Life Cycle Assessment on SKF's Spherical Roller Bearing

ÅSA EKDAHL

Department of Environmental Systems Analysis
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Abstract

The objective of this report is to investigate the environmental properties of SKF's spherical roller bearing (SRB) 24024 and to identify parameters and processes that cause major environmental impact. The increasing environmental concern in today's society puts pressure on the manufacturing companies to have the knowledge of the environmental impacts caused by their products and LCA is a tool for this.

The SRB 24024 is a spherical roller bearing within the medium size range and is produced in large scale. SKF's spherical roller bearings are heavy-duty bearings that are self-aligning and have a high load carrying capacity, which makes them suitable in many applications. The SRB 24024 is a good representative for SKF's SRBs.

The method used in this project is LCA and the study is performed from cradle to gate including a case study to exemplify the use of the bearing. LCA is a method to assess the potential environmental impacts associated with a specific product or service. All stages in the life cycle are taken into account and use of natural resources, transportation, energy consumption, waste and emissions are considered. LCA can be used for identification of improvement possibilities, decision-making etc. but has also an important application in learning about environmental impacts caused by substances and processes used in the life cycle. This is mainly what is done in this study.

One of the difficulties while performing an LCA is allocating emissions, energy consumption etc. to the product being studied. To investigate the difference the choice of allocation method may have on the study an investigation of three different allocation methods within the D-factory at SKF in Göteborg is performed.

The results of the inventory analysis are presented for each bearing component. Differences and similarities are discussed. It can be seen that the rings are the components consuming the most of the energy supply as well as having the largest air emissions. This is mainly due to the fact that they constitute the largest part of the bearing but also that they are heat treated and machined in several steps.

The total inventory results are also characterised and the inventory results are in this way connected to the environmental impact categories they contribute to. The results are discussed.

Sammanfattning

Syftet med rapporten är att undersöka de miljömässiga egenskaperna hos SKFs sfäriska rullager (SRB) 24024 samt att identifiera de parametrar och processer som orsakar betydande miljöpåverkan. Den ökande miljömedvetenheten i dagens samhälle utövar press på tillverkningsindustrin och kräver av företagen att de har kunskap om den miljöpåverkan deras produkter ger upphov till. Livscykelanalys (LCA) är ett verktyg för detta.

SRB 24024 är ett sfäriskt rullager i det dimensionsintervall som hos SKF kallas medium och det produceras i stor skala. SKFs sfäriska rullager är självinställande och klarar höga belastningar vilket gör att de är lämpliga för många applikationer. SRB 24024 är en bra representant för SKFs SRB.

Metoden som använts i den här studien är LCA och studien är utförd från vagga till grind men inkluderar en fallstudie för att exemplifiera användningen av SRB 24024. LCA är en metod för att uppskatta den potentiella miljöpåverkan associerad med en speciell produkt eller tjänst. Alla steg i livscykeln inkluderas och användning av naturresurser, transporter, energi, avfall och emissioner beaktas. LCA kan användas för att identifiera förbättringsmöjligheter och ligga till grund för beslutsfattande etc. men har även en betydande funktion vad det gäller att öka kunskapen om och förståelsen för den miljöpåverkan som orsakas av ämnen och processer vilka används i livscykeln, vilket framförallt är syftet med den här studien.

En av svårigheterna vid utförandet av en LCA är allokering av emissioner, energikonsumtion etc. till den studerade produkten. För att belysa den effekt valet av allokeringsmetod kan ha på studiens resultat utförs en särskild studie i D-fabriken hos SKF i Göteborg där resultaten från tre olika allokeringsmetoder jämförs.

Inventeringsresultatet presenteras för varje komponent i rullagret och därefter diskuteras skillnader och likheter mellan dem. Jämförelsen visar att ringarna står för både den största konsumtionen av energi och de största emissionerna till luft. Detta beror främst på att ringarna utgör den största och tyngsta delen av rullagret men också på att de värmebehandlas bearbetas i flera steg.

Resultaten från inventeringen klassificeras i miljöpåverkanskategorier vilka sedan karakteriseras. På detta sätt knyts inventeringsresultaten till de miljöeffekter de bidrar till. Resultaten från karakteriseringen diskuteras.

Acknowledgements

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Åsa Ekdahl
Göteborg May 2000

Contents

1 Introduction

In this section an introduction to the study is given including background, purpose and directives and delimitation.

1.1 Background

The increasing environmental concern in today's society puts pressure on the industry to produce less environmental damaging products. At this point, this is principally experienced by industries producing consumer goods but these industries are in their turn increasing the pressure on their suppliers. So far it is in most cases questions about environmental management systems but the nature of the questions are slowly changing and becoming more product-related. Questions about LCA work and performed LCAs are becoming more frequent. With this as a background SKF decided that it was time to perform an LCA on one of their key products.

In resent years Life Cycle Assessment (LCA) has become one of many useful tools in assessing the environmental aspects and potential impacts associated with a product. In LCA the product is followed from the cradle to the grave, i.e. from raw material acquisition, through production, use and waste disposal. LCA is multidisciplinary and deals with the social system, the technical system, the natural system and their relationships.

LCA may be used for identification of improvement possibilities, decision-making, choice of environmental performance indicators and market claims but LCA has also an important application in learning. This is what has been done in this project. The study has been performed on behalf of the division for Spherical Roller Bearings, medium size (SRB Medium) which is a division within SKF Sverige AB.

1.2 Purpose

The purpose of the thesis is to investigate the environmental properties of SKF's spherical roller bearing (SRB) 24024. This is to be done from the cradle to the factory gate and include a case study of a typical application for SRB 24024. The purpose is further to identify parameters and processes that causes major environmental impact.

1.3 Directives and delimitation

The methodology used for fulfilling the purpose of this study is an LCA based on quantitative data. This study deals with the life cycle, from cradle to gate, of the bearing. Use of natural resources, transportation, energy consumption, waste and emissions to air and water are considered. In the study the production and the use of the bearing takes place in Sweden. The main production plant for SRB is located in Sweden but the bearings are sold worldwide. Alternative processes will not be studied.

2 Spherical Roller Bearings

In this chapter SKF and Spherical Roller Bearings are described.

2.1 SKF

In 1907 the Swedish engineer Sven Wingquist invented the Self-Aligning Ball Bearing (SABB). A basic form of ball bearing existed even in early Roman times but the breakthrough did not arrive until the 19th century. In the same year that the self-aligning ball bearing became a commercial reality, SKF was founded.

At the close of its first trading year SKF had 15 employees, today the company is the world's leading manufacturer of roller bearings and has over 40 000 employees worldwide. Bearings, seals and special steel are some of SKF's products. The production takes place in over 80 sites around the world and SKF is represented in 130 countries. The head office is located in Göteborg, Sweden [www.skf.com, 2000].

2.2 The spherical roller bearing

In 1919 SKF invented the spherical roller bearing (SRB), see Figure 1. The spherical roller bearing is a heavy-duty bearing with very high load carrying capacity. The bearing is self-aligning and is therefor insensitive to errors of alignment of the shaft relative to the housing as well as shaft deflection and bending. It is primarily designed for radial loads, axial loads in any direction or a combination of radial and axial loads. In applications the bearing is fit into a bearing housing.

The spherical roller bearing has five different types of components.

- *Outer ring* - which has a spherical raceway and fits into the housing
- *Inner ring* - which has two separate raceways, that are inclined at an angle to the bearing axis, and which fits into the shaft
- *Rollers* - that are barrel-shaped and incorporated in two rows between the inner and outer rings
- *Cages* - that keep the rollers separated from each other
- *Guide ring* - which is centred on the inner ring to guide the rollers and separates the two rows.

The SRB has a large number of long, large diameter symmetrical rollers, which gives the bearing a very high load carrying capacity.

The spherical raceway of the SRB outer ring, which is shared by the two rows of rollers, is what makes the bearing able to accommodate shaft-to-housing misalignment. The inner ring assembly, which is composed of the rollers, cages and the guide ring, is because of the spherical outer profile allowed to move out of alignment with the outer ring. [SKF, 1996]

Figure 1: The Spherical Roller Bearing (SRB) is a heavy-duty bearing with very high load carrying capacity due to the two rows of rollers. The bearing is self-aligning and therefor insensitive to errors of alignment. The bearing in the figure is not a SRB 24024 but a spherical roller bearing with fewer rollers. The appearance is however very similar. [SKF Sverige AB]

2.2.1 SRB 24024

The bearing considered in this study is a spherical roller bearing within the medium size range. The SRB 24024 is produced by SRB Medium and has the following properties:

Components: outer ring, inner ring, guide ring, 2 cages and 52 rollers
Outer diameter: 180 mm
Inner diameter: 120 mm
Width: 60 mm
Weight: 5.40 kg

3 Theoretical Framework

In this chapter theory concerning LCA is introduced. The three phases of an LCA: Goal and Scope Definition, Inventory Analysis and Impact Assessment are described in general and guidelines are discussed.

3.1 LCA in general

3.1.1 Life cycle assessment

An LCA is a mapping and/or a comparison between different alternative life cycles or between different parts of the life cycle. LCA has a major advantage as a sorting tool to separate major and minor environmental impacts from each other. Thus defining the “hot spots”.

With the use of LCA it is possible to identify which kind of environmental impact will be effected by different choice of alternatives and thereby also make clear what is not changed. This can be applied to present situations as well as changes that are to be made in the future. LCA is intended to provide information that may be used for environmental improvements but can also be used to identify processes, substances and systems in a life cycle that are major contributors to environmental impacts. These stages can later be studied in detail with the help of other tools such as economical or technical tools.

The three main stages in an LCA study are shown in Figure 2 below and are also described in the following sections.

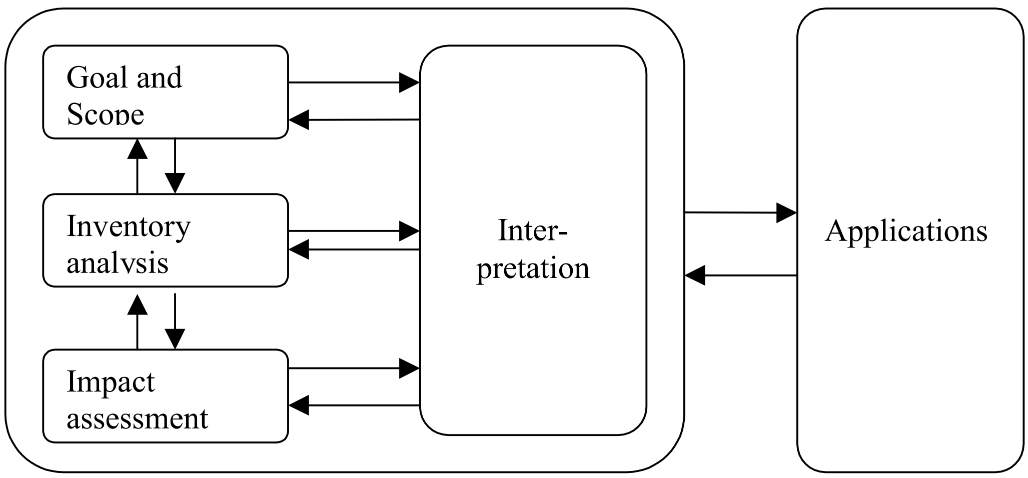

Figure 2: The three main stages in an LCA study according to ISO 14040. [ISO 14040, 1997]

3.1.2 Standardisation

"Standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose." [ISO, http://www.iso.ch/infoe/intro.htm, May 2000]

The International Organisation for Standardisation (ISO) has conducted a standardisation of the LCA methods. ISO is a non-governmental, worldwide federation of national standards bodies from some 130 countries, one from each country, which was established in 1947. The standards on LCA are a part of the ISO 14000 series, which is a series of international, voluntary environmental standards developed under ISO Technical Committee 207. Published documents and ongoing work address the following areas [ISO, 1998]:

- Environmental management systems
- Environmental auditing and other related environmental investigations
- Environmental performance evaluation
- Environmental labelling
- Life cycle assessment
- Environmental aspects in product standards
- Terms and definitions

The ISO standards concerning LCA developed so far are [ISO, 1998]:

- **ISO 14040:1997** Environmental management – Life cycle assessment – Principles and framework
- **ISO 14041:1998** Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis
- **ISO/CD 14042** Environmental management – Life cycle assessment – Life cycle Impact assessment
- **ISO/DIS 14043** Environmental management – Life cycle assessment – Life cycle Interpretation
- **ISO/TR 14048** Environmental management – Life cycle assessment – Life cycle assessment data documentation format
- **ISO/TR 14049** Environmental management – Life cycle assessment – Examples for the application of ISO 14041

3.2 Goal and scope definition

Defining the goal of the study includes stating the intended application of the study, the reasons for carrying it out and to whom the results are intended to be communicated. LCA is an iterative process and some choices may have to be made at a later stage in the study, they are however still seen as part of the goal and scope definition.

The goal and scope definition shall include [Bauman H and Tillman A-M, 1999]:

- Functional unit, which will be used as a reference unit for all data
- System boundaries, e.g. which processes to include in the analysed system
- Types of impacts being considered and thus choice of for which parameters data will be collected in the inventory analysis.
- Level of detail in the study and thus the data requirements
- Whether or not to perform a critical review and if so of what type.

3.2.1 Functional unit

Since the method is quantitative the function needs to be expressed in quantitative terms. This is done through a functional unit. Definition and choice of functional unit is one of the most crucial activities in this stage. The functional unit describes the function, benefit and performance of the product. It also forms a basis in the evaluation and comparison of different alternatives. The functional unit must be clearly defined, measurable and relevant to input and output data. [Bauman H and Tillman A-M, 1999]

Example: If the purpose of the study is to compare different types of flooring material the function is to protect the floor. One obvious difference between different flooring materials is the durability of the material i.e. the time it will last. In this example the functional unit could be: *One square meter of protected floor area for ten years*.

3.2.2 System boundaries

To be able to assess the environmental loads from a certain process there are a few things that need to be specified. The environmental loads can vary depending on a lot of parameters. Therefore system boundaries need to be specified.

3.2.2.1 Boundaries in relation to natural systems

The starting point of the life cycle is the extraction of raw materials from the nature. Sometimes it is very hard to draw the line between the natural and the technical systems, and thus to decide what to include in the inventory analysis and what to include in the impact assessment. This is one of the reasons why it is difficult to describe the impacts of land use in LCA terms.

3.2.2.2 Geographical boundaries

Different parts of a products life cycle may occur in different geographical areas and this needs to be specified since the sensitivity to pollutants etc. may vary a lot between these areas. The infrastructure such as electricity production, waste management and transport systems often vary from region to region and if the region which contains the activity is not specified it may have consequences for the result of the study.

Are site specific or generic data to be used? If generic data are to be used, which geographic area should they cover? Due to what has been mentioned above the answers to these questions can have an impact on the results.

Depending on weather the LCA is done to investigate the environmental load from the production of a product or to investigate the difference between processes average or marginal data can be used. A change in the production is most likely to effect the margin and is therefor probably best estimated by marginal data. If the average data are to be used there are other things to consider like what the data should be the average of.

Example: If the electricity needed for a process is to be estimated with average data the geographic region covered by the data can influence the results considerably. In Sweden electricity mainly originates from water- and nuclear power. The average data for electricity production in Sweden will clearly differ from average data for electricity production in Europe where electricity produced with nuclear power and combustion of fossil fuel is most common.

When using weighting methods the indices may be specific for the geographical area. Some methods used today are based on political goals for example reduction targets in the public environmental policy, and are therefore specific for each country.

3.2.2.3 Time boundaries

The time boundaries are depending on the goal of the LCA study. If the goal is to investigate what environmental impacts the product can be held responsible for, it can be answered by an LCA with bookkeeping perspective, i.e. retrospective. If the goal instead is to investigate the impacts of changes in material or processes etc. it is probably better achieved by a change-oriented LCA that looks forward in time and tries to find alternative ways of action.

The applicability of the results from the LCA may depend on the time period represented by the gathered data. If, for example, the production has been changed it is very important to know whether the data are based on production before or after the change was completed. The result can also have a "best before date" if process changes are being planned for the future.

Some impact categories or rather methods to calculate potential impacts are time dependent, for example Global Warming Potentials (GWP) and Ozone Depletion Potentials (ODP).

3.2.2.4 Boundaries within the technical system

Cut-off criteria

While performing an LCA a decision to cut off the life cycle, and not follow a flow further upstream or downstream, may be based on the assumption that the contribution to environmental loads from the excluded processes is negligible in relation to the rest of the life cycle. The decision to cut off the life cycle while performing a change LCA may be based on what is relevant, i.e. what processes will be affected of the changes. Processes that will not be affected need not be included in the LCA.

Sometimes the LCA is not done from the cradle to the grave but the system is only studied from cradle-to-gate, gate-to-gate or gate-to-grave. This also means cutting off processes within the life cycle.

Allocation

There are situations when several products share the same process or process chain. If the environmental load is to be expressed in relation to only one of the products an allocation problem arises. There are three basic cases when allocation problems are encountered [Bauman H and Tillman A-M, 1999]:

- Processes which have outputs of many products
- Waste treatment processes that have inputs of many different products
- Open loop recycling, i.e. when a product is recycled into a different product.

Allocations can sometimes be avoided through increasing the level of detail of the model or through system expansion. Where allocation cannot be avoided the environmental loads are to be partitioned between the different functions of the system. A good base for this is physical relationships. If the physical relationships cannot be used, relationships, such as economic value between products can be used. One should always be careful when using allocation models because of the differences in result one might get from using different basis for the allocation. [Bauman H and Tillman A-M, 1999]

3.3 Inventory analysis (LCI)

Inventory analysis is the second stage of the LCA and here a system is built according to the requirements specified in the goal and scope definition. The model may be described as an incomplete mass and energy balance over the system, taking only environmental relevant flows into account.

The inventory analysis should include [Bauman H and Tillman A-M, 1999]:

- Construction of a flow model according to the system boundaries - The flow model is usually documented as a flow chart showing the activities included in the analysed system and the product flows between these activities.
- Data collection for all activities in the product system - These data should include inputs and outputs of all activities, i.e.:
  - raw materials, including energy carriers
  - products
  - solid waste and emissions to air, ground and water
- Calculation of environmental loads of the system in relation to the functional unit.

Technical systems and processes often fulfil more then one function, which can make the inventory modelling complicated. In these cases the environmental loads of such a process have to be partitioned i.e. allocated between its different products or functions.

3.4 Impact assessment (LCIA)

The impact assessment aims at describing the impacts of the environmental loads quantified in the inventory analysis. Another purpose is to aggregate the information from the LCI into fewer parameters. This is done through:

3.4.1 Classification

Classification means sorting the inventory parameters according to the type of environmental impact they contribute to. The emissions are grouped into a number of impact categories. One substance can occur in several different impact categories. For example, NO_x will contribute both to acidification and eutrophication.

Substances acting in parallel categories should in principle be allocated between them in proportion to their contribution. In practice this is not possible and therefore the whole emission is noted under all relevant impact categories even if this may introduce some double counting [Nordic Guidelines on Life Cycle Assessment, 1995].

3.4.2 Characterisation

Characterisation is mainly a quantitative process in which the relative contributions to each impact category are assessed. The contributions are then aggregated within the impact categories. The characterisation should be based on a scientific analysis of the cause-effect chain in the natural systems and are thereby objective. The choice of impact categories and characterisation methods is however subjective.

3.4.3 Weighting

Weighting is considered to be the most controversial step in life cycle assessment. Weighting means aggregation of characterisation results across impact categories, which can be done by making use of one or several of the weighting methods available today. These methods try to express how the society is thought to value the results from the inventory or characterisation. The weighting is in this sense objective but the choice of weighting method may be subjective [Bauman H and Tillman A-M, 1999].

The base of the weighting factors can be:

- *Monetarisation* - Our values are described as cost of various environmental damages or as prices on various environmental goods. The price can be derived from individuals "willingness-to pay" or be revealed by their behaviour.
- *Authorised targets* - The difference between current levels of pollution and targeted levels can be used to derive weighting factors.
- *Authoritative panels* - Panels can be made up of scientists, decision-makers in a company or the government etc.

Since the base for the factors differ between the methods they may present very different results even though applied on the same study. This is one of the reasons why more then one weighting method should be used. Classification and characterisation are mandatory according to ISO, whereas weighting is optional [ISO/CD 14042, 1999].

4 Methods

In this chapter the methods used to perform the LCA are presented.

4.1 Methods during data collection

4.1.1 Interviews

Interviews with key persons have been performed through discussions on site, if possible. This has proved to be the most efficient method for receiving data immediately. A discussion also tends to reveal things not yet considered as well as different views. This method creates a personal connection between the interviewer and the interviewed that has shown to be very useful later on in the study. The established contact makes it easier to follow up the results by phone.

The method is very time consuming, especially when the distance between the parties is great. Therefore the interviews sometimes have been performed over the telephone, fax, mail, e-mail or a combination of those listed above. This has also given good results, if not immediate.

4.1.2 Literature studies

The environmental reports written each year by the companies have shown to be a useful tool in gathering life cycle inventory data. Sometimes the level of aggregation has been too high and the literature studies then have had to be accompanied by interviews with the person responsible for the report.

4.1.3 Tests

Simple tests have been performed in order to avoid allocations. This includes weighting of the corrugated board box.

5 Goal and Scope Definition

In this section the goal and the scope of the study are defined. The investigated product, the system boundaries and the functional unit are all defined and explained.

5.1 Goal of the study

The purpose of the study is to investigate the environmental properties of SKF's spherical roller bearing (SRB) 24024. The study is to be done from the cradle to the gate and includes a case study of a typical application for the bearing type.

The purpose is further to identify parameters and processes that cause major environmental impact. The environmental impacts caused by the production of each component will be compared.

A comparison between different allocation methods within the D-factory at SKF in Göteborg will also be performed.

The intended application of the study is to increase the knowledge of the potential environmental impacts that can be associated with the life cycle of SKF's spherical roller bearing. The intended audience is mainly employees at SKF.

The LCA is critically reviewed by the supervisors at Chalmers and SKF as well as by the examiner at Environmental System Analysis at Chalmers University of Technology.

5.2 Scope of the study

5.2.1 Product definition

The criteria for choosing this particular bearing type has been that the bearing is:

- produced in large scale
- representative for SRB medium
- sold to more than one customer
- sold to a customer in Sweden

Further the raw material should be delivered from Ovako Steel in Hofors and the rings should be turned at the plant in Göteborg. During the work it has been discovered that the inner ring is not, after all, manufactured at Ovako Steel in Hofors but at Ovako Steel La Foulerie in France.

From these criteria the type SRB 24024 was chosen. It is a spherical roller bearing within the smaller dimension range of SRB medium. The outer diameter of the bearing is 180 mm, the inner diameter is 120 mm and the width is 60 mm. The bearing is entirely made of steel and weights 5,40 kg.

5.2.2 Functional unit

The functional unit of this study is *one spherical roller bearing of type 24024 ready for sale*. This signifies one complete bearing, rust treated and packed in a corrugated board box.

5.2.3 System boundaries

5.2.3.1 Boundaries in relation to natural systems

The raw material for the bearing steel is scrap, which is regarded, as a resource not traced back to the cradle. Otherwise raw material acquisition is included whenever possible.

The study considers emissions to air and water. Waste treatment is included wherever possible. When not possible the waste has been treated as an outflow not followed to the grave.

5.2.3.2 Time boundaries

Almost all of the site-specific data are based on the production in the year 1998. A small amount of data is based on the production in 1996 while some is estimated from the production in 1999 (from January till October).

No dramatic changes are planned within the processes at the production sites and therefore there is no definite time limit to when the site-specific data will be out of data.

5.2.3.3 Geographical boundaries

The manufacturing of the bearing takes place at the plant in Göteborg, Sweden, which locates the main production for SRB. The bearings are sold worldwide but the plant in the case study presented here is located in Sweden.

All included activities are located in Sweden except for the production of the inner bearing ring, which takes place in France and the SKF distribution central, which is located in Belgium. The data representing the production of the corrugated board box used as package is average data for the production in Europe.

All of the data representing production of the bearing components used in the study is site specific except for the data concerning the production of the corrugated board box. The data for the iron powder production is site-specific but aggregated with the data for the activities up-stream the actual powder production. Even the transports needed up-streams are included in the data set.

The data for energy production and transports are taken from the CIT Ekologik database on "Energy and transports".

5.2.3.4 Boundaries within the technical system

Real capital like tools, buildings, machinery and infrastructure is not included in this study.

The allocation methods used in the study vary between the activities but the method most widely used is allocation based on weight. Allocations according to internal distribution keys and production time are other methods that also have been used.

The bearing is packed in flow film and a corrugated board box. The corrugated board box is included in this study while the flow film is not.

In many of the activities included in the life cycle steel scrap is produced. In this study hundred percent of the steel scrap is recycled. This assumption is based on statements made by the companies participating in the life cycle. The steel scrap produced at SKF and Ovako Steel in Sweden is transported to Ovako Steel in Hofors for recycling.

5.2.4 Choice of environmental parameters

Parameters that describe the use of resources, waste, emissions to air and water and energy consumption are included.

5.2.5 Choice of methods for aggregation and evaluation

In the LCIA the characterisation methods used are:
- Acidification (max)
- Ecotoxicity, aquatic
- Eutrophication (max)
- Global warming (100 years)
- Human toxicity, air
- Human toxicity, water
- Photochemical oxidant creation (0-4 days high NO_x)
- Resource depletion (reserve based)

The characterisation methods and indices are taken from the CIT Ekologik index list (May 2000).

5.2.6 Strategy for gathering data

Data from all stages in the life cycle of the spherical roller bearing have been gathered. The data have then been documented according to the SPINE data documentation criteria in the software SPINEDataTool supplied by CPM at Chalmers University of Technology.

There are no defined classes of quality demands for the data. Most of the data used in this study is first hand numeric data supplied by people within the production. Companies' environmental reports have been used, sometimes accompanied by explanations by the people responsible for the publications. When data have not been available persons familiar with the processes studied have made qualified estimations.

6 Inventory Analysis

This section includes the data collection and the defining of the flowchart for the production. The processes constituting the life cycle are described as well as the means of transportation.

6.1 Flowchart

To be able to describe the system for producing a product it is useful to construct a flowchart of the subsystems. In Figure 3 below the flowchart for the spherical roller bearing is shown. The bearing contains of an inner and an outer ring, rollers, a guide ring and two cages. It is packed in a corrugated board box.

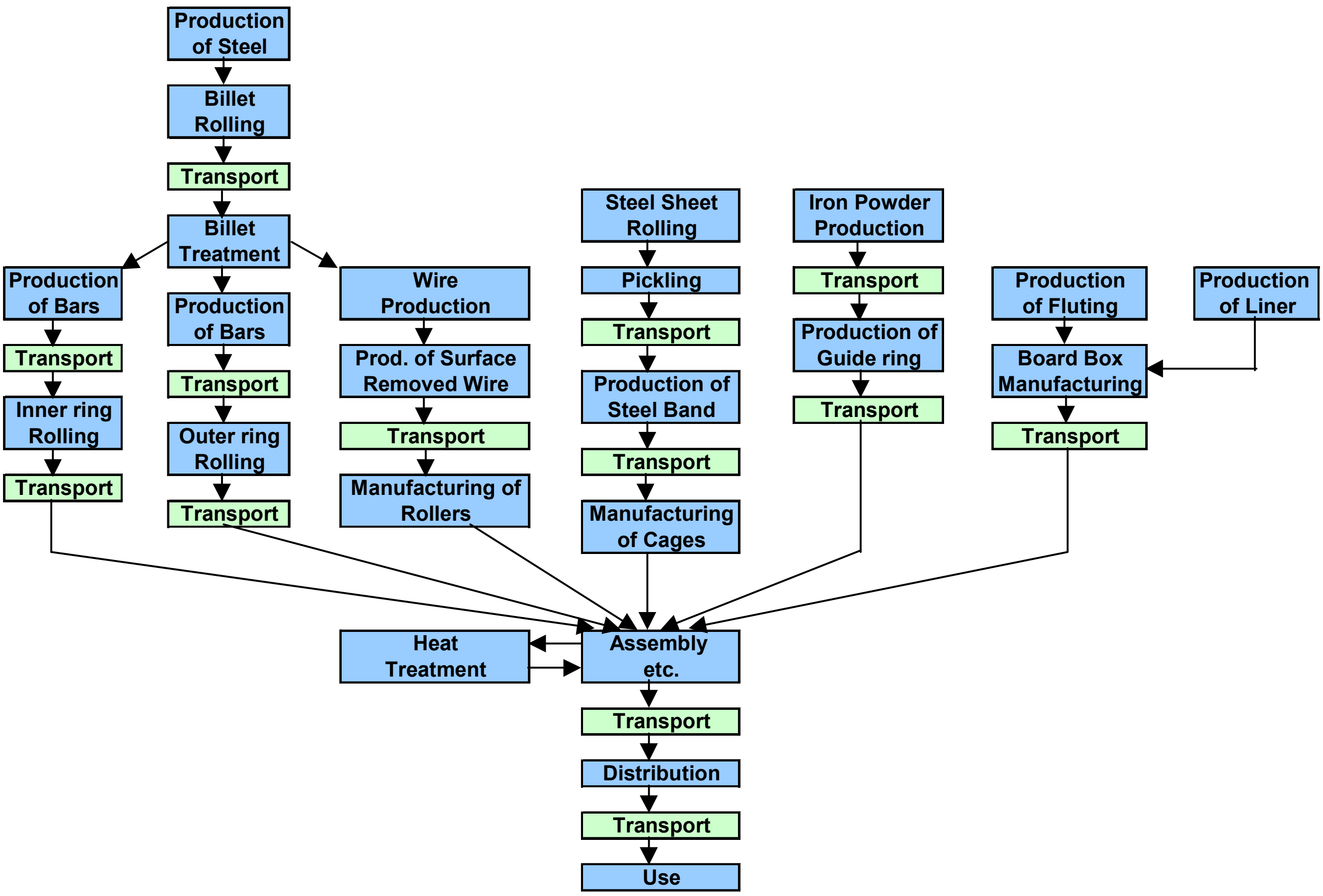

Figure 3: Flowchart for the life cycle of the SKF Spherical Roller Bearing 24024.

6.2 Production of steel and billets

The steel produced at Ovako Steel in Hofors, Sweden, the raw material for the outer and inner rings as well as the rollers, is completely produced from scrap. When the scrap arrives at Ovako Steel it is sorted according to quality and alloying elements. The scrap is melted in an electric arc furnace where oxygen and carbon is added. The addition of oxygen and carbon makes the slag porous and in turn makes the process more effective. When the scrap is completely melted and the material analysis is satisfactory the melted steel is deslagged and pored in to a ladle furnace where the steel is degassed and final adjustments of the alloys are made.

When ingots have been teemed and then stripped they are placed in a pit furnace. The ingots soak in the pit furnace for several hours to get the right temperature for hot rolling. When the ingot has been rolled in the first pair of rolls it is transported to the oxygen scarfing where surface defects are removed. The ingot is then rolled to its final dimensions. Depending on what will become of the ingot it is rolled to round or square billets. Both the rollers and the rings are made from square billets, i.e. the final product from the rolling mill in Hofors is, in this study, square billets of dimension 150 mm.

The complete data set for the production of steel and billets can be found in Appendix, sections **1.1.1** and **1.1.2**.
The flowchart for the production of steel and billets can be seen in Appendix, sections **2.1** and **2.2**.

6.3 Production of rings

The inner ring is produced at Ovako La Foulerie in Carignan, France and the outer ring is produced at Ovako Steel in Hofors, Sweden. The process steps at the SKF plant in Göteborg, Sweden are almost the same for the outer- as well as for the inner ring. Because of the similarity in process steps the processes will only be described once. There is one difference though; the outer ring is not honed, as is the case with the inner ring.

6.3.1 Production of the inner ring

The production of the inner ring takes place at the ring mill at Ovako La Foulerie in Carignan, France. The raw material is 60-mm bars that are hot rolled in the rolling mill at Ovako Steel in Hällefors.

6.3.1.1 Billet treatment

When the square billets arrive at Ovako Steel in Hällefors they are first processed in the "billet treatment". Here the billets are checked for defects. First the oxide scale on the surface of the billets is blasted off in a centrifugal blast then the billets are checked for cracks etc. To be able to locate cracks and other defects a current is run through the billet and a coloured magnetic powder is used to mark cracks. The billets are then ground only where they have been marked.

The end parts of the billets are also tested with ultra sound. Sometimes the billets have internal defects caused by the rolling or the cutting of the billets in the rolling mill may have caused damages to the billets. This can be revealed with ultra sound methods. If some defects are detected, the affected part is sawn off.

The complete data set for the billet treatment can be found in Appendix, section **1.1.3**.
The flowchart for the billet treatment can be seen in Appendix, section **1.1**.

6.3.1.2 Production of hot rolled bars

When the billets have been checked for defects they are transported to the rolling mill, at the same plant, for rolling to smaller dimensions. The billets are heated in a walking beam furnace and when they have reached the right rolling temperature they are taken to the first pair of rollers. The rolling mill has 16 pairs of rollers and depending of the desired dimension the billets go through as many pairs of rollers as needed. The final dimension on the bars used for the production of the inner ring to this specific bearing is 60 mm and the billet is rolled in 6 pairs of rollers.

After the rolling the bars are air-cooled and then cut according to customer orders. They are packed and transported to the customer.

The complete data set for the production of hot rolled bars, 60 mm, can be found in Appendix, section **1.1.4**.
The flowchart for the production of hot rolled bars can be seen in Appendix, section **2.4**.

6.3.1.3 Production of the inner ring

The bars are transported to Ovako La Foulerie by train. At the ring mill the bars are heated in an induction furnace and then hot sheared. After forging and rolling the rings have their final dimensions. The rings are calibrated to make sure the dimensions are right. Before the rings are packed in flow film and transported to SKF in Göteborg they are heat-treated. The transport to Göteborg is carried out by train.

The complete data set for the production of the inner ring can be found in Appendix, section **0**.
The flowchart for the production of the inner ring can be seen in Appendix, section **2.5**.

6.3.2 Production of the outer ring

The outer ring is produced at the ring mill at Ovako Steel in Hofors. The raw material is bars with the dimension 70-mm. The bars are rolled in the rolling mill at Ovako Steel in Hällefors.

The complete data set for the hot rolling of bars, 70 mm, can be found in Appendix, section **1.1.5**.
The flowchart for the production of hot rolled bars can be seen in Appendix, section **2.4**.

6.3.2.1 Billet treatment

See billet treatment section **6.3.1.1**.

6.3.2.2 Production of hot rolled bars

See production of hot rolled bars, section **6.3.1.2**.

6.3.2.3 Production of the outer ring

The production of the outer ring takes place in ring mill number 7 at Ovako Steel in Hofors. The rings are made from round bars, diameter 70 mm, manufactured in the rolling mill at Ovako Steel in Hällefors, Sweden.

The billets are first heated in an induction furnace. The billet are then cut in pieces, upset, pre-pierced and pierced. This is all done in one machine. The rings are then enlarged, through rolling, and the raceways are shaped. After the rolling the rings are air-cooled. The rings are also inspected for defects i.e. cracks etc.

The rings are heat treated to obtain the required material properties and the oxide scale formed during the treatment is then blasted of. The rings are packed in flow film before transportation by train to SKF in Göteborg, Sweden.

The complete data set for the production of the outer ring can be found in Appendix, section **0**.
The flowchart for the production of the outer ring can be seen in Appendix, section **2.6**.

6.3.3 Ring processes at SKF in Göteborg

6.3.3.1 Turning

At SKF in Göteborg the rings, outer as well as inner ring, are turned to their final shape. For the SRB 24024, which is manufactured in production channel 4, the turning takes place at the D-factory. After the turning both the rings are heat-treated. The heat treatment is located in another factory within the SKF industrial area.

6.3.3.2 Heat treatment

The function of the heat treatment is to make the metal gain properties that will make the ring stronger and more resistant. Before the heat treatment the steel is soft and brittle but the heat treatment makes the steel hard and tough, which are necessary qualities for bearing rings.

The rings are heated to 855 degrees Celsius and then quenched to 235 degrees Celsius in a salt bath. The rings are kept in the salt bath for the time needed for the material to change. The salt bath is half Sodium nitrite and half Potassium nitrate kept in solution. The salt bath also gives the rings a protective layer of salt.

The rings are then air-cooled to room temperature and after that washed in a water bath that holds a temperature of 70 degrees Celsius. Even after the washing a thin layer of salt covers the rings.

6.3.3.3 Grinding and honing

Back in the D-factory the rings are ground. All surfaces on both rings are ground but only the inner ring is honed. Now the surfaces are smooth. Before assembly with the other components the rings are washed to make sure that no dirt will follow with the rings and jeopardise the quality of the bearing.

The complete data set for the ring processes at SKF in Göteborg can be found in Appendix, sections **0** and **0**.
The flowchart for the ring processes at SKF in Göteborg can be seen in Appendix, section **2.15**.

6.4 Production of rollers

Square billets with a diameter of 150 mm produced at the rolling mill at Ovako Steel in Hofors are transported by train to Ovako Steel in Hällefors. At the rolling mill in Hällefors the billets are hot rolled to wire rod and then, in another mill at the same plant, peeled and drawn to surface removed wire. The wire is transported to SKF in Göteborg where the rollers are manufactured.

6.4.1 Production of surface removed wire

6.4.1.1 Billet treatment

See Billet treatment section **6.3.1.1**.

6.4.1.2 Production of hot rolled wire rod

The hot rolled wire rods are produced at the Ovako Steel rolling mill in Hällefors, as the bars used to produce the rings. The final dimension of the wire used for the production of rollers to this specific bearing is 14,50 mm. This is the smallest dimension produced in the rolling mill and the billets go through all 16 pairs of rolls. See also section **6.3.1.2** on production of hot rolled bars.

After the rolling the wire is coiled and then air-cooled. The coils are transported to the production of surface removed wire at another mill at the same plant.

The complete data set for the production of hot rolled wire rod can be found in Appendix, section **1.2.1**.
The flowchart for the production of hot rolled wire rod can be seen in Appendix, section **2.7**.

6.4.1.3 Production of surface removed wire

In the plant for production of surface removed wire the wire is blasted in a centrifugal blast where oxide scale is removed. After the blasting the wire is soft annealed in an electric furnace with a protective atmosphere. The atmosphere is composed of methanol and nitrogen. The coil is then air cooled and stored. When the wire comes from the rolling mill the material is very hard and brittle, the soft annealing is done in order to make the material softer so it can be machined and drawn.

The wire is decoiled and straightened before being peeled. After the peeling the wire dimension is roughly the right one. The wire is then brushed/ground to make soap stuck on the wire. The soap is used as lubricant in the drawing process where the wire is drawn through a cone shaped hole that gives it the final dimension. The surface of the wire is then checked for defects and the wire is coiled. The coil is washed and then phosphatised. The coil is stored until transported to SKF in Göteborg by train.

The complete data set for the production of surface removed wire can be found in Appendix, section **1.2.2**.
The flowchart for the production of surface removed wire can be seen in Appendix, section **2.8**.

6.4.2 Production of rollers

At the SKF plant in Göteborg, Sweden the wire is cut and pressed to rollers. When the rollers have been pressed they have the roughly the right shape but they need to be turned to become absolutely spherical. The rollers are also trumbled so that the surface will be smooth, which is extremely important.

The rollers are heat treated, like the rings see section 6.3.3.2 on heat treatment of the rings. The reason is also the same, to get the right material properties. The rollers are calibrated. Their dimensions are measured and they are sorted in groups with dimension intervals of three micrometers. The rollers are later combined with rings, which also differ a little in dimensions, to create bearings with a wide range of different radial internal clearance.

The rollers are transported by industrial truck to the D-factory, within the SKF industrial area, for assembly.

The complete data set for the production of rollers can be found in Appendix, section **1.2.3**.
The flowchart for the production rollers can be seen in Appendix, section **1.1**.

6.5 Production of cages

The cages are made of steel from SSAB Tunnplåt in Borlänge. The quality of the steel is developed especially for cages to SKF spherical roller bearings and the steel is therefore called "kulhållarplåt". The raw material is 80 % virgin iron and 20 % recycled steel. The production of virgin iron is not included in this study.

6.5.1 Production of pickled hot rolled steel sheets

6.5.1.1 Hot rolling and pickling of steel sheets

SSAB's steel mills in Luleå and Oxelösund supply the billets processed at SSAB's hot rolling mill in Borlänge, Sweden. At the hot rolling mill the billets are heated to approximately 1250 degrees Celsius in two fuel fired furnaces. The billets are rolled to the dimension 2,75 mm and coiled.

When the steel is hot rolled iron oxide forms on the metal surface. Through pickling in acid baths the iron oxide is removed from the steel sheets. The acid in the baths is hydrochloric acid and it is reused within the plant. After the pickling the sheets are treated with rust preservative that will prevent new formation of iron oxide. The coils are transported to Dickson Plåt Service Center AB in Göteborg by train.

The complete data set for the hot rolling and pickling of steel sheets can be found in Appendix, section **1.3.1** and**1.3.2**.
The flowchart for the Hot rolling and pickling of steel sheets can be seen in Appendix, section **2.10**.

6.5.1.2 Production of steel band

At Dickson Plåt Service Center AB in Göteborg the steel sheets are cut to the desired width. In this case 215,0 mm. The cutting machine decoils the steel sheets, cuts them and recoils them again. The coil is packed in flow film and transported to SKF in Göteborg by truck.

The complete data set for the production of steel band can be found in Appendix, section **1.3.3**.
The flowchart for the production of steel band can be seen in Appendix, section **2.11**.

6.5.2 Production of cages

At the SKF plant in Göteborg the steel is pressed and cut in several process steps to obtain the desired shape. First the sheet is decoiled and then cut in roundels. The roundels are pressed and spaces are cut for the rollers. In order for the machines to work smoothly the steel is oiled. After the pressing and cutting the cage has to be cleaned from the oil, and is then turned and blasted in two steps to get its final dimensions and to become smooth. The second blast has finer grit and will make sure that the surface is smooth enough. The last process step is phosphatising. The cages are transported, by industrial trucks, to the D-factory within the SKF industrial area for assembly.

The complete data set for the production of cages can be found in Appendix, section **1.3.4**.
The flowchart for the production of cages can be seen in Appendix, section **2.12**.

6.6 Production of the guide ring

The production of the guide ring takes place at SKF Mekan AB in Katrineholm, Sweden. The raw material for the guide ring is steel powder that is produced at Höganäs AB in Höganäs, Sweden. It is transported to SKF Mekan by truck.

6.6.1 Production of steel powder

The raw material for the steel powder produced at Höganäs AB is iron ore concentrate and the data in this study therefor represents a production based on

100 % virgin iron. The decision was taken by Höganäs AB who has also aggregated the data concerning the production of steel powder and the processes upstream, including transports, due to secrecy.

6.6.1.1 Production of sponge iron

At Höganäs dried and screened iron ore concentrate is mixed with coke, anthracite and lime that have been dried, crushed and screened. The mix is packed and reduced in a tunnel furnace. This is here the sponge iron is formed. The sponge iron is removed from the ceramic forms, used for the reduction, and then crushed and ground. The crushed sponge iron is stored.

The flowchart for production of sponge iron can be found in Appendix, section **2.13.1**

6.6.1.2 Production of steel powder

The crushed sponge iron is ground a second time, screened and equalised. After the equalising the sponge iron is soft annealed, crushed, screened and equalised once again. Now it has become steel powder.

The complete data set for the steel powder production can be found in Appendix, section **1.4.1**.
The flowchart for steel powder production can be found in Appendix, section **2.13.2**

6.6.1.3 Customer mix

Höganäs AB produces various kinds of steel powder. The unalloyed steel powder is mixed with alloys and lubricants to satisfy customer specifications. The steel powder used to manufacture the guide ring for SRB 24024 is an unalloyed steel powder with 0,75% zinkstearate as lubricant.

The unalloyed steel powder and the lubricant are weighted and carefully mixed and screened. The powder is packed in bags and transported to SKF Mekan in Katrineholm by truck.

The flowchart for customer mixing can be found in Appendix, section **2.13.3**.

6.6.2 Production of the guide ring

6.6.2.1 Sintering

The sintering method used at SKF Mekan in Katrineholm is called solid phase sintering. With this method the particles sinter to each other through reaction and diffusion over their surfaces without melting. The green bodies, steel powder pressed to shape, are placed on a transportation band that takes them through the three main zones of the sintering furnace:

1. Drying zone
2. High temperature zone
3. Cooling zone

In the drying zone the lubricant melts and vaporises. The temperature in this zone is 700-900 degrees Celsius. The sintering takes place in the high temperature zone at temperatures between 1120 and 1130 degrees Celsius. The sintering time can vary but is normally around 30 minutes. In the cooling zone a reducing atmosphere is kept in order to prevent oxidation.

After the sintering the guide rings are trumbled to reduce sharp or rough edges. The rings are packed and transported to SKF in Göteborg by truck.

The complete data set for production of the guide ring can be found in Appendix, section **0**.
The flowchart for production of the guide ring can be found in Appendix, section **2.14**.

6.7 Production of the corrugated board box

The corrugated board box that is used to pack the manufactured bearing is made of miniwell, which is manufactured of two layers of Kraftliner with one layer of semichemical fluting in-between. The miniwell also has a thin layer of polymer on the outside; this has not been included in the study. The corrugated board box is manufactured by Sydpack in Malmö and then transported to A-förpackningar in Göteborg who is the distributor for SKF. Since it has not been possible to get data from Sydpack the data used are data representing average production of Kraftliner, semichemical fluting and corrugated board boxes in Europe.

6.7.1 Production of Kraftliner

The raw material for Kraftliner is mostly virgin fibres i.e. wood. The wood chips are cooked to pulp by the Kraft cooking process. It is a highly alkaline cooking process with caustic soda and sodium-sulphide as active cooking chemicals. The pulp yield is normally around 55% i.e. 1000 kg of dry wood gives 550 kg of pulp. The spent cooking liquor is drained off and washed out of the pulp. The liquor is concentrated and burnt for steam production and recovery of the cooking chemicals. The pulp is defiberised in refiners, screened and washed before being sent to the paper mill.

The pulp is mechanically treated and the pH-level of the pulp slurry is adjusted with acid and some additives are added to facilitate the paper production. Finally the pulp slurry is screened and diluted. The paper is then formed from the head box onto the wire and dewatered in the press section where water is taken out of the sheet by pressing between felts. To get its final dryness of 92% the sheets run against heated cylinders.

Kraftliner is normally a two ply product. The base brown ply contains recycled paper pulp and the top ply is normally wood pulp from the integrated pulp production that is more refined and cleaner to give the top surface the right characteristics and printability. [FEFCO, 1997]

The complete data set for Production of Kraftliner can be found in Appendix, section **0**.

6.7.2 Production of semichemical fluting

The raw material for semichemical fluting is, like for Kraftliner, mostly virgin fibres. The production process is almost the same as for Kraftliner except that the cooking process is semichemical. It is a slightly alkaline cooking process with sodium sulphite and sodium carbonate as active cooking chemicals. The pulp yield is normally around 80 %. [FEFCO, 1997]

The complete data set for Production of semichemical fluting can be found in Appendix, section **1.5.1**.

6.7.3 Production of corrugated board

A corrugated board is composed of layers of paper: liner (linerboard) and fluting (corrugating medium), it is manufactured on a corrugator, which consists of several steps running in line. In the process five steps are distinguished:

1. Shaping of the corrugated medium into continuous rolling waves (the flutes) and gluing the first linerboard facing
2. Gluing one or more web of single faces and facings forming corrugated board.
3. Creasing and cutting of the corrugated board web in the machine direction.
4. Cutting the corrugated board web in the cross-machine direction.
5. Stacking the corrugated sheets before finishing.

The corrugated sheets are die-cut into box blanks i.e. any pre-cut section of corrugated board to be formed into a set-up box or portion of a box. The box itself is then ready for use. [FEFCO, 1997]

The complete data set for production of corrugated board box can be found in Appendix, section **1.5.3**.

6.8 Transports

The transports within the life cycle are carried out both by train and truck.

6.8.1 Train transports

Within Sweden the train transports are supplied by SJ. According to SJ the train transports are very well planned and the capacity of the trains well utilised. The energy source for the trains is electricity except when they are on the production plants private sidings. These are very short distances and they make a negligible contribution to the pollution from the transports and is not considered further in this study. The electricity used within Sweden is based on renewable energy, and has in this study been approximated by hydropower.

Even the train transport to France is completely made by electricity-powered trains but here the electricity is based on different energy sources depending on the energy-system in each country. In this study electricity supply outside Sweden has been given the properties of average data for electricity production in Europe. The data for the train transports include the production of the electricity supplied.

Table 1: Train transports included in the life cycle of the Spherical Roller Bearing 24024. The number in the last column shows how many times this distance is present in the life cycle. [Eltebo, SJ, Meglic, NTR]

From:	To:	Distance (km):	Comment:	No.:
Hofors (Ovako)	Hällefors (Ovako)	181	Billets to Hällefors, bars to Hofors	2
Borlänge (SSAB)	Göteborg (Dicksons)	448	Steel Sheets	1
Hofors (Ovako)	Göteborg (SKF)	484	Outer ring	1
Hällefors (Ovako)	Göteborg (SKF)	335	Surface removed wire	1
Hällefors (Ovako)	Carignan (Ovako)	1854	Bars. Distance include 43 km ferry-transport	1
Carignan (Ovako)	Göteborg (SKF)	1571	Inner ring. Distance include 43 km ferry-transport	1

6.8.2 Truck transports

The data sets for the truck transports include the production of diesel. Different transportation suppliers carry out the truck transports. The suppliers vary among the companies but may also vary from one occasion to the next. Since it is reasonable to believe that the suppliers have trucks with different environmental properties the truck transports within the study have all been approximated by Euro0, except for the transport within Göteborg that has been approximated with Euro2. This may not be true but may be seen as a worst-case scenario.

Table 2: Truck transports included in the life cycle of the Spherical Roller Bearing 24024. [Microsoft AutoRoute Express Europe 2000]

From:	To:	Distance (km):	Comment:
Höganäs (Höganäs)	Katrineholm (SKF)	464	Steel Powder
Katrineholm (SKF)	Göteborg (SKF)	360	Guide ring
Malmö (Sydpack)	Göteborg (SKF)	273	Corrugated Board Box
Göteborg (SKF)	Tongeren (SKF)	1310	Bearing. The ferry-transport is not included.
Tongeren (SKF)	Borlänge (Avesta-Sheffield)	1556	Bearing. The ferry-transport is not included.

7 Inventory results

*In this section the inventory results concerning air emissions (selected substances), energy consumption and total waste for the components are presented. The complete inventory lists are found in Appendix, section **1**. Tables of the non-elementary flows can also be found in Appendix, sections **1.8** and **1.9***

7.1 Rings

The activities included in the production of the rings are:

- Production of bearing steel
- Production of square billets, 150 mm
- Train transport of square billets from Hofors to Hällefors
- Billet treatment
- Production of bars, 70 mm
- Production of bars, 60 mm
- Train transport of bars, 70 mm, from Hällefors to Hofors
- Transport of bars, 60 mm, from Hällefors to Carignan
- Production of outer ring
- Train transport of the outer ring from Hofors to Göteborg
- Production of inner ring[1]
- Transport of inner ring from Carignan to Göteborg
- Ring machining[2]
- Heat treatment
- Production of electricity
- Production of district heat
- Production of natural gas
- Production of LPG
- Production of light fuel oil

[1] The data set for the production of the inner ring at Ovako La Foulerie in France includes no emissions to air (not known) and emissions to water expressed in mg/l (but the water flux is unknown). Therefore neither emissions to water or air are presented here. [Hamilton U. and Mimer-Carpentier M. Ovako La foulerie]

[2] Due to allocation problems and lack of data no emissions to air or water are included in the data set for the machining of the rings at SKF in Göteborg

Table 3: Emissions to air from the production processes and transports (including the production of energy carrier) between the production sites for the outer and inner ring (for one bearing).

Substance:	**Unit:**	**Total:**	**Dominating source:**
CO_2	kg	3,20E+00	Production of electricity, Swedish average
CO	kg	1,38E-02	Heat treatment at SKF in Göteborg
NO_x	kg	8,26E-03	Production of electricity, Swedish average
NMVOC[3]	kg	4,87E-03	Production of LPG
SO_2	kg	4,87E-03	Production of LPG
CH_4	kg	4,58E-03	Production of electricity, Swedish average
Particulates	kg	1,48E-03	Production of district heating, Swedish average

Table 4: Energy consumption for the ring production processes for one bearing, not including transportation between the production sites.

Substance:	**Unit:**	**Total:**	**Dominating consumer:**
Electricity	MJ	7,91E+01	Ring machining at SKF in Göteborg
District heat	MJ	1,75E+01	Ring machining at SKF in Göteborg
Natural gas	MJ	8,51E+00	Ring machining at SKF in Göteborg
LPG	MJ	1,03E+01	Production of bars, 70 mm, at Ovako in Hällefors
Light fuel oil	MJ	5,33E+00	Production of square billets at Ovako Steel in Hofors
Fuel oil, unspecified	MJ	1,13E-01	Transport between Hällefors and Carignan

Table 5: Total waste, elementary and non-elementary for the production and transportation (including production of energy carrier) of the rings for one bearing.

Waste	**Elementary:**	**Non-elementary:**	**Total:**	**unit:**
	1,89E+00	7,42E+00	9,31 E+00	kg

[3] NMVOC stands for non-methane volatile organic compounds.

7.2 Rollers

The activities included in the production of the rollers are:
- Production of bearing steel
- Production of square billets, 150 mm
- Train transport of square billets from Hofors to Hällefors
- Billet treatment
- Production of wire rod, 14,50 mm
- Production of surface removed wire, 13,50 mm
- Train transport of wire from Hällefors to Göteborg
- Production of rollers[4]
- Production of electricity
- Production of district heat
- Production of natural gas
- Production of LPG
- Production of light fuel oil

Table 6: Emissions to air from the production processes and transports between the production sites of the rollers for one bearing.

Substance:	Unit:	Total:	Dominating source:
CO_2	kg	2,19E+00	Production of district heating, Swedish average
CO	kg	1,78E-02	Production of surface removed wire at Ovako in Hällefors
NO_x	kg	5,72E-03	Production of district heating, Swedish average
NMVOC[3]	kg	2,22E-03	Production of district heating, Swedish average
SO_2	kg	3,40E-03	Production of district heating, Swedish average
CH_4	kg	3,86E-03	Production of district heating, Swedish average
Particulates	kg	1,11E-03	Production of district heating, Swedish average

[4] Due to allocation problems and lack of data no emissions to air or water are included in the data set for the roller production at SKF in Göteborg

Table 7: Energy consumption for the production processes, not including transportation between the production sites of the rollers for one bearing.

Substance:	Unit:	Total amount:	Dominating consumer:
Electricity	MJ	4,81E+01	Production of rollers at SKF in Göteborg
District heat	MJ	2,17E+01	Production of rollers at SKF in Göteborg
Natural gas	MJ	7,65E+00	Production of rollers at SKF in Göteborg
LPG	MJ	4,69E+00	Production of wire rod at Ovako in Hällefors
Light fuel oil	MJ	3,78E+00	Production of square billets at Ovako in Hofors
Hot water	MJ	5,85E-04	Production of surface removed wire at Ovako in Hällefors

Table 8: Total waste, elementary and non-elementary for the production and transportation (including production of energy carrier) of the rollers for one bearing.

Waste	Elementary:	Non-elementary:	Total:	unit:
	1,38E+00	1,24E+02	1,25E+02	kg

7.3 Guide ring

The activities included in the production of the guide ring are:
- Production of steel powder[5]
- Production of the sintered guide ring
- Transportation of steel powder from Höganäs to Katrineholm
- Transportation of the guide ring from Katrineholm to SKF in Göteborg
- Production of electricity

Table 9: Emissions to air from the production processes and transports between the production sites of the guide ring.

Substance:	Unit:	Total:	Dominating source:
CO_2	kg	0,20E+00	Production of Steel Powder, cradle to gate
CO	kg	8,78E-06	Production of electricity, Swedish average
NO_x	kg	3,39E-04	Production of Steel Powder, cradle to gate
NMVOC[3]	kg	3,55E-05	Production of Steel Powder, cradle to gate
SO_2	kg	1,90E-04	Production of Steel Powder, cradle to gate
CH_4	kg	8,62E-04	Production of Steel Powder, cradle to gate
Particulates	kg	1,00E-04	Production of Steel Powder, cradle to gate

[5] The activity "production of steel powder" is a cradle to grave activity. This includes transports, production of energy carriers etc. This is the reason why only the electricity used to sinter the guide ring is seen in the table. [Edlund, Höganäs AB]

Table 10: Energy consumption for the guide ring production processes[5], not including transportation between the production sites.

Substance:	Unit:	Total:	Dominating consumer:
Electricity	MJ	1,22E+00	Sintering of the guide ring at SKF Mekan in Katrineholm

Table 11: Total waste, elementary and non-elementary for the production of the guide ring and transportation (including production of energy carrier).

Waste	Elementary:	Non-elementary:	Total:	unit:
	1,70E-01	5,40E-02	2,24E-01	kg

7.4 Cages

The activities included in the production of the cages are:

- Production of hot rolled steel sheets
- Pickling of hot rolled steel sheets
- Production of steel bands
- Production of cages
- Transportation of pickled steel sheets from Borlänge to Göteborg
- Transportation of cut steel sheets from Göteborg to SKF in Göteborg
- Production of electricity
- Production of district heat
- Production of natural gas
- Production of LPG
- Production of diesel

Table 12: Emissions to air from the production processes and transports between the production sites of the cages for one bearing.

Substance:	Unit:	Total:	Dominating source:
CO_2	kg	6,20E-01	Production of district heating, Swedish average
CO	kg	7,26E-05	Production of electricity, Swedish average
NO_x	kg	1,36E-03	Production of district heating, Swedish average
NMVOC[3]	kg	9,98E-04	Production of district heating, Swedish average
SO_2	kg	1,16E-03	Production of district heating, Swedish average
CH_4	kg	7,75E-04	Production of district heating, Swedish average
Particulates	kg	2,97E-04	Production of district heating, Swedish average

Table 13: Energy consumption for the production processes, not including transportation between the production sites of the cages for one bearing.

Substance:	Unit:	Total:	Dominating consumer:
Electricity	MJ	1,22E+01	Production of cages at SKF in Göteborg
District heat	MJ	6,77E+00	Production of cages at SKF in Göteborg
Natural gas	MJ	6,25E-01	Production of cages at SKF in Göteborg
LPG	MJ	1,46E+00	Production of hot rolled steel sheets at SSAB in Borlänge
Diesel	MJ	3,60E-02	Production of steel bands at Dicksons Plåt Service in Göteborg
Fuel oil, unspecified	MJ	1,61E+00	Production of hot rolled steel sheets at SSAB in Borlänge

Table 14: Total waste, elementary and non-elementary for the production and transportation (including production of energy carrier) of the cages for one bearing.

Waste	Elementary:	Non-elementary:	Total amount:	unit:
	2,70E-01	2,18E+00	2,45E+00	kg

7.5 Corrugated board box

The activities[6] included in the production of the corrugated board box are:

- Production of semichemical fluting
- Production of Kraftliner
- Production of the corrugated board box
- Transportation of the box from Malmö[7] to SKF Göteborg
- Production of electricity
- Production of natural gas
- Production of LPG
- Production of light fuel oil
- Production of heavy fuel oil
- Production of diesel

[6] It should be noted that the data for the corrugated board box, except for the transportation, are all average data for Europe. [FEFCO, 1997]

[7] The corrugated board box is produced at Sydpack AB in Malmö and then transported to A-förpackningar in Göteborg who is the distributor for SKF. [Lindgren, A-förpackningar]

Table 15: Emissions to air from the production processes and transports between the production sites of one corrugated board box.

Substance:	Unit:	Total:	Dominating source:
CO_2	kg	3,20E-01	Production of Kraftliner, European average
CO	kg	1,82E-05	Production of heavy fuel oil
NO_x	kg	3,47E-04	Production of Kraftliner, European average
NMVOC[3]	kg	1,26E-04	Production of heavy fuel oil
SO_2	kg	5,79E-05	Production of heavy fuel oil
CH_4	kg	7,29E-05	Production of heavy fuel oil
Particulates	kg	2,67E-05	Production of heavy fuel oil

Table 16: Energy consumption for the production processes, not including transportation between the production sites of one corrugated board box.

Substance:	Unit:	Total:	Dominating consumer:
Electricity	MJ	4,86E-01	Production of Kraftliner, European average
Natural gas	MJ	3,93E-01	Production of the corrugated board box, European average
LPG	MJ	1,16E-02	Production of the corrugated board box, European average
Light fuel oil	MJ	1,11E-01	Production of Kraftliner, European average
Heavy oil	MJ	4,17E-01	Production of Kraftliner, European average
Diesel	MJ	8,13E-03	Production of Kraftliner, European average
Coal	MJ	9,92E-03	Production of Semichemical fluting, European average

Table 17: Total waste, elementary and non-elementary for the production and transportation (including production of energy carrier) of the corrugated board box.

Waste	Elementary:	Non-elementary:	Total:	unit:
	3,43E-02	9,20E-02	1,26E-01	kg

7.6 Recycling of steel within the studied life cycle

Most of the components for the SRB 24024 are manufactured from steel produced at the steel mill at Ovako Steel AB in Hofors. Ovako Steel AB is an SKF group company and is the main supplier of bearing steel for SKF bearings. The production at Ovako Steel is entirely based on scrap which together with intimate relations with SKF makes Ovako a suitable receiver of the steel scrap produced along the process chains constituting the SRB 24024 flowchart.

Whenever metal is being worked scrap is produced. The scrap can take various forms:

- *Rejects* products that don't fulfil the product requirements. Mostly clean and easy to collect.
- *Process scrap* scrap that is produced in the processes e.g. end pieces sawn off at the billet treatment. This scrap is easy to collect and therefore also easily recycled.
- *Turning chips* produced during turning operations. The chips have various sizes and shapes and are most of the times mixed with cutting fluid and not always easy to separate.
- *Grinding dust* very fine metal powder produced while grinding. The grinding dust is mixed with cutting fluid. To be able to recycle the dust it has to be separated from the fluid and pressed to briquettes.

Since metal is worked all through the life cycle the occurrence of scrap is inevitable. All the scrap that occur within the life cycle is recycled except for some of the grinding dust produced at SKF in Göteborg and the steel powder loss at SKF Mekan in Katrineholm, at least according to the companies. The relation between SKF and Ovako makes recycling easy.

- The scrap produced at the steel, rolling and ring mills in Hofors is, of course, recycled within the steel mill.
- The scrap produced at the billet treatment, rolling mill and during the production of surface removed wire in Hällefors is transported to the steel mill in Hofors by train for recycling.
- The scrap produced at the SKF-factories in Göteborg is transported to the steel mill in Hofors by train. In the D-factory the grinding dust is separated from the cutting fluid and pressed to briquettes and subsequently possible to recycle. In the other factories the grinding dust is sent to landfill.
- After use at Avesta-Sheffield in Degerfors the bearing is recycled within the steel mill at the same plant.
- For the other activities the producing companies assure that the scrap is recycled but do not present how.

8 Impact Assessment

In this section the classification and characterisation is performed and the results are discussed.

8.1 Classification and characterisation

The classification and characterisation has been performed in one step. The impact categories presented in the tables below are those with at least one contributing substance.

All activities within the life cycle including the production of electricity, LPG, natural gas, light fuel oil, heavy fuel oil, diesel and district heating are included.

As been stated earlier substances can contribute to more than one impact category. The substances for which this is the case have been noted under all relevant categories even though this may introduce some double counting. [Lindfors et al., 1995]

8.1.1 Acidification

Substances that contribute to acidification are emitted from almost all of the activities in the studied life cycle. Emissions of these substances have been characterised and added as SO_2 equivalents. Both emissions to air and water are included. The results are shown in the table below.

Table 18: Acidification (max) [CIT Ekologik, Index list May 2000]

Acidification (max)	**Substance:**	**Environ-ment:**	**Quantity:**	**Factor:**	**Result:**	**Unit:**
Category indicator:	Acid as H^+	Water	1,75E-07	3,20E+01	5,60E-06	kg
Acidification potentials	H_2S	Air	2,63E-05	1,88E+00	4,94E-05	kg
Unit:	H_2S	Water	3,52E-09	1,88E+00	6,62E-09	kg
kg SO_2 equivalents	HCl	Air	2,07E-04	8,80E-01	1,82E-04	kg
	HF	Air	1,13E-05	1,60E+00	1,81E-05	kg
	HNO_3	Water	1,97E-09	5,10E-01	1,00E-09	kg
	NH_3	Air	3,97E-07	1,88E+00	7,46E-07	kg
	NH_3	Water	1,06E-08	1,88E+00	1,99E-08	kg
	NH^{4+}	Water	6,42E-07	3,55E+00	2,28E-06	kg
	NO_x	Air	2,85E-02	7,00E-01	2,00E-02	kg
	SO_2	Air	1,11E-02	1,00E+00	1,11E-02	kg
	SO_x	Air	3,41E-04	1,00E+00	3,41E-04	kg
Total, kg SO_2 equivalents:					**3,16E-02**	**kg**

NO_x is the substance that gives the largest contribution to the acidification. The main source for NO_x is the transport from SKF's central distribution centre in Tongeren, Belgium to the customer Avesta-Sheffield in Degerfors, Sweden. The transportation is carried out by truck. The truck has been estimated to have environmental performance Euro0, which might be seen as a worst-case scenario.

Sulphur dioxide (SO_2) is the substance having the second largest influence. The main contributing activity here is the production of district heating, Swedish average. SKF uses district heating at the factories in Göteborg where the factory producing the rollers is the main consumer.

The third largest contributor to this impact category is sulphur oxides (SO_x). SO_x includes different sulphur oxides and is used when the type of oxide have not been specified. Their impact on the acidification is estimated to be the same as SO_2. The main emitter of SO_x is the production of Kraftliner. The reason for this is probably that the data set is the result of an extensive study with the goal to put together average data for the production in Europe and in this study the sulphur oxides all have been reported in the same category. Emissions of SO_x have only been reported from three activities, that were all part of this study, and it is not surprisingly that these three did not report any emissions of SO_2.

Emissions of acid of course affect the acidification potential. No emissions of hydrochloric acid (HCl) to water are included in the data sets whilst emissions to air where reported for many of the transportation activities and the activities for production of energy ware. The largest emission to air originates from the production of district heating.

8.1.1.1 Discussion

Since the presentation of air emissions from the sites differ and not always is complete there is reason to believe that the contribution to acidification in reality is higher than what is expressed here.

The activities contributing most to this characterisation method are generic. One of the reasons for this may be that the air emissions are poorly accounted for in many of the site-specific activities included in the study. For the transports and production of energy ware on the other hand, generic data have been used and here more emissions to air have been inventoried.

The environmental load is quite evenly distributed among the components but the production of rollers uses more district heating and could therefore be made responsible for the largest part.

8.1.2 Ecotoxicity, aquatic

Ecotoxicity in aquatic environment is expressed in cubic meter of polluted water and only emissions to water are considered.

Table 19: Ecotoxicity, aquatic [CIT Ekologik, Index list May 2000]

Ecotoxicity, aquatic	Substance:	Environ-ment:	Quantity:	Factor:	Result:	Unit:
Category indicator:	As	Water	1,18E-07	2,00E+06	2,36E-01	m^3
Ecotoxicity aquatic	Cd	Water	6,13E-08	2,00E+09	1,23E+02	m^3
potentials	Cr^{3+}	Water	5,23E-07	1,00E+07	5,23E+00	m^3
Unit:	Cu	Water	1,58E-07	2,00E+07	3,16E+00	m^3
m^3 polluted water	Ni	Water	4,34E-07	3,30E+06	1,43E+00	m^3
	Oil	Water	1,01E-03	5,00E+05	5,05E+02	m^3
	Pb	Water	4,70E-07	2,00E+07	9,40E+00	m^3
	Phenol	Water	9,24E-09	5,90E+07	5,45E-01	m^3
	Zn	Water	7,14E-07	3,80E+06	2,71E+00	m^3
Total, m^3 polluted water:					**6,50E+02**	**m^3**

The substance giving the largest contribution to this impact category is oil and the activity responsible for the largest emissions of oil to water is the production of LPG. LPG is used as fuel in the furnaces heating the steel before rolling.

Cadmium (Cd) and Lead (Pb) are counted as two of the heavy metals and have some of the highest indices in this characterisation method. The main source for Cd and Pb within the life cycle is again the production of LPG.

The fourth most contributing substance to the intoxication of water is the Chromium ion Cr^{3+}. The main source is again the production of LPG.

Copper (Cu) and Zinc (Zn) originates mostly from the production of light fuel oil.

8.1.2.1 Discussion

The site-specific data differ quite much when it comes to accounted water emissions. At many of the sites water emissions are not accounted for at all. This gives reason to believe that the characterisation result would give higher values if the data had been more complete.

The substances accounting for the largest contributions to this characterisation method have all their main sources in the production of energy ware with the production of LPG as the most contributing. LPG is used in the walking beam and pit furnaces the largest part of the material heated in these furnaces is part of the ring process chain.

8.1.3 Eutrophication (max)

Almost all activities within the life cycle release substances that contribute to eutrophication. The substances could be released either to water or to air. Eutrophication is expressed in kg of NO_x- equivalents

Table 20: Eutrophication (max) [CIT Ekologik, Index list May 2000]

Eutrophi-cation (max)	Substance:	Environ-ment:	Quantity:	Factor:	Result:	Unit:
Category indicator:	BOD, fossil	Water	1,20E-03	1,69E-01	2,03E-04	kg
Eutrophi-cation potentials	COD, fossil	Water	3,56E-03	1,69E-01	6,02E-04	kg
Unit:	HNO_3	Water	1,97E-09	7,69E-01	1,51E-09	kg
kg NO_x equivalents	NH_3	Air	3,97E-07	2,69E+00	1,07E-06	kg
	NH_3	Water	1,06E-08	2,69E+00	2,85E-08	kg
	NH^{4+}	Water	6,42E-07	2,54E+00	1,63E-06	kg
	Nitrates	Water	2,14E-03	7,69E-01	1,65E-03	kg
	Nitrogen	Air	4,81E-01	3,23E+00	1,55E+00	kg
	Nitrogen	Water	3,67E-08	3,23E+00	1,19E-07	kg
	NO^{2-}	Water	3,04E-08	1,00E+00	3,04E-08	kg
	NO^{3-}	Water	2,66E-07	7,69E-01	2,05E-07	kg
	NO_x	Air	2,85E-02	1,00E+00	2,85E-02	kg
	Phosphate	Water	3,43E-09	7,69E+00	2,64E-08	kg
	PO_4^{3-}	Water	2,45E-06	7,69E+00	1,88E-05	kg
	TOC	Water	4,18E-09	6,51E-01	2,72E-09	kg
	Tot-N	Water	2,05E-04	3,23E+00	6,62E-04	kg
	Tot-P	Water	4,74E-08	2,35E+01	1,12E-06	kg
Total, kg NO_x equivalents:					**1,59E+00**	**kg**

Emissions of nitrogen to air are the main contributor to this category. The emissions originate from the protective atmosphere kept in the furnaces for soft annealing and heat treatment in the process chains for rings and rollers.

The principal source for emissions of NO_x, the second largest contributor to this category, is the transport from SKF's central distribution centre in Tongeren, Belgium to the customer Avesta-Sheffield in Degerfors, Sweden. The transportation is carried out by truck. The truck has been estimated to have environmental performance Euro0, which might be seen as a worst-case scenario.

The third most important substances are nitrates and the nitrate reported within this study is potassium nitrate that is used in the salt bath cooling the rings after the heat treatment. Some potassium nitrate follows the wastewater through the municipal sewer to the wastewater treatment plant in Göteborg and then to the recipient Göta River.

The Tot-N mainly originates from the production of light fuel oil. The oil is used in the steel mill and when producing the corrugated board box.

8.1.3.1 Discussion

The data reported from the specific sites differ quite much when it comes to accounted air and water emissions. Sometimes just a few substances are reported, sometimes no substances at all. This gives reason to believe that the characterisation result would give higher values if the data had been more complete.

Even in this characterisation method the environmental load is distributed among the components but if one should be pointed out it is the rings. They are the once heat-treated and they also consume more light fuel oil then the other components.

8.1.4 Global warming (100 years)

Global warming potential with, in this case, a time perspective of one hundred years is expressed in kg CO_2 equivalents.

Table 21: Global warming (100 years) [CIT Ekologik, Index list May 2000]

Global warming (100 years)	**Substance:**	**Environ-ment:**	**Quantity:**	**Factor:**	**Result:**	**Unit:**
Category indicator:	Aldehydes	Air	2,90E-09	1,10E+01	3,19E-08	kg
Global warming	BOD, fossil	Water	1,20E-03	1,38E+00	1,65E-03	kg
potentials	BOD5, fossil	Water	2,03E-06	1,38E+00	2,79E-06	kg
Unit:	CH_4	Air	1,10E-02	2,10E+01	2,31E-01	kg
kg CO_2 equivalents	CO_2	Air	7,26E+00	1,00E+00	7,26E+00	kg
	CO	Air	4,49E-02	3,00E+00	1,35E-01	kg
	CO	Water	5,60E-08	3,00E+00	1,68E-07	kg
	COD, fossil	Water	3,56E-03	1,38E+00	4,90E-03	kg
	CH	Air	4,48E-04	1,10E+01	4,93E-03	kg
	N_2O	Air	2,25E-05	3,10E+02	6,98E-03	kg
	NO_x	Air	2,85E-02	7,00E+00	2,00E-01	kg
	PAH	Air	5,54E-08	1,10E+01	6,09E-07	kg
	Propene	Air	1,33E-09	1,10E+01	1,46E-08	kg
Total, kg CO_2 equivalents:					**7,84E+00**	**kg**

In this impact category CO_2 is by far the largest contributor. It is released from almost all activities but the production of electricity, Swedish average is the main emitter. The largest consumer of electricity among the components is the rings.

There are two principle sources to emissions of methane (CH_4): the production of electricity and the production of district heating.

The principal source for emissions of NO_x is the transport from SKF's central distribution centre in Tongeren, Belgium to the customer Avesta-Sheffield in Degerfors, Sweden. The transportation is carried out by truck. The truck has been estimated to have environmental performance Euro 0, which might be seen as a worst-case scenario.

Emissions of CO to air are originating from the protective atmosphere kept in the furnaces for heat treatment of the rings at SKF in Göteborg.

8.1.4.1 Discussion

The declared air emissions vary a lot between site-specific data. This gives reason to believe that not all the air emissions have been inventoried and that the characterisation result would give a higher value if the data had been more complete.

The rings are using a large part of the supplied electricity as well as the district heating. The heat treatment at SKF in Göteborg is only heat-treating the rings. Together this makes the rings accountable for the largest contribution in this characterisation method.

8.1.5 Human toxicity

Human toxicity is here expressed in kg contaminated bodyweight. The toxicity is presented both for air emissions and emissions to water.

8.1.5.1 Air

Table 22: Human toxicity, Air [CIT Ekologik, Index list May 2000]

Human toxicity, Air	**Substance:**	**Environ-ment:**	**Quantity:**	**Factor:**	**Result:**	**Unit:**
Category indicator:	As	Air	2,49E-07	4,70E+03	1,17E-03	kg
Human toxicity	Benzo(a)pyrene	Air	1,19E-11	1,70E+01	2,02E-10	kg
potentials, Air	Cd	Air	2,35E-07	5,80E+02	1,36E-04	kg
Unit:	CN-	Air	1,37E-07	6,70E-01	9,18E-08	kg
kg contaminated	CO	Air	4,49E-02	1,20E-02	5,39E-04	kg
bodyweight	Cr	Air	6,45E-08	6,70E+00	4,32E-07	kg
	Cu	Air	1,33E-06	2,40E-01	3,19E-07	kg
	Dioxin	Air	3,78E-11	3,30E+06	1,25E-04	kg
	Fe	Air	1,09E-06	4,20E-02	4,58E-08	kg
	HF	Air	1,13E-05	4,80E-01	5,42E-06	kg
	H_2S	Air	2,63E-05	7,80E-01	2,05E-05	kg
	Hg	Air	3,03E-07	1,20E+02	3,64E-05	kg
	Mn	Air	3,62E-08	1,20E+02	4,34E-06	kg
	Mo	Air	1,27E-08	3,30E+00	4,19E-08	kg
	Ni	Air	4,00E-06	4,70E+02	1,88E-03	kg
	NO_x	Air	2,85E-02	7,80E-01	2,22E-02	kg
	PAH	Air	5,54E-08	1,70E+01	9,42E-07	kg
	Pb	Air	1,17E-06	1,60E+02	1,87E-04	kg
	Phenol	Air	1,33E-12	5,60E-01	7,45E-13	kg
	Sn	Air	3,68E-10	1,70E-02	6,26E-12	kg
	SO_2	Air	1,11E-02	1,20E+00	1,33E-02	kg
	SO_x	Air	3,41E-04	1,20E+00	4,09E-04	kg
	Toulene	Air	1,25E-06	3,90E-02	4,88E-08	kg
	V	Air	1,65E-06	1,20E+02	1,98E-04	kg
	Zn	Air	1,45E-05	3,30E-02	4,79E-07	kg
Total, kg contaminated bodyweight:					**4,03E-02**	**kg**

NO_x is the substance that gives the largest contribution to this category. The main source is the transport from SKF's distribution centre in Tongeren, Belgium to the customer Avesta-Sheffield in Degerfors, Sweden. The transportation is carried out by truck, which has been estimated to have environmental performance Euro0, which might be seen as a worst-case scenario.

Nickel (Ni) originates primary from the production of district heating. The heating is used in SKF's factories in Göteborg.

The third largest contributor to this impact category is sulphur dioxide (SO_2). The main contributing activity is the production of district heating, Swedish average. SKF uses district heating at the factories in Göteborg where the factory producing the rollers is the main consumer.

8.1.5.2 Water

Table 23: Human toxicity, Water [CIT Ekologik, Index list May 2000]

Human toxicity, Water	**Substance:**	**Environ-ment:**	**Quantity:**	**Factor:**	**Result:**	**Unit:**
Category indicator:	As	Water	1,18E-07	1,40E+00	1,65E-07	kg
Human toxicity	Cd	Water	6,13E-08	2,90E+00	1,78E-07	kg
potentials, Water	CN^-	Water	1,08E-07	5,70E-02	6,16E-09	kg
Unit:	CO	Water	5,60E-08	2,00E+00	1,12E-07	kg
kg contaminated	Cr^{3+}	Water	5,23E-07	5,70E-01	2,98E-07	kg
bodyweight	Cr	Water	3,43E-07	5,70E-01	1,96E-07	kg
	Cu	Water	1,58E-07	2,00E-02	3,16E-09	kg
	F^-	Water	6,45E-06	4,10E-02	2,64E-07	kg
	Fe	Water	6,67E-05	3,60E-03	2,40E-07	kg
	HNO_3	Water	1,97E-09	7,80E-04	1,54E-12	kg
	NH^{4+}	Water	6,42E-07	1,70E-03	1,09E-09	kg
	Ni	Water	4,34E-07	5,70E-02	2,47E-08	kg
	Nitrates	Water	2,14E-03	7,80E-04	1,67E-06	kg
	NO^{2-}	Water	3,04E-08	2,20E-02	6,69E-10	kg
	NO^{3-}	Water	2,66E-07	7,80E-04	2,07E-10	kg
	Oil	Water	1,01E-03	9,20E-04	9,29E-07	kg
	Pb	Water	4,70E-07	7,90E-01	3,71E-07	kg
	Phenol	Water	9,24E-09	4,80E-02	4,44E-10	kg
	Sn	Water	4,00E-05	1,40E-03	5,60E-08	kg
	Tot-CN	Water	2,59E-08	5,70E-02	1,48E-09	kg
	Tot-P	Water	4,74E-08	4,10E-05	1,94E-12	kg
	Zn	Water	7,14E-07	2,90E-03	2,07E-09	kg
Total, kg contaminated bodyweight:					**4,52E-06**	**kg**

The substances with the largest impact in this category are nitrates, which in this case represents potassium nitrate emitted at the heat treatment of the rings at SKF in Göteborg.

The substance making the second largest contribution to this impact category is oil and the activity responsible for the largest emissions of oil to water is the production of LPG. LPG is used as fuel in the furnaces heating the steel before rolling.

Lead (Pb) is counted as one of the heavy metals and has one of the highest indices in this characterisation method. The main source for Pb within this life cycle is the production of LPG.

The fourth most contributing substance to the intoxication of water is the Chromium ion Cr^{3+}. The main source is again the production of LPG.

8.1.5.3 Discussion

The site-specific data differ quite much when it comes to accounted air and water emissions. This gives reason to believe that the characterisation result would give a higher value if the data had been more complete.

The component responsible for the largest contribution to the human toxicity (air) is the rollers even though the rings make quite a large contribution as well. For the human toxicity (water) it is very clear that the rings have the largest influence on the results. This is due to the fact that the rings consume most of the LPG supplied within the life cycle.

8.1.6 Photochemical oxidant creation (0-4 days, high NO_x)

The photochemical oxidant formation potential is expressed in kg ethene equivalents.

Table 24: Photochemical oxidant creation (0-4 days, high NO_x) [CIT Ekologik, Index list May 2000]

Photo-chemical oxidant creation (0-4 days, high NO_x)	**Substance:**	**Environ-ment:**	**Quantity:**	**Factor:**	**Result:**	**Unit:**
Category indicator:	Aldehydes	Air	2,90E-09	4,43E-01	1,28E-09	kg
Photo-chemical ozone	Aromatics	Air	5,75E-07	7,61E-01	4,38E-07	kg
creation potentials	Benzene	Air	1,73E-05	4,02E-01	6,95E-06	kg
Unit:	CH_4	Air	1,10E-02	7,00E-03	7,70E-05	kg
kg ethene equivalents	CO	Air	4,49E-02	3,20E-02	1,44E-03	kg
	CO	Water	5,60E-08	3,20E-02	1,79E-09	kg
	Ethene	Air	3,35E-09	1,00E+00	3,35E-09	kg
	Ethylene oxide	Air	1,21E-05	4,16E-01	5,03E-06	kg
	Formaldehy de	Air	7,59E-07	3,79E-01	2,88E-07	kg
	HC	Air	4,48E-04	3,37E-01	1,51E-04	kg
	NMVOC	Air	3,77E-02	4,16E-01	1,57E-02	kg
	Pentane	Air	3,97E-06	3,00E-01	1,19E-06	kg
	Phenol	Air	1,33E-12	4,16E-01	5,53E-13	kg
	Propene	Air	1,33E-09	1,06E+00	1,41E-09	kg
	Toluene	Air	1,25E-06	5,65E-01	7,06E-07	kg
	VOC	Air	6,20E-04	3,77E-01	2,34E-04	kg
Total, kg ethene equivalents:					**1,76E-02**	**kg**

The substance that has the largest influence on the formation of photochemical oxidants is NMVOC (non-methane volatile organic compounds). It originates primary from the production of LPG.

The emission having the second largest influence is the emissions of CO, originating from the protective atmosphere kept in the furnaces for heat treatment of the rings at SKF in Göteborg.

Emissions of volatile organic compounds (VOC) originate primary from the production of electricity.

Hydrocarbons (HC) are the substances that make the fourth largest contribution to this category. The main source is the transport from SKF's distribution centre in Tongeren, Belgium to the customer Avesta-Sheffield in Degerfors, Sweden. The transportation is carried out by truck, which has been estimated to have environmental performance Euro0, which might be seen as a worst-case scenario.

There are two principle sources to emissions of methane (CH_4): the production of electricity and the production of district heating.

8.1.6.1 Discussion

The air emissions that are declared vary a lot among the site-specific data. This gives reason to believe that the characterisation result would give higher values if the data had been more complete.

It is easily seen that the rings are responsible for the largest contributions to this characterisation method. This is primary because of the consumption of energy and the release of carbon monoxide from the heat treatment.

8.1.7 Resource depletion (Reserve based)

Reserve-based resource depletion is defined as the part of an identified resource that meets minimum physical and chemical criteria to current mining and production practices. Only resources, whose depletion is judged to become, or still be, a problem within the next one hundred years are considered in the characterisation method. [Lindfors et al., 1995]

Table 25: Resource depletion (Reserve based) [CIT Ekologik, Index list May 2000]

Resource depletion (Reserve based)	Substance:	Environment:	Quantity:	Factor:	Result:
Category indicator:	Aluminium	Resource	2,44E-06	3,57E-14	8,71E-20
Abiotic resource depletion	Aluminium	Non-elementary	1,71E-02	3,57E-14	6,10E-16
potential, reserve base	Bauxite	Resource	2,39E-12	1,19E-14	2,84E-26
Unit:	Brown Coal	Resource	6,80E-02	7,00E-16	4,76E-17
kg reservebase-1	Coal, MJ-1	Non-elementary	9,92E-03	7,00E-16	6,94E-18
	Copper ore (0,35 % Cu)	Resource	4,17E-09	1,03E-14	4,30E-23
	Cr	Non-elementary	2,05E-01	1,68E-12	3,44E-13
	Crude oil, feedstock	Resource	1,41E-08	8,09E-15	1,14E-22
	Crude oil	Resource	2,56E+00	8,09E-15	2,07E-14
	Fe	Resource	1,03E-07	1,32E-14	1,36E-21
	Hard coal, feedstock	Resource	8,64E-02	7,00E-16	6,05E-17
	Hard Coal	Resource	6,43E-01	7,00E-16	4,50E-16
	Iron ore	Resource	1,56E-01	4,35E-15	6,79E-16
	Iron	Non-elementary	6,71E-08	1,32E-14	8,86E-22
	LPG	Resource	2,24E-08	9,15E-15	2,05E-22
	Natural gas	Resource	5,23E-01	9,15E-15	4,79E-15
	Peat	Resource	1,81E-08	7,00E-16	1,27E-23
	Uranium (as pure U)	Resource	5,57E-04	5,96E-10	3,32E-13
Total:					**7,04E-13**

Chromium (Cr) is the substance that gives the major contribution to the resource depletion category. Cr is used as an alloy in the production of bearing steel and is therefore used in the steel mill at Ovako Steel in Hofors.

The uranium (U) used within this life cycle is completely consumed by the production of electricity in the nuclear power plants where it is used as fuel.

Crude oil is used primary to produce electricity, or at least that is what is included in this study. It is obvious that crude oil is also needed to produce many of the greases and oils used within the production and manufacturing of the bearing. The production of these is however not included here.

The production of natural gas is the main consumer of natural gas.

The production of steel powder, and thereby the production of the guide ring is based on virgin iron while the rings and rollers are produced from scrap. This makes the guide ring the only component who needs iron ore. It would be different if the scrap was traced to the cradle and if allocations would have been made between the use of scrap and the use of virgin iron.

8.1.7.1 Discussion

It was decided to include also substances that are so called non-elementary, i.e. not traced back to the cradle, in the category for resource depletion. It is reasonable to assume that if they where traced back to the cradle the environmental impact would be greater than what is expressed here.

Since the rings consume most of the bearing steel produced as well as they consume more energy (electricity and natural gas) then the other components they are affecting resource depletion more then the others.

9 Different Allocation Methods Used within the D-factory at SKF in Göteborg

The turning, grinding and honing of the bearing rings as well as the assembly of the bearing takes place at the SKF D-factory in Göteborg, Sweden. In the factory three different divisions are located: SRB medium, LSB (Large Size Bearings) and SRB component. SRB component is producing the rollers and cages for the SRB's. Some of the production at SRB component takes place at the D-factory while most of the production is located in other factories within the SKF industrial area in Göteborg. This is the case for the rollers and cages for the SRB 24024.

Since not all of the production in the D-factory is included in the life cycle of the SRB 24024 the total environmental load from the factory has to be partitioned to represent only the part included in the process tree of the studied bearing.

Interviews with key persons working within the D-factory indicates that SRB medium may be held responsible for 70 % of the consumption of supply material, such as hydraulic oil, and of the production of waste. SRB medium is covering a specific dimensional interval and the bearings are manufactured in different product lines. SRB 24024 is produced in channel 4. To be able to allocate the environmental loads to one produced SRB 24024, the total environmental load from the SRB medium has to be further allocated; this can be done in different ways. In this chapter three different allocation methods are investigated and the results they give are compared. The methods are all highly uncertain. The dimension range within channel 4 is small and therefore further partitioning has been based on number of produced bearings

Allocation according to weight or size may be other method applicable to this allocation problem. These methods are not investigated in this study.

9.1 Allocation according to the existing distribution key

To be able to allocate the cost for supply material as well as for waste treatment and energy consumption a distribution key was developed by the company. Although many key-persons have been interviewed no one has been able to make clear the bases for the key nor have they been able to tell when the key was developed. Nevertheless this distribution key is used within SRB medium today.

The key allocates 11.62 % of the supply material and waste treatment to the product channel 4 where SRB 24024 is manufactured.

Since no further information about the distribution key has been found, allocation on this basis is highly uncertain. But still, it is the method used at SKF today.

9.2 Allocation according to the economic value of SRB 24024

The bearings produced in the D-factory at SKF in Göteborg cover a wide range both concerning size and applications. Some of the SRB types are produced in large scale while some are produced according to customer requirements. The large spectrum of bearings implies a wide cost range and therefore also a wide price range.

It intuitively sounds reasonable that each of the bearing types should carry it's own costs. There are however numerous parameters that influence the final price of the bearing, some of them are presented in the table below.

Table 26: Some of the parameters that influence the cost for production and thereby also the final price of a bearing.

Parameters that will keep the price down:	Parameters that will higher the price:
• Large scale production • Commonly used and/or inexpensive raw material and/or components • Few and/or non-complicated production operations	• Produced only according to customer orders • Expensive and/or uncommon raw material and/or components • Many and/or complicated production operations

Large-scale production implies effectiveness in the processes. Commonly used raw material implies that the raw material acquisition is effective, the fewer the operations the less energy consumption and less waste. These are of course not facts but assumptions based on reasoning.

According to this allocation based on economic value (or price) might seem as a fair way of allocating the environmental load of the bearing. This is however not always true. For example, what is normally considered as a low cost material may turn into an expensive one if the use is small.

Sometimes a part of the cost of the more expensive products is allocated to the less expensive products that are sold in large scale. This means, that in contrary to what have been said before, the products will not carry there own cost, some will carry a larger portion and some will carry a smaller one. Another aspect of allocation according to economic value is that the value may not stay the same over time. The cost of different raw material may change as well as the demand for the products, which in turn may alter the production and therefore also the cost relations between different product groups.

The SRB 24024 is a common bearing type, produced in large scale. Whether it is carrying it's own cost or in fact more or for that matter less has not been possible to investigate within the time limits of this thesis. Allocation according to economic value of the bearing may therefore be considered as a very uncertain method for assessing the environmental load that the bearing can be held responsible for.

The economic value for the total production at SRB Medium located in the D-factory was in 1998 almost 254 million SEK and the value of one SRB 24024 was 661 SEK.

There is also another way of looking at and treat economic allocation. If a product stands for a large portion of the company's turnover it might be considered reasonable that it also should stand for an equally large portion of the company's environmental load. Whether or not this is a good allocation method will not be further investigated here.

9.3 Allocation according to the number of produced SRB 24024

A third way of dealing with a process in which many different products are produced is to allocate according to the number of produced products. This may be considered a method suited for a production where the product range is not too wide since it will address the same environmental load to each and one of the products produced. Whether the product range is too wide or not is however highly subjective and most of the times even other parameters influences the environmental load of the product. The difference between the products, how small and insignificant it may seem, may be significant for the environmental load caused by the product. For this method, to be reliable and fair, a good knowledge is needed, not only for the product studied but also of the other products and the way they are produced.

Within SRB medium the size range is fairly small, the bearings are produced in similar processes but the specific differences between them have not been studied explicitly in this study and therefore allocation according to number of produced products have to be highly uncertain.

In 1998 the production at SRB Medium, within the D-factory, was 341 460 bearings.

9.4 Comparison between the different allocation methods

When the inventory results for the processes in the D-factory, allocated in the three different ways, are compared one can see that they differ significantly. The allocation according to the existing distribution key is by far the method giving the lowest values. The results from the allocation based on economic value gives 2.42 times higher values while the allocation method based on number of produced products gives values that are 2.73 times higher.

Table 27: Presentation of the different allocation methods used in the D-factory and the difference between them.

Allocation method:	Relative to the distribution key:
Distribution key	100 %
Economic value in 1998	242 %
Number of produced products in 1998	273 %

These results show why the choice of allocation method is so vital in life cycle inventory and life cycle assessment. In this study the allocation according to the existing distribution key has been used. This decision is based on the fact that this is what SKF uses today. It is impossible, within the limits of this study, to investigate if this is the best method or if any of the other methods is more suitable. All of the allocation methods investigated here are highly uncertain.

10 Case Study

This case study is based on the use of spherical roller bearing of type 24024 at the Avesta-Sheffield plant for continuous casting located in Degerfors. The background for choosing this particular application is that this is a common application for this bearing type and that Avesta-Sheffield is one of SKF's important customers.

A visit to the plant of interest has been made and interviews with the Production Superintendent Maintenance have been performed both at the visit and by phone and e-mail.

10.1 Avesta-Sheffield AB

Avesta-Sheffield's plant in Degerfors, Sweden employs 730 people and the main products are stainless steel sheets and billets for stainless steel bars. The steel is melted in an electric arc furnace, continuous cast and rolled in the rolling mill.

10.1.1 Continuous casting

Continuous casting is a method of pouring steel directly from the furnace into a billet, bloom, or slab directly from its molten form. This avoids the need for large, expensive mills for rolling ingots into billets. Continuous cast billets also solidify in a few minutes versus several hours for an ingot. Because of this, the chemical composition and mechanical properties are more uniform.

Steel from the electric arc furnace is poured into a shallow vessel, the so-called tundish, at the top of the continuous caster. As steel carefully flows from the tundish down into the water-cooled copper mould of the caster, it solidifies into a ribbon of red-hot steel. At the bottom of the caster, torches cut the continuously flowing steel to form billets, slabs or blooms.

10.2 Use at Avesta-Sheffield

In the caster about 1100 bearings of different types are used but the SRB 24024 is used in pairs at four different places along the conveyor belt in gear drives in rolls. The gear drives are very important parts of the rolls since it is the gear drives that make the rolls move and thereby also the conveyor belt that transports the billets.

In each roll there are two SRB 24024 and two split bearings. The split bearings are more sensitive then the SRB 24024 and since they are placed in the centre of the rolls they are directly under the cast steel and thereby exposed to more extreme conditions, especially heat, then the SRB 24024. The tremendously hot environment demand that the split bearings are water-cooled and the easiest way to do this is to water cool the whole roll and thereby also the SRB 24024.

The environment is not only hot but also very dirty. Grease is pumped through the bearings to remove particles that could damage the bearing and of course function as lubrication. When the grease has gone through the bearing it has been mixed with the cooling water. The greasy water is cleaned in six sand filters and then treated in a grease separator. The grease is collected in containers and transported to destruction, in this particular case, incineration. The amount of grease sent to destruction is about 3 tons every year, for the whole plant. There is also an excessive part that goes of as steam during the process of continuous casting. Avesta-Sheffield are not obliged to measure the grease content in the steam let out into the air from the continuous casting plant and therefore it is not possible to get data for the amounts. The use of grease is about 20 kilos per bearing and year.

The bearings are changed every 1,5-3 years because the split bearings have to be changed. The SRB 24024 are normally not damaged but it is customary to change all the bearings in one roll at the same time since a stop in the production is very costly. When the bearings have been removed they are melted at the same plant and recycling is thereby 100 %.

11 Conclusions

In this chapter the parameters and processes of importance are discussed, future potentials for LCA within SKF is investigated as well as suggestions for further work concerning data documentation.

11.1 Parameters and Processes of Importance

11.1.1 Air emissions

It is important to notice that air emissions are not included in all data sets and in some they are insufficient. The discussion below is based on the air emissions reported during the life cycle inventory.

11.1.1.1 CH_4

Air emissions of methane (CH_4) contribute to global warming and photochemical oxidant creation. The component contributing most to the emission of methane to air is the rings, see Figure 4. Within process chain of the rings, the production of electricity causes the largest emissions of methane.

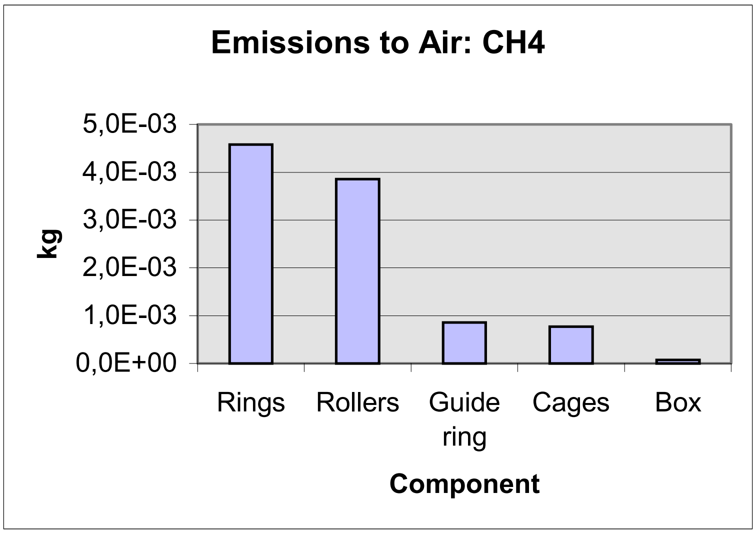

Figure 4: Emissions of methane (CH_4) to air contributes to global warming and photochemical oxidant creation. The diagram presents a comparison of the emissions for each component.

11.1.1.2 CO

Emissions of carbon monoxide (CO) to air will contribute to global warming, human toxicity and photochemical oxidant creation. The emission of carbon monoxide in this study originates mainly from the production of surface removed wire at Ovako Steel in Hällefors, which is a process in the process chain of the rollers, see Figure 5. When the wire is soft annealed a mixture of methane and nitrogen gas is kept in the electric furnace as a protective atmosphere to prevent oxide formation, and this causes the formation of CO. The heat treatment of the rings in Göteborg is also a considerable contributor to the emissions of carbon monoxide.

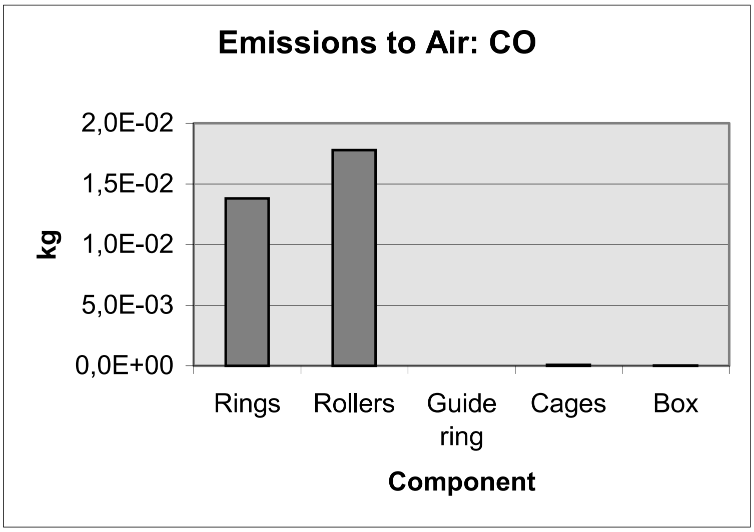

Figure 5: Emissions of carbon monoxide (CO) to air contributes to global warming, human toxicity and photochemical oxidant creation. The diagram presents a comparison of the emissions for each component.

11.1.1.3 CO_2

Air emissions of carbon dioxide (CO_2) contribute to global warming. The component responsible for emitting the largest amount of carbon dioxide is the rings, see Figure 6, and the activity with the largest emissions is the electricity production, which in turn includes combustion of fossil fuel.

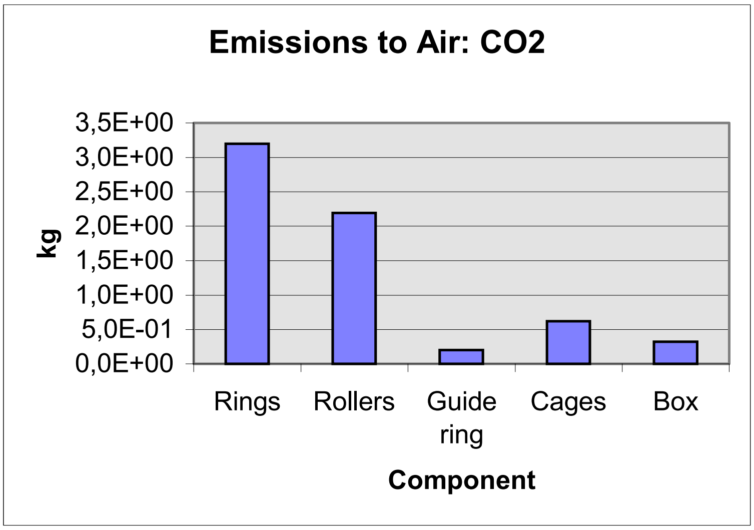

Figure 6: Emissions of carbon dioxide (CO_2) to air contributes to global warming. The diagram presents a comparison of the emissions for each component.

11.1.1.4 NMVOC

Emissions of non-methane volatile organic compounds (NMVOC) to air contribute to the photochemical oxidant creation. The emissions originate, within this study, mostly from the production of energy carriers. The component making the largest contribution is the rings, see Figure 7 and the main source is the production of liquefied petroleum gas (LPG). The LPG is used in the activities for hot rolled square billets and hot rolled bars as a fuel in the furnaces used to heat the material before rolling.

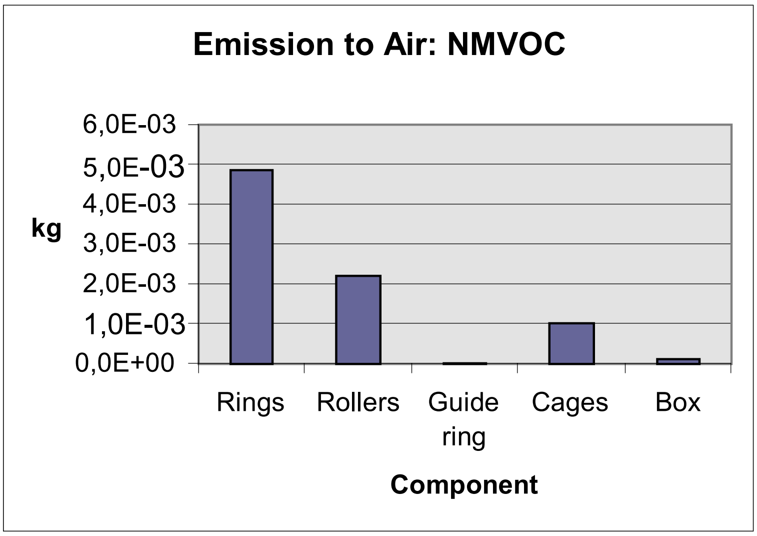

Figure 7: Emissions of non-methane volatile organic compounds (NMVOC) to air contribute to the photochemical oxidant creation. The diagram presents a comparison of the emissions for each component.

11.1.1.5 NO_x

The emissions of NO_x to air contribute to acidification, eutrophication, global warming and human toxicity. Within this study the emissions originate mostly from the production of electricity, which in turn includes combustion of fossil fuel. The rings are the components responsible for the highest emissions, see Figure 8.

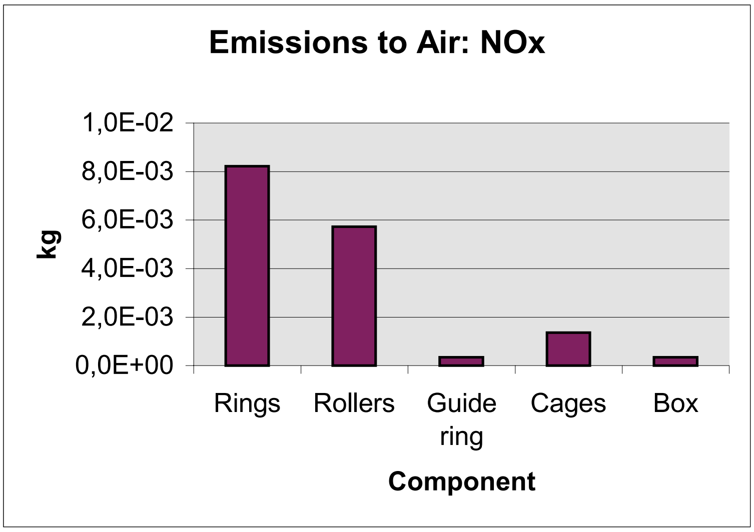

Figure 8: Emissions of nitrous oxides (NO_x) to air contribute to acidification, eutrophication, global warming and human toxicity. The diagram presents a comparison of the emissions for each component.

11.1.1.6 Particulates

The production of district heating causes emissions of particulates. Within the production chain of the rings quite large amounts of district heat are used thereby making the rings the component responsible for the largest emissions of particulates, see Figure 9.

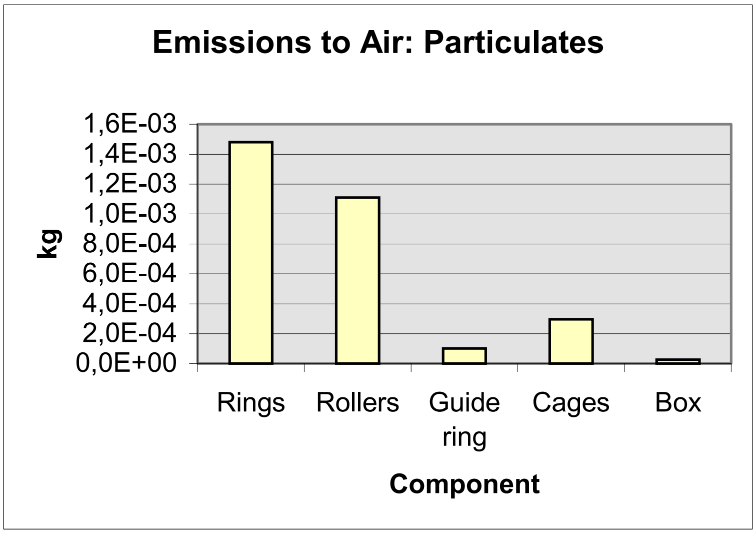

Figure 9: The diagram presents the emissions of particulates to air for each component.

11.1.1.7 SO_2

Air emissions of sulphur dioxide contribute to acidification and human toxicity and again the rings are responsible for the largest emissions, see Figure 10. This is caused by the production of liquefied petroleum gas (LPG). The LPG is used in the activities for hot rolled square billets and hot rolled bars as a fuel in the furnaces used to heat the material before rolling.

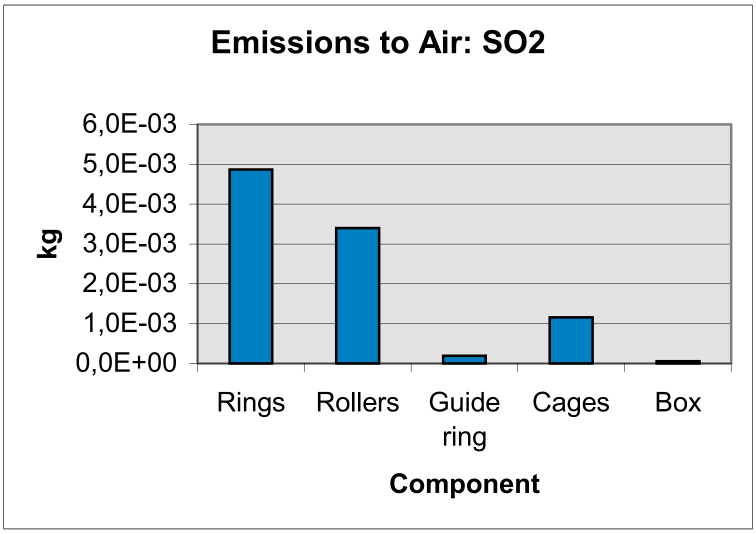

Figure 10: Emissions of sulphur dioxide (SO_2) to air contribute to acidification and human toxicity, comparison between the components. The diagram presents a comparison of the emissions for each component.

11.1.2 Waste

Wastes have been reported both as elementary (no further treatment necessary) and non-elementary (further treatment necessary). Most of the waste reported needs further treatment and are therefore sorted under the non-elementary waste category.

11.1.2.1 Elementary waste

The production of electricity causes the most elementary waste. Exactly what this is caused by is hard to say since the most of this non-elementary waste has been inventoried as "other waste". The component making the largest contribution is the rings.

11.1.2.2 Non-elementary waste

The non-elementary waste is by far the largest waste category. Here everything is included no matter what waste treatment is needed. The production of the rollers is the largest contributor but it should be noted that almost all of this waste is wastewater that has been used for washing the wire after phosphatising. This wastewater is sent to SAKAB for destruction.

11.1.3 Comparison between the components

11.1.3.1 Rings

Looking at the results presented above it is easily seen that the rings are dominating most of the categories. One of the reasons for this is that the process chain for the rings includes many operations. For example the material is heated and reheated several times and the rings are rolled and machined i.e. turned, ground etc. in several steps. All of these processes are very energy consuming.

The rings are also the component having the largest weight and volume thus requiring more material then any of the other components. This makes the contribution from the steel mill larger as well as it influences the energy consumption during heating.

11.1.3.2 Rollers

The rollers have the most non-elementary waste. It is more then fifteen times higher then the rings. Almost all of it is wastewater from the phosphatising of the surface removed wire. This water has such high values of phosphates and other chemicals that it has to be sent to SAKAB for further processing. Since it needs waste-treatment it is sorted under the non-elementary waste category.

When it comes to energy carriers the rollers are the main consumer of district heat and the only consumer of hot water. This is mainly because many of the processes within the rollers process chain are performed with the material in room temperature, that is without heating the material, and thereby the buildings are not heated by heat lost in the processes but must instead be separately heated. At SKF in Göteborg this is done with district heat, at Ovako Steel in Hällefors hot water is used. The difference between the two can be discussed but the hot water is supposed to have a higher temperature then the district heat.

11.1.3.3 Cages

The cages have the largest consumption of unspecified fuel oil and diesel. The unspecified fuel oil is used at SSAB Tunnplåt in Borlänge. In this study it is referred to as unspecified because information on which fuel oil is used has been unavailable. Looking at the other activities it could be reasonable to believe light fuel oil is used.

The cages are also the main users of diesel. The diesel is consumed at Dickson Plåt Service Center in Göteborg and supplies internal transports. Internal transports are not accounted for in all activities. Sometimes they are included and sometimes excluded but mainly for one and the same reason. There are allocation difficulties arising when dealing with internal transports. Most of the time the transports are common for the whole production site and it is difficult to sort out what means of transportation is used and what distances when is comes to a specific product. At SKF in Göteborg this is the case. The transports are all carried out by electric industry trucks but these trucks run between the factories and when they need to be charged this is done at the factory where they currently are. The internal transports are therefore included in the electricity bill for the factory and an obvious allocation problem arises. This allocation has not been performed in this study.

11.1.3.4 Guide ring

The guide ring is not the main contributor to any of the categories mentioned here. The fact that the guide ring does not contribute to the different categories in the same extent as the other components is due to that it is light and small. It does not need the same amount of material and the production processes are few.

When looking in the table for the air emissions it might look like the production of steel powder is a large emitter of the substances accounted for here. This is not completely true since the activity of steel powder production is a cradle to gate activity and thereby includes all upstream activities. It has however not been possible to separate this due to Höganäs AB's secrecy policy. [Edlund K. Höganäs AB]

11.1.3.5 Corrugated board box

The data constituting the process chain for the corrugated board box is all average data for production in Europe and it is hard to draw any conclusions from it. The corrugated board box is the only "component" using heavy fuel oil and coal. This is most probably because the data are average for Europe where the use of heavy fuel oil and coal is more common.

11.1.3.6 Discussion

It is not surprising to see that the rings are the component contributing the most to the air emissions. It is important to remember that the data on air emissions are not satisfactory in all activities and would give other results if they were more complete. It is reasonable to believe that the rings would stand for the largest contribution anyway but the amount of the different substances would be substantially higher for all components.

The major sources of air emissions in this study are the production of the energy carriers: electricity, district heat and heavy fuel oil. The reason for this is again that air emissions sometimes are poorly accounted for in the other activities and of course that the production processes the studied product acquires are very energy demanding.

The energy consumption varies quite much between the components. The consumption of energy carriers for each of the components is presented in Figure 11, primary energy carriers, and Figure 12, secondary energy carriers.

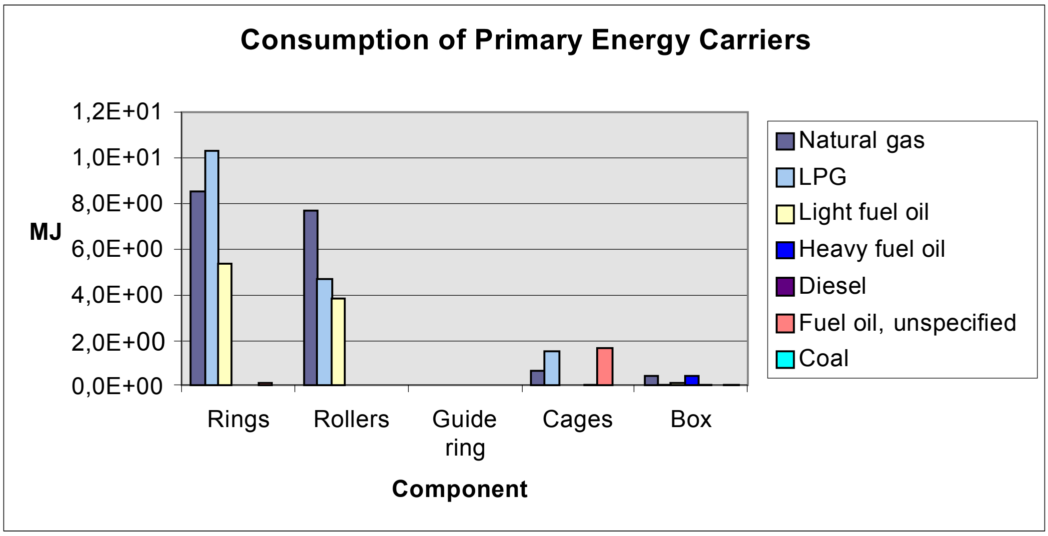

Figure 11: Diagram over the consumption of primary energy carriers within the bearing life cycle.

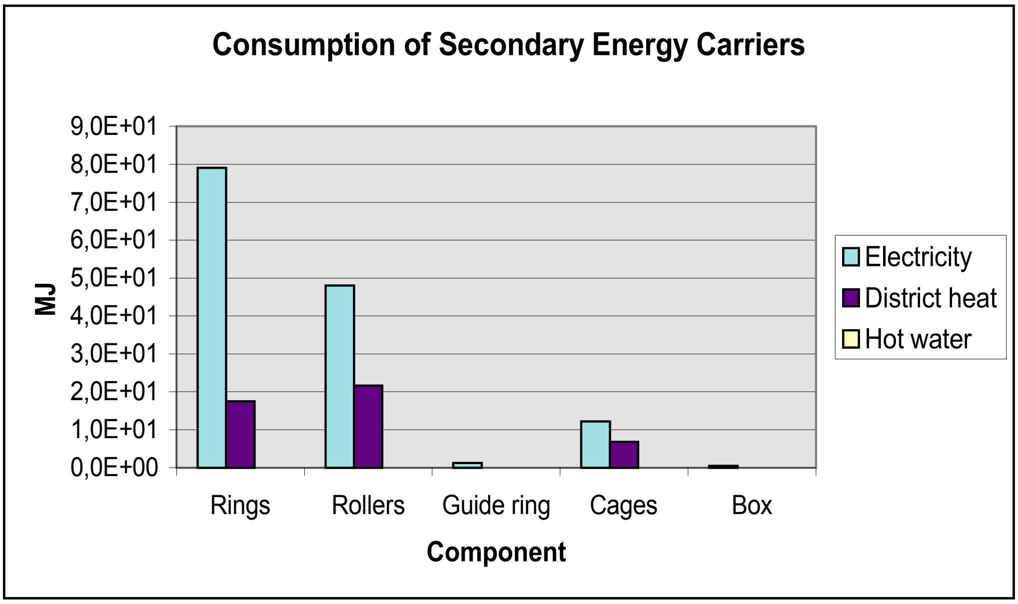

Figure 12: Diagram over the consumption of secondary energy carriers within the bearing life cycle.

It should also be noted that the contribution to the air emissions from transportation does not show at all here. The transports make a substantial contribution but since electric trains are used for the main part the emissions are not that high even though the goods transported is heavy and the amount of loaded goods on the trains and trucks used are limited by weight.

12 Potential Use of LCA within SKF

In this section the potential use of LCA studies within SKF is investigated and suggestions for further studies are given.

12.1 Mapping

One of the applications for LCA is learning, in many different aspects; both about the manufacturers own processes and the rest of the processes in the flowchart for the product studied. Depending of the level of detail of the system studied the mapping will fulfil different purposes. On a not too detailed level, like in this study, the mapping will give a view of where the raw material for each component is produced and where the processing takes place as well as the transportation between the industrial plants and where the major environmental load is generated.

Generally the producer has a good view of his suppliers but knows almost nothing of the supplier's suppliers. This knowledge could be useful and it can be achieved through an LCA study. One way of make use of this knowledge is when process changes are to be made to accomplish more environmental friendly products or processes. It is important to make sure that a change in one end of the process chain does not influence the performance of another process in a negative way. This is explored further in the following section, section 12.2.

12.2 Product and process development

An LCA-study gives a good view of the production system and the main purpose of the study may be to define the "hot spots" within the production. This can be the main purpose of the study or it can be a positive side effect. Depending on whether the goal is to locate the "hot spots" within the whole process chain or within the own production the level of detail of the study may vary a lot.

One method could be to perform a gate-to-gate LCA that only concerns with the own production plant. To give a good base for improvements the study needs to be detailed. This kind of LCA might very well give the "hot spots" within the production but the environmental improvements at the plant studied may not result in an all over environmental improvement. For example, if a process is excluded from the site in order to lower the environmental load it might imply that the process has to be carried out somewhere else. This could be a good decision for the plant in focus but it might be negative for the environmental load of the product. This of course depends on a lot of different factors, among them the appearance of the rest of the life cycle.

If the study instead is performed as an LCA from cradle-to-gate it might be difficult to identify “hot spots” in one of the included activities since the level of detail of each activity may not be very high. Instead it can be possible to identify the “hot spots” of the whole life cycle, and the environmental improvements may be made on a more general level.

Through the use of LCA it is possible to sort out what is to be considered small and/or large when it comes to environmental load. This can be considered in separate activities or in the process tree as a whole. The major contributors may be studied further but it is important not to overlook the not so big contributors. It’s important to remember that in the long run even small contributions can add up to a large quantity.

12.3 Marketing

12.3.1 Environmental product declaration (EPD)

Customers on all levels in today’s society are becoming more and more interested in the environmental performance of the products they use. This applies to private persons as well as to international companies. In turn this requires that the producers declare the environmental performance of their products. This could be done through certified environmental product declarations.

The certified environmental product declaration is based on the coming ISO14025 standard that is concerned with the so-called type III declaration. The system for EPD is national but efforts are made for the different national systems to work together. The system does not include any valuations or predetermined demands that have to be fulfilled and is open for all kinds of products and services.

The base for a certified environmental product declaration is an LCA. Such an LCA should answer the question: What can this product be held responsible for? Since one of the main purposes of EPDs is for interested parties to be able to compare products, which carry out the same function, with each other the LCA must be comparable. This is achieved through the definition of product specific rules (PSR). The rules define how the LCA should be carried out and are defined by the producing companies. For example if an EPD is to be done for a car all the interested car producing companies take part of the defining of the product specific rules. The PSR should deal with system boundaries, functional unit, allocation methods etc. In the case where the producer is alone on the market, like the case for SKF in Sweden, the PSR should be decided on in dialogue with other interested parties such as customers, suppliers etc.

When the EPD has been certified by a third party it is published on the Internet and thereby official and also available for everyone interested. The EPD is composed of three parts:

1. Description of the manufacturer/importer and the product or service
2. Presentation of environmental properties
3. Information from the company and certifying authority

The producer has the possibility to update the EPD continuously, for example when processes are changed. [Miljöstyrningsrådet, 1998]

12.3.2 Customer demands

The increasing use of LCA also increases the demand for accurate LCA data. The ability to supply LCA practitioners with site-specific data implies the possibility to influence the way the environmental properties of the produced product are described. The LCA practitioners can be research institutes or other manufacturers.

If the LCA practitioner is another manufacturing company the results from an LCA may be a part of another LCA being performed at that company e.g. the results from an LCA on a bearing may be a part of an LCA performed on a car. This has been the case in this study. Höganäs AB has done an LCA on the steel powder used to manufacture the guide ring and the results from that study has been used as input data in this study.

If data acquired for one specific LCA is documented and stored in a non-aggregated manner the data can easily be updated and reused in other studies and for other products. This facilitates future work on LCA and will lower the cost for the study since the data acquisition is the most costly phase of the LCA.

12.4 Thoughts on information and routines at SKF Göteborg

12.4.1 Data documentation

12.4.1.1 SPINE

All data gathered within the work of this thesis have been documented according to SPINE documentation criteria. The software SPINE DataTool developed by CPM at Chalmers University of Technology has been used for documentation. This ensures that the data is sufficiently documented to be reused within future LCA studies at SKF.

12.4.1.2 Earlier LCA studies conducted at SKF

There have been earlier LCA studies conducted at SKF. The data sets from these studies have not however been saved in a common database or in any specified format. This implies that the data are not easily reused.

The LCA studies performed earlier at SKF have been conducted by persons not working permanently within the SKF organisation. This complicates the matter even further since interviews with the LCA practitioner are practical ways of filling data gaps.

12.4.1.3 Distribution key

One of the allocation methods used within the D-factory at SKF in Göteborg had been based on an existing distribution key. This is the distribution key used today to allocate waste, energy and supply material within the factory.
Even though the key is used today no one has been able to give any information on how it was developed or when. This makes the key extremely uncertain. A better documentation on the principles for the distribution key would make allocation easier thereby making the assessment of environmental load in connection with the specific product more accurate.

12.5 Further studies

12.5.1 Life cycle inventory

In this study the completeness of the data is not always satisfying. Some of the activities are poorly inventoried especially when it comes to air and water emissions. The assessment of environmental load caused by the bearing would be more fair if the inventory would be more detailed.

12.5.2 Improvement assessment

This thesis aimed at investigating the environmental properties of the SRB 24024. The level of detail was not sufficiently high to make any improvement suggestions. A future study can use this study as a base and then go deeper into the activities of special interest in order to supply data and suggestions for environmental improvements.

12.5.3 Comparison

A very interesting and natural continuing on this study is to do a comparative study on a competitive product. This could for example be done on a sealed SRB 24024. It would be fairly easy since the only data needed would be for the seal and for the specific grease needed in each case respectively. The use phase would also have to be treated.

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September, 1999
For data documentation and the software SPINE Datatool

http://www.ntm.a.se/
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On information on steel processes

13.3 Additional material

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Microsoft "AutoRoute Express Europe 2000"

13.4 Interviews

Name:	Company:	Telephone:	E-mail:
Andersson Göran	SSAB Tunnplåt AB	+46-243-700 00	goran.s.andersson@ssab.com
Andersson Ulf	SKF Sverige AB	+46-31-337 10 00	ulf.andersson@skf.com
Ardevall Tomas	SKF Sverige AB	+46-31-337 10 00	tomas.ardevall@skf.com
Arvidsson Eva-Maria	Ovako Steel AB	+46-290-250 00	eva-maria.arvidsson@skf.com
Bengtsson Ove	Ovako Steel AB	+46-591-600 00	ove.bengtsson@skf.com
Edlund Katarina	Höganäs AB	+46-42-33 80 00	katarina.edlund@hoganas.com
Eltebo Jenny	SJ Cargo		jenny.eltebo@g.sj.se

Göthe Dick	SKF Sverige AB	+46-31-337 10 00	dick.gothe@skf.com
Hamilton Urban	Ovako La Foulerie	+33-324 29 87 87	urban.hamilton@skf.com
Janco Lino	SKF Sverige AB	+46-31-337 10 00	lino.janco@skf.com
Kreij Per	Ovako Steel AB	+46-290-250 00	per.kreij@skf.com
Larsson Lars-Gunnar	Ovako Steel AB	+46-290-250 00	lars-gunnar.larsson@skf.com
Larsson Per	Ovako Steel AB	+46-591-60 000	per.k.larsson@skf.com
Lindgren Åke	A-förpackningar	+46-31-721 22 21	ake.lindgren@westpack.se
Lindhe Bo	SKF Mekan AB	+46-150-740 00	bo.lindhe@skf.com
Meglic Marie	Nordisk Transport Rail (NTR)	+46-410-54000	marie.meglic@ntr.se
Mimer-Carpentier Maria	Ovako La Foulerie	+33-324 29 87 87	maria.mimer@skf.com
Rösselhart Kjell	Dickson Plåt Service Center AB	+46-31-43 01 00	
Stenberg Bengt-Olov	Ovako Steel AB	+46-591-600 00	bengt-olov.stenberg@skf.com
Stüffe Ola	Ovako Steel AB	+46-290-250 00	ola.stuffe@skf.com
Sundqvist Mikael	SKF Sverige AB	+46-031-337 10 00	mikael.sundkvist@skf.com
Widheden Johan	CIT Ekologik	+46-31-772 10 00	johan.widheden@cit.chalmers.se
Öhrn Lars-Göran	Avesta-Sheffield AB	+46-586-470 00	lars.goran.ohrn@avestasheffield.com

Appendix

1 Inventory Data Sets for Each Activity

The inventory data presented below are here presented for the study's functional unit. For each activity a functional unit is presented, this is the functional unit used within that specific activity during the life cycle inventory.

1.1 Rings

1.1.1 Production of bearing steel

Production site:	Ovako Steel AB 813 82 HOFORS SWEDEN Tel: +46-290-25000
Product:	Bearing steel ingot
Year data are based on:	1998
Functional unit:	One ton of bearing steel ingot
Raw material:	Scrap
Allocation method(s):	Weight
Reference(s)/contact person:	Ola Stüffe E-mail: ola.stuffe@skf.com Tel: +46-290-25000
Additional information:	The steel used for SRB 24024 is SKF 3 or 100Cr6. This is the most common steel grade at Ovako Steel but this data set is for average steel produced at Ovako Steel in Hofors. Emissions to water are not included due to allocation difficulties.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Aluminium	1,71E-02	kg
	Anthracite	1,89E-01	kg
	Brick	1,14E-01	kg
	Carbon black	2,29E-03	kg
	Carbon, graphite	6,74E-02	kg
	Chromium	2,05E-01	kg
	Electricity	2,49E+07	J
	Ingot mould	1,48E-01	kg
	Light fuel oil	3,35E+05	J
	Limestone	5,12E-01	kg
	Magnesite	5,07E-02	kg
	Municipal water	1,48E+00	kg
	Natural sand	4,83E-02	kg
	O2	5,86E-01	kg
	Olivine	1,09E-01	kg
	Silicon	6,31E-02	kg
	Steam	5,53E-01	kg
	Steel scrap	1,44E+01	kg
Emissions to air	Chlorinated benzenes	5,93E-07	kg
	Chlorinated phenols	1,62E-07	kg
	CO	5,10E-03	kg
	CO2	9,44E-01	kg
	Dioxin	3,37E-11	kg
	Hg	2,78E-07	kg
	NOx	2,00E-03	kg
	SO2	3,19E-05	kg
Non-elementary outputs: Waste	Brick	1,14E-01	kg
	Dust	2,46E-01	kg
	Ingot mould	1,48E-01	kg
	Magnesite	5,07E-02	kg
	Olivine	1,09E-01	kg
	Slag	2,70E-02	kg
	Steel scrap	4,18E-01	kg
Other - Inputs	Surface water	4,54E+02	kg
Other - Outputs	Waste water	4,56E+02	kg

1.1.2 Production of hot rolled square billets, 150 mm

Production site:	Ovako Steel AB 813 82 HOFORS SWEDEN Tel: +46-290-25000
Product:	Square billet 150 mm
Year data are based on:	1998
Functional unit:	One ton of square billets 150 mm
Raw material:	Steel ingot
Allocation method(s):	Weight
Reference(s)/contact person:	Lars-Gunnar Larsson E-mail: lars-gunnar.larsson@skf.com Tel: +46-290-25000
Additional information:	Emissions to water are not included due to allocation difficulties.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Brick	1,55E-03	kg
	Dolomite	2,81E-04	kg
	Electricity	2,25E+06	J
	Grease	5,11E-04	kg
	Hydraulic oil	5,70E-04	kg
	Light fuel oil	7,41E+06	J
	LPG	1,45E+06	J
	Municipal water	1,32E+00	kg
	N2	1,14E-04	kg
	O2	3,78E-01	kg
	Polymers	4,92E-08	m3
Emissions to air	CO2	1,43E-01	kg
	NOx	1,69E-03	kg
	SO2	5,07E-04	kg
Non-elementary outputs: Waste	Brick	1,55E-03	kg
	Dolomite	2,81E-04	kg
	Oil	1,08E-03	kg
	Other rest products	2,71E-01	kg
	Slag	2,89E-01	kg
	Sludge	8,65E-02	kg
	Steel scrap	2,09E+00	kg

Other - Inputs	Surface water	1,92E+01	kg
Other - Outputs	Waste water	2,05E+01	kg

1.1.3 Billet treatment

Production site: Ovako Steel AB
713 80 HÄLLEFORS
SWEDEN
Tel: +46-591-60000

Product: Ground square billets 150 mm

Year data are based on: 1998

Functional unit: One ton of ground billet 150 mm

Raw material: Square billets 150 mm

Allocation method(s): Weight

Reference(s)/contact person: Per K Larsson
E-mail: per.k.larsson@skf.com
Tel: +46-290-25000

Additional information: Emissions to water are not known and therefore not reported.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Blasting grit	2,11E-03	kg
	Electricity	4,50E+05	J
	Hydraulic oil	1,39E-04	kg
	Light fuel oil	6,02E+05	J
	Magnetic powder	7,29E-04	kg
Emissions to air	NOx	4,04E-05	kg
	SO2	2,27E-05	kg
Elementary waste	Blasting grit	2,11E-03	kg
Non-elementary outputs: Waste	Hydraulic oil	1,39E-04	kg
	Steel scrap	5,67E-02	kg

1.1.4 Production of hot rolled of bars, 60 mm

Production site:	Ovako Steel AB 713 80 HÄLLEFORS SWEDEN Tel: +46-591-60000
Product:	Hot rolled round bars 60 mm
Year data are based on:	1998
Functional unit:	One ton of hot rolled round bars 60 mm
Raw material:	Square billets 150 mm
Allocation method(s):	Different dimensions go through different numbers of rolls. The rolls are estimated to have the same consumption of energy, other supply material as well as and the allocation has then been based on process time.
Reference(s)/contact person:	Ove Bengtsson E-mail: ove.bengtsson@skf.com Tel: +46-290-25000

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Cutting fluid	5,00E-05	kg
	Electricity	1,57E+06	J
	Hydraulic oil	5,35E-04	kg
	Hydrochloric acid	1,86E-05	kg
	Light fuel oil	1,48E+05	J
	LPG	4,02E+06	J
Emissions to air	CO	2,52E-05	kg
	CO2	2,63E-01	kg
	NOx	4,67E-04	kg
	SO2	4,35E-06	kg
	Soot	2,45E-07	kg
Emissions to water	BOD	8,11E-07	kg
	Cd	1,67E-11	kg
	COD	1,26E-05	kg
	Cr	7,98E-10	kg
	Cu	7,98E-10	kg
	Fe	1,80E-07	kg
	Mineral oil products	2,65E-07	kg

	Ni	1,73E-08	kg
	Pb	7,98E-10	kg
	Suspended solids	7,20E-07	kg
	Zn	1,86E-09	kg
Non-elementary outputs: Waste	Hazardous	4,84E-03	kg
	Hydrochloric acid	1,86E-05	kg
	Oxide scale	3,34E-02	kg
	Steel scrap	1,79E-01	kg
Other - Inputs	Surface water	3,00E-01	kg

1.1.5 Production of hot rolled bars, 70 mm

Production site: Ovako Steel AB
713 80 HÄLLEFORS
SWEDEN
Tel: +46-591-60000

Product: Hot rolled round bars 70 mm

Year data are based on: 1998

Functional unit: One ton of hot rolled round bars 70 mm

Raw material: Square billets 150 mm

Allocation method(s): Different dimensions go through different numbers of rolls. The rolls are estimated to have the same consumption of energy, other supply material as well as and the allocation has then been based on process time.

Reference(s)/contact person: Ove Bengtsson
E-mail: ove.bengtsson@skf.com
Tel: +46-290-25000

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Cutting fluid	6,73E-05	kg
	Electricity	2,13E+06	J
	Hydraulic oil	7,24E-04	kg
	Hydrochloric acid	2,53E-05	kg
	Light fuel oil	2,01E+05	J
	LPG	5,46E+06	J
Emissions to air	CO	3,44E-05	kg
	CO2	3,58E-01	kg
	NOx	6,20E-04	kg
	SO2	5,94E-06	kg
	Soot	3,32E-07	kg
Emissions to water	BOD	1,10E-06	kg
	Cd	2,28E-11	kg
	COD	1,71E-05	kg
	Cr	1,09E-09	kg
	Cu	1,09E-09	kg
	Fe	2,43E-07	kg
	Mineral oil products	3,60E-07	kg
	Ni	2,36E-08	kg
	Suspended solids	9,82E-07	kg
	Zn	2,53E-09	kg
Non-elementary outputs: Waste	Filter dust	1,12E-03	kg
	Hazardous	6,59E-03	kg
	Hydrochloric acid	2,66E-05	kg
	Oxide scale	4,43E-02	kg
	Steel scrap	2,07E-01	kg
Other - Inputs	Surface water	4,07E-01	kg
Other - Outputs	Pb	1,09E-09	kg

1.1.6 Production of the inner ring

Production site: Ovako La Foulerie S.A.
2 Rue de la Foulerie
08110 CARIGNAN
FRANCE
Tel: +33-324298787

Product: Inner bearing ring: IP-24024d / IL 24024d

Year data are based on: 1998

Functional unit: One ton of inner ring IL 24024d

Raw material: Hot rolled round bars 60 mm

Allocation method(s): Weight

Reference(s)/contact person: Urban Hamilton
E-mail: urban.hamilton@skf.com
Maria Mimer-Carpentier
E-mail: maria.mimer@skf.com
Tel: +46-290-25000

Additional Information: Emissions to air are not known and water emissions have been reported as mg/l but the water flux is not known. This is why neither air nor water emissions are included in the data set.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Electricity	1,43E+07	J
Non-elementary outputs: Waste	Hazardous	2,48E-02	kg
	Packaging waste	1,18E-02	kg
	Steel scrap	4,23E-01	kg
	Waste water	2,34E-02	kg

1.1.7 Production of the outer ring

Production site:	Ovako Steel AB 813 82 HOFORS SWEDEN Tel: +46-290-25000
Product:	Outer bearing ring OP-24024 CW 33
Year data are based on:	1998
Functional unit:	One ton of rings produced in ring mill 7
Raw material:	Hot rolled round bars 70 mm
Allocation method(s):	Weight
Reference(s)/contact person:	Per Kreij E-mail: per.kreij @skf.com Tel: +46-290-25000
Additional information:	Air and water emissions have been reported as not known. This is why they have not been included in the data set.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Blasting grit	1,23E-01	kg
	Electricity	9,83E+06	J
	Grease	5,50E-03	kg
	Hydraulic oil	6,73E-03	kg
	LDPE	1,22E-03	kg
Non-elementary outputs: Waste	Blasting grit	1,23E-03	kg
	Steel scrap	9,35E-01	kg

1.1.8 Heat treatment

Production site:	SKF Sverige AB 415 50 GÖTEBORG SWEDEN Tel: +46-31-3371000
Product:	Heat-treated bearing rings IP 24024 and OP 24024
Year data are based on:	1998
Functional unit:	One ton of heat-treated rings
Raw material:	Bearing rings IP 24024 and OP 24024
Allocation method(s):	Weight
Reference(s)/contact person:	Mikael Sundkvist E-mail: mikael.sundkvist@skf.com Tel: +46-31-3371000

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Electricity	1,03E+07	J
	Methanol	1,40E-02	kg
	N2	2,45E-01	kg
	Potassium nitrate	9,50E-03	kg
	Propane	2,11E-03	kg
	Sodium nitrite	9,50E-03	kg
Emissions to air	CO	1,01E-02	kg
	CO2	7,90E-04	kg
	H2	1,45E-03	kg
	N2	2,22E-01	kg
Emissions to water	Potassium nitrate	2,14E-03	kg
	Sodium nitrite	2,14E-03	kg
Other - Inputs	Surface water	2,14E+00	kg
Other - Outputs	Waste water	2,14E+00	kg

1.1.9 Assembly etc.

Production site:	SKF Sverige AB 415 50 GÖTEBORG SWEDEN Tel: +46-31-3371000
Product:	Spherical Roller Bearing (SRB) 24024
Year data are based on:	1998 (data on waste are based on 1996)
Functional unit:	One SRB 24024 packed in a corrugated board box
Raw material:	Bearing rings IP 24024 and OP 24024, 54 rollers RS 24024 C, 2 cages CP 24024 CJ2/VX 645, Guide ring RG 24024C/VX 201, Corrugated board box made of miniwell
Allocation method(s):	Existing distribution key
Reference(s)/contact person:	Patrik Lindroth E-mail: patrik.lindroth@skf.com Tel: +46-31-3371000
Additional information:	Emissions to air and water have not been included in the data set due to allocation difficulties.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Cutting fluid	1,92E-02	kg
	District heating	1,75E+07	J
	Electricity	2,52E+07	J
	Hydraulic oil	2,01E-02	kg
	Mineral oil products	3,69E-02	kg
	Natural gas	8,51E+06	J
Non-elementary outputs: Waste	Board	1,16E-02	kg
	Emulsion	5,00E-01	kg
	Grease	4,08E-04	kg
	Grinding dust	4,13E-01	kg
	Industrial	1,06E-01	kg
	Oil	7,81E-03	kg
	Other paper	9,91E-03	kg

	Steel scrap	2,14E+00	kg
	Waste water	1,66E-02	kg
	Wood products	1,99E-02	kg

1.2 Rollers

1.2.1 Production of wire rod, 14,50 mm

Production site: Ovako Steel AB
713 80 HÄLLEFORS
SWEDEN
Tel: +46-591-60000

Product: Hot rolled wire rod 14,50 mm

Year data are based on: 1998

Functional unit: One ton of hot rolled wire rod 14,50 mm

Raw material: Square billets 150 mm

Allocation method(s): Different dimensions go through different numbers of rolls. The rolls are estimated to have the same consumption of energy, other supply material as well as and the allocation has then been based on process time.

Reference(s)/contact person: Ove Bengtsson
E-mail: ove.bengtsson@skf.com
Tel: +46-290-25000

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Cutting fluid	5,01E-05	kg
	Electricity	1,59E+06	J
	Hydraulic oil	5,50E-04	kg
	Hydrochloric acid	1,88E-05	kg
	Light fuel oil	1,48E+05	J
	LPG	4,06E+06	J
Emissions to air	CO	2,55E-05	kg
	CO2	2,66E-01	kg
	NOx	4,83E-04	kg
	SO2	4,39E-06	kg

	Soot	2,48E-07	kg
Emissions to water	BOD	8,34E-07	kg
	Cd	1,69E-11	kg
	COD	1,27E-05	kg
	Cr	8,09E-10	kg
	Cu	8,09E-10	kg
	Fe	1,81E-07	kg
	Mineral oil products	2,70E-07	kg
	Ni	1,76E-08	kg
	Pb	8,09E-10	kg
	Suspended solids	7,51E-07	kg
	Zn	1,88E-09	kg
Non-elementary outputs: Waste	Hazardous	4,90E-03	kg
	Hydrochloric acid	1,88E-05	kg
	Oxide scale	3,38E-02	kg
	Steel scrap	1,08E-01	kg
Other - Inputs	Surface water	3,03E-01	kg

1.2.2 Production of surface removed wire, 13,50 mm

Production site:	Ovako Steel AB 713 80 HÄLLEFORS SWEDEN Tel: +46-591-60000
Product:	Surface removed wire 13,50 mm
Year data are based on:	1998
Functional unit:	One ton of surface removed wire 13,50 mm
Raw material:	Hot rolled wire rod 14,50 mm
Allocation method(s):	Weight
Reference(s)/contact person:	Bengt-Olov Stenberg E-mail: bengt-olov.stenberg@skf.com Tel: +46-591-60000
Additional information:	Emissions to water has been reported as not known.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Blasting grit	9,85E-03	kg
	Chemicals	2,78E-03	kg
	Cutting fluid	7,26E-04	kg
	Electricity	5,09E+06	J
	Hot water	5,85E+02	J
	Hydraulic oil	2,39E-04	kg
	Methanol	1,45E-02	kg
	N2	3,02E-01	kg
	Other paper	1,74E-04	kg
	Soap	2,02E-04	kg
	Sodium nitrite	2,89E-04	kg
	Surface water	1,73E+02	kg
Emissions to air	CH4	8,73E-04	kg
	CO	1,53E-02	kg
	CO2	2,40E-03	kg
	H2	2,19E-03	kg
	N2	2,58E-01	kg
	O2	1,75E-03	kg
Non-elementary outputs: Waste	Blasting grit	9,85E-03	kg
	Emulsion	1,00E-03	kg
	Sludge	3,27E-03	kg
	Steel scrap	3,20E-01	kg
	Waste paper	1,74E-04	kg
	Waste water	1,20E+02	kg
Other - Outputs	Waste water	5,36E+01	kg

1.2.3 Manufacturing of rollers

Production site:	SKF Sverige AB 415 50 GÖTEBORG SWEDEN Tel: +46-31-3371000
Product:	Roller RS-24024 C
Year data are based on:	1998 (data on waste are based on 1996)
Functional unit:	52 rollers RS-24024 C, 1,5288 kg
Raw material:	Surface removed wire 13,50 mm
Allocation method(s):	Weight

Reference(s)/contact person: Tomas Ardevall
E-mail: tomas.Ardevall@skf.com
Tel: +46-31-3371000

Additional information: Emissions to air and water are not included due to allocation difficulties.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Anticorrosive agent	1,48E-03	kg
	Blasting grit	5,94E-03	kg
	Cutting fluid	1,19E-03	kg
	Dissolvent	1,56E-02	kg
	District heating	2,17E+07	J
	Electricity	2,94E+07	J
	Hydraulic oil	7,28E-03	kg
	Natural gas	7,65E+06	J
	Trumbling chip	9,13E-02	kg
Non-elementary outputs: Waste	Emulsion	1,92E-01	kg
	Grinding dust	2,03E-01	kg
	Mineral oil products	2,44E-03	kg
	Other paper	9,30E-03	kg
	Other rest products	9,73E-02	kg
	Paper and board	1,07E-02	kg
	Sludge	1,81E-01	kg
	Steel scrap	8,55E-01	kg
	Trumbling chip	1,24E-01	kg
	Waste water	1,20E-01	kg
	Wood	1,83E-02	kg

1.3 Cages

1.3.1 Production of steel sheets

Production site: SSAB Tunnplåt AB
781 84 BORLÄNGE
SWEDEN
Tel: +46-243-70000

Product: Hot rolled steel sheet

Year data are based on: Published June 1999

Functional unit: One ton of hot rolled steel sheets

Raw material: Steel billets

Allocation method(s): Weight

Reference(s)/contact person: Göran Andersson
E-mail: goran.s.andersson@ssab.com
Tel: +46-243-70000

Additional Information: Data are taken from SSAB Tunnplåt's environmental product declaration (not certified) on hot rolled steel sheets. Data are average of their production of hot rolled steel sheets.

INVENTORY RESULTS	Substances:	Total:	Unit:
Non-elementary inputs	Electricity	6,00E+05	J
	Fuel oil, unspecified	1,61E+06	J
	LPG	1,31E+06	J
	Raw steel	1,70E+00	kg
	Recycled steel	4,25E-01	kg
Emissions to air	CO2	2,08E-01	kg
	NOx	3,52E-04	kg
	SO2	2,75E-04	kg
Emissions to water	Oil	1,46E-09	kg
	Suspended solids	8,33E-09	kg
Non-elementary outputs: Waste	Oxide scale	2,29E-03	kg
Non-elementary outputs: Co-products	Steam	5,25E+05	J

1.3.2 Pickling of hot rolled steel sheets

Production site:	SSAB Tunnplåt AB 781 84 BORLÄNGE SWEDEN Tel: +46-243-70000
Product:	Pickled hot rolled steel sheet
Year data are based on:	Published July 1999
Functional unit:	One ton of pickled hot rolled steel sheets
Raw material:	Hot rolled steel sheet
Allocation method(s):	Weight
Reference(s)/contact person:	Göran Andersson E-mail: goran.s.andersson@ssab.com Tel: +46-243-70000
Additional Information:	Data are taken from SSAB Tunnplåt's environmental product declaration (not certified) on pickled hot rolled steel sheets. Data are average of their production of hot rolled steel sheets.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Electricity	3,66E+04	J
	Hydrochloric acid	1,83E-03	kg
	LPG	1,46E+05	J
	Steel	2,08E+00	kg
Emissions to air	CO2	1,02E-02	kg
	NOx	1,22E-05	kg
Emissions to water	Fe	2,03E-07	kg
	Suspended solids	1,02E-06	kg
Non-elementary outputs: Waste	Iron oxide	1,02E-02	kg
	Sludge	2,03E-04	kg
	Steel scrap	4,07E-02	kg

1.3.3 Production of steel band

Production site:	Dickson Plåt Service Center Marieholmsgatan 90 415 02 GÖTEBORG SWEDEN Tel: +46-31-400160
Product:	Steel band 2,75*215,0
Year data are based on:	1998
Functional unit:	One ton of cut steel sheets
Raw material:	Pickled hot rolled steel sheets
Allocation method(s):	Weight
Reference(s)/contact person:	Kjell Rösselhart Tel: +46-31-400160
Additional Information:	Emissions to air and water are not known.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Diesel	3,60E+04	J
	Electricity	7,10E+01	J
	Steel	5,92E-04	kg
	Wood products	1,28E-02	kg
Non-elementary outputs: Waste	Steel scrap	5,92E-02	kg

1.3.4 Production of cages

Production site:	SKF Sverige AB 415 50 GÖTEBORG SWEDEN Tel: +46-31-3371000
Product:	Cage CP-24024 CJ2/VX645
Year data are based on:	1998 (data on waste are based on 1996)
Functional unit:	2 cages CP-24024 CJ2/VX645, 0,2476 kg

Raw material: Steel band 2,75*215,0

Allocation method(s): Weight

Reference(s)/contact person: Tomas Ardevall
E-mail: tomas.ardevall@skf.com
Tel: +46-31-3371000

Additional information: Emissions to air and water are not included due to allocation difficulties.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Anticorrosive agent	3,06E-03	kg
	Blasting grit	3,41E-03	kg
	Chemicals	1,25E-02	kg
	Dissolvent	2,42E-03	kg
	District heating	6,77E+06	J
	Electricity	1,16E+07	J
	Hydraulic oil	1,44E-02	kg
	Natural gas	6,25E+05	J
	Steel	1,97E+00	kg
	Trumbling chip	4,83E-03	kg
Non-elementary outputs: Waste	Blasting grit	5,22E-03	kg
	Emulsion	2,53E-01	kg
	Mangane phosphate	6,61E-03	kg
	Mineral oil products	2,49E-03	kg
	Other paper	3,82E-03	kg
	Paper and board	4,39E-03	kg
	Steel scrap	1,73E+00	kg
	Trumbling chip	5,80E-03	kg
	Waste	3,99E-02	kg
	Waste water	7,25E-03	kg
	Wood	7,51E-03	kg

1.4 Guide ring

1.4.1 Production of steel powder

Production site:	Höganäs AB 263 83 HÖGANÄS SWEDEN Tel: +46-42-338000
Product:	Steel powder PNC 30
Year data are based on:	1996
Functional unit:	One kg of steel powder PNC 30
Raw material:	Virgin iron, Steel scrap, Coke, Anthracite, Limestone
Allocation method(s):	Weight
Reference(s)/contact person:	Katarina Edlund E-mail: katarina.edlund@hoganas.com Tel: +46-42-338000
Additional information:	The production of steel powder is a cradle to grave activity. The inventory results from all included activities have been aggregated and it has not been possible to specify what belongs to each of the sub-activity. Metadata are also insufficient due to secrecy.

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Aluminium	2,34E-06	kg
	Bauxite	2,39E-12	kg
	Bentonite	1,44E-07	kg
	Biomass	1,35E-08	kg
	Brown coal	8,34E-04	kg
	CaCO3	1,73E-07	kg
	Caliche	1,23E-04	kg

	Clay	3,68E-08	kg
	Coal	1,60E-06	kg
	Copper ore	2,97E-05	kg
	Copper ore (0,35 % Cu)	4,17E-09	kg
	Crude oil	4,80E-03	kg
	Crude oil, feedstock	8,71E-09	kg
	Dolomite	1,45E-07	kg
	Fe	1,03E-07	kg
	Feldspar	1,06E-07	kg
	Hard coal	2,99E-04	kg
	Hard coal, feedstock	8,64E-02	kg
	Iron ore	1,55E-01	kg
	Lead ore	3,70E-07	kg
	Limestone	9,03E-03	kg
	LPG	2,24E-08	kg
	Manganese	6,09E-10	kg
	Na2CO3	1,70E-07	kg
	NaCl	1,73E-07	kg
	Natural gas	4,75E+05	J
	Natural sand	1,18E-06	kg
	Olivine	3,37E-03	kg
	Peat	1,81E-08	kg
	Softwood	2,69E-05	kg
	Uranium (as pure U)	4,42E-07	kg
	Uranium ore	1,67E-08	kg
	Wood	1,40E-06	kg
Non-elementary inputs	Brick	2,85E-04	kg
	Cast compound	7,59E-04	kg
	Ceramic	6,64E-04	kg
	Emulsifying agent	8,07E-07	kg
	Fe3P	1,81E-03	kg
	H2SO4	2,32E-06	kg
	Lime	1,40E-06	kg
	Na2SO4	8,74E-09	kg
	Oxygen	1,62E-05	kg
	Solvey soda	1,70E-07	kg
	Zinc stearate	7,24E-04	kg
Emissions to air	Acetaldehyde	1,99E-13	kg
	Acetylene	6,69E-10	kg
	Aldehydes	1,90E-09	kg
	Alkanes	1,93E-08	kg
	Alkenes	1,47E-09	kg
	Aromates (C9-C10)	2,90E-08	kg
	As	4,96E-09	kg
	Ashes	1,97E-08	kg
	Benzene	2,52E-08	kg
	Benzo(a)pyrene	2,24E-12	kg
	Butane	1,39E-10	kg
	Ca	3,33E-10	kg
	Cd	3,11E-09	kg

	CH4	8,36E-04	kg
	CN-	2,38E-10	kg
	CO	5,68E-10	kg
	CO2	1,85E-01	kg
	Cr	3,62E-08	kg
	Cu	2,03E-08	kg
	Dioxin	1,79E-14	kg
	Dissolved solids	5,69E-06	kg
	Ethane	1,33E-09	kg
	Ethene	3,35E-09	kg
	Fe	1,09E-06	kg
	Formaldehyde	2,30E-09	kg
	H2S	4,49E-10	kg
	HC	5,39E-09	kg
	HCl	3,19E-06	kg
	HF	3,65E-06	kg
	Hg	1,80E-10	kg
	Metals	1,23E-09	kg
	Mn	1,99E-08	kg
	Mo	1,05E-08	kg
	N2O	3,73E-07	kg
	Na	3,12E-09	kg
	NH3	3,44E-08	kg
	NH4NO3	3,91E-08	kg
	Ni	1,97E-08	kg
	NMVOC	2,78E-05	kg
	NOx	2,57E-04	kg
	Other organics	3,80E-09	kg
	PAH	3,54E-08	kg
	Particulates	9,34E-05	kg
	Pb	1,27E-08	kg
	Pentane	2,38E-10	kg
	Phenol	1,33E-12	kg
	Propane	2,17E-09	kg
	Propene	1,33E-09	kg
	Radioactive	4,52E+07	Bq
	Rn-222	1,44E+03	Bq
	Se	7,89E-11	kg
	SO2	1,70E-04	kg
	Suspended solids	8,54E-08	kg
	Toluene	8,34E-10	kg
	Tot-N	4,73E-09	kg
	V	1,60E-08	kg
	VOC	1,02E-05	kg
	Zn	3,74E-08	kg
Emissions to water	Acid as H+	1,50E-07	kg
	Al	1,02E-07	kg
	Aromates (C9-C10)	8,44E-09	kg
	As	3,81E-10	kg
	BOD	6,14E-09	kg
	BOD5	6,48E-09	kg

	Cd	1,37E-10	kg
	Cl-	9,49E-04	kg
	CN-	3,44E-10	kg
	Co	2,86E-08	kg
	COD	3,07E-06	kg
	Cr	3,91E-09	kg
	Cr3+	7,18E-10	kg
	Cu	7,68E-09	kg
	Dissolved solids	5,14E-05	kg
	DOC	3,38E-16	kg
	F-	1,64E-07	kg
	Fe	1,14E-07	kg
	Fluoride	1,71E-08	kg
	H2S	1,13E-11	kg
	HC	2,46E-08	kg
	HNO3	1,97E-09	kg
	Metals	6,14E-09	kg
	Mn	2,25E-07	kg
	Na+	2,42E-09	kg
	NH3	1,03E-09	kg
	NH4+	6,42E-07	kg
	NH4-N	4,10E-08	kg
	Ni	8,73E-09	kg
	Nitrogen	1,86E-08	kg
	NO2-	3,04E-08	kg
	NO3-	2,66E-07	kg
	NO3-N	3,17E-10	kg
	Oil	2,30E-06	kg
	Other organics	1,72E-06	kg
	Pb	2,73E-08	kg
	Phenol	9,24E-09	kg
	Phosphate	3,43E-09	kg
	PO43-	2,41E-09	kg
	Rock salt	5,12E-06	kg
	Sb	1,23E-12	kg
	Sn	9,68E-08	kg
	SO42-	3,86E-05	kg
	Sr	2,85E-07	kg
	Suspended solids	1,71E-06	kg
	TOC	4,18E-09	kg
	Tot-C	2,02E-07	kg
	Tot-CN	2,59E-08	kg
	Tot-N	3,48E-06	kg
	Tot-P	3,67E-08	kg
	V	2,89E-10	kg
	Zn	1,96E-08	kg
Elementary waste	Ashes	4,82E-12	kg
	Building	9,76E-07	kg
	Bulky	2,78E-02	kg
	Chemicals	2,08E-07	kg
	Filter dust	1,50E-03	kg

	Granite	7,11E-02	kg
	Hazardous	4,31E-03	kg
	Highly radioactive	2,33E-06	kg
	Industrial	2,50E-02	kg
	Low radioactive	1,61E-13	m3
	Medium radioactive	1,61E-13	m3
	Mineral	2,67E-07	kg
	Radioactive	1,64E-07	kg
	Reject	1,52E-03	kg
	Rocks	5,46E-06	kg
	Rubber	3,13E-08	kg
	Slags & ashes (energy production)	1,50E-04	kg
	Slags & ashes (waste incineration)	4,01E-10	kg
	Sludge	7,49E-04	kg
	Solid	3,90E-06	kg
	Tunnel furnace ashes	1,88E-02	kg
	Unspecified	1,54E-03	kg
Non-elementary outputs: Waste	Ashes	1,90E-05	kg
	Brick	2,85E-04	kg
	Ceramic	4,74E-04	kg
	Slag	1,02E-02	kg
	Sulphur	8,93E-05	kg
	Tar	1,64E-03	kg
Non-elementary outputs: Co-products	Pig iron	1,72E-03	kg
Non-elementary outputs: Unspecified	Benzene	4,73E-04	kg
	Blast furnace gas	4,93E-02	m3
	Coke gas	3,18E-03	m3
Other - Inputs	Ground water	2,32E-09	kg
	Hydro power	5,08E+04	J
	Hydro power-water	2,93E-02	kg
	Sea water	4,59E-05	kg
	Surface water	4,75E-11	kg
	Unspecified fuel	2,87E-01	J
	Water	1,85E+01	kg
	Wind power	1,08E+02	J
Other - Outputs	Coke dust	4,54E-03	kg

1.4.2 Production of the guide ring

Production site:	SKF Mekan AB Fredsgatan 3 Box 89 641 21 KATRINEHOLM SWEDEN Tel: +46-150-74000
Product:	Guide ring RG-24024 C / VX201
Year data are based on:	1998
Functional unit:	One guide ring RG-24024 C / VX201, 0,086 kg
Raw material:	Steel powder PNC 30
Allocation method(s):	weight
Reference(s)/contact person:	Bo Lindhe E-mail: bo.lindhe@skf.com Tel: +46-150-74000
Additional information:	Emissions to water are not known.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Ceramic	7,23E-04	kg
	Chemicals	1,01E-03	kg
	Electricity	1,22E+06	J
	Hydraulic oil	2,89E-04	kg
	Mineral oil products	5,60E-04	kg
	Propane	1,44E-02	kg
Emissions to air	Cd	1,20E-07	kg
	Cr	1,30E-08	kg
	Cu	5,40E-08	kg
	Ni	4,90E-08	kg
	Zn	1,30E-05	kg
Non-elementary outputs: Waste	Chemicals	3,36E-02	kg
	Inorganic (except metals)	2,52E-03	kg
	Oil	5,20E-04	kg
	Steel powder	4,50E-03	kg
	Zinc stearate	3,60E-05	kg

1.5 Corrugated board box

1.5.1 Production of semichemical fluting

Production site:	European average
Product:	Semichemical fluting
Year data are based on:	1996
Functional unit:	One ton of semichemical fluting
Raw material:	Wood and recovered paper
Allocation method(s):	Weight
Reference(s)/contact person:	KRAFT Institute Norrtullsgatan 43 113 45 STOCKHOLM SWEDEN Tel: +46-8-303440
Additional information:	"European Database for Corrugated Board Life Cycle Studies" can be ordered without charge from KRAFT Institute at the above address.

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Bio fuel	1,31E+04	J
	Hardwood	2,36E-02	kg
	Peat	6,70E+04	J
	Softwood	2,23E-03	kg
Non-elementary inputs	Board	5,38E-05	kg
	Calciumhydroxide	3,22E-05	kg
	CaO	7,44E-06	kg
	Coal	9,92E+03	J
	Core and core plug	6,92E-05	kg
	Defoamers	3,22E-06	kg
	Diesel	1,24E+03	J
	Electricity	3,77E+04	J
	Phosphoric acid	4,96E-07	kg
	H2SO4	2,16E-05	kg
	Heavy oil	7,19E+04	J
	Hydrochloric acid	2,48E-06	kg
	LDPE	1,74E-06	kg
	Light fuel oil	2,48E+02	J

	Lubricant	4,22E-06	kg
	Mangane oxide	2,48E-05	kg
	Na2CO3	5,21E-05	kg
	NaOH	2,46E-04	kg
	Natural gas	3,22E+04	J
	NH3	2,75E-04	kg
	Nitric acid	1,49E-06	kg
	Other paper	2,23E-03	kg
	Pitch despergent	2,23E-06	kg
	Pulps	7,44E-04	kg
	S	2,48E-04	kg
	SO2	3,47E-05	kg
	Sodium chlorate	2,48E-07	kg
	Sodium sulphate	1,24E-06	kg
	Steel	7,44E-07	kg
Emissions to air	CO	4,46E-06	kg
	CO2	2,76E-02	kg
	H2S	2,98E-06	kg
	NOx	3,72E-05	kg
	SOx	1,31E-04	kg
Emissions to water	BOD	3,22E-05	kg
	COD	3,08E-04	kg
	Suspended solids	5,46E-05	kg
Non-elementary outputs: Waste	Ashes	4,02E-04	kg
	Unspecified	5,70E-04	kg
Non-elementary outputs: Co-products	Electricity	7,44E+01	J
	Thermal energy	1,02E+04	J

1.5.2 Production of Kraftliner

Production site: European average

Product: Kraftliner

Year data are based on: 1996

Functional unit: One ton of Kraftliner

Raw material: Wood and recovered paper

Allocation method(s): Weight

Reference(s)/contact person: KRAFT Institute
Norrtullsgatan 43
113 45 STOCKHOLM
SWEDEN
Tel: +46-8-303440

Additional information: "European Database for Corrugated Board Life Cycle Studies" can be ordered without charge from KRAFT Institute at the above address.

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Bark	1,08E+05	J
	Hardwood	1,16E-02	kg
	Peat	9,92E+03	J
	Softwood	2,00E-01	kg
Non-elementary inputs	Al2(SO4)3	1,11E-03	kg
	biocides	1,32E-05	kg
	Board	8,27E-06	kg
	CaCO3	4,80E-04	kg
	CaO	6,78E-04	kg
	Core and core plug	3,16E-04	kg
	Defoamers	1,57E-04	kg
	Diesel	4,96E+03	J
	Electricity	3,69E+05	J
	H2SO4	2,43E-03	kg
	Heavy oil	2,80E+05	J
	Hydrochloric acid	1,16E-05	kg
	Light fuel oil	8,93E+04	J
	Lubricant	2,98E-05	kg
	Na2CO3	3,14E-04	kg
	Na2SO4	3,14E-04	kg
	NaOH	1,54E-03	kg

	Natural gas	1,72E+05	J
	Pitch despergent	3,31E-06	kg
	Retention aids	9,43E-05	kg
	S	2,81E-05	kg
	Sizing agents	2,65E-04	kg
	Starch	6,95E-04	kg
	Steel	8,27E-06	kg
	Waste paper	3,80E-02	kg
Emissions to air	CO_2	2,61E-01	kg
	H_2S	2,32E-05	kg
	NO_x	1,98E-04	kg
	SO_x	1,42E-04	kg
Emissions to water	BOD	1,11E-03	kg
	COD	2,86E-03	kg
	Suspended solids	4,14E-04	kg
Non-elementary outputs: Waste	Ashes	7,11E-04	kg
	Unspecified	3,27E-03	kg
Non-elementary outputs: Co-products	Electricity	1,16E+03	J
	Tall oil	4,13E-03	kg
	Thermal energy	5,29E+04	J
	Turpentine	2,15E-04	kg

1.5.3 Production of the corrugated board box

Production site: European average

Product: Corrugated board box

Year data are based on: 1996

Functional unit: One Corrugated board box, 106,7 g

Raw material: Kraftliner and semichemical fluting

Allocation method(s): Weight

Reference(s)/contact person: KRAFT Institute
Norrtullsgatan 43
113 45 STOCKHOLM
SWEDEN
Tel: +46-8-303440

Additional information: "European Database for Corrugated Board Life Cycle Studies" can be ordered without charge from KRAFT Institute at the above address.

The box is made of two layers of Kraftliner and one layer of semichemical fluting.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Diesel	1,93E+03	J
	Electricity	7,90E+04	J
	Glue	2,48E-09	kg
	Heavy oil	6,55E+04	J
	Light fuel oil	2,12E+04	J
	LPG	1,16E+04	J
	Natural gas	1,89E+05	J
	Starch	5,11E-03	kg
Emissions to air	CO2	1,72E-02	kg
	NOx	3,08E-05	kg
	SOx	6,74E-05	kg
Emissions to water	BOD	5,78E-05	kg
	COD	2,56E-04	kg
	Suspended solids	4,82E-05	kg
Non-elementary outputs: Waste	Board	8,60E-02	kg
	Industrial	1,02E-03	kg

1.6 Use

1.6.1 Use at Avesta-Sheffield

Site:	Avesta-Sheffield AB Degerfors Stainless 693 81 DEGERFORS SWEDEN Tel: +46-586-470 00
Year data are based on:	1998
Functional unit:	Use of the bearing for one and a half year
Allocation method(s):	Weight
Reference(s)/contact person:	Lars-Göran Öhrn Tel: +46-586-470 00 E-mail: lars.goran.ohrn@avetsasheffield.com
Additional information:	The bearing is changed after one and a half year. After use the bearing is recycled within the plant.

INVENTORY RESULTS	Substance:	Total:	Unit:
Non-elementary inputs	Grease	3,00E+01	kg

1.7 Production of energy ware used in the producing activities

The data sets are totals for the functional unit for the study and provide all producing activities except for the production of steel powder and the manufacturing of the inner ring. In the data sets for the activities the energy supply in MJ has been inventoried and the production therefore represents production of "ready to use" energy ware such as LPG and Diesel expressed in MJ. All data on production of energy ware are taken from CIT Ekologik's database on transport and energy.

1.7.1 Production of Diesel

INVENTORY RESULTS	Substance:	Total:	Unit
Resources	Crude oil	1.13e-003	kg
	Hard coal	2.18e-005	kg
	Hydro power-water	1.23e-002	kg
	Lignite	1.82e-005	kg
	Natural gas	4.69e-005	kg
	Uranium (as pure U)	1.32e-009	kg
	Wood	1.12e-006	kg
Emissions to air	As	2.02e-011	kg
	Cd	3.97e-011	kg
	CH4	4.50e-006	kg
	CN-	3.13e-013	kg
	CO	7.50e-007	kg
	CO2	4.77e-004	kg
	Cr	3.91e-011	kg
	Dioxin	3.87e-015	kg
	H2S	2.15e-010	kg
	HCl	1.09e-008	kg
	HF	1.17e-009	kg
	Hg	4.85e-012	kg
	N2O	8.20e-009	kg
	NH3	3.75e-010	kg
	Ni	1.86e-009	kg
	NMVOC	9.00e-006	kg
	NOx	2.98e-006	kg
	Particulates	1.85e-006	kg
	Pb	1.62e-010	kg
	Radioactive	1.17e+005	Bq
	SO2	3.10e-006	kg

Emissions to water	Al	3.56e-008	kg
	As	1.16e-010	kg
	BOD5	5.16e-009	kg
	Cd	6.44e-011	kg
	Cl-	3.07e-005	kg
	CN-	2.73e-010	kg
	CO	6.97e-011	kg
	COD	1.70e-007	kg
	Cr	8.60e-010	kg
	Cu	2.83e-010	kg
	F-	1.30e-009	kg
	H2S	8.95e-012	kg
	Ni	3.48e-010	kg
	Oil	1.05e-006	kg
	Other organics	8.78e-007	kg
	Pb	4.50e-010	kg
	PO43-	2.73e-009	kg
	Radioactive	1.10e+003	Bq
	Sb	9.79e-013	kg
	Sn	7.67e-008	kg
	SO42-	1.21e-006	kg
	Tot-N	2.48e-007	kg
	V	2.29e-010	kg
	Zn	9.66e-010	kg
Non-elementary outputs: Waste	Hazardous	1.35e-006	kg
	Highly radioactive	3.86e-006	kg
	Industrial	1.32e-004	kg

1.7.2 Production of District heat, Swedish average

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Crude oil	2.07e-001	kg
	Hard coal	2.26e-001	kg
	Hydro power	2.82e+006	J
	Hydro power-water	1.59e+000	kg
	Lignite	4.26e-003	kg
	Natural gas	7.62e-002	kg
	Uranium (as pure U)	2.18e-005	kg
Non-elementary inputs	Biomass	6.10e-001	kg
	Heat	1.34e+007	J
	Peat	1.85e-001	kg
Emissions to air	Acetylene	2.05e-006	kg
	Alkanes	7.48e-006	kg
	Alkenes	2.28e-006	kg
	Aromates (C9-C10)	5.19e-007	kg
	As	2.18e-007	kg
	Benzene	3.60e-006	kg
	Butane	2.32e-006	kg
	Cd	6.70e-008	kg
	CH4	2.54e-003	kg
	CO	3.90e-007	kg
	CO2	1.51e+000	kg
	Cr3+	1.51e-006	kg
	Cu	1.23e-006	kg
	Dioxin	5.74e-013	kg
	Ethane	5.92e-006	kg
	Ethylene	1.21e-005	kg
	Formaldehyde	7.57e-007	kg
	HCl	1.85e-004	kg
	Hg	1.13e-008	kg
	N2O	5.51e-006	kg
	Ni	2.06e-006	kg
	NMVOC	2.31e-003	kg
	NMVOC, diesel engines	8.08e-006	kg
	NMVOC, natural gas combustion	5.65e-006	kg
	NMVOC, petrol engines	1.17e-015	kg
	NMVOC, power plants	3.31e-006	kg
	NOx	4.10e-003	kg
	Particulates	1.29e-003	kg
	Pb	9.91e-007	kg
	Pentane	3.97e-006	kg
	Propane	5.00e-006	kg
	Propylene	2.28e-006	kg
	Radioactive	1.51e+010	Bq
	Rn-222	7.99e+004	Bq

	Sb	1.75e-007	kg
	Se	1.39e-007	kg
	SO2	3.86e-003	kg
	Toluene	1.25e-006	kg
	V	1.22e-006	kg
	VOC	4.77e-005	kg
	VOC, coal combustion	1.85e-007	kg
	VOC, diesel engines	4.34e-006	kg
	VOC, natural gas combustion	1.23e-014	kg
	Xylene	3.64e-007	kg
	Zn	1.44e-006	kg
Emissions to water	As	1.49e-008	kg
	BOD	6.79e-007	kg
	Cd	8.35e-009	kg
	COD	2.20e-005	kg
	Cr3+	1.11e-007	kg
	Cu	3.64e-008	kg
	Dissolved solids	1.32e-004	kg
	Ni	5.74e-008	kg
	Oil	1.36e-004	kg
	Pb	5.78e-008	kg
	Radioactive	1.42e+008	Bq
	Sn	9.87e-006	kg
	SO42-	2.45e-004	kg
	Sr	6.24e-007	kg
	Suspended solids	2.04e-006	kg
	Tot-N	3.29e-005	kg
	Zn	1.63e-007	kg
Non-elementary outputs: Waste	Ashes	9.18e-003	kg
	Bulky	6.75e-002	kg
	Hazardous	2.73e-002	kg
	Highly radioactive	3.58e-005	kg
	Industrial	1.97e-001	kg
	Slags & ashes (energy production)	3.64e-004	kg

1.7.3 Production of Electricity, Swedish average (large industries)

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Bentonite	1.97e-004	kg
	Biomass	3.58e-001	kg
	Copper ore (0.7% Cu)	4.07e-002	kg
	Crude oil	1.40e+000	kg
	Hard coal	3.43e-001	kg
	Hydro power	6.97e+007	J
	Iron ore	1.41e-003	kg
	Lead ore (1% Pb)	5.06e-004	kg
	Lignite	2.74e-003	kg
	Natural gas	3.09e-002	kg
	Uranium (as pure U)	5.29e-004	kg
	Wind power	1.48e+005	J
Non-elementary inputs	Lime	1.90e-003	kg
	Oxygen	2.23e-002	kg
	Sulphuric acid	3.19e-003	kg
Emissions to air	CH4	2.54e-003	kg
	CO	4.91e-004	kg
	CO2	1.76e+000	kg
	N2O	2.82e-006	kg
	NH3	2.28e-008	kg
	NOx	2.78e-003	kg
	PAH	1.38e-011	kg
	Particulates	4.00e-004	kg
	Rn-222	1.97e+006	Bq
	SO2	1.83e-003	kg
	VOC	5.53e-004	kg
Emissions to water	COD	5.05e-008	kg
	Dissolved solids	2.02e-004	kg
	NH3	9.59e-009	kg
	Oil	4.82e-007	kg
	Tot-N	2.06e-005	kg
Non-elementary outputs: Waste	Demolition (inactive)	1.33e-003	kg
	Highly radioactive	8.69e-004	kg
	Other	2.10e+000	kg

1.7.4 Production of Heavy fuel oil

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Biomass	1.28e-005	kg
	Crude oil	1.21e-002	kg
	Hard coal	2.83e-004	kg
	Hydro power-water	1.70e-001	kg
	Lignite	2.67e-004	kg
	Natural gas	5.17e-004	kg
	Uranium (as pure U)	2.09e-008	kg
Emissions to air	As	3.28e-010	kg
	Benzene	3.29e-007	kg
	Cd	6.71e-010	kg
	CH4	4.84e-005	kg
	CN-	3.29e-009	kg
	CO	7.88e-006	kg
	CO2	6.26e-003	kg
	Cr3+	5.55e-010	kg
	Dioxin	4.88e-014	kg
	H2S	2.46e-009	kg
	HCl	1.64e-007	kg
	HF	1.75e-007	kg
	Hg	7.34e-011	kg
	N2O	9.67e-008	kg
	NH3	4.59e-009	kg
	Ni	2.49e-008	kg
	NMVOC, oil combustion	9.63e-005	kg
	NOx	3.35e-005	kg
	Particulates	1.86e-005	kg
	Pb	2.18e-009	kg
	Radioactive	1.68e+003	Bq
	SO2	4.07e-005	kg
Emissions to water	As	1.38e-009	kg
	Cd	6.67e-010	kg
	Cl-	3.29e-004	kg
	Cr3+	9.97e-009	kg
	F-	1.38e-007	kg
	Ni	4.11e-009	kg
	Oil	1.11e-005	kg
	Other organics	8.55e-006	kg
	Pb	5.00e-009	kg
	PO43-	3.34e-008	kg
	Radioactive	1.57e+001	Bq
	SO42-	1.28e-005	kg
	Tot-N	1.24e-006	kg
Non-elementary outputs: Waste	Hazardous	1.25e-005	kg

	Industrial	1.25e-003	kg
	Radioactive	5.84e-008	kg

1.7.5 Production of Light fuel oil

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Crude oil	2.31e-001	kg
	Hard coal	4.44e-003	kg
	Hydro power-water	2.51e+000	kg
	Lignite	3.70e-003	kg
	Natural gas	9.66e-003	kg
	Uranium (as pure U)	2.69e-007	kg
	Wood	2.26e-004	kg
Emissions to air	As	4.12e-009	kg
	Cd	8.08e-009	kg
	CH4	9.13e-004	kg
	CN-	6.37e-011	kg
	CO	1.52e-004	kg
	CO2	9.69e-002	kg
	Cr	7.95e-009	kg
	Dioxin	7.88e-013	kg
	H2S	4.38e-008	kg
	HCl	2.21e-006	kg
	HF	2.25e-007	kg
	Hg	9.85e-010	kg
	N2O	1.67e-006	kg
	NH3	7.61e-008	kg
	Ni	3.79e-007	kg
	NMVOC	1.83e-003	kg
	NOx	6.05e-004	kg
	Particulates	3.76e-004	kg
	Pb	3.30e-008	kg
	Radioactive	2.38e+010	Bq
	SO2	6.30e-004	kg
Emissions to water	Al	7.23e-006	kg
	As	2.35e-008	kg
	BOD5	1.05e-006	kg
	Cd	1.32e-008	kg
	Cl-	6.25e-003	kg
	CN-	5.56e-008	kg
	CO	1.42e-008	kg
	COD	3.45e-005	kg
	Cr	1.75e-007	kg
	Cu	5.75e-008	kg
	F-	2.64e-007	kg
	H2S	1.83e-009	kg
	Ni	7.09e-008	kg

	Oil	2.14e-004	kg
	Other organics	1.78e-004	kg
	Pb	9.13e-008	kg
	PO43-	5.54e-007	kg
	Radioactive	2.24e+008	Bq
	Sb	1.99e-010	kg
	Sn	1.56e-005	kg
	SO42-	2.47e-004	kg
	Tot-N	5.05e-005	kg
	V	4.66e-008	kg
	Zn	1.97e-007	kg
Non-elementary outputs: Waste	Hazardous	2.74e-004	kg
	Highly radioactive	7.83e-007	kg
	Industrial	2.68e-002	kg

1.7.6 Production of LPG

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Biomass	5.05e-004	kg
	Crude oil	4.80e-001	kg
	Hard coal	1.12e-002	kg
	Hydro power-water	6.73e+000	kg
	Lignite	1.06e-002	kg
	Natural gas	2.05e-002	kg
	Uranium (as pure U)	8.25e-007	kg
Emissions to air	As	1.30e-008	kg
	Benzene	1.30e-005	kg
	Cd	2.66e-008	kg
	CH4	1.91e-003	kg
	CN-	1.30e-007	kg
	CO	3.12e-004	kg
	CO2	2.48e-001	kg
	Cr3+	2.19e-008	kg
	Dioxin	1.93e-012	kg
	H2S	9.73e-008	kg
	HCl	6.50e-006	kg
	HF	6.93e-006	kg
	Hg	2.90e-009	kg
	N2O	3.83e-006	kg
	NH3	1.82e-007	kg
	Ni	9.87e-007	kg
	NMVOC, oil combustion	3.81e-003	kg
	NOx	1.32e-003	kg
	Particulates	7.38e-004	kg
	Pb	8.63e-008	kg
	Radioactive	6.65e+004	Bq
	SO2	1.61e-003	kg

Emissions to water	As	5.45e-008	kg
	Cd	2.64e-008	kg
	Cl-	1.30e-002	kg
	Cr3+	3.94e-007	kg
	F-	5.45e-006	kg
	Ni	1.63e-007	kg
	Oil	4.41e-004	kg
	Other organics	3.38e-004	kg
	Pb	1.98e-007	kg
	PO43-	1.32e-006	kg
	Radioactive	6.22e+002	Bq
	SO42-	5.05e-004	kg
	Tot-N	4.90e-005	kg
Non-elementary outputs: Waste	Hazardous	4.95e-004	kg
	Industrial	4.95e-002	kg
	Radioactive	2.31e-006	kg

1.7.7 Production of Natural gas

INVENTORY RESULTS	Substance:	Total:	Unit:
Resources	Crude oil	1.77e-003	kg
	Natural gas	3.71e-001	kg
Emissions to air	CH4	3.76e-005	kg
	CO	6.16e-006	kg
	CO2	5.64e-002	kg
	N2O	8.38e-007	kg
	NMVOC, natural gas combustion	3.04e-005	kg
	NOx	2.67e-004	kg
	SO2	4.28e-006	kg
Non-elementary outputs: Waste	Hazardous	1.35e-001	kg
	Industrial	9.72e-001	kg

1.8 Resources not traced back to the cradle

Many of the resources used within the life cycle are not traced back to the cradle. In this study they are called non-elementary inputs. These are substances that on their way from the nature to the studied technical system have been processed in some way. The grade of refining can differ a lot and the environmental impact from these substances can not be assessed if they are not included in the studied system. Within the time limits of this thesis it has not been possible to conduct this work, however, some of the non-elementary inputs where included in the characterisation category "resource depletion" if indices for the substance in question existed.

Below a table of all the non-elementary inputs is presented. The ones included in the characterisation are marked with an asterisk.

Substance:	Unit:	Total:
$Al_2(SO_4)_3$	kg	1,11E-03
Aluminium*	kg	1,71E-02
Anthracite	kg	1,89E-01
Anticorrosive agent	kg	4,54E-03
biocides	kg	1,32E-05
Biomass	kg	6,10E-01
Blasting grit	kg	1,45E-01
Board	kg	6,21E-05
Brick	kg	1,16E-01
$CaCO_3$	kg	4,80E-04
Calciumhydroxide	kg	3,22E-05
CaO	kg	6,86E-04
Carbon black	kg	2,29E-03
Carbon, graphite	kg	1,08E-01
Cast compound	kg	7,59E-04
Ceramic	kg	1,39E-03
Chemicals	kg	1,63E-02
Chromium*	kg	2,05E-01
Coal*	J	9,92E+03
Core and core plug	kg	3,85E-04
Cutting fluid	kg	5,98E-02
Defoamers	kg	1,60E-04
Dissolvent	kg	2,15E-02
Dolomite	kg	2,81E-04
Emulsifying agent	kg	8,07E-07
Fe_3P	kg	1,81E-03
Phosphoric acid	kg	4,96E-07
Fuel oil, unspecified	J	1,73E+06
Glue	kg	2,48E-09
Grease	kg	2,04E+01
H_2SO_4	kg	5,65E-03
Heat	J	1,34E+07
Hot water	J	5,85E+02
Hydraulic oil	kg	5,16E-02
Hydrochloric acid	kg	1,91E-03
Ingot mould	kg	1,48E-01
Iron*	kg	6,71E-08
LDPE	kg	1,22E-03
Lime	kg	1,90E-03
Limestone	kg	5,12E-01
Lubricant	kg	3,40E-05
Magnesite	kg	5,07E-02
Magnetic	kg	7,29E-04

powder		
Mangane oxide	kg	2,48E-05
Manganese	kg	3,76E-10
Methanol	kg	2,85E-02
Mineral oil products	kg	3,74E-02
Municipal water	kg	2,80E+00
N_2	kg	5,47E-01
Na_2CO_3	kg	3,66E-04
Na_2SO_4	kg	3,14E-04
NaOH	kg	1,78E-03
Natural sand	kg	4,83E-02
NH_3	kg	2,75E-04
Nitric acid	kg	1,49E-06
O_2	kg	9,87E-01
Olivine	kg	1,09E-01
Other paper	kg	2,41E-03
Oxygen	kg	1,62E-05
Peat	kg	1,85E-01
Pitch despergent	kg	5,54E-06
Polymers	m3	4,92E-08
Potassium nitrate	kg	9,50E-03
Propane	kg	1,65E-02
Pulps	kg	7,44E-04
Raw steel	kg	1,70E+00
Recycled steel	kg	4,25E-01
Retention aids	kg	9,43E-05
S	kg	2,76E-04
Silicon	kg	6,31E-02
Sizing agents	kg	2,65E-04
SO_2	kg	3,47E-05
Soap	kg	2,02E-04
Sodium chlorate	kg	2,48E-07
Sodium nitrite	kg	9,79E-03
Sodium sulphate	kg	1,24E-06
Solvey soda	kg	1,70E-07
Starch	kg	5,80E-03
Steam	kg	5,53E-01
Steel	kg	6,09E+00
Steel scrap	kg	1,97E+01
Surface water	kg	1,73E+02
Trumbling chip	kg	9,61E-02
Waste paper	kg	3,80E-02
Wood products	kg	1,28E-02
Zinc stearate	kg	7,24E-04

1.9 Substances not followed to the grave

Much of the waste produced within the life cycle is not followed to the grave. In this study the substances are called non-elementary outputs. These are substances that have to be processed in some way on their way from the technical system to the nature. The type of processing can differ a lot and the environmental impact from these substances can not be assessed if these additional processes are not included in the studied system. This has not been possible within the time limits of this thesis.

Below a table of all the non-elementary outputs is presented.

Substance:	Unit:	Total:
Ashes	kg	0,01031
Blasting grit	kg	1,63E-02
Board	kg	9,76E-02
Brick	kg	1,16E-01
Bulky	kg	0,0841
Ceramic	kg	4,74E-04
Chemicals	kg	3,36E-02
Demolition (inactive)	kg	1,33E-03
Dolomite	kg	2,81E-04
Dust	kg	2,46E-01
Emulsion	kg	9,46E-01
Filter dust	kg	1,12E-03
Grease	kg	4,08E-04
Grinding dust	kg	6,16E-01
Hazardous	kg	0,2076
Highly radioactive	kg	1,63E-03
Hydraulic oil	kg	1,39E-04
Hydrochloric acid	kg	6,40E-05
Industrial	kg	1,399
Ingot mould	kg	1,48E-01
Inorganic (except metals)	kg	2,52E-03
Iron oxide	kg	1,02E-02
Magnesite	kg	5,07E-02
Mangane phosphate	kg	6,61E-03
Mineral	kg	1,65E-06
Mineral oil products	kg	4,93E-03
Oil	kg	9,41E-03
Olivine	kg	1,09E-01
Other	kg	2,1432
Other paper	kg	2,30E-02
Other rest products	kg	3,68E-01
Oxide scale	kg	1,53E-01
Packaging waste	kg	1,18E-02
Paper and board	kg	1,51E-02
Radioactive	kg	1,48E-05
Rubber	kg	1,93E-08
Slag	kg	1,65E+00
Slags & ashes	kg	8,96E-05
Slags & ashes (energy production)	kg	4,19E-03
Slags & ashes (waste incineration)	kg	2,47E-10
Sludge	kg	2,71E-01
Steel powder	kg	4,50E-03
Steel scrap	kg	9,56E+00
Sulphur	kg	8,93E-05
Tar	kg	1,64E-03
Trumbling chip	kg	1,30E-01
Unspecified	kg	3,85E-03
Waste	kg	3,99E-02
Waste paper	kg	1,74E-04
Waste water	kg	1,20E+02
Wood	kg	2,58E-02
Wood products	kg	1,99E-02
Zinc stearate	kg	3,60E-05

2 Flow charts

In this section more detailed flowcharts for the different activities within the life cycle of the spherical roller bearing 24024 are presented.

2.1 Production of bearing steel

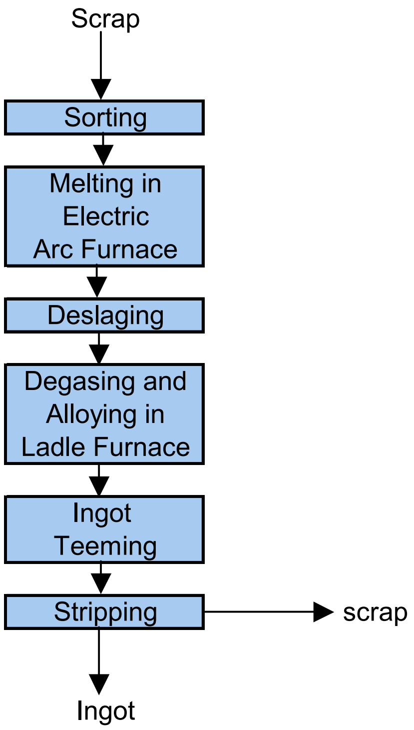

Figure 1: Flow chart for the production of bearing steel at the Ovako steel mill in Hofors.

2.2 Production of square billets

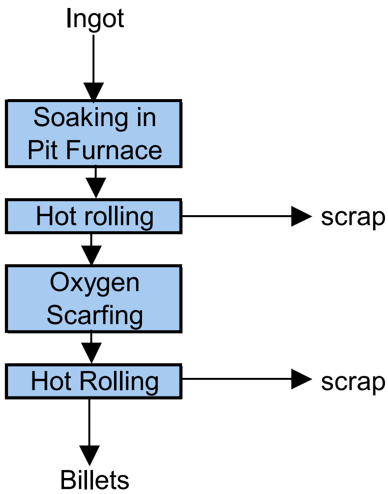

Figure 2: Flow cart for the production of square billets at the Ovako rolling mill in Hofors.

2.3 Billet treatment

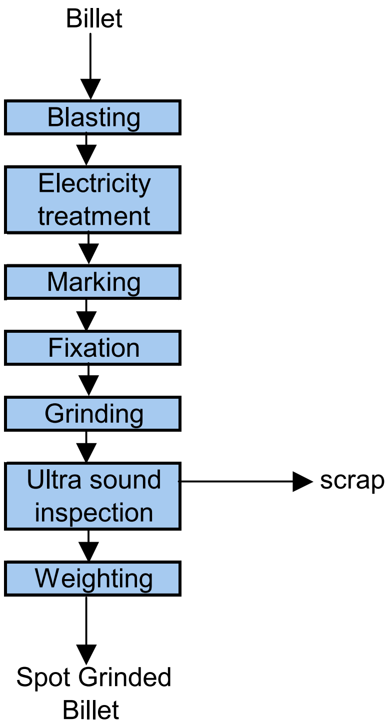

Figure 3: Flow chart for the billet treatment at the Ovako plant in Hällefors.

2.4 Production of hot rolled bars

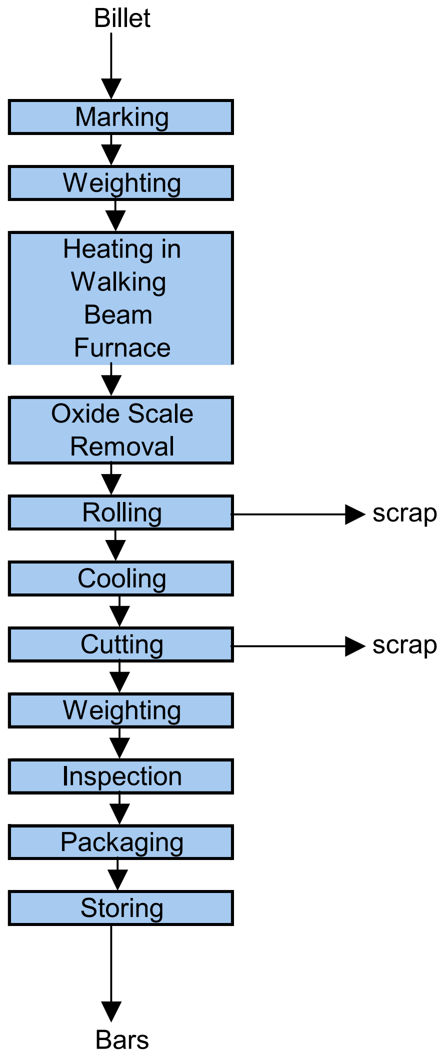

Figure 4: Flow chart for the production of hot rolled bars at the Ovako rolling mill in Hällefors.

2.5 Production of hot rolled inner bearing ring

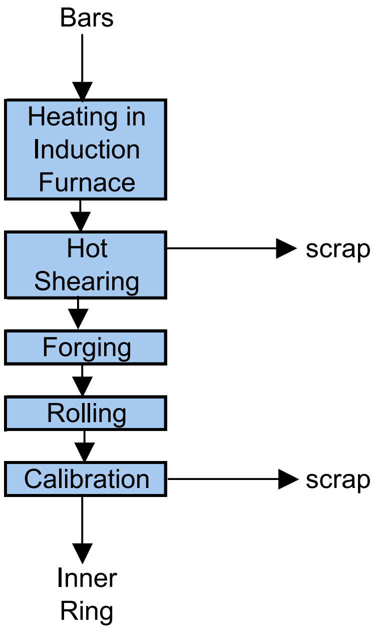

Figure 5: Flow chart for the production of the hot rolled inner bearing ring at the Ovako La Foulerie ring mill.

2.6 Production of hot rolled outer bearing ring

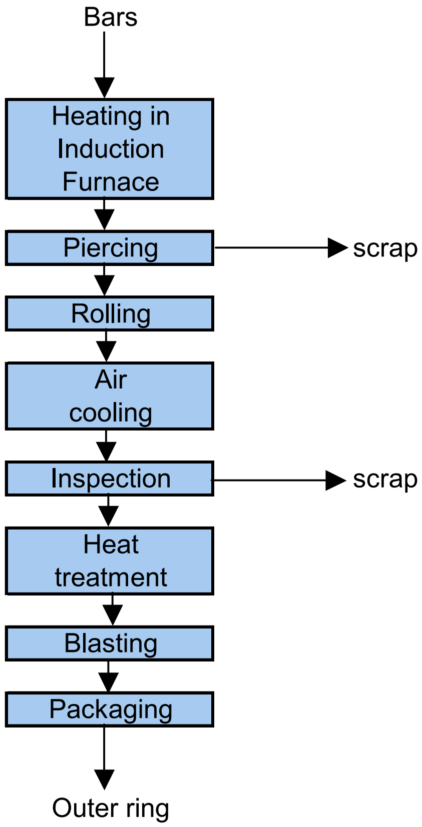

Figure 6: Flow chart for the production of the hot rolled outer bearing ring at the Ovako ring mill in Hofors.

2.7 Production of hot rolled wire rod

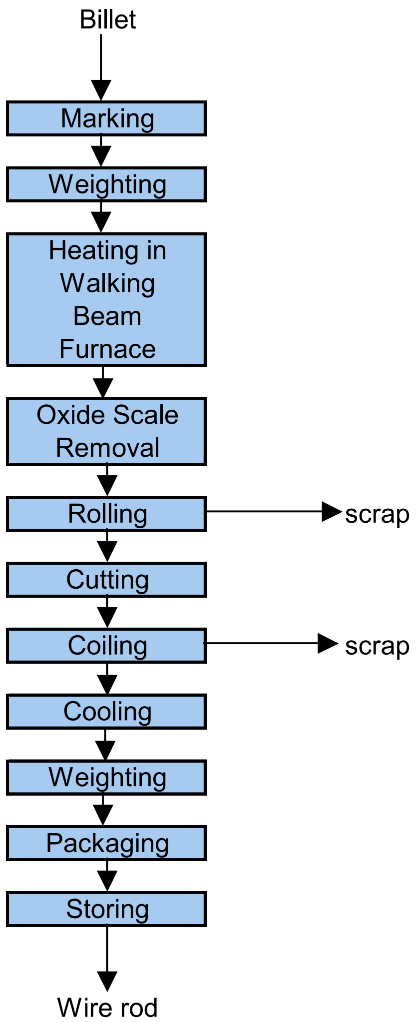

Figure 7: Flow chart for the production of hot rolled wire rod at the Ovako rolling mill in Hällefors.

2.8 Production of surface removed wire

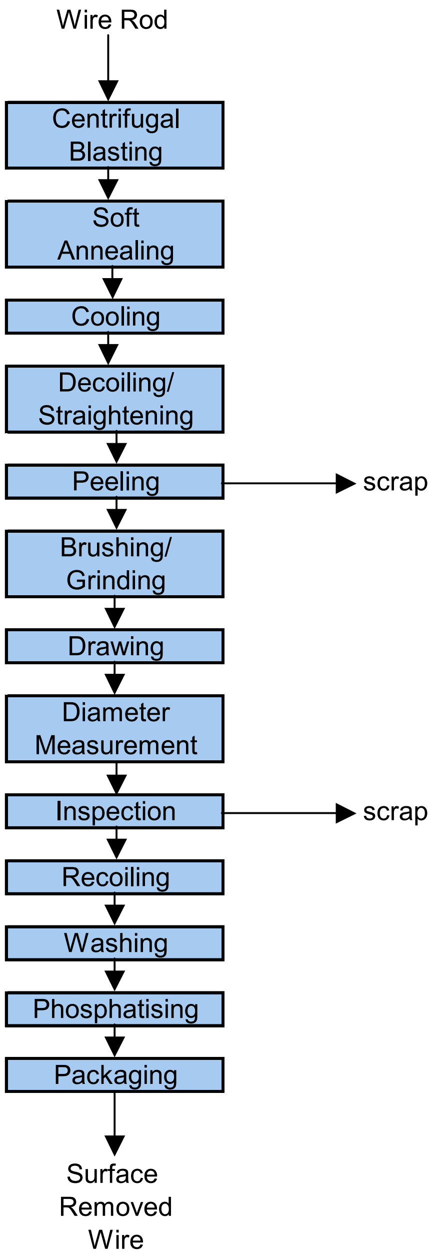

Figure 8: Flow chart for the production of surface removed wire at the Ovako plant in Hällefors.

2.9 Production of bearing rollers

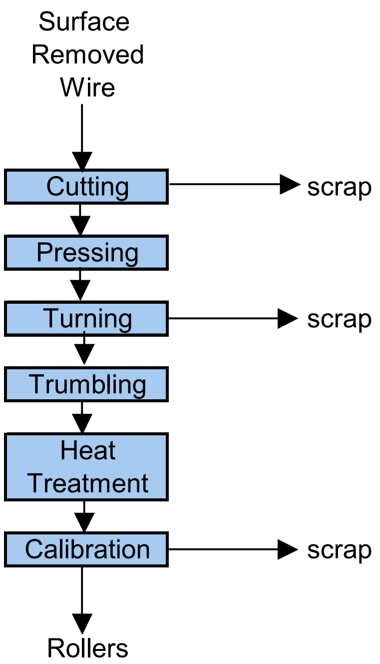

Figure 9: Flow chart for the production of bearing rollers at the SKF plant in Göteborg.

2.10 Production of hot rolled pickled steel sheets

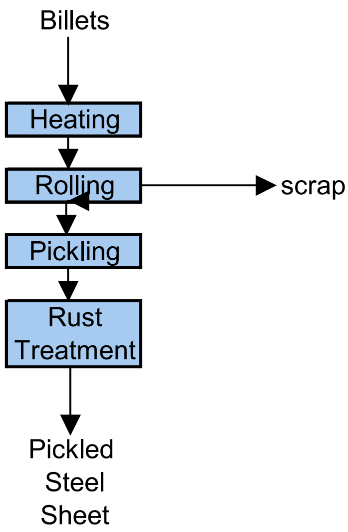

Figure 10: Flow chart for the production of hot rolled pickled steel sheets at the SSAB plant in Borlänge.

2.11 Production of steel band

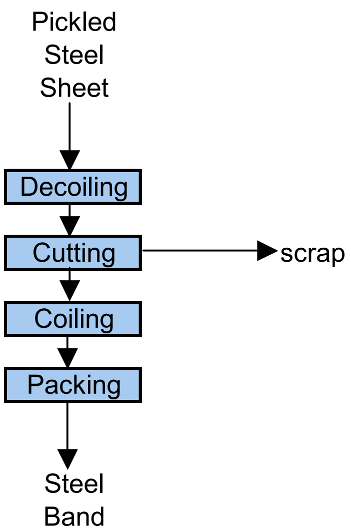

Figure 11: Flow chart for the production of steel band at Dicksons Plåt Service in Göteborg.

2.12 Production of bearing cages

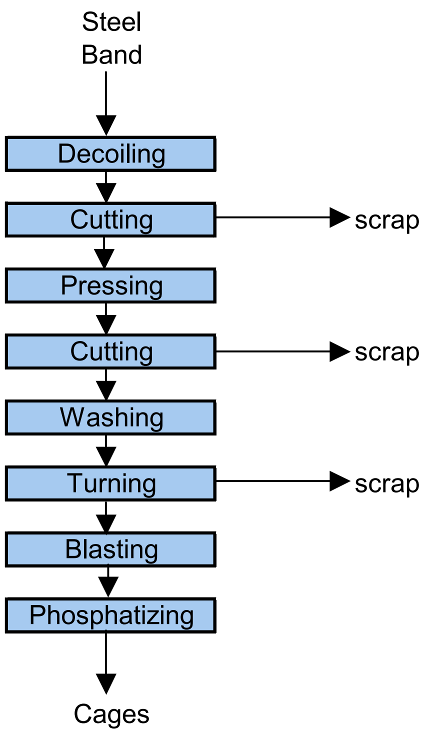

Figure 12: Flow chart for the production of bearing cages at the SKF plant in Göteborg.

2.13 Prod. of steel powder

2.13.1 Prod. of sponge iron

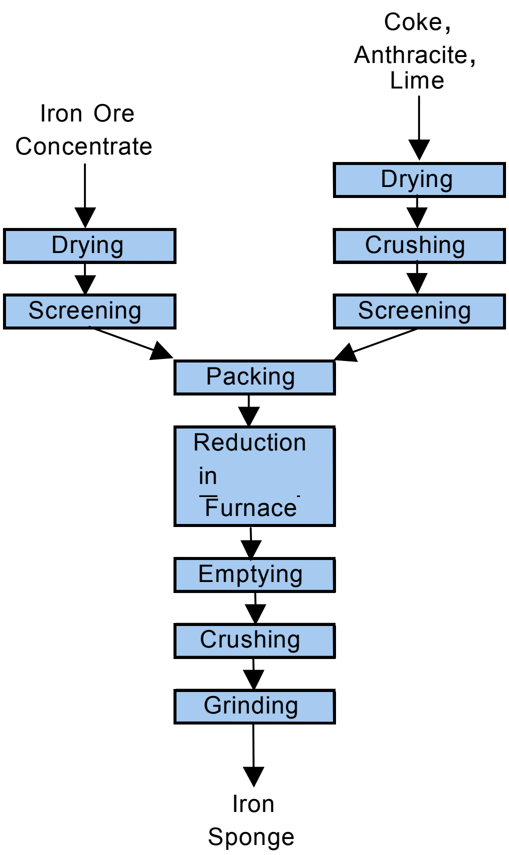

Figure 13: Flow chart for the production of sponge iron at the Höganäs plant in Höganäs.

2.13.2 Prod. of steel powder

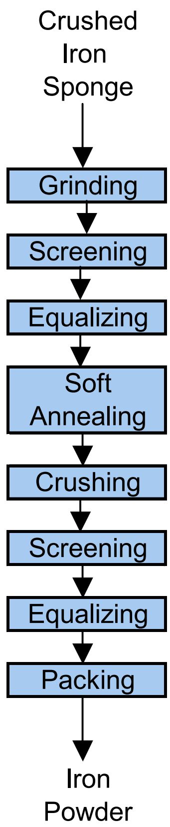

Figure 14: Flow chart for the production of steel powder at the Höganäs plant in Höganäs.

2.13.3 Prod. of PNC-30

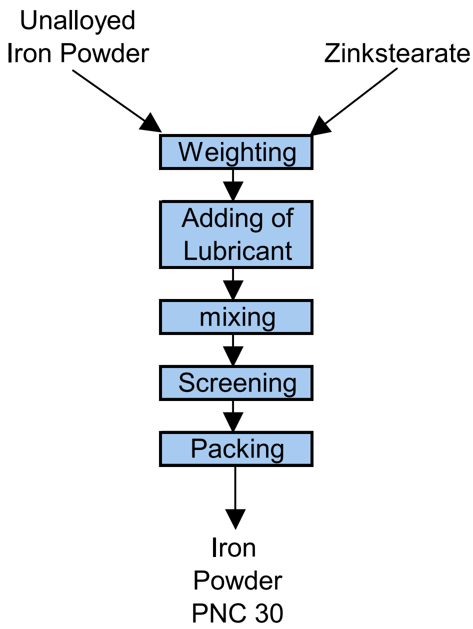

Figure 15: Flow chart for the production of the customer mix PNC-30 at the Höganäs plant in Höganäs.

2.14 Production of the guide ring

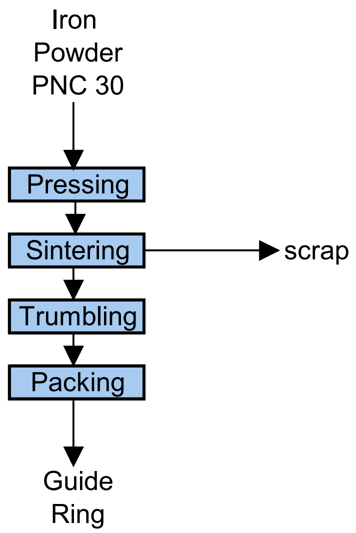

Figure 16: Flow chart for the production of the bearing guide ring at the SKF Mekan plant in Katrineholm.

2.15 Ring processes and bearing assembly

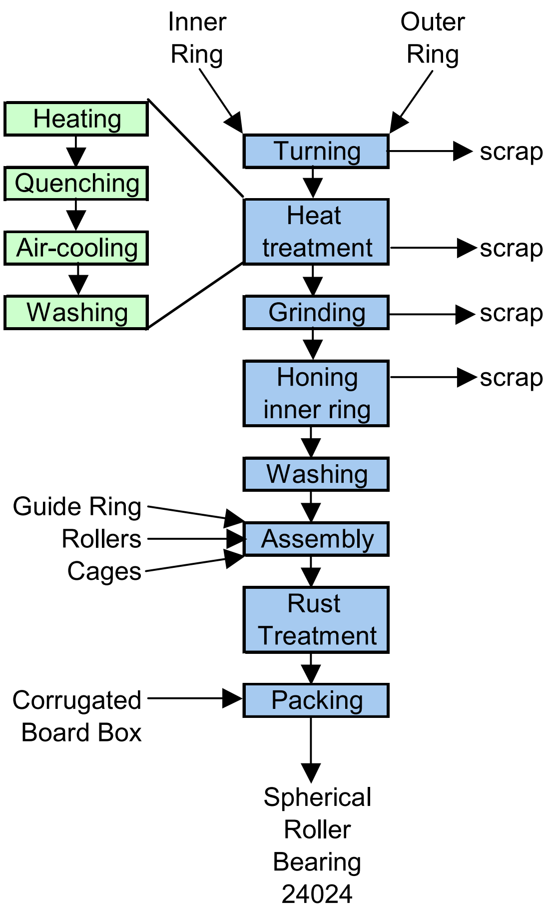

Figure 17: Flow chart for the ring processes and the bearing assembly at the SKF plant in Göteborg.