for latex mattresses (QUL, Oeko-Control).

Table 5, Data sources used for LCI

Material/process	Source	Comment
Raw steel	BUWAL [30]	Averaged data, 23% recycled steel
Steel wire	Manufacturer + SPIN [31]	Dutch production, 1993
Steel springs	Manufacturers	Switzerland, the Netherlands
Polyether (PUR) foam	APME/ISOPA [11]	1996, new report in Sept. 1997
Raw natural latex	Rubber foundation, Delft [32]	1996
Synthetic latex (SBR)	PWMI, Report 4 [44]	1997
Latex foaming	Literature a.o. [10,28], euroLATEX	euroLATEX is working on more detailed data.
Mattress manufacturing	Manufacturers	Greece, The Netherlands
Transport of raw materials	BUWAL [30]	
Transport of foam, mattresses	Manufacturers	Greece, The Netherlands
Raw Cotton	Danish reports textile products [33, 51]	1994, 1997
Spinning, yarning, dyeing	Ecolabel reports [33,34,51]	
Wool	LCA study carpets [35]	1993, Dutch production
Polyester	Danish report textile prod.[51]	
Weaving	Manufacturer	Belgian production
Waste disposal	Tauw	Assumption
Electricity and fuels	ETH [36]	Appr. 1990, Eur. Production, UCPTTE model
Wood	RIVM (The Netherlands)	1992, European average

Data reliability and completeness

Market study:

The data are not complete for all EU countries. The data from national mattress manufacturing associations are considered to be more reliable than the Eurostat data.

Functional unit:

The collected data relate to requirements for different types of mattresses and the corresponding testing. These data are assumed to be reliable, as they originate from recent consumer tests and standards.

The subject of fitness for use has been discussed with mattress manufacturers (associations).

Manufacturing processes mattresses:

Data have been obtained from four mattress manufacturers, varying in completeness. The energy data (three factories) relate to the total of production and office use.

PUR foam:

Recent data were published by APME/ISOPA [11]. The authors of this APME publication were contacted for additional information. The data are assumed to be reliable, only additives which are being used are not included. An update of the publication became available in October 1997.

Emissions due to additives are not included in the quantitative part of the LCA.

Latex foam:

The energy use needed for producing latex foam from NR and SBR with the Dunlop or Talalay process is estimated, because at present no exact data are available. In annexe 4 the assumptions leading to the estimation are presented.

Quantitative data about emissions during the foaming, vulcanising, washing and drying were not available. For this reason possible emissions, e.g. zinc compounds to water, are described in a qualitative way.

Both the estimations about energy use and the description of possible emissions have been discussed with the latex foam manufacturers association euroLATEX.

Steel springs:

Data for processing of steel to wire and springs are from two manufacturers of wire and springs respectively. It is not known in how far the energy for wire production may vary according to the exact process used. According to our knowledge the data for the production of the springs (coiling) are reliable. The use of oil for the lubrication during drawing and coiling processes is not included in the LCA.

Textiles:

Use been made of two ecolabel studies for textile products, an LCA study for carpets and a recent Danish Life Cycle screening study for textiles [33,34,35,51]. The raw cotton energy data include the energy consumed for production of chemical (pesticides etc.). The data for wool do not include pesticides etc.

Within the framework of the EU ecolabel study Textile II new information is being collected at present. For the present study on mattresses this information is not used, because relevant interim reports were finished by the end of september 1997.

Assumptions:

Manufacturing process mattresses:

Energy data used are from three factories, varying in production capacity (appr. 100 - 200 mattresses/day) and degree of automation. Their average energy use per m² mattress is assumed to be representative for all mattress factories. Energy use for the heating of the production area and storehouses has not be taken into account.

Data regarding waste resulting from mattress production are available for two factories. The amount of waste is respectively 0.11 and 0.125 kg / m² mattress. The waste consists mainly of textile, non woven polyester and PUR or latex foam. One factory recycles foam waste (appr. 0.05 kg / m² mattress). Based on these data 0.07 kg waste / m² mattress has been included in the LCA.

Scandinavian bed/mattress:

The example product is defined as a combination of a wooden base with spring interior, a mattress pad and a spring interior mattress. The amounts of different materials for the wooden base and pad have been estimated, based on [2].

Steel springs:

The polypropylene or polyester fleece which is used for pocket springs is not taken into account, because the weight % is very low compared to the steel.

PUR foam:

The example composition of flexible PUR foam as mentioned in [11] is assumed to be representative for all PUR foams used in mattresses.

Waste resulting from the foaming process is not taken into account, because this production waste is normally recycled.

Latex foam:

An average composition of 50% natural and 50% synthetic (SBR) rubber is assumed for the latex foam.

Shell/ticking:

Based on product information we assumed a composition of cotton and wool for the shell of foam mattresses. For the spring interior 2 kg cotton, 1 kg felt and 0.5 kg non-woven polyester per m² mattress are used as average values.

The black and white cotton used in the shell of mattresses originate from second selection cotton (white cotton only) and from mechanical recycling of textile waste from textile factories. The textiles are first cut, shredded and carded to loose fibres. Next this material is processed to a layer, the wadding [55]. Because no data are available and because it is expected that the energy use of the whole process will be relatively low, only transport to the mattress factory is taken into account for this "cotton".

For wool it is assumed that the amount of chemicals used, like pesticides, is negligible.

Felt: because the felt is made out of wool and/or cotton, a composition of 50% wool and 50% cotton is assumed.

The ticking has been assumed to consist of cotton. For this cotton the used data relate to production of raw cotton and relevant chemicals, spinning, weaving and dyeing and transports.

Coconut fibre:

Data relate to rubberized fibre, average composition 50% fibres, 50 % natural latex [37].

For the coconut fibre itself only transport has been taken into account, because the fibre is considered to be a by-product of the coconut tree.

Glue:

According to information from manufacturers the amounts of glue (fixing different layers) is normally less than 1% of the total weight of a mattress.

Therefore glues have not been included in the quantitative part of the LCA, but are assessed qualitatively in section 8.3.

Transport:

The transport distances for the different materials and for the mattresses which are used in the LCA are taken from reference studies (cotton, wool, PUR precursors), from information from manufacturers (mattresses, spring interior) or estimated.

For latex and PUR foam and for mattresses the energy use due to transport is based on information about the actual amounts of mattresses which can be transported in a truck. The common calculation method which is based on energy use per tkm (tonnes transported x distance) would not be correct for these products with such a low density, so instead energy use per km has been used.

Disposal:

In the quantitative part of the LCA for the example products it has been assumed that disposal is by landfill. Leaching of materials from mattresses on a landfill is not taken into account in the quantitative part of the LCA, because of the large number of additives which might be present in old mattresses and because of the lack of data.

Disposal is assessed qualitatively in section 8.4. From literature [39] it is known that mattresses can be recycled. However, as far as known, recycling of mattresses in the EU is only practised on a very small, experimental scale.

9 LIFE CYCLE IMPACT ASSESSMENT LIFE CYCLE IMPACT ASSESSMENT LIFE CYCLE IMPACT ASSESSMENT

9.1 Classification and characterization Classification and characterization Classification and characterization

In an LCA the environmental impacts are quantified as far as possible. For this quantification the classification and characterisation procedures are used. These procedures are usually performed with the aid of LCA software.

In the LCA software program all inventory data (raw materials, emissions and solids) are grouped into several environmental impact categories (e.g. acidification, greenhouse effect). This is called *classification*. For example all emission that have an acidifying effect (e.g. NO_x, SO₂ and NH₃) are grouped together under impact category 'acidification'.

Then the emissions are converted into standard units (e.g. kg SO₂ equivalents for acidification or kg CO₂ equivalents for the greenhouse effect) with the aid of 'equivalence factors'. This quantification is called *characterisation*. The equivalence factors allows one to add up different emissions. For example the acidifying effect of an emission of NO_x can be added to the acidifying effect of an emission of SO₂. The equivalence factors as defined by CML [26] are used. The result of the characterisation is an absolute 'score' representing the total impact (e.g. '10 grammes of SO₂ equivalents acidification' or '5 MegaJoules of energy'). These scores together are called the '*environmental profile*'.

In the LCA the following environmental impact categories will be considered, according to the SETAC list and LCA practice:

- 1 abiotic resource depletion (exhaust)
- 2 greenhouse effect (global warming)
- 3 human toxicity
- 4 acidification
- 5 ozone depletion
- 6 eutrophication/oxygen demand
- 7 photochemical oxidation (smog)
- 8 ecotoxicity
- 9 landscape demolition (and ecology)
- 10 use of energy (renewable and non renewable)
- 11 nuisance
- 12 solid waste

In the following section these impact categories are elucidated.

Within LCA the classification and characterisation procedures are standard procedures. The used equivalence factors mostly originate from extensive research of behaviour of substances in the environment. The equivalence factors for the greenhouse effect, acidification, eutrophication, smog formation, ozone depletion are well accepted. The equivalence factors used for the impact categories 'human toxicity' and 'ecotoxicity' are still subject to discussion in the scientific field.

In the next pages the different impact categories are explained in more detail.

Environmental impact category 1: abiotic resource depletion

Scarce resources are defined in [26] as raw materials which are likely to be exhausted within 100 years. The energy-sources gas, oil and uranium ore are considered as scarce according to estimates of resources by the *World resources institute*. The global reserves of iron, coal, sulphur, phosphor and other used raw materials are not likely to be exhausted within 100 years.

Environmental impact category 2: Emission of greenhouse gases

The greenhouse effect is an important global environmental problem. The change of the composition of the atmosphere causes changes in the heat balance of the planet. The most important contributing substance to the effect is carbon dioxide gas. Also the emission of N₂O and methane contributes to this impact.

CO₂ is emitted in the life cycle of mattresses whenever fossil fuels are burnt. The CO₂ from organic material (e.g. wood) which is finally released into the environment by incineration, also known as short cyclic CO₂, has not been taken into account in the calculations here because it has been fixed from the atmosphere a short time ago. Therefore it has no net effect on the current composition of the atmosphere and hence does not make any contribution to the greenhouse effect.

The emissions of fossil CO₂, methane and N₂O are multiplied with equivalence factors (according to [26]) and added up. The score is expressed in kg CO₂ equivalents.

Environmental impact category 3: Emission of substances toxic to human beings

Several emissions to air and water contribute to this impact category. For the quantification of this impact category these emissions are multiplied with equivalence factors and added up. The score is given in units of kg polluted humans, polluted up to a certain threshold value.

In the calculations for this impact category equivalence factors were used that are only based on toxicity values (ADI values) and immission levels. Biodegradability and other important factors are not yet incorporated in the equivalence factors. Recently the University of Leiden has recalculated equivalence factors for almost hundred substances, in which also the degradation of the substance in the environment and chronic toxicologic effects are taken into account [39]. This set of equivalence factors however is still far from complete. For this reason these new equivalence factors have not been used yet in the current LCA. The result of the quantification of this impact category are based on the 'old' equivalence factors and should be regarded as indicative.

Environmental impact category 4: Emission of acidifying compounds

This impact category, also known as 'acid rain', concerns the acidification of the environment by human activities (air at first and subsequently soils and water). Acidified soils and waters have a very poor ecological quality. The acidification can also cause (toxic) heavy metals to mobilize and become available to living organisms. For the quantification of this impact category all airborne emissions of acidic compounds are multiplied with equivalence factors and added up. The impact is expressed in g SO₂ equivalents.

Environmental impact category 5: Emission of ozone layer depleting compounds

The depletion of the protective ozone layer in the stratosphere is a well known environmental problem. The problem is caused by halogen-containing gasses, such as chlorofluorocarbons (CFCs), hydrogenchlorofluorocarbons (HCFCs) and Halons. This impact is expressed in g CFC11.

Environmental impact category 6: Emission of eutrophating compounds and oxygen demand

Eutrophication concerns the enrichment of water by nutrients, such as phosphates, nitrogen and potassium. Above certain limits this can cause an excess of algae growth.

The algae cannot be grazed away by microfauna in time, and the algae start to decompose, which process demands oxygen from the water. The life forms in the water can subsequently be decimated because of this lack of oxygen.

The emissions of nutrients are multiplied with equivalence factors and then added up. The eutrophication is expressed in g PO₄ equivalents.

Also the (bio)degradation of other compounds can decrease the amount of oxygen in the water. This oxygen demand is expressed in grammes of chemical oxygen demand (COD).

The nitrification of soils by airborne emissions of nitrogen (e.g. NO_x and NH₃) can result in the domination of some plants in the vegetation (nettles and blackberry bushes). This impact is very local and not included in this study.

Environmental impact category 7: Photochemical oxidation

This impact category concerns the well-known problem of smog, which often causes acute air quality problems in densely populated areas. Under the influence of sunlight hydro-carbons (C_xH_y) can lead to the formation of ozone, which is toxic to humans and can cause damage to crops and natural vegetation, especially near urban areas.

For the quantification of this impact category all airborne emissions of volatile hydrocarbons are multiplied with equivalence factors and added up. The impact is expressed in g ethylene equivalents.

Environmental impact category 8: Emission of substances toxic to flora and fauna

In order to calculate this environmental impact category emissions of several substances are of relevance.

It concerns waterborne emission, such as hydrocarbons and heavy metals. For the assessment of this impact category a limited number of equivalence factors are available, based on MTC values (maximum tolerable concentration) [26].

It must be stressed that biodegradation in the environment is not taken into account in the current set of equivalence factors; only the toxicity is taken into account. Recently the University of Leiden has recalculated equivalence factors for almost hundred substances, in which amongst others also the biodegradation is taken into account. Because of the limitation of this new list [40] and because it is not yet accepted generally, these factors have not been used yet in the current LCA. The result of the quantification of this impact category are based on the 'old' equivalence factors and should be regarded as indicative.

Environmental impact category 9: Landscape demolition and ecology

Damage to the natural landscape is expressed here as the decrease in total natural landscape and the subsequent loss of biodiversity in a given area. In general the biodiversity of an area is reduced with an increasing influence of man in the area. For mattresses fuels and minerals are extracted from the environment and processed into products. The mining operations and the necessary chemical plants, storage and transport systems take up space at the expense of the former natural landscape. Also agriculture, latex tree plantations and landfills take up space.

Besides loss of biodiversity also aesthetical damage can be done to the landscape.

This impact category can not yet be quantified, because both the necessary data and an accepted arithmetic quantification method are lacking.

Environmental impact category 10: Use of energy

From the discussion of the former impact categories it can be concluded that the fuel related emissions have several impacts. For this reason the use of energy is taken as a separate impact category. This impact category is expressed in MegaJoules of energy.

Environmental impact category 11: Nuisance

In this impact category nuisance due to odours, noise or physical nuisances are described. Odorous emissions can be recalculated to m^3 air with the aid of odour threshold values. The other impacts can not be quantified, because both the necessary data and accepted arithmetic quantification methods are lacking.

Environmental impact category 12: Solid Waste

Solid waste is defined as wastes destined for landfilling. Also wastes that remain after treatment (e.g. incineration) are included in this impact category. This impact category is expressed in kilograms solid waste.

9.2 Assessment of the four example products

In this section the results of the quantification of the environmental impacts of the four example products will be presented. The inventory data which have been used are given in annexe 3.

For each impact category a graph with the scores of the spring interior, polyether foam and latex foam example product is given. In these graphs for each example product the contributions of its different materials and processes on the different impact categories are shown. Additionally a short explanation per impact category is given. Some of the materials mentioned in this explanation are used in the manufacturing of foam materials:

polyol and TDI: used in PUR foam;
NR and SBR: used in latex foam.

The results for the Scandinavian bed/mattress are presented in annexe 5, because this bed/mattress is not directly comparable with the other example products. The description of the environmental effects of the spring interior mattress in this section also applies for the Scandinavian example product.

It has to be emphasized that the presented LCA results refer to the chosen example products only. This means that LCA results for specific mattresses may differ from the results of the corresponding example products. For this reason a direct comparison between the different types of mattresses is not possible! The aim of this LCA is to identify for each type of mattress the environmental key issues.

Environmental impact category 1: exhaustion of abiotic resources (exhaust)

For the spring mattress the dominating effects are the use of oil and gas related to the production of steel, PET, cotton and polyol.

The score for the polyether mattress is dominated by the use of gas and oil for the production of polyol.

The use of gas and oil for the production of SBR is dominant for the latex mattress.

Environmental impact category 2: emission of greenhouse gases (greenh.)

Carbon dioxide is by far the most important cause of this category. It is emitted from the combustion of fuels during the production processes and transport. The main contributions are caused by the production of steel, PET, polyol, SBR and cotton.

Environmental impact category 3: emission of substances toxic to human beings (humantx)

For spring mattresses emissions of C_xH_y and SO_2 related to the production of steel, PET and polyol are the major effect.

Emissions of C_xH_y , SO_2 caused by the production of polyol and cotton and emission of NO_x caused by the production of polyol are dominant for the polyether mattress.

For the latex mattress C_xH_y , SO_2 and NO_x caused by the production of SBR are dominant.

Environmental impact category 4: emission of acidifying substances (acidif.)

For spring mattresses emissions of SO_2 and NO_x from production of polyol, TDI, steel, PET and cotton are the biggest effects.

For polyether mattresses emission of SO_2 and NO_x from production of polyol and TDI is dominant.

For latex mattresses emissions of SO_2 and NO_x from production of SBR are dominating.

Environmental impact category 5: emission of ozone layer depleting compounds

This category is not included in the figures, because as far as known there are no emissions in the life cycle of the example products that are ozone depleting.

Regulation EG Nr. 3093/94, dated 15-12-1994, addresses the phase out in the EU of the main ozone depleting chemicals. The production, import and trade is thus forbidden since 1-1-1995 for chlorofluorocarbons (CFCs) and since 1-1-1996 for 1,1,1 trichloroethane and carbontetrachlorid. The use of CFCs is - except for some special applications - forbidden since 16-6-1995.

Hydrochlorofluorocarbons (HCFCs) are to be phased out before 1-1-2015. However, HCFCs may only be used for special applications from 1-1-1996 on. These applications include cleaning (e.g. metal parts). Use as blowing agent in the production of flexible polyether foam is not permitted.

The Ozone Depleting Potential (ODP) of HCFCs is on average about one tenth of the ODP of CFCs.

Environmental impact category 6: emission of eutrophating compounds (eutroph)

This effect is mainly caused by emissions of phosphorous and nitrogen containing compounds and by the chemical and biological oxygen demand (COD, BOD).

For the spring mattress the above-mentioned emissions are related to the production of NR and polyol.

For the polyether mattress the main emissions are caused by the production of polyol, for the latex mattress by the NR production.

Environmental impact category 7: photochemical smog (smog)

Emission of hydrocarbons (C_xH_y) related to the use of oil and gas for the production of polyol, steel, PET, SBR and cotton constitute the main contributions to this effect.

Environmental impact category 8: emission of substances toxic to flora and fauna (ecotox-W)

The scores refer to waterborne emissions. For polyether emissions of phenol and C_xH_y related to polyol production are by far the most important effect.

For spring mattresses apart from these emissions also emission of crude oil related to the production of steel and emission of C_xH_y caused by PET is relevant.

For latex mattresses emissions of crude oil and C_xH_y due to SBR production dominate.

Environmental impact category 9: landscape demolition and ecology

As indicated before, this impact category can not yet been quantified.

Environmental impact category 10: use of energy (energy)

For spring mattresses the production of steel, PET and PUR foam are relevant.

The energy use related to the polyether mattress is mainly due to the production of polyol and TDI.

For the latex mattress the energy score is mainly caused by SBR and - to a lesser extent - NR (mainly due to caloric value). The energy use of latex foaming (including vulcanising and drying) seems to be less important. The data for this energy use are however estimated.

For Scandinavian mattresses (not represented in the graph below, see annexe 5) the wood from the frame also contributes to the score. This is due to the energy content of the wood itself (caloric value), not to the production processes!

Environmental impact category 11: nuisance (odour)

H_2S and NH_3 from the polyol production are the main odorous substances regarding polyether mattresses. The same applies for spring mattresses, with additionally H_2S and NH_3 emission related to the steel production.

Environmental impact category 12: solid waste (solids)

As was to be expected, the main contribution is by the disposed mattress itself. For polyether mattresses mineral waste resulting from the production of polyol is also relevant, for spring mattress production waste resulting from the production of steel is to a lesser extent relevant.

9.3 Qualitative assessment of other materials and additives

As mentioned before, glues, textiles other than cotton, wool and polyester, and additives are not assessed quantitatively in the LCA because of their low percentage and lack of data. In this section these substances will be discussed shortly:

Glues:

For mattresses several kinds of glues may be used [28]:

- Latex glue, containing natural and/or synthetic latex solved in water or a organic solvent. The amount of latex is about 40 to 50 %.
The main environmental effect for waterbased latex glue is related to the production of the latex. For solvent based latex glue also the production of the organic solvent and the emission of the solvent (Volatile Organic Compounds) during gluing are relevant.
- Styrene glue, consisting of styrene (solvent and harder), polyester (binder) and additives, e.g. cobalt compounds (accelerator). The main environmental effects are probably due to the production of styrene, polyester and additives. Also part of the styrene may be emitted during gluing.
- Hot melt. This glue is dosed at a temperature of about 170 °C. Different compositions are used, e.g. based on polyolefine, thermoplastic rubber, resin or ethylene vinyl acetate [41,42]. The environmental impact is probably mainly caused by the production of ingredients, because as far as known no emissions occur during gluing.
- Waterbased acrylic glue [43]. The main environmental effects are to be expected from the production of acryl.

Textiles:

Apart from cotton, other (blends of) woven materials based on polyester, polypropylene, viscose, polyurethane, polyamide and silk may be used in textiles for mattresses. The total amount of these materials will normally not exceed 5%. The contribution of these materials to the overall scores of the mattresses for the environmental impact categories is expected to be small.

According to several LCAs for textiles [33,34,35,51], the use of pesticides is an environmental key issue. Another relevant aspect is the use of dyeing agents. Dyes which contain or may form carcinogenic amines may be used [51]. Both aspect could be taken into account in the proposals for ecological criteria.

Additives used in latex foam:

In the production of latex foam several additives are being used. This applies for natural latex as well as for synthetic latex.

Some of these additives may be toxic, e.g. organometallic compounds. Other additives may form toxic compounds, e.g. nitrosamines or carbon disulphide [5, 10,50]. These may be emitted from the mattress during use. According to [5] a combination of humidity and elevated temperature (> 40°C) may cause carbon disulphide emission from latex foam. It is however not clear whether carbon disulphide emission during use of the mattress is a relevant aspect.

In the production of natural latex also formaldehyde and/or pentachlorophenol, both toxic compounds, may be used.

Because normally the latex foam is washed with water, part of the additives which have not been bonded chemically during the foaming, will be washed out. This may lead to emissions of toxic compounds to the aquatic environment. Regarding this aspect no data are available.

Finally toxic additives may be emitted from the mattress during disposal, see section 8.4.

Additives include [10]:

- Activators:
Mostly 5 parts of zinc oxide and 2 parts of fatty acids (mostly stearic acid) are added per 100 parts of rubber.
- Fillers:
These may be used in cheaper latex foams for mattresses. Clay, calcium silicate, magnesium silicate and calcium carbonate are common fillers. These materials are normally inert and non-toxic.
- Antioxidants:
Mostly about 1-2 w% is added.
Many kinds of antioxidants are being used, the most important being amines and phenolic compounds.
- Accelerators (for vulcanization):
The main types are organic bases, thiazole derivatives, thiuram sulphides, dithiocarbamates and xanthates. Some of these accelerators can emit nitrosamines during production, e.g. ZDEC (zinc diethyl dithiocarbamate). Replacement by accelerators which can not form nitrosamines is possible, but sometimes technical or cost problems are involved [49]. According to [5] ZDEC is still being used widely for latex foam for mattresses. For latex foam used for carpets some manufacturers use zinc dibenzyl dithiocarbamate which is said to be less prone to form nitrosamine than ZDEC. For technical and/or financial reasons use of this accelerator is still difficult for latex foam for mattresses [5]. Details about types and amounts of accelerators which are at present actually being used for latex foam used in mattresses are not known.
Many nitrosamines have proved to be carcinogenic by animal testing [50].
In Germany a maximum level of 2.5 microgram nitrosamines/m³ air has been set for the latex industry [5]. According to latex foam manufacturers (euroLATEX) the actual levels of nitrosamines in the air of production and storage facilities are below the detection limit of the used analysis methods.
Traces of nitrosamines formed in latex foam may still be present in a mattress during use. In a German test [5] performed in 1995 concentrations up to 24 microg/kg latex were found in commercially available mattresses. A similar test in 1996 [53] showed concentrations below 6 microg/kg latex. It is not clear whether this difference is due to a different method of analysis or to changes in the composition of the mattresses.
- Flame retardants
In some countries (e.g. UK) mattresses have to be flame retarded. For this purpose different compounds are used, according to the flammability level required. Some of the compounds which may be used are toxic for the environment and human beings, e.g. brominated aromatic compounds and antimony trioxide.

A typical formulation for latex foam is as follows [10]:

	dry parts by weight	
SBR latex		50
Soap (potassium oleate)		1
Natural latex	50	
Zinc diethyl dithiocarbamate (ZDEC, vulc. accel.)	0.75	
Zinc 2-mercaptobenzothiazole (vulc. accel.)		1
Sulphur	2.25	
Antioxidant		0.75
Gel sensitizer	0.8	
Ingredients added during foaming:		
Zinc oxide		3
Sodium silicofluoride (Dunlop process)		2

Additives used in polyether (PUR) foam [12]:

Below an overview is given of the most important types of additives which are being used in PUR foam. Some of these additives are toxic for human beings and ecosystems, e.g. tin dioctate and diphenyl amine.

- Catalysts for polyaddition and cross-linking:
These are mostly organometallic compounds, especially tin(II) compounds, e.g. tin(II) dioctate.
- Catalysts for gas reaction:
Widely used are tertiary amines like 1,4 diazabicyclo(2,2,2) octane.
- Emulsifiers/foam stabilizers:
Especially polyetherpolysiloxane-copolymers are being used.
- Blowing agents:
The reaction between water and diisocyanate produces carbon dioxide, which acts as a blowing agent. Sometimes auxiliary blowing agents are being used. Because of environmental legislation the blowing agent methylene chloride is or will be replaced by other agents like (liquid) carbon dioxide.
- Anti oxidants:
Compounds like diphenyl amine derivatives are used.
- Flame retardants:
In some countries (e.g. UK) mattresses have to be flame retarded. For this purpose phosphorous- and/or halogen-containing compounds (normally 5 - 20 w%) are added to the PUR foam.

TDI (and MDI), although not an additive but a precursor, has to be mentioned separately because it is a toxic compound. During manufacturing of PUR foam TDI may be emitted. According to the German Environmental Protection Agency (UBA) about 50 g TDI is emitted per tonne TDI processed in PUR foam plants. However, this figure originates from 1983. According to [64] this emission was mainly caused by the filling of 20 tonnes TDI containers at manufacturing plants. Nowadays this emission is reduced to about 20 g per tonne TDI (calculated value), among others by the application of vapour recovery during filling of the containers. Further emissions of TDI may occur during the foaming process and during the first days after the production of the PUR foam. The PUR industry has investigated the possibilities to reduce TDI emissions, e.g. by gas scrubbing or active coal filtering [64]. The TLV (Threshold Limit Value) value for TDI is 0.005 ppm or 0.036 mg/m³, based on 8 hours/day exposure [65]. TDI which is released to the environment has a half-life time of about 0.5 to 3 hours in air [64], and 0.5 seconds to 3 days in water [66]. The TDI is hydrolysed and relatively inert polymeric ureas are formed.

Two typical formulations for PUR foam are given below [12]:

Standard flexible foam:

	parts by weight
Trifunctional polyether	100
TDI 80/20	44
Water	3.5
Foam stabilizer	0.7
Tertiary amine	0.13
Tin dioctate	0.16

High Resilient Foam (HR):

Contains organic-filled polyether, e.g. PHD polyol

	parts by weight
PHD polyol	100
TDI 80	41
Water	3.5
Foam stabilizers	0.4
Triethylenediamine	0.15
Alkanolamine	1.5
Tin dioctate	0.1
Halogenated alkylphosphate	2.0

Coconut fibres (coir fibre)

Coconut palms are grown and harvested primarily for the production of copra (coconut meat), out of which coconut oil is produced. According to [71] due to the low price of copra, use of fertilizers is not economical and they are only used in a negligible extent. The husk of the coconut has to be removed in order to obtain the copra. [71] mentions that only a small proportion of the husks is utilized for making coir fibre for doormats, mattresses, etc. The other part of the husks is either left under the tree to decompose or - if the husks are removed in a central location - placed on a large pile of husks (solid waste). Based on this information it is reasonable to assume that the main environmental impacts connected to the production of coconut fibre material is the energy needed for transport of the fibre material by boat (appr. 1.2 MJ/kg fibre). Energy use of mechanical treatment is expected to be very small. If the coconut fibre material is rubberized, the environmental impacts related to the production and vulcanization of natural rubber have to be taken into account. The Life Cycle Inventory data can be found in annexe 3: coconut fibre rubberized (category others) and natural rubber, raw (category rubber).

9.4 Waste treatment of mattressesWaste treatment of mattressesWaste treatment of mattressesWaste treatment of mattresses

Amounts and destination

The life cycle of mattresses often consists of several use phases. After having served full time on a regular bed the mattress is often moved to the guest room or the attic for occasional use, e.g. in case guests are staying in the house. Also the mattress can end up in the second hand trade. Finally each mattress that is sold is disposed of as waste. As mattresses don't fit into normal household waste collection containers, they are usually collected as bulky waste i.e. together with old furniture, refrigerators, carpets etcetera. From the bulky waste large metal objects are picked out and sold to metal scrap dealers. The remainder (including mattresses) is incinerated or is dumped on a landfill. We have inquired from Eurostat and OESO if there are any statistics on the treatment of bulky waste available. It appears that there are statistics available on the amounts of bulky waste collected in the different member States, but no statistics are available on the destination of the waste. It is expected that the majority of the waste is destined for landfilling, although waste incineration is becoming more and more common practice in Europe.

In the table below an overview is presented of the amounts of bulky waste generated by households in some EU-countries [56]. For the other countries no statistics are available.

table 6: amounts of bulky waste generated per annum by households in some EU Member States

country	amount of bulky waste collected (kton)	population (millions)
Belgium (1994)	352	10.1
Denmark (1994)	240	5.2
Germany (1993)	3818	81.2
France (1994)	4500	57.1
Netherlands (1994)	749	15.3
Austria (1990)	182	7.9
Total	9841	176.8

The total amount of bulky waste collected in these countries amounts to 9841 kt per 176,8 million inhabitants. If this is extrapolated to the total population in the EU-15 (368,7 million inhabitants in 1993) there is an estimated volume of 20522 kt bulky waste collected in the EU. For the current project it is interesting to know what the share of mattresses is in this total amount. The amount of old mattresses can be estimated. If we take an average life span of 10 years, the amount of mattresses sold in 1987 should approximately correspond with the amount of mattresses disposed of in 1997. According to UN statistics in 1987 the production of mattresses in the EU-12 amounted 9.256 thousand items. It may be assumed that sales are approximately in the same order, as imports and export are relatively of minor importance in the market for mattresses. If we extrapolate this amount in the EU-12 to the EU-15 (5% more population) it can be estimated that in the EU-15 about 9750 thousand mattresses are disposed of in 1997. Based on an estimated average weight of 9,4 kg [Beco-1997] it can be calculated that in the EU-15 approximately **92 ktonnes of mattress-waste** is

disposed of annually. This corresponds to approximately 0.5 % of the total amount of bulky waste in the EU-15. This value should be regarded as a rough indication.

As mentioned before there are no statistics available on the destination of the bulky waste, but there are statistics available on the destination of 'municipal waste'. In the European waste statistics bulky waste resides under category 'municipal waste', which is a broad category, also covering waste paper, garden waste, office waste and street waste.

In the tables below an overview is given of the disposal of municipal waste in the EU [60].

table 7: Destination of municipal waste in the EU-15 (situation 1990) [60]

country (population)	population served (%)	% of waste incinerated	% of waste landfilled	% of waste recycled	other destinations (composting included)
Austria (7,7)	99	12	68	16	3
Belgium (10)	100	23	50		27
Denmark (5,1)		63	28	9	
Finland (5)	75	2	78	19	
France (56,7)	99	37	47	4	11
Germany (79,4)	96	17	78		6
Greece (10,1)	100	0	94		6
Ireland (3,5)		0	100		
Italy (57,7)		6	90		4
Luxembourg (0,4)	100	69	31		
Netherlands (15)	>99	38	50	5	7
Portugal (9,9)	88	0	32		68
Spain (39)	90	6	74		20
Sweden (8,6)	100	41	44	13	3
UK (57,4)	100	12	70		18
Total (population weighted average)	97	17	69	2	12

From the table it can be concluded that in the beginning of the nineties on the average approximately 17% of household waste was incinerated, 69% was landfilled, 2% recycled and the rest (12%) was 'treated otherwise'[60]. As bulky waste can lead to problems in waste incineration plants because of the size of the objects, it may be assumed that the major part of old mattresses is dumped on a landfill. In several countries (e.g. Germany, The Netherlands) there is however a tendency the last years to increase incineration with heat recovery for combustible waste (including bulky waste).

In remote rural parts, where the waste collection service is very poor or even lacking, or in regions where people have to pay to get rid of their bulky waste also uncontrolled landfill or incineration may take place.

Recycling initiatives

Several pilot projects have been performed regarding the possible recycling of materials from mattresses. In Germany a Pilot project was performed in Stuttgart in

1995 in which more than 19.000 mattresses were disassembled for recycling of different materials. Steel and PUR-foam were sold to recyclers. The costs of disassembly were about 25 ECU. The pilot project was stopped after a year and did not lead to large scale disassembly of mattresses.

In the Netherlands a feasibility study was initiated by the joint mattresses producers [57]. From the study it was concluded that a return system (collection of the old mattress by the mattress branch self) with successive disassembly of mattresses and recycling of several materials might be feasible. Environmental impacts would be reduced and sales would be promoted. From the study it appeared that to consumers the problem of getting rid of the old mattress is a threshold for buying of a new one. The return system would take away this threshold. Further investigations, including pilot tests are proposed for the next year.

The European Isocyanate producers Association (ISOPA) has a Recycling Committee, that is following and stimulating the recycling activities in the field of polyurethanes. In the table below an overview is presented of the possibilities of flexible PUR foam from furniture and bedding [39,61]. According to the Isopa in Europe at present 85.000 tonnes of production waste from soft foam production are recycled, of which 25.000 tonnes in 'rebonding' and about 60.000 are shipped to the USA for the production of carpet underlayment. At present no post consumer flexible foams from furniture and bedding are recycled on a large scale.

table 8: recycling options for flexible PUR foam from bedding and furniture [61]

option	status	remarks
rebonding	commercial for preconsumer materials and automotive foams (car seats), practised by many companies	production wastes are rebonded into foams for a wide range of application (e.g. flooring, sound insulation, sports mats, carpet underlayment etc.)
powdering	commercial, practised by the German company Metzeler	the powder can be used up to 25% in new flexible foams
glycolysis	under development	markets for glycolysate under development
energy recovery	under development (in industrial power stations) commercial (in municipal waste Incineration plants with energy recovery)	

According to [57] in the United States it is quite common to renovate old mattresses for product re-use. As far as known this is not common practice in Europe.

Environmental effects of landfill

Emission of volatile components in the mattresses will take place primarily in the production stage. The remainder of volatile compounds will be emitted during use, or, eventually, in a landfill. In the landfill the mattress will be subjected to slow degradation. In an aerobe environment the steel will slowly oxidise and the rust will leach into the soil or groundwater. The plastic and latex foam and fabrics may also be biodegraded very slowly in the long term, both aerobe and anaerobe. The additives or intermediate degradation products of the materials, especially from the foam materials, may leach out into the soil or groundwater. The substances can be transported from the landfill into the surroundings, polluting the soil and water. In case these substances are toxic or persistent compounds, damage might be done to ecosystems or humans. Heavy

metals, which are used as catalyst additives do not degrade and can be toxic (e.g arsenic, lead, mercury, cadmium etc.).

Generally speaking the leaching of substances from plastics is very low. The plastic forms a durable matrix in which the substances are fixed. Nevertheless leaching may occur. Some substances are better fixed in the plastics than others. Leaching tests with plastic foils and recycled plastics used for water embankment materials have shown leaching of monomers, plasticizers and metal compounds [58]. As foam materials have a relatively large contact surface per weight unit, it is expected that on the long term leaching of additives will occur from the foam materials in mattresses.

Environmental effects of incineration

In a municipal waste incineration plant (MWIP) the plastics, textiles and organic fibre from the mattress will be burned completely. Apart from any mineral fillers used in the materials no residues will remain. In case the MWIP is equipped with a heat recovery system, part of the caloric value of the material will be recovered. According to [60] about 42 % of the EU waste incineration capacity is equipped with heat recovery. In [67] the incineration of latex foam was investigated, leading to the conclusion that this does not pose environmental problems.

The emissions of the waste incineration plant strongly depend on the treatment of the flue gasses. Usually the MWIPs are equipped with air cleaning equipment like condensers, electrostatic filters, wet scrubbers, which can remove over 99% of contaminants from the flue gasses. Not all MWIPs are equally 'clean'. Airborne emissions from MWIPs, reported in [59] include CO₂, SO_x, NO_x, heavy metals, fly ash/dust particles and dioxins.

These are emissions reported from individual plants. Average emission data representing an average European waste incineration plant are not known. In EC guideline 89/369 maximum emission levels for new incineration plants are given for heavy metals, dust, hydrochloric acid, hydrogen fluoride and sulphur dioxide.

The materials in the mattress will contribute to MWIP emissions when incinerated, but the actual contributions depend on the composition of the mattress and the state of environmental technology of the incineration plant. In case the mattress has a high sulphur content (e.g. from vulcanisation of latex) this will result in a relatively high SO_x emission. In case the mattress contains heavy metal additive, these metals will end up in the ashes/filter residues and possibly partly be emitted with the flue gasses. The incineration of all carbon-containing materials in the mattress will contribute to the greenhouse effect.

In order to gain insight in the relative importance of the calculated 'absolute' environmental scores of the example products, these scores are divided by reference values. This step is called normalisation. This way an indication is obtained of the significance of an absolute score.

It is most common to use current emission values as reference for normalisation. These reference values can be derived from national and international emission statistics. Because these reference values do not reflect environmental priorities the results of the normalisation procedure can only be regarded as indications.

The absolute scores (environmental profiles) of the analyzed example products were divided by the following reference values, originating from [52]. These values reflect the average daily use- or emission values in Europe per capita:

- abiotic depletion: 1×10^{-10} %of world reserves/capita/day (based on Dutch consumption pattern)
- greenhouse gasses: 33 kg CO₂ eq/capita/day
- human toxicity: 0,3 g/capita/day
- acidification: 266 gSO₂eq/capita/day
- eutrophication: 145 g PO₄ eq/capita/day
- (summer)smog: 49 g ethylene eq/capita/day
- energy: 460 MJ/capita/day
- aquatic ecotoxicity: 3452 m³/capita/day
- solid waste: 2,35 kg/capita/day

The values include all household-, agricultural- and industrial usage/emissions occurring on the West-European territory. Impacts occurring outside the EU from consumption of foreign products in the EU are not included.

The results of the normalisation are presented in the graph below. For each environmental impact category **the normalised score represents the impact of an example product during its whole lifetime**, expressed in days of inhabitants equivalents. A normalised score of 6 for final waste means thus that the amount of final waste related to the mattress in question equals the amount of waste produced within 6 days by the average European. One has to realise that the result of the normalisation shows in how far an example product contributes to the present environmental impacts. It is not possible to draw direct conclusions about the seriousness of this contribution from the normalised scores.

11 LIFE CYCLE INTERPRETATION LIFE CYCLE INTERPRETATION LIFE CYCLE INTERPRETATION

In chapter 9 the normalised scores of the LCA for the example products were presented. The normalised scores for the example products turned out to be highest for the environmental impact categories energy, greenhouse effect, acidification, final waste, smog and human toxicity.

The corresponding environmental impacts can be attributed to the following causes, which can be regarded as key issues:

- the total energy use for the production of the materials PUR foam, latex foam, and steel (contribution to impact categories energy, greenhouse effect and acidification);
- the disposal of old mattresses, usually by landfill (final waste);
- the emission of C_xH_y , SO_2 and NO_x caused by the production of SBR, steel, polyol and cotton (human toxicity and smog).

Additionally the qualitative assessment of materials, additives and disposal shows some aspects which are probably key issues:

- heavy metals and emission of TDI related to the production of PUR foam;
- toxic additives and additives which may form toxic substances, related to the production of latex foam;
- pesticides used for cotton and wool production;
- toxic or carcinogenic dyes used for textiles;
- use of volatile organic compounds for cleaning/degreasing of metal parts;
- use of galvanic treatment for surface treatment of metallic parts;
- volatile or toxic compounds used in glues;
- formaldehyde emission by chipboard (scandinavian bed/mattress only).

12.1 IntroductionIntroductionIntroductionIntroduction

Based on the Life Cycle Assessment environmental "key issues" in the life cycle of bed mattresses were defined in the preceding chapter. The ecolabel criteria have to focus on these key issues. The criteria should also be feasible for a certain part of the existing market and must be verifiable by means of standardized (or at least well described) tests or analysis methods. Furthermore the criteria should address aspects which mattress manufacturers can control and influence. In the following sections proposals for ecological criteria as well as fitness for use criteria are presented. An indication as to which parts of a mattress have to comply with the criteria is given in section 11.4.

12.2 Ecological criteriaEcological criteriaEcological criteriaEcological criteria

The proposed ecological criteria are based on the results of the LCA for the example products and on the comments of the AHWG. The criteria are grouped on basis of the relevant materials used for mattresses, viz. latex foam, PUR foam, steel springs, coconut fibre, textiles, wood and glues.

Latex foam

Key issues for latex foam are the use of energy and environmental effects related to additives.

According to the LCA the use of energy due to SBR manufacturing is dominant for latex foam. The energy use for 1 kg natural rubber, including overseas transport, is about 16 MJ/kg rubber (the total energy content is about 50 MJ/kg, including the calorific value of natural rubber, which is about 30 MJ/kg). For SBR the energy use is about 100 MJ/kg rubber (including the calorific value of SBR). However, according to euroLATEX for an equal hardness of latex foam 25% more NR is needed as compared to SBR. Also the energy consumption for vulcanizing and drying is about 30% higher for NR latex foam than for SBR foam.

euroLATEX and CEFIC [72,73] state that at present only about 10% of the latex foam used for mattresses has a high NR content. Furthermore they state that it is not possible for a latex foam manufacturer to change the NR/SBR ratio considerably. The shrinkage during production of NR foam is higher than the shrinkage of SBR foam. This means that manufacturers would have to change the moulds if they want to change the NR/SBR ratio considerably. Especially for the Talalay process this is very costly.

Regarding product quality euroLATEX, CEFIC and mattress manufacturers [74] state that the product characteristics (comfort, lifetime, etc.) are not equal for NR foam and SBR foam mattresses.

Because of the above-mentioned comments, it is proposed not to define a criterion regarding the ratio NR/SBR.

The association of European latex foam manufacturers, euroLATEX, has established the euroLATEX Eco Standard for latex foam. The first part of the requirements for this Eco Standard is based upon limit values for PCP, heavy metals, pesticides, formaldehyde and butadiene in the latex foam. These compounds are relevant because of their human and eco toxicity. The extractable concentrations of these compounds in the foam are determined by means of standard analysis methods, like extraction followed

by photometric, gas chromatographic or mass spectrometric analysis. We propose to include these requirements in the ecolabel for mattresses:

1. Concentrations in latex foam for the following substances below limit value, test methods according to euroLATEX eco standard:

	<i>substance</i>	<i>limit value</i>
1a	<i>pentachlorophenol (PCP)</i>	<i>not detectable (< 0.1 ppm)</i>
1b	<i>extractable heavy metals:</i>	
	<i>arsenic</i>	<i>0.5 ppm</i>
	<i>lead</i>	<i>0.5 ppm</i>
	<i>cadmium</i>	<i>0.1 ppm</i>
	<i>chromium (total)</i>	<i>1 ppm</i>
	<i>cobalt</i>	<i>0.5 ppm</i>
	<i>copper</i>	<i>2 ppm</i>
	<i>nickel</i>	<i>1 ppm</i>
	<i>mercury</i>	<i>0.02 ppm</i>
1c	<i>extractable formaldehyde</i>	<i>75 ppm</i>
1d	<i>toxic pesticides:</i>	<i>not detectable</i>
	<i>lindane, hexachlorohexane, hexachloro- benzol, aldrin, endrin, dieldrin, heptachlor(epoxide), methoxychlor, mirex, malathion, dichlorfenthion, parathion-methyl and -ethyl, DDE, DDD, DDT, diazinon and dichlorvos.</i>	
1e	<i>butadiene</i>	<i>not detectable (< 1 ppm)</i>

The second part of the euroLATEX Eco Standard requirements defines limit values for compounds in air sampled from a test room which contains a latex sample. Because as far as known the test room and the related test procedures are not standardized and require specific equipment, we propose not to include this part of the requirements in the EU ecolabel criteria. Instead criteria about dyeing agents and for the concentration of nitrosamines in the foam are suggested.

Use of dyeing agents is considered essential by latex foam manufacturers for quality assurance procedures, product identification and sometimes consumer preferences [72]. For this reason it is proposed to exclude only certain types of dyes and pigments, similar to the existing EU ecolabel for bed linen and T-shirts [70]. Furthermore it is assumed that the aspect of heavy metals in dyes and pigments is dealt with in criterion 1b.

2. No use of dyes which can release or be cleaved to carcinogenic aromatic amines, or are themselves classified as carcinogenic in accordance with Council Directive CD 67/548/EEC, amended by CD 94/69/EC and CD 88/379/EEC, amended by CD 93/18/EEC.

Nitrosamines, many of which are carcinogenic, may be formed by certain accelerators used in the latex foaming process. Based upon the German Φ kocontrol Label and QUL Label (see section 4.4) for latex foam mattresses and on the tests of mattresses by Φ kotest [5,9,53] we propose to include a criterion about the nitrosamine content of latex foam. The following criterion is suggested:

3. Concentration of nitrosamines in latex foam below 10 mg/kg (ppb), test method according to Φ kotest [5,9,53].

PUR foam

Key issues are 1) use of energy and 2) environmental effects related to TDI and additives.

The energy use is mainly caused by the production of polyol and TDI. No criterion regarding energy use is proposed, because as far as known the energy use related to the production of polyol and TDI can not be reduced significantly.

TDI emission during production of PUR foam is important with regard to occupational health and environmental effects. The occupational health aspect is not within the scope of the EU Ecolabel, so no criterion regarding TDI concentration in the air of production and storage facilities will be defined. Emissions of TDI in the air may cause short term environmental effects, because of the human and eco toxicity. Because of the rapid hydrolysis of TDI in air and water, no long term environmental effects are to be expected.

Taken into account that the major TDI emissions into the air are due to the filling of TDI containers and the production of the PUR foam, a criterion regarding this aspect is proposed. Because at present sometimes MDI, diphenylmethane diisocyanate, is used instead of TDI for the manufacturing of PUR foam, it is suggested to refer to diisocyanates rather than to TDI:

4. *During filling of diisocyanates containers at the PUR foam manufacturing plant use must be made of a vapour recovery system or a carbon filter, in so as to prevent diisocyanate emission into the air.*

Like latex foam, PUR foam may contain pigments or - to a much smaller extent - dyeing agents. These are used by foam manufacturers to indicate the density of the produced PUR foam [75]. Normally the foam is produced as a so called slabstock, out of which pieces are cut. Because of this process, indicating the density by e.g. stickers is not feasible. Therefore it is proposed to allow pigments and dyes and to exclude certain types as mentioned in the EU Ecolabel for bed linen and T-shirts [70]. It is assumed that limiting the amount of heavy metals in pigments and dyes is accomplished by criterion 6, which addresses the amount of heavy metals in the (coloured) PUR foam.

5. *No use of dyes which can release or be cleaved to carcinogenic aromatic amines, or are themselves classified as carcinogenic in accordance with Council Directive CD 67/548/EEC, amended by CD 94/69/EC and CD 88/379/EEC, amended by CD 93/18/EEC.*

PUR foam may contain several heavy metals, originating from additives (e.g. accelerators) or pigments. Analysis of samples of flexible PUR foam used for car seats [69] showed that heavy metal concentrations vary considerably. Concentrations of e.g. cadmium and mercury were below 0.1 ppm, for tin concentrations varied between 35 and 195 ppm. According to Europur and ISOPA [75,76] the necessary use of tin octoate in PUR foam used for mattresses implies a concentration of 800 to 1000 ppm tin in the PUR foam. Based on the analyses and the information of manufacturers the following criterion is suggested:

6. *Concentrations in PUR foam for the following substances below limit value, test method according to NEN 6465 (grinding of sample, followed by treatment for 2 hours with boiling HCl/HNO₃ (aqua regia)):*

	<i>substance</i>	<i>limit value</i>
-	<i>arsenic</i>	<i>1 ppm</i>
-	<i>lead</i>	<i>10 ppm</i>
-	<i>cadmium</i>	<i>0.1 ppm</i>

- chromium (total)	1 ppm
- cobalt	5 ppm
- copper	10 ppm
- nickel	1 ppm
- mercury	0.1 ppm
- tin	800 ppm

Textiles

From several studies [33,34,35,51] it is known that the use of pesticides is an important environmental aspect connected with the production of cotton and wool. Analysis of the amount of pesticides in these textiles is however very costly. For this reason and because the weight percentage of these textile materials in mattresses is relatively low, we propose not to set a criterion for this aspect.

Presence of heavy metals and/or carcinogenic aromatic amines in dyes used for textiles is another important environmental aspect [33,34,51]. A criterion for heavy metals may relate to the dyes themselves or to the textile end product. Technical requirements (e.g. catalysts for polyester production) or specific requirements and/or national legislation with regard to flame retardancy may ask for the use of heavy metals like cobalt and antimony in the textiles. For this reason we propose to define a criterion for the heavy metals in dyes and pigments and not for heavy metals in the textile end product:

7. Heavy metals in dyes and pigments for textiles:

No use of metal complex dyes or pigments based on the following metals: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, tin or zinc.

8. Aromatic amines in dyes for textiles:

No use of dyes which can release or be cleaved to carcinogenic aromatic amines, or are themselves classified as carcinogenic in accordance with Council Directive CD 67/548/EEC, amended by CD 94/69/EC and CD 88/379/EEC, amended by CD 93/18/EEC.

Other criteria for textiles, which relate to the weaving and wet processing of textiles, are in our opinion not appropriate for the ecolabel for mattresses, because textiles constitute only a small part of a mattress. Furthermore it will often be difficult for mattress manufacturers to check and control compliance with such criteria.

Steel springs

Most environmental effects for steel springs are related to the energy use during the production of raw steel. Criteria related to this process are not feasible in our opinion, because the energy use of the raw steel production can not be reduced significantly at present. Also the energy use of the example spring interior mattress is related for only 25% to the steel and for 75% to other materials.

Recent LCA studies [72,73] on the cleaning/degreasing of metals with aqueous cleaning or organic solvents show that it is not possible to state in general which method of metal cleaning is preferable from an environmental point of view. Emissions of halogenated hydrocarbons which may be used for cleaning or degreasing contribute to the greenhouse effect and photochemical oxidation. The amount of emitted solvent depends however strongly on the cleaning/degreasing equipment which is used. Modern, closed equipment will not cause a significant emission. For this reason the proposed criterion focuses on the use of closed systems for cleaning equipment based on organic solvents.

9. *Degreasing and/or cleaning of steel wire and/or steel springs with (halogenated) organic solvents must be carried out in a closed cleaning/degreasing system.*

Galvanic processes which might be used to treat steel are normally environmentally relevant, because of heavy metal waste and emissions to water. As far as known, use of galvanic layers is not essential for steel springs for mattresses.

The following criteria regarding surface treatment and degreasing and/or cleaning of the steel springs are suggested:

10. *The surface of the steel spring must not be covered with a galvanic, metallic layer.*

Coconut fibre

For non-rubberized coconut fibres no criteria are proposed, because as far as known there are no significant environmental impacts for this material. If the fibres are rubberized, the criteria for latex foam apply:

11. *If the coconut fibre material is rubberized, the latex must comply with criteria 1, 2 and 3 for latex foam.*

Black and white cotton

These materials, which originate from second selection cotton and from mechanical recycling of textile waste from textile factories, may be used without prejudice.

Glues

Mattresses may be produced without glue or with organic solvent containing glue, water based glue or hot melt glue. Organic solvents may be toxic and/or carcinogenic (e.g. benzene) and contribute to the photochemical oxidation (smog). Because alternatives for organic solvent glue are available, the following criteria are proposed:

12. *The amount of volatile organic compounds (VOCs) must be below 10 w%.*

13. *The glue must be free of benzene and chlorobenzenes.*

Wood

The Scandinavian bed/mattresses normally contain wooden or chipboard parts. Emission of formaldehyde, which is toxic and irritating, might be a problem for poor quality chipboard. For E1 quality chipboard a maximum level is set for the emission or content of formaldehyde. The following criterion is proposed:

14. *Chipboard must be E1 quality.*

Height of mattresses

Several comments on the previous draft of this report mentioned the fact that the amount of material used for a mattress was not taken into account in the criteria, although it is important from an environmental point of view. A practical way to incorporate this aspect in the ecolabel is to define a maximum height for each type of mattress.

The height of a mattress is more or less proportional to the mass of the mattress. Assuming that for a certain mattress type the composition (w% of different materials) is independent of the height, the environmental impact for this mattress type would be proportional to the height.

Looking at the quality of a mattress, there is a relation between the height and the quality. This is especially true for the conformity, *i.e.* the ability of a mattress to provide sufficient and overall support for all parts of the human body. According to information of mattress manufacturers the conformity of a mattress will improve with increasing height of a mattress up to a certain maximum. Above this point an increase of the height will not result in a better conformity. This means that one could define a criterion

for the maximum height of a mattress without restricting the conformity. Because there are no standard test method and requirements for the conformity, this maximum height should be based on an analysis of the existing heights for the different types of mattresses.

According to tests and product information from Greece, Germany and The Netherlands (in total 60 different mattresses) the average heights of mattresses are as follows:

	Average height (cm)	Deviation (cm)
Spring interior	20.8	1.5
Latex foam	16.2	1.4
PE foam	15.0	1.9

Based on these data one could consider to set a threshold at e.g. 1.1 * average height:

15. *Maximum height of mattress (measured acc. to DIN EN 1334):*

Spring interior: 22.9 cm

Latex foam: 17.8 cm

PUR foam: 16.5 cm

12.3 Fitness for use criteria

In section 6.3 some considerations about quality and durability were presented. Hardness can not be used as a criterion, because it is a subjective aspect. For conformity and damp permeability no standardized test methods and requirements exist. It is suggested to define only a criterion for durability, based on loss of height and loss of hardness of a mattress after loading. The following two criteria are based upon the experience of several mattress- and mattress foam manufacturers [72,74,77].

The loss of height and loss of hardness of the mattress after repetitive loading cycles of the mattress are tested according standard prEN 1957 : 1995. The loading is carried out by moving a specified roll 30.000 times hence and forth over the mattress.

16. *The loss of height of the mattress must not exceed 10%.*

17. *The loss of hardness must be below 20% (hardness expressed in N/mm).*

12.4 Application and test methods for ecological criteria

Mattress may contain small parts of a certain material, e.g. textile straps for carrying the mattress or buttons. It is suggested to exclude those small parts from the ecological criteria:

The ecological criteria apply only for those parts consisting of the material in question which exceed the following limits:

Material	Criterion	Limit (weight in grammes)
Latex foam	1, 2, 3	100
PUR foam	4, 6	100
Textiles 7, 8		50
Steel	9, 10	- , applicable for interior springs and frame

Coconut fibre	11	100
Glue	12, 13	- , applicable for all glue used
Wood	14	100

A declaration by the supplier of the material in question, which proves compliance with a criterion may replace analysis for the following criteria: 2, 4, 5, 7, 8, 9, 10, 11 (2), 12, 13, 14.

12.5 Market feasibility of proposed criteria

The above-mentioned proposals have been defined with the market feasibility and comments from the AHWG in mind. Figures for the percentages of presently sold mattresses, which would comply with the criteria can not be given, because of lack of data. This applies especially for the criteria which focus on additives in foam materials, because a great manifold of compounds is being used. Below the status (as far as known) of presently sold mattresses with regard to the proposed criteria is summarized.

Criterion 1 has been defined by euroLATEX, which represent a big part of the latex foam manufacturers in Europe. Compliance with this criterion is probably possible for the majority of the latex foam used presently.

No information about the type of pigments and dyes presently used in foam material (criteria 2, 7) is available. According to euroLATEX the dyes used in latex foam normally comply with these criteria.

All latex mattresses (seven) in a German test [53] in 1996 complied with criterion 3 on nitrosamines. In a similar test in 1995 [5] 7 out of 15 mattresses did not comply with criterion 3. According to euroLATEX the sample taking and preparation may influence the results of the analysis.

In order to reduce diisocyanate emissions (criterion 4) relatively simple technical adjustments have been taken or may be taken by PUR foam manufacturers.

It is expected that colouring of PUR foam is normally carried out without the use of dyes mentioned in criterion 5.

The limit values for heavy metals in PUR foam (according to criterion 6) may be exceeded if some specific additives are being used. At present no detailed information about used additives is available.

For ticking material no information is available about the exact type of dyes and pigments which are used (criteria 7,8).

For cleaning and degreasing of steel (springs) it is expected that especially small manufacturers of these parts may not use water based cleaning or closed systems for organic solvents (criterion 9). Steel springs in mattresses for domestic use are normally not coated with a metallic layer (criterion 10).

It is not known what part of coconut fibres for use in mattresses is rubberized and what part of the used latex would comply with criterion 11.

For glues it is expected that the major part of the glues presently used in mattresses will comply with criteria 12 and 13.

It is expected that chipboard used for Scandinavian beds is normally of an E1 quality (criterion 14).

Regarding the height of mattresses it is expected that appr. 90% of the mattresses on the European market would meet criterion 15. For the fitness for use criteria 16 and 17 it is expected that the majority of the presently sold mattresses will comply.

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14 ABBREVIATIONS ABBREVIATIONS ABBREVIATIONS ABBREVIATIONS

ADI:	Acceptable Daily Intake
AHWG:	Ad Hoc Working Group
APME:	Association of Plastics Manufacturers in Europe
BOD:	biological oxygen demand
CEN:	Comitè Européen de Normalisation (European Committee for Standardization)
CFCs:	chlorofluorocarbons
COD:	chemical oxygen demand
euroLATEX:	association of European latex foam manufacturers
HCFCs:	hydrochlorofluorocarbons
ISOPA:	European Isocyanate Producers Association
LCA:	life cycle assessment
LCI:	life cycle inventory
MBS:	mercaptobenzthiazyl sulphonamide
MDI:	diphenylmethane diisocyanate
NR:	natural rubber
PE:	polyethylene
PET:	polyethylene terephthalate (polyester)
PUR:	polyurethane
SBR:	styrene butadiene rubber
SETAC:	Society of Environmental Toxicology and Chemistry
TDI:	toluene diisocyanate
TLV:	threshold limit value
TMTD:	tetramethylthiuram disulphide
VOC:	volatile organic compounds
ZDEC:	zinc diethyl dithiocarbamate

15 LITERATURE LITERATURE LITERATURE LITERATURE

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ANNEXE 1: EUROPEAN STANDARDS FOR MATTRESSES

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ANNEXE 1: EUR

Dokumentnummer
NNNNNNNNNN

DIN 13013	Krankenhausmatratzen aus Latexschaum; Masse, Anforderungen, Pruefung
DIN 13014	Krankenhausmatratzen aus Polyetherschaum; Masse, Anforderungen, Pruefung
DIN 13047	Vakuum-Matratze; Masse, Anforderungen, Pruefung
DIN EN 597-1	Moebel - Bewertung der Entzuendbarkeit von Matratzen und gepolsterten Bettboeden
DIN EN 597-2	Moebel - Bewertung der Entzuendbarkeit von Matratzen und gepolsterten Bettboeden
DIN EN NEN1334	Wohnmoebel - Betten und Matratzen - Messverfahren und Toleranzempfehlungen
OENORM	
DIN EN NEN 1725	Wohnmoebel - Betten und Matratzen - Sicherheitstechnische Anforderungen und Pruefverfahren
OENORM	
DIN EN NEN 1957	Betten und Matratzen - Pruefverfahren zur Bestimmung der funktionellen Eigenschaften
OENORM	
DIN EN NEN 1959	Betten und Matratzen - Produktinformationen
OENORM	
RAL-GZ 441/1	Polyetherschaum-Matratzen - Guetesicherung
RAL-GZ 441/2	Federkern-Matratzen; Guetesicherung
RAL-RG 441	Polyetherschaum-Matratzen; Guetesicherung
BWB TL7210-0033	Technische Lieferbedingungen; Matratzen aus Schaumstoff
BWB TL 8105-0016	Technische Lieferbedingungen; Matratzen-Verpackung
VG 85095	Matratzengarnituren = Mattresses-sets
VG 85100	Matratzen und Polster; Technische Lieferbedingungen
DIN 13047	Vakuum-Matratze; Masse, Anforderungen, Pruefung
DIN EN 597-1	Moebel; Bewertung der Entzuendbarkeit von Matratzen
DIN EN 597-2	Moebel; Bewertung der Entzuendbarkeit von Matratzen
DIN EN 1334	Wohnmoebel; Betten und Matratzen; Messverfahren und Toleranzempfehlungen
RAL-AGt 2 BA	Matratzen-Bezugsstoff
RAL-AGt 8 MF	Federkern-Matratzen
RAL-AGt 8 M	Federkern-Matratzen; Technische Grundlage fuer RAL-TESTATE
RAL-AGt 8 MF	Technische Grundlage fuer RAL-TESTATE; Federkern Matratzen
RAL-AGt 8 MG	Schaumgummi-Matratze; Technische Grundlage fuer RAL TESTATE
RAL-AGt 8 MG	Schaumgummi-Matratzen; Technische Grundlage fuer RAL-TESTATE
RAL-AGt 8 MG	Technische Grundlage fuer RAL-TESTATE; Schaumgummi Matratzen
RAL-AGt 8 MS	Schaumkunststoff-Matratzen; Technische Grundlage fuer RAL-TESTATE

RAL-AGt 8 MS	Schaumkunststoff-Matratzen; Technische Grundlage fuer RAL-TESTATE
RAL-AGt 8 MS	Technische Grundlage fuer RAL-TESTATE; Schaumkunststoff Matratzen

RAL-RG 441	Polyaetherschaum-Matratzen; Guete- und Pruefbestimmung
RAL-RG 443	Federkern-Matratzen; Guetebedingungen
RAL-TG 2 BA	Matratzen-Bezugsstoff
RAL-TG 8 MF	Technische Grundlage fuer RAL-TESTATE; Federkern Matratzen
RAL-TG 8 MG	Technische Grundlage fuer RAL-TESTATE; Schaumgummi Matratzen
RAL-TG 8 MS	Technische Grundlage fuer RAL-TESTATE; Schaumkunststoff Matratzen
BWB TL 7210-0033	Technische Lieferbedingungen; Matratzen aus Schaumstoff
NF D64-010-1	MOEBEL. BEWERTUNG DER ENTZUENDBARKEIT VON MATRATZEN
NF D64-010-2	MOEBEL. BEWERTUNG DER ENTZUENDBARKEIT VON MATRATZEN
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NF D64-501	Haushaltfedermatratzen, Kenndaten
NF D64-511	Bettwerk. Bestandteile von Schaumstoffmatratzen, Eigenschaften und Pruefung
NBN T 46-007 H	Mousse de polyurethane pour coussins de dossier et de siege et pour accoudoirs de meubles, et pour matelas-specifications
BS 1877:Part 10:19	Haushaltsbettzubehoer. Lieferbedingung fuer Matratzen
BS 3173	Specification for spring units for mattresses
BS 5223:Part 1	Specification for hospital bedding. Adult size spring interior mattresses
BS 5223:Part 2:199	Krankenhausbettzeug. Matratzenkerne aus weichem PUR schaum
BS 7068:1989	Luftgefuellte Matratzen fuer Kranke = Specification
BS 7337:1990	Matratzen- und Bettueberzuege = Specification for
BS 7397:1991	Pruefung von Matrazen. Bettraahmen und Bettgestellen
BS EN 597-1:1995	Moebel. Bewertung der Entzuendbarkeit von Matratzen
BS EN 597-2:1995	Moebel. Bewertung der Entzuendbarkeit von Matratzen
OENORM A 1605	Moebel-Pruefbestimmungen; Polstermoebel und Matratzen
OENORM A 1605	Moebel-Pruefbestimmungen - Textile Moebelstoffe
OENORM A 1681	Polstermoebel - Betten und Matratzen - Benennung
OENORM S 1690	Gekrollte Naturfaserstoffr fuer die Fuellueng oder Auflage von Matratzen und Polstern.
NEN 3373	Cellular polyurethane for backrests, seats, armrests of furniture and for mattresses; requirements.
UNE 53231	Plastics. Core of flexible polyurethane foams for domestic mattresses. Characteristics and test methods.

Bonnell spring interior mattress

Pocket spring mattress

Polyether mattress

Latex mattress (pinfoam)

Source: Pullman product information

SCANDINAVIAN BED/MATTRESS (source [2])
ANNEXE 3: INVENTORY DATA ANNEXE 3: INVENTORY DATA
ANNEXE 3: INVENTORY DATA ANNEXE 3: INVENTORY DATA

In this annexe the processes are presented that were used in the LCA software to calculate the environmental aspects. Every process has inputs (raw materials, energy other materials), and outputs (emissions, solids, products). The following process modules are presented:

Material

- Chemicals
 - ethyleneglycol
 - Polybutadiene I
 - Polyol APME
 - Styrene I
 - TDI APME
 - therephtalic acid
- Ferro metals
 - steel 23% recycled B
 - steel spring
- Plastics
 - Flex. PUR foam
 - PET I
 - polyethylene P
- Textiles
 - cotton "raw"
 - cotton yarn
 - cotton, secondary
 - cotton, woven, dyed
 - PET yarn
 - PET, woven, dyed
 - wool
- Wood
 - Spruce (Vuren) T
- Rubber
 - Latex foam
 - Nat.Rubber, raw
 - NR foam
 - SBR foam
 - SBR raw I
- Others
 - coconut fibre rubberiz
 - jute
 - polyester, woven
- Heat
 - furnace gas B
 - furnace oil B
- Processing
 - Plastics
 - Blow moulding T
- Waste processing
 - waste treatm mattress
 - waste treatm. prod.w.
 - waste treatment PE
- Assemblies
 - spring mattress 1m2

polyether mattress 1m2
latex mattress 1m2
scand. mattress 1m2

Category: Material

Title : ethyleneglycol production bj

Author :

Source : Van den Bergh en Jurgens, Rotterdam, Holland, august 1990

Date : 29/01/92

Comment : ethyleneglycol production; to be used for petp therephtalic
production; source:Van den Bergh en Jurgens.weak data

Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
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Others	Amount	Un.	Comment
ethene bj	0.44	kg	

OUTPUT

Airborne emissions	Amount	Un.	Comment
ethyleneglycol	0.00002	kg	
ethyleneoxide	0.00005	kg	
H2	0.00001	kg	polyhydroxy compounds

Waterborne emissions	Amount	Un.	Comment
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Solid emissions	Amount	Un.	Comment
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Main products	Amount	Quantity	Un.	Pct.	Sub-category
Disposal fraction		Comment			
ethyleneglycol	1	Mass	kg	100	Chemicals
not defined					

End.

Project : Mattresses
 Category: Material
 Title : Flexible PUR foam
 Author : Tauw/ejd
 Source : ISOPA/APME, Eco-profilers of the Eur. Plastics Ind.,
 Report 9, PUR precursors, 1996
 Date : 09/04/97
 Comment :
 Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
Others	Amount	Un.	Comment
Polyol APME	0.713	kg	
TDI APME	0.285	kg	
transp.TDI/polyol	0.0998	tkm	
Electricity	1.5	MJe	
diesel engine truck B	2	MJ	Based on data transport matr.

OUTPUT

Airborne emissions	Amount	Un.	Comment
CO2	0.051	kg	

Waterborne emissions	Amount	Un.	Comment
Solid emissions waste, polym.	0.02	kg	

Main products	Amount	Quantity	Un. Pct. Sub-category
Disposal fraction		Comment	
Flex. PUR foam not defined	1	Mass	kg 100 Chemicals

Avoided products	Amount	Un.	Comment
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End.

Category: Material
 Title : Polybutadiene I
 Author : Delft University of Technology
 Source : PWMI, report 4, table 19, Brussels 1993
 Date : 01/09/95
 Comment : Component of polymers as ABS and HIPS.
 Source: Idemat95
 Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
crude coal	0.083	kg	
crude oil	0.959	kg	HHV=45MJ/kg
crude gas	0.701	kg	HHV=54.1MJ/kg
barrage water	23	kg	
uranium ore	0.018	kg	
energy (undef.)	0.01	MJ	
iron ore	0.0004	kg	
limestone mineral	0.0002	kg	
water	82.4	kg	
bauxite ore	0.0003	kg	
NaCl	0.0064	kg	

Others	Amount	Un.	Comment
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OUTPUT

Airborne emissions	Amount	Un.	Comment
dust (SPM)	0.0023	kg	
CO	0.0014	kg	
CO2	1.3	kg	
SOx	0.013	kg	
H2S	0.000001	kg	
NOx	0.013	kg	
HCl	0.00008	kg	

H2	0.00005	kg
CxHy	0.02	kg
metals	0.000005	kg

Waterborne emissions	Amount	Un.	Comment
COD	0.002	kg	
BOD	0.0004	kg	
Acid as H+	0.00012	kg	
metallic ions	0.00031	kg	
NH4+	0.0008	kg	
Cl-	0.001	kg	
dissolved organics	0.00018	kg	
crude oil	0.0003	kg	
CxHy	0.0004	kg	
phosphate	0.00003	kg	

Solid emissions	Amount	Un.	Comment
industrial waste	0.0025	kg	
mineral waste	0.011	kg	
slags	0.004	kg	
chemical waste	0.022	kg	(non toxic)

Main products	Amount	Quantity	Un.	Pct.	Sub-category
Disposal fraction		Comment			
Polybutadiene I Plastics	1	Mass	kg	100	Chemicals

End.

Project : Mattresses
Category: Material
Title : Polyether-polyol APME
Author : Tauw/ejd
Source : APME/ISOPA, Eco-profiles of Eur. plastics industry, report 9,
PUR precursors, 1996
Date : 27/03/97
Comment : Production of polyether-polyol used for PUR.
Based on averaged 1990 data from 8 European manufacturers
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
crude coal	0.215	kg	fuel
crude gas	0.553	kg	"
crude oil	0.243	kg	"
uranium	0.0289	mg	
crude lignite	0.27	kg	"
barrage water	50	kg	0.5 MJ
crude oil	0.482	kg	feedstock
crude gas	0.373	kg	"
crude coal	0	kg	"
biomass	1	MJ	
NaCl	1660	g	
bauxite ore	0.35	g	
SO2	18.4	g	
sulphur	2.5	g	
sand	2.2	g	
iron (in ore)	2.1	g	
phosphate ore	9.3	g	
limestone mineral	600	g	

Others	Amount	Un.	Comment
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OUTPUT

Airborne emissions	Amount	Un.	Comment
dust (SPM)	7	g	
CO	1.5	g	
CO2	3.4	kg	
NH3	0.25	g	
H2S	0.005	g	
HCl	0.15	g	
HF	0.003	g	
NOx	17.9	g	
SO2	15	g	
CxHy	11.3	g	
organic comp.	0.64	g	
CxHy chloro	0.28	g	
H2	0.57	g	
metals	0.005	g	

Waterborne emissions	Amount	Un. Comment
CxHy	1.4 g	
BOD	2 g	
COD	12.1 g	
acid	0.16 g	
metallic ions	131 g	
suspended substances	70 g	
oil	0.03 g	
detergent	0.03 g	
phenol	0.002 g	
dissolved substances	0.55 g	
org. comp.	1.1 g	
Na+	478 g	
Ca+	44 g	
Cl-	1070 g	
SO42-	4.3 g	
CxHy chloro	0.21 g	
nitrate	6.1 g	
P2O5	1.4 g	
N	2.3 g	

Solid emissions	Amount	Un. Comment
mineral waste	787 g	
slags	11 g	
fly ash	11 g	
industrial waste	89 g	
chemical waste	2.3 g	
final waste (inert)	7.5 g	

Main products	Amount	Quantity	Un. Pct. Sub-category
Disposal fraction		Comment	
Polyol APME	1	Mass	kg 100 Chemicals
not defined			

End.

Category: Material
Title : Styrene I
Author : Delft University of Technology
Source : PWMI, report 4, table 16, Brussels 1993
Date : 00/00/00
Comment : Component of polymers as ABS, PPE and PS.
Source: Idemat95
Cluster : No

INPUT

Raw materials	Amount	Un. Comment
crude coal	0.031 kg	
crude oil	0.937 kg	HHV=45MJ/kg
crude gas	1.008 kg	HHV=54.1MJ/kg
barrage water	0.0014 kg	
uranium ore	0.00034 kg	
energy (undef.)	20.4 MJ	
iron ore	0.0003 kg	
limestone mineral	0.0002 kg	
water	2.9 kg	
bauxite ore	0.002 kg	
NaCl	0.012 kg	

Others	Amount	Un. Comment
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OUTPUT

Airborne emissions	Amount	Un. Comment
dust (SPM)	0.003 kg	
CO	0.0015 kg	
CO2	1.5 kg	
SOx	0.043 kg	
H2S	0.000005 kg	
NOx	0.024 kg	
HCl	0.00003 kg	
H2	0.00002 kg	
CxHy	0.022 kg	
metals	0.00001 kg	

Waterborne emissions	Amount	Un. Comment
COD	0.0025 kg	

BOD	0.00005	kg
Acid as H+	0.0001	kg
metallic ions	0.001	kg
NH4+	0.00006	kg
Cl-	0.0002	kg
CxHy	0.0005	kg

Solid emissions	Amount	Un. Comment
industrial waste	0.0025	kg
mineral waste	0.011	kg
slags	0.004	kg
chemical waste	0.022	kg (non toxic)

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
Styrene I Plastics	1	Mass	kg 100	Chemicals

End.

Project : Mattresses
 Category: Material
 Title : TDI APME
 Author : Tauw/ejd
 Source : APME/ISOPA, Eco-profiles of Eur. plastics industry, report 9,
 PUR precursors, 1996
 Date : 27/03/97
 Comment : Production of toluene-diisocyanate used for PUR.
 Based on averaged 1990 data from 8 European manufacturers
 Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
crude coal	0.229	kg	fuel
crude gas	1.109	kg	"
crude oil	0.246	kg	"
natural uranium	0.039	mg	
crude lignite	0.42	kg	"
barrage water	70	kg	0.7 MJ
crude oil	0.286	kg	feedstock
crude gas	0.4	kg	"
crude coal	0.0273	kg	"
NaCl	288	g	
bauxite ore	0.13	g	
SO2	77	g	
sulphur	4.6	g	
sand	0.58	g	
iron (in ore)	0.53	g	
limestone mineral	78.5	g	

Others Amount Un. Comment

OUTPUT

Airborne emissions	Amount	Un.	Comment
dust (SPM)	7.1	g	
CO	3.3	g	
CO2	4.76	kg	
NH3	0.14	g	
H2S	0.005	g	
HCl	0.22	g	
HF	0.01	g	
NOx	28.5	g	
SO2	18.5	g	
CxHy	17.3	g	
organic comp.	0.6	g	
CxHy chloro	0.38	g	
H2	0.57	g	
metals	0.005	g	

Waterborne emissions	Amount	Un.	Comment
CxHy	0.3	g	"
BOD	0.2	g	
COD	1.4	g	
acid	0.68	g	
metallic ions	0.26	g	
suspended substances	12.1	g	
oil	0.03	g	
detergent	0.03	g	
phenol	0.003	g	
org. comp.	1.8	g	
Na+	0.61	g	
Ca+	23.9	g	
Cl-	82.8	g	
SO42-	36.1	g	

Solid emissions	Amount	Un.	Comment
mineral waste	183	g	
slags	13.7	g	
fly ash	13.7	g	
industrial waste	205	g	
chemical waste	16	g	
final waste (inert)	1.8	g	

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
TDI APME	1	Mass	kg	100 Chemicals
not defined				

production.

Waterborne emissions	Amount	Un. Comment
dissolved substances	0.0008765	kg
suspended substances	0.000317965	kg
BOD	0.0000051648	kg
COD	0.000001194	kg
NH3	0.000006353	kg
Cyanide	0.0000001	kg
Fe	0.000099994	kg
fluorine	0.000033084	kg
sulphates	0.0000002	kg sulfide counted as SO4.
hydrochloric acid	0.002	kg
Na+	0.000001481	kg
nitrate	0.000002251	kg
crude oil	0.00051308	kg
phenol	0.0000003	kg
sulphates	0.000001331	kg

Solid emissions	Amount	Un. Comment
produc. waste (not inert)	0.3985	kg

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
steel 23% recycled B	1	Mass	kg 100	Ferro metals
Ferro metals				

End.

Project : Mattresses
Category: Material
Title : Spring steel
Author : Tauw/ejd
Source : dutch manufacturers of steel wire and mattresses
Date : 02/05/97
Comment : drawing of steel wire + bending wire to spring coil
Cluster : No

INPUT

Raw materials	Amount	Un. Comment
Others	Amount	Un. Comment
steel 23% recycled B	1	kg
Electricity	0.394	kWh 0.15 kWh drawing, 0.244 kWh coiling
furnace gas B	2	MJ drawing wire, 0.0533 m3 gas
truck Id B 75%	0.6	tkm transport wire to spring factory + spring transport to mattr. manuf.

OUTPUT

Airborne emissions	Amount	Un. Comment
Waterborne emissions	Amount	Un. Comment
Solid emissions	Amount	Un. Comment

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
steel spring	1	Mass	kg 100	Ferro metals
not defined				

End.

Category: Material
Title : PET I
Author : University of Technology Delft
Source : PWMI/APME, Ecoprofiles of the European plastics industry, report 8,
Polyethylene terephthalate, table 1, Brussels 1995
Date : 15/08/95
Comment : production of 1 kg PET granulate
Source:
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
crude coal	0.1428	kg	
crude oil	1.092	kg	
crude gas	0.5413	kg	
energy (undef.)	12.92	MJ	wasted energy HHV-LHV
iron ore	550	mg	
energy from hydro power	0.55	MJ	
uranium ore	0.7387	g	
NaCl	4900	mg	
limestone mineral	270	mg	
magnesium (ore)	50	mg	
water	17.5	kg	
bauxite ore	310	mg	
sand	20	mg	

Others Amount Un. Comment

OUTPUT

Airborne emissions	Amount	Un.	Comment
dust (SPM)	0.0038	kg	
CO	0.018	kg	
CO2	2.33	kg	
SOx	0.025	kg	
NOx	0.0202	kg	
HCl	0.0011	kg	
CxHy	0.04	kg	
metals	0.00001	kg	

Waterborne emissions	Amount	Un.	Comment
COD	0.0033	kg	
BOD	0.001	kg	
Na+	0.0015	kg	
Acid as H+	0.00018	kg	
metallic ions	0.00012	kg	
Cl-	0.00071	kg	
crude oil	0.00002	kg	
CxHy	0.0004	kg	
P2O5	0.00001	kg	
sulphates	0.00004	kg	

Solid emissions	Amount	Un.	Comment
mineral waste	0.03	kg	
slags	0.0096	kg	
industrial waste	0.0035	kg	
chemical waste	0.00203	kg	(1.9g inert)

Main products	Amount	Quantity	Un.	Pct.	Sub-category
Disposal fraction		Comment			
PET I	1	Mass	kg	100	Plastics
Plastics					

End.

Category: Material

Title : polyethylene production P

Author : Tauw milieu/dsn

Source : PWMI/APME, ecoprofiles of the European plastics industry, 1992-1994
report 3, table 13, page 9

Date : 11/05/95

Comment : production of 1 kg PE, both HDPE and LDPE; averaged over all
polymerisation plants for which data are available. Source; PWMI

Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
crude gas	0.7	kg	feedstock
crude oil	0.78	kg	feedstock
crude coal	0.095	kg	fuel
crude oil	0.07	kg	fuel
crude gas	0.251	kg	fuel
barrage water	50	kg	
limestone mineral	0.00015	kg	
iron ore	0.0002	kg	
water	18	kg	
bauxite ore	0.0003	kg	

rock salt	0.007	kg
clay	0.00002	kg
uranium ore	0.04167	kg

Others	Amount	Un. Comment
--------	--------	-------------

OUTPUT

Airborne emissions	Amount	Un. Comment
dust (SPM)	0.002	kg
CO	0.0008	kg
CO2	1.1	kg
SOx	0.007	kg
NOx	0.01	kg
HCl	0.00006	kg
HF	0.000001	kg
CxHy	0.021	kg
aldehydes	0.000005	kg
unspecified emission	0.000005	kg (other organics)
heavy metals	0.000001	kg (unknown)
H2	0.000001	kg

Waterborne emissions	Amount	Un. Comment
COD	0.001	kg
BOD	0.000015	kg
Acid as H+	0.00007	kg
nitrate	0.000005	kg
metallic ions	0.0003	kg
NH4+	0.000005	kg
Cl2	0.00012	kg
dissolved organics	0.00002	kg
suspended substances	0.0004	kg
crude oil	0.0004	kg
CxHy	0.0001	kg
phenol	0.000001	kg
dissolved substances	0.0004	kg
P	0.000005	kg
unspecified emission	0.00001	kg (nitrogen, other organics)
sulphates	0.00001	kg

Solid emissions	Amount	Un. Comment
produc. waste (not inert)	0.0341	kg
chemical waste	0.00007	kg

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
polyethylene P	1	Mass	kg 100	Plastics
others				

Category: Material
 Title : Polypropyleenproductie Tauw
 Author : RKR
 Source : PWMI
 Date : 30/05/03
 Comment : Aangemaakt voor bloempottenonderzoek
 Cluster : No

INPUT

Raw materials	Amount	Un. Comment
crude coal	0.01945	kg
crude oil	0.9133	kg
crude gas	0.6666	kg
barrage water	12	kg
uranium ore	0.000207	kg
wood	0.00102	kg
unspecified energy	0.01	MJ
iron ore	0.0002	kg
limestone mineral	0.0001	kg
water	1.6	kg
bauxite ore	0.0003	kg
rock salt	0.006	kg
clay	0.00002	kg
ferro-manganese	0.000001	kg

Others	Amount	Un. Comment
--------	--------	-------------

OUTPUT

Airborne emissions	Amount	Un. Comment
--------------------	--------	-------------

particulates 0.0008 kg
 CO 0.0004 kg
 CO2 0.528 kg
 SOx 0.004 kg
 HF 0.00001 kg
 NOx 0.006 kg
 HCl 0.00001 kg
 CxHy 0.008 kg
 unspecified organic subst 0.000001 kg
 unspecified metals 0.000001 kg

Waterborne emissions Amount Un. Comment
 COD 0.0002 kg
 BOD 0.00003 kg
 H+ 0.00004 kg
 N 0.000001 kg
 unspecified metals 0.0002 kg
 NH4+ 0.000005 kg
 Cl- 0.00005 kg
 S-compounds 0.000005 kg
 dissolved substances 0.00002 kg
 suspended substances 0.0002 kg
 oil 0.0002 kg
 CxHy 0.00007 kg
 phenol 0.000001 kg
 dissolved substances 0.0004 kg
 N 0.00001 kg

Solid emissions Amount Un. Comment
 prod. waste unspecified 31 g

Main products Amount Quantity Un. Pct. Sub-category
 Disposal fraction Comment
 T-polypropylene 1 Mass kg 100 Plastics
 others

End.

 Project : Mattresses
 Category: Material
 Title : Cotton
 Author : Tauw/ejd
 Source : dk-TEKNIK, Textile Products, Impact Assessment and Criteria
 for Eco-labelling, 1994 (draft)
 Date : 02/05/97
 Comment : Spinning, weaving and wet treatment not included!
 Cluster : No

INPUT

Raw materials Amount Un. Comment

Others Amount Un. Comment
 furnace oil B 44 MJ 48.6 MJ prim. energy per kg baled
 lint, incl. production of chemicals
 (fertilizers, etc.)
 truck Id B 75% 0.5 tkm
 deep-sea vessel B 15 tkm

OUTPUT

Airborne emissions Amount Un. Comment

Waterborne emissions Amount Un. Comment

Solid emissions Amount Un. Comment

Main products Amount Quantity Un. Pct. Sub-category
 Disposal fraction Comment
 cotton "raw" 1 Mass kg 100 textile
 not defined

End.

 Project : Mattresses
 Category: Material
 Title : Cotton
 Author : Tauw/ejd

cotton yarn	1	kg	
Electricity	4.7	MJe	weaving acc. to Belgian factory
furnace gas B	3.5	MJ	7 MJ/kg energ. for wet treatment. Assuming 50% oil, 50% gas
furnace oil B	3.5	MJ	7 MJ/kg energ. for wet treatment. Assuming 50% oil, 50% gas
truck ld B 75%	0.3	tkm	Assumption 300 km average distance

OUTPUT

Airborne emissions	Amount	Un.	Comment
--------------------	--------	-----	---------

Waterborne emissions	Amount	Un.	Comment
COD	50	g	waste water of wet treatment

Solid emissions	Amount	Un.	Comment
-----------------	--------	-----	---------

Main products	Amount	Quantity	Un.	Pct.	Sub-category
Disposal fraction		Comment			
cotton, woven, dyed	1	Mass	kg	100	textile
not defined					

End.

Project : Mattresses
Category: Material
Title : PET yarn
Author : Tauw/ejd
Source : dk-TEKNIK/DTI clothing and textile, Env. Assessment of textiles, 1997, ISBN 87-7810-838-1
Date : 28/07/97
Comment :
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
---------------	--------	-----	---------

Others	Amount	Un.	Comment
PET I	1	kg	
furnace oil B	13.6	MJ	polym. & spinning of fibres
Electricity	30	MJe	spinning of yarn

OUTPUT

Airborne emissions	Amount	Un.	Comment
--------------------	--------	-----	---------

Waterborne emissions	Amount	Un.	Comment
----------------------	--------	-----	---------

Solid emissions	Amount	Un.	Comment
-----------------	--------	-----	---------

Main products	Amount	Quantity	Un.	Pct.	Sub-category
Disposal fraction		Comment			
PET yarn	1	Mass	kg	100	textile
not defined					

End.

Project : Mattresses
Category: Material
Title : PET fabric
Author : Tauw/ejd
Source : dk-TEKNIK, Textile Products, Impact Assessment and Criteria for Eco-labelling, 1994 (draft) + PWMI
Date : 26/06/97
Comment :
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
---------------	--------	-----	---------

Others	Amount	Un.	Comment
PET yarn	1	kg	
Electricity	4.7	MJe	weaving acc. to Belgian factory
furnace gas B	3.5	MJ	7 MJ/kg energ. for wet treatment.

furnace oil B	3.5	ment. Assuming 50% oil, 50% gas MJ 7 MJ/kg energ. for wet treat- ment. Assuming 50% oil, 50% gas
truck ld B 75%	0.3	tkm Assumption 300 km average distance

OUTPUT

Airborne emissions	Amount	Un. Comment
--------------------	--------	-------------

Waterborne emissions	Amount	Un. Comment
COD	50	g waste water of wet treatment

Solid emissions	Amount	Un. Comment
-----------------	--------	-------------

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
PET, woven, dyed not defined	1	Mass	kg	100 textile

End.

Project : Mattresses
 Category: Material
 Title : wool
 Author : Tauw/ejd
 Source : J. Potting, K. Blok, De milieugerichte LCA van 4 typen
 vloerbedekking, Wetenschapswinkel Utrecht, 1993
 Date : 02/05/97
 Comment : including yarning
 Cluster : No

INPUT

Raw materials	Amount	Un. Comment
---------------	--------	-------------

Others	Amount	Un. Comment
truck ld B 75%	0.5	tkm sheep farm to wool washing + harbour to mattress factory
deep-sea vessel B	15	tkm transport to Europe
furnace oil B	6.1	MJ drying washed wool 3.6 - 8.5 MJ

OUTPUT

Airborne emissions	Amount	Un. Comment
--------------------	--------	-------------

Waterborne emissions	Amount	Un. Comment
----------------------	--------	-------------

Solid emissions	Amount	Un. Comment
organisch residu	113	g yarning

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
wool not defined	1	Mass	kg	100 textile

End.

Project : Mattresses
 Category: Material
 Title : Spruce (Vuren)
 Author : Delft University of Technology
 Source : Meer energiekentallen in relatie..., RIVM 1992. Importgegevens hard
 Date : 02/03/95
 Comment : Import distribution Sweden 33%, Finland 32%, Germany 8%, Russia 8
 Source: IDEMAT 95. Equal to Spruce I, only truck long dist. B
 instead of truck I.
 Cluster : No

INPUT

Raw materials	Amount	Un. Comment
wood	1.5	kg Dry matter
water	1.43	kg Water content 49%

Others	Amount	Un. Comment
crude oil Northsea I	0.006	kg Tree felling 259 MJ

Electricity Europe I	0.053	MJ	Debarking 9.8kWh/t DM
Electricity Europe I	0.0712	MJ	Sawing 147 kWh/t DM
crude oil Northsea I	0.0069	kg	330MJ/t DM
truck long-distance B	0.3	tkm	2(150*0.001)
Coastal-ship I	1.6	tkm	1600km*0.001

OUTPUT

Airborne emissions	Amount	Un.	Comment
water	1.33	kg	

Waterborne emissions	Amount	Un.	Comment
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Solid emissions	Amount	Un.	Comment
wood (sawdust)	0.1	kg	

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
Spruce (Vuren) T	1	Mass	kg 100	Wood
not defined		Wood with 10% watercontent		

End.

Project : Mattresses
Category: Material
Title : Latex foam
Author : Tauw/ejd
Source : See Nat.Rub.+SBR, assumption for ratio Nat.Rub./SBR
Date : 27/07/97
Comment : Provisional, energy for foaming estimated!!
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
---------------	--------	-----	---------

Others	Amount	Un.	Comment
Nat.Rubber, raw	0.5	kg	
SBR raw I	0.5	kg	
diesel engine truck B	2	MJ	Derived from transport data for mattresses
furnace gas B	4	MJ	Estimation by Tauw
Electricity	2	MJe	Estimation by Tauw

OUTPUT

Airborne emissions	Amount	Un.	Comment
--------------------	--------	-----	---------

Waterborne emissions	Amount	Un.	Comment
----------------------	--------	-----	---------

Solid emissions	Amount	Un.	Comment
-----------------	--------	-----	---------

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
Latex foam	1	Mass	kg 100	Rubber
not defined				

End.

Project : Mattresses
Category: Material
Title : Nat.Rubber raw
Author : Tauw/ejd
Source : PRe (Rubber foundation, Delft)
Date : 09/04/97
Comment : Natural rubber from latex tree, dried, pressed in bales, not vulcanized
Cluster : No

INPUT

Raw materials	Amount	Un.	Comment
---------------	--------	-----	---------

latex	1	kg	
crude coal	27.5	g	
energy from hydro power	157	kJ	
energy from uranium	997	kJ	

land use	80.7	cm2
crude lignite	36.2	g
crude gas	4.78	g
crude oil	79.1	g
unspecified energy	287	kJ
wood	93	g

Others	Amount	Un. Comment
--------	--------	-------------

OUTPUT

Airborne emissions	Amount	Un. Comment
aldehydes	2.9	mg
ammonia	1.45	mg
benzene	15	mg
benzo(a)pyrene	0.131	mg
Cd	0.701	mg
CO	1.44	g
CO2	465	g
Cu	9.5	mg
CxHy	731	mg
CxHy aromatic	1.24	mg
dust	266	mg
HCl	18.1	mg
Hg	2.99	mg
methane	285	mg
N2O	40.2	mg
non methane VOC	235	mg
NOx	2.76	g
Pb	3.5	mg
radioactive substances	214	kBq
SO2	3.49	g
V	457	mg
Zn	2.13	mg

Waterborne emissions	Amount	Un. Comment
BOD	435	mg
Cl-	469	mg
COD	10	g
crude oil	18.2	mg
CxHy aromatic	396	mg
dissolved substances	918	mg
NH3	599	mg
N	3	g
P	1	g
radioactive substances	1.96	kBq
sulphates	496	mg
suspended substances	435	mg
Zn	453	mg

Solid emissions	Amount	Un. Comment
final waste (inert)	10.5	g
high active nuclear waste	0.418	mm3
low,med. act. nucl. waste	25	mm3
produc. waste (not inert)	122	mg
wood (sawdust)	17.6	g

Main products	Amount	Quantity	Un. Pct. Sub-category
Disposal fraction		Comment	
Nat.Rubber, raw not defined	1	Mass	kg 100 Rubber

End.

Project : Mattresses
Category: Material
Title : NR foam
Author : Tauw/ejd
Source : See Nat.Rub.
Date : 27/07/97
Comment : Provisional, energy for foaming estimated!!
Cluster : No

INPUT

Raw materials	Amount	Un. Comment
---------------	--------	-------------

Others	Amount	Un. Comment
Nat.Rubber, raw	1	kg
diesel engine truck B	2	MJ Derived from transport

data for mattresses
 furnace gas B 4 MJ Estimation by Tauw
 Electricity 2 MJe Estimation by Tauw

OUTPUT

Airborne emissions Amount Un. Comment
 Waterborne emissions Amount Un. Comment
 Solid emissions Amount Un. Comment
Main products Amount Quantity Un. Pct. Sub-category
 Disposal fraction Comment
 NR foam 1 Mass kg 100 Rubber
 not defined

End.

Project : Mattresses
 Category: Material
 Title : SBR foam
 Author : Tauw/ejd
 Source : See SBR
 Date : 27/07/97
 Comment : Provisional, energy for foaming estimated!!
 Cluster : No

INPUT

Raw materials Amount Un. Comment
 Others Amount Un. Comment
 SBR raw I 1 kg
 diesel engine truck B 2 MJ Derived from transport
 data for mattresses
 furnace gas B 4 MJ Estimation by Tauw
 Electricity 2 MJe Estimation by Tauw

OUTPUT

Airborne emissions Amount Un. Comment
 Waterborne emissions Amount Un. Comment
 Solid emissions Amount Un. Comment
Main products Amount Quantity Un. Pct. Sub-category
 Disposal fraction Comment
 SBR foam 1 Mass kg 100 Rubber
 not defined

End.

Project : Mattresses
 Category: Material
 Title : Styrene Butadiene Rubber (SBR) raw I
 Author : Delft University of Technology
 Source : See Styrene and Polybutadiene
 Date : 16/08/95
 Comment : Copolymer of Butadiene and Styrene with ratio 77/23,
 without carbonblack
 Cluster : No

INPUT

Raw materials Amount Un. Comment
 Others Amount Un. Comment
 Polybutadiene I 0.77 kg
 Styrene I 0.23 kg

OUTPUT

Airborne emissions Amount Un. Comment

Waterborne emissions Amount Un. Comment

Solid emissions Amount Un. Comment

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
SBR raw I not defined	1	Mass	kg 100	Rubber

End.

Project : Mattresses
Category: Material
Title : Coconut fibre
Author : Tauw/ejd
Source : F. Hirsinger, LCI for oleochemical raw materials, Tenside Surf. Det.
32 (1995) 5
Date : 02/05/97
Comment :
Cluster : No

INPUT

Raw materials Amount Un. Comment

Others	Amount	Un. Comment
Nat.Rubber, raw	0.5	kg latex appr. 50 w% of rubberized fibre
deep-sea vessel B	5	tkm transport fibres 10.000 km

OUTPUT

Airborne emissions Amount Un. Comment

Waterborne emissions Amount Un. Comment

Solid emissions Amount Un. Comment

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
coconut fibre rubberiz not defined	1	Mass	kg 100	others

End.

Project : Mattresses
Category: Material
Title : jute
Author : Tauw/ejd
Source : J. Potting, K. Blok, De milieugerichte LCA van 4 typen
vloerbedekking, Wetenschapswinkel Utrecht, 1993
Date : 02/05/97
Comment :
Cluster : No

INPUT

Raw materials Amount Un. Comment

Others	Amount	Un. Comment
Electricity	3.1	MJ weaving
deep-sea vessel B	20	tkm India to Europe
inland vessel	0.08	tkm

OUTPUT

Airborne emissions Amount Un. Comment

Waterborne emissions Amount Un. Comment

Solid emissions Amount Un. Comment
prod. waste unspecified 60 g

Main products	Amount	Quantity	Un. Pct.	Sub-category
Disposal fraction		Comment		
jute	1	Mass	kg 100	others

Assembly: packaging PE foil

Comment:

Material: polyethylene P 0,23 kg
Processing: waste treatment PE 0,23 kg
Processing: Blow moulding T 0,23 kg

Assembly: scand spring matr 1m2

Comment:

Material: steel spring 2,5 kg wooden frame + springs
Material: cotton, woven, dyed 0,5 kg mattress pad
Material: Flex. PUR foam 1 kg mattress pad
Material: Latex foam 1,5 kg mattress pad
Material: Spruce (Vuren) T 10 kg wooden frame
Material: polyethylene P 0,4 kg packaging frame part + pad
Assembly: D-spring mattress 1m2 1 p
Processing: Blow moulding T 0,4 kg
Energy: diesel engine truck B 16,8 MJ
Energy: Electricity 6,3 MJe average of 2 big manufacturers
Processing: waste treatm mattress 15,5 kg
Processing: waste treatm. prod.w. 0,07 kg
Processing: waste treatment PE 0,4 kg

1. The following specific characteristics for latex foam are assumed:

- specific heat = $1.5 \text{ kJ kg}^{-1} \text{ K}^{-1}$
- density = 80 kg / m^3

2. Talalay process steps, energy per kg latex foam:

2.1 Cooling, + 20 °C to - 30 °C

$50 * 1.5 = 75 \text{ kJ}$, assumed efficiency = 25% :

300 kJ = 0.3 MJ

2.2 Vulcanising , - 30 °C to + 115 °C

$145 * 1.5 = 218 \text{ kJ}$, assumed efficiency = 50% :

440 kJ = 0.4 MJ

2.3 Drying, 80 °C

assumed water content = 1 kg water / kg foam = 8 vol.%

20 °C to 80 °C, foam: $60 * 1.5 = 180 \text{ kJ}$

20 °C to 80 °C, water: $60 * 4.2 = 250 \text{ kJ}$

evaporation 1 kg water: 2260 kJ

assumed efficiency 50%:

5400 kJ = 5.4 MJ

2.4 Compounding, vacuum, mechanical equipment:

1 MJ

Total energy use Talalay = $0.3 + 0.4 + 5.4 + 1 =$

7.1 MJ / kg foam

3. Dunlop (NSF) process:

No deep freezing;
Vulcanising: 100 °C;
Lower water content
(drying time shorter
as compared to Talalay)

Estimation Dunlop process: **5 MJ / kg foam**

4. Average energy consumption (Talalay + Dunlop): 6 MJ / kg foam

Used energy is probably primarily gas (heating) and electricity (cooling, mechanical equipment, heating):

Assumption: **2 MJ electricity / kg latex foam**

4 MJ gas / kg latex foam

ANNEXE 5: LCA RESULTS SCANDINAVIAN BED/MATTRESS

ANNEXE 5: LCA RESULTS SCANDINAVIAN BED/MATTRESS ANNEXE 5: LCA RESULTS SCANDINAVIAN BED/MATTRESS ANNEXE 5: LCA RESULTS SCANDINAVIAN BED/MATTRESS

In this annexe the LCA results for the Scandinavian example product are presented. A description of the environmental effects can be found in section 8.2. The causes for environmental effects of the Scandinavian example product are comparable with those of the spring interior mattress.

Scores of characterisation for Scandinavian example product

Normalised scores for Scandinavian example product

ANNEXE 6: CHANGES IN THE REPORT ANNEXE 6: CHANGES IN THE REPORT ANNEXE 6: CHANGES IN THE REPORT ANNEXE 6: CHANGES IN THE REPORT

Changes as compared to the previous report (R3535924.C04/EJD):

Page	Change
5,6	present status of project explained
15	density PUR foam 25 - 35 kg/m ³ instead 40 - 60 kg/m ³
15	MDI also used for PE mattresses
17	additional info on coir fibre and black/white cotton
46	remark about aim and scope of LCA (printed bold)
59	several chemicals deleted, not used for flex. PUR foam
59	half-life time TDI in air 0.5 to 3 hours instead of 2 days.
60	environmental aspects of coconut fibres
64	degradation of foam material to CO ₂ and methane deleted
67	'solid waste' instead of 'household waste'
71	explanation on energy use and energy content of latex foams
72	criterion (2) about ratio NR/SBR deleted
72	criterion 2: certain dyes allowed
73	criterion 4: use of carbon filter added
73	criterion (6) about prevention of TDI emission deleted
73	>>> certain dyes/pigments allowed <<<
74	criterion 5: allowed concentration of tin changed
74	criterion (9) about pesticides in textile deleted
75	criterion 8 (12): changed, (halogenated) organic solvent allowed if used in a closed system

75 criterion 10 for rubberized coconut fibres added
75 black and white cotton added (allowed)
76 criterion 14 added for maximum height of mattress
77 section 11.4: limits above which ecological criteria apply changed
77 section 11.5 added: market feasibility of proposed criteria