Environmental Aspects of the Use-Phase for Bearings in Trains

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Abstract

This master thesis was performed in co-operation with SKF Sverige AB and the Department of Environmental Systems Analysis at Chalmers. The purpose of the project is to investigate the environmental aspects of the use-phase for bearings in trains. A Life Cycle Assessment (LCA) has been made, and together with earlier results, it is intended to give a deeper understanding of the environmental performance for the whole life cycle of bearings.

The environmental impact related to the use of wheel bearings in three generations of trains is studied, and comparisons are made between processes within the life cycle of the bearings, and between the bearings in the different generations of trains. The environmental aspects are related to friction losses when the bearings are in operation, and the use of electricity, water, detergents and oil products during maintenance.

The results show that the largest emissions of the use-phase for the bearings are related to electricity use caused by friction losses when the bearings are in operation in the trains. The emissions relation between operation and maintenance varies with the way the electricity is produced, but the emissions from operation are up to 1 000 times higher.

The electricity use related to the bearings is up to 30 percent higher for the heavy train with Spherical Roller Bearings (SRBs), compared to the lighter one with the same bearings and the heavier one with Taper Bearing Units (TBUs). When the mass of the trains is considered, the bearings in the train with TBUs show a 30-40 percent lower electricity use.

The environmental impact related to the transport of the trains to a wheel axle dismounting site can be of the same size as that from trains bearings in operation, if a detour of about 500 km or more is needed.

During maintenance, most electricity is used for heating of washing water and heating of SRBs for mounting. The emissions from naphtha production, oil and grease production and waste oil handling are noticeably lower for the maintenance of TBUs, due to lower grease use, and the use of water and detergent for washing, instead of naphtha.

The study can be used as a motivation to perform more explicit investigations of the environmental impact of different construction, maintenance and transports alternatives, and of how to include the results in product development and everyday work.

Sammanfattning

Detta examensarbete har utförts i samarbete med SKF Sverige AB och Avdelningen för Miljösystemanalys på Chalmers. Syftet med projektet är att undersöka miljöaspekterna under användningsfasen för lager i tåg. För detta har en livscykelanalys (LCA) gjorts, som tillsammans med tidigare resultat är tänkt att ge en djupare förståelse av miljöprestanda under lagrens hela livscykel.

Miljöpåverkan relaterad till användning av hjullager i tre generationer av tåg studeras, och jämförelser görs mellan olika processer inom livscykeln och mellan de olika tåggenerationerna. Miljöaspekterna härrör från friktionsförluster när lagren är i drift, samt från användning av el, vatten, tvättmedel och oljeprodukter för underhåll.

Resultaten visar att de största utsläppen under användningsfasen för lagren är relaterade till elanvändning orsakad av friktionsförluster när lagren är i drift i tågen. Förhållandena i utsläpp mellan drift och underhåll varierar beroende på hur elen produceras, men utsläppen från drift är upp till 1 000 gånger högre.

Elanvändningen relaterad till lagren är upp till 30 procent högre för det tunga tåget med sfäriska rullager (Spherical Roller Bearings, SRBs), jämfört med det lättare tåget med samma lager och det tyngre med koniska lagerenheter (Taper Bearing Units, TBUs). Tar man hänsyn till tågens vikt använder lagren i tåget med TBU:er 30-40 procent mindre el.

Miljöpåverkan från transport av hela tågen till platsen för demontering av hjulaxlar kan vara i samma storleksordning som den från tåglager i drift, om en omväg på 500 km eller mer är nödvändig.

Vid underhåll används mest el för uppvärmning av tvättvatten och för uppvärmning av de sfäriska rullagren vid monteringen. Utsläppen från naftaproduktion, olje- och fettproduktion, samt hantering av använd olja är märkbart lägre för underhåll av TBU:er på grund av lägre fettförbrukning, och användning av vatten och tvättmedel istället för nafta.

Studien kan användas som inspiration till att utföra mer specifika undersökningar av miljöpåverkan från olika alternativ för konstruktion, underhåll och transporter, och av hur resultaten kan inkluderas i produktutveckling och dagligt arbete.

One love, one aim - different name, different city.
Same old shitty pollution. This kid he sees no other solution
but to leave with the last train.
He's tired of the fast lane and the acid rain.
The massive pain that we all feel at times.

"Looking for Love" LOOPTROOP

Preface

This report is the result of my master thesis work at the study programme for Engineering Physics at Chalmers University of Technology, Göteborg. The project was performed at SKF Sverige AB and at the Department of Environmental Systems Analysis (ESA) at Chalmers, with Ulf Andersson, Environmental Coordinator SKF Sverige AB as industrial supervisor and Björn Andersson, Assistant Professor at ESA as academic supervisor and examiner. I would like to thank you both for your advice and support.

I would also like to thank

Fredrik Hallström, Manager Nordic Area, Railway Business Unit, SKF,
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Ann-Kristin Castagna, Co-ordinator of Environmental Affairs, TGOJ Mälardalen,
and Bengt Uhlin, Project Director Project Management, Bombardier Transportation,

for your help with information about the use-phase for bearings in trains.

Göteborg, January 2003.

Karl Jonasson

Contents

1 Introduction

1.1 Background

In the Environmental Declaration for 1995, SKF claims that “continuous product refinement over the years has increased the energy savings obtained with SKF rolling bearings” [SKF, 1996]. In principle it is taken for granted that using the company’s products is good for the environment. One way to investigate if this is true is to perform a Life Cycle Assessment (LCA), and study the environmental impact of the products “from cradle to grave”. During the past five years a couple of LCAs has been made for SKF products, all of them comprising only “cradle to gate”. This means that they cover resource extraction, refinement of raw materials, product manufacturing and possibly recycling, but not the use of the products in an application.

This study could be seen in a context of an increased focus on environmental impact and energy efficiency during the use-phase of industrial products. The close connection between energy efficiency and sustainable development is discussed for example in Rosen [2002], where the author argues that attention must be paid not only to developing sustainable energy supply systems, but also to increasing the efficiencies of processes using the energy. In a study of environmental and economical aspects of the use-phase for truck tires in Western Europe [van Beukering & Janssen, 2000], emphasis is laid on the use-phase, as this contributes to more than 95 percent of the environmental impact during the life cycle of a tire, due to the influence of tire use on fuel consumption.

In the railway sector these questions are discussed within the EU-project RAVEL (Rail Vehicle Eco-Efficient Design), which is a collaboration project between different manufacturers, operators and universities [RAVEL, 2002]. One of the participants, Bombardier Transportation, has made an LCA of the train Regina, and presented selected results in a Type II Environmental Product Declaration (EPD), according to ISO 14021 [Bombardier, 2001b; Miljöstyrningsrådet, 2002].

1.2 Purpose

The purpose of this work is to study the environmental impact of the use-phase of some SKF products. Using LCA methodology, I will investigate the environmental impact of the use of rolling bearings in trains. Comparison will be made between different processes of the bearing life cycle, and between different generations of the selected bearing application.

1.3 Choice of application

The applications discussed for the study were e.g. machinery in the paper and steel industries, pumps, fans, wind power stations and different transport vehicles. The transport sector seemed particularly interesting, as the mobility of the world population probably will continue to rise for at least 50 years [Schafer & Victor, 2000]. Also the carbon dioxide emissions from passenger transport will increase for another 20 years, unless we see an improvement in energy efficiency in the coming years [Schafer & Victor, 1999].

After consultation with a few key persons within SKF, with knowledge of the company's products for trains and trucks, we decided that the study should deal with the use of rolling bearings in trains. SKF provides both bearings and bearing housings for trains, called axleboxes, which are mounted in direct connection with the train's wheels to make the wheel axle able to rotate (see figure 1). The bearings used for this purpose are in this study referred to as "train bearings", even though there are other fields of application for bearings in trains (e.g. in the traction system). What type of rolling bearings used for the wheel axle varies according to performance needs and train design, but the function is essentially the same.

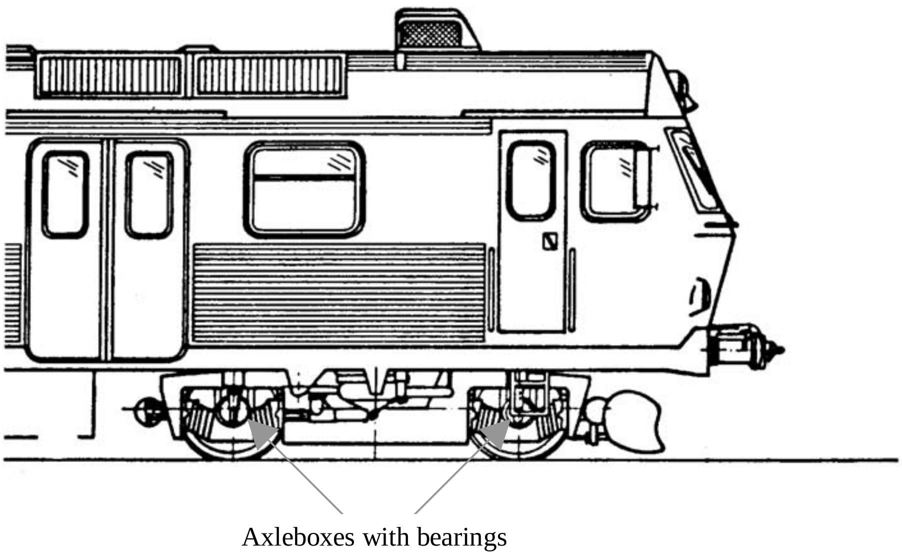

Figure 1: The axleboxes are located outside the wheels at both ends of the wheel axles. The figure shows a sketch of the train X10 [SKF, 1990].

Discussions with Fredrik Hallström at the SKF Railway Business Unit concluded with a proposal to study the commuter and regional trains X1, X10 and Regina. They represent three generations of so-called Electric Multiple Units (EMUs) with similar fields of application, and they are all equipped with SKF axleboxes and rolling bearings. X1 was manufactured by ASEA during the years 1967-1975, X10 by ASEA/ABB Traction 1982-93 and Regina is manufactured by Adtranz, today Bombardier Transportation, since the year 2000. The latest change of generations involves a change from un-sealed Spherical Roller Bearings (SRBs), used in X1 and

X10, to pre-lubricated, sealed Tapered Bearing Units, so-called TBUs, used in Regina. Roughly one million SKF TBUs are today in use in trains throughout the world.

Just over 100 X1s and 100 X10s were manufactured, and most of them are still in use (see tables, chapter 2). The X1s and half of the X10s are used in the Stockholm area, and the rest of the X10s are found in the Gothenburg area and in Skåne. During the 1990s some of the X10s were rebuilt with a different interior, and renamed to X11. These are also included under the designation X10 in this study, as the basic performance is the same. The Reginas are used on the Swedish West coast, in Mälardalen and in Bergslagen.

2 Bearings in trains

The three trains studied are called Electric Multiple Units (EMUs), and they all consist of two linked cars, denoted by A and B, sometimes with different traction properties and axle configuration. In the railway sector, un-powered axles are denoted by numbers and powered axles by letters, e.g. “2” and “B” means two un-powered and powered axles, respectively. An “o” means that each axle has individual traction and an apostrophe means that the axles are mounted on a bogie and not directly on the train car [World Rail Fans, 2002]. General information on the studied EMUs can be found in tables 1-3 below.

Table 1: General information on X1 [Diehl & Nilsson, 2000]. The values are mean values for the 94 X1s in use.

	X1-A	X1-B	X1-A + X1-B
Manufacturer	ASEA	ASEA	ASEA
Number in use	94	94	94
Number built	104	104	104
Number of seats	98	98	196
Axle configuration	Bo’ Bo’	2’ 2’	Bo’ Bo’ + 2’ 2’
Axlebox bearings	8 x 2 = 16 SRBs	8 x 1 = 8 SRBs	24 SRBs
Power (kW)	4 x 280 = 1120	-	4 x 280 = 1120
Length (mm)	24775	24775	49550
Wheel diameter (mm)	920	920	920
Duty mass (tons)	49.09	29.06	78.15
Maximum velocity (km/h)	120	120	120
Manufacturing year	1967-1975	1967-1975	1967-1975

Table 2: General information on X10 [Diehl & Nilsson, 2000]. The values are mean values for the 101 X10s and X11s in use. (Some vehicles can have a differing number of seats.)

	X10-A/X11-A	X10-B/X11-B	X10-A + X10-B/ X11-A + X11-B
Manufacturer	ASEA/ABB Traction	ASEA/ABB Traction	ASEA/ABB Traction
Number in use (X10/X11)	54/47	54/47	54/47
Number built (X10/X11)	54/47	54/47	54/47
Number of seats (X10/X11)	92/90	92/78	184/168
Axle configuration	Bo’ Bo’	2’ 2’	Bo’ Bo’ + 2’ 2’
Axlebox bearings	8 x 2 = 16 SRBs	8 x 2 = 16 SRBs	32 SRBs
Power (kW)	4 x 320 = 1280	-	4 x 320 = 1280
Length (mm)	24934	24934	49868
Wheel diameter (mm)	920	920	920
Duty mass (tons)	60.47	42.79	103.26
Maximum velocity (km/h)	140	140	140
Manufacturing year	1982-1993	1982-1993	1982-1993

Table 3: General information on Regina 2-cars [Diehl & Nilsson, 2000; Bombardier, 2001a]. (There will also be 9 Regina 3-cars in use at the end of 2002.)

	Regina A	Regina B	Regina A + Regina B
Manufacturer	Adtranz/Bombardier Transportation	Adtranz/Bombardier Transportation	Adtranz/Bombardier Transportation
Number in use (2002-10-29)	48	48	48
Number built (2002-10-29)	50	50	50
Number of seats (interreg./reg.)			163/196
Axle configuration	Bo' Bo'	2' Bo'	Bo' Bo' + 2' Bo'
Axlebox bearings	8 x 1 = 8 TBUs	8 x 1 = 8 TBUs	16 TBUs
Power (kW)	4 x 265 = 1060	2 x 265 = 530	6 x 265 = 1590
Length (mm)	26950	26950	53900
Wheel diameter (mm)	840	840	840
Duty mass (tons)	60	60	120
Maximum velocity (km/h)	180/200	180/200	180/200
Manufacturing year	2000-	2000-	2000-

The SRB used in X1-A, X1-B and X10 has the SKF product number 23226 CC/C3W33, and the axleboxes are called 723724, 723721 and 4000850 respectively (see figures 2 and 3). The Regina TBU is named 1639605 C and contains the bearing BT2B 641157 CB. The axlebox has the number 432758 (see figure 4). General information on the bearings is presented in table 4, together with data on the SRB 24024 CC/W33, studied in an earlier, production-phase LCA performed at SKF [Ekdahl, 2001]. The latter bearing is of the same type and material as the 23226 CC/C3W33 used in X1 and X10, but this is bigger, has fewer rollers and weighs 2.66 times more. With this in mind, the inventory results for the both bearings can be compared later in the study (see section 3.3.3).

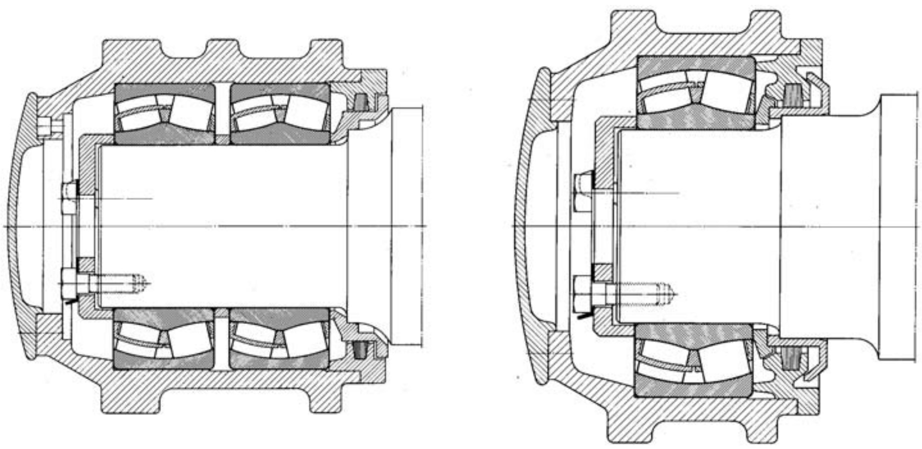

Figure 2: Cross-section of the axleboxes 723724 and 723721 used in X1-A and X1-B, with the bearing 23226 CC/C3W33 [SKF, 1971].

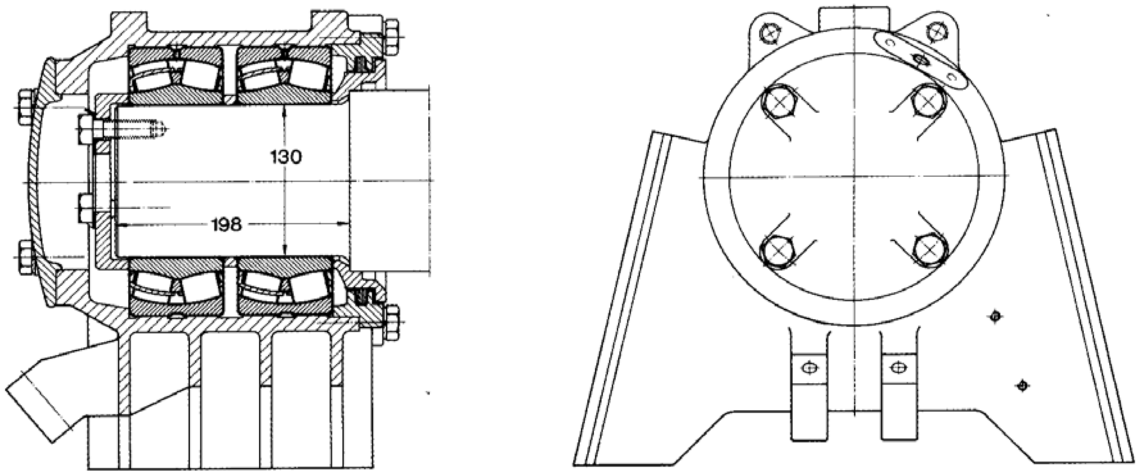

Figure 3: *The axlebox 4000850 used in X10, with the bearing 23226 CC/C3W33 [SKF, 1990].*

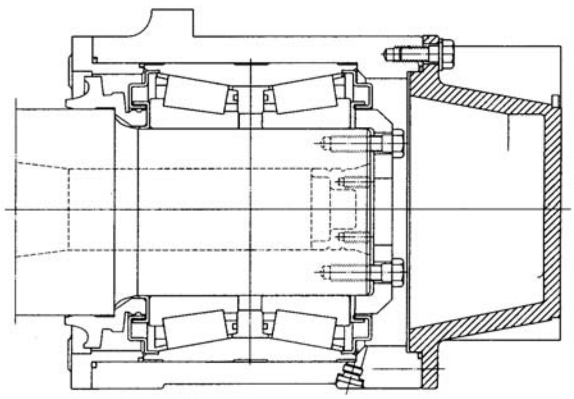

Figure 4: *Cross-section of the axlebox 432758 used in Regina, with the bearing BT2B 641157 CB. The TBU is called 1639605 C [SKF, 1999b].*

Table 4: *General information on the bearings 23226 CC/C3W33, BT2B 641157 CB and 24024 CC/W33 [SKF, 2003; SKF, 2001]. The last-mentioned weighs 2.66 times less than 23226 CC/C3W33, but is of the same type and material.*

	23226 CC/C3W33	BT2B 641157 CB	24024 CC/W33
Bearing type	Spherical Roller Bearing (SRB)	Single row Taper Roller Bearing (TRB), paired back-to-back	Spherical Roller Bearing (SRB)
Inner diameter (mm)	130	130	120
Outer diameter (mm)	230	230	180
Total width (mm)	80	182	60
Mass (kg)	14.5	27.7	5.45
Number of rollers	2 x 19	2 x 17	2 x 26

3 Life Cycle Assessment (LCA)

3.1 Goal and scope definition

3.1.1 Problem specification

The goal of this LCA is to investigate the environmental impact of the use-phase for bearings in trains. Three generations of trains, so-called Electrical Multiple Units (EMUs), will be studied, and comparison will be made between processes within the life cycle of the bearings, and between the bearings in the different generations of EMUs.

Together with earlier results, e.g. in Ekdahl [2001], the study is intended to give a deeper understanding of the environmental performance for the whole life cycle of bearings. The study will primarily be used for learning within SKF and for communication to customers and other stakeholders.

3.1.2 Functional unit

The function of bearings in train wheels is to be the link between wheel axle and train car, and make the axle able to rotate. The functional unit (fu) is here defined as 2 axleboxes with bearings, mounted on a wheel axle in use on its matched Electric Multiple Unit (EMU) during 100 000 km of transport. Unless otherwise stated, all the calculations in the LCA will be related to the functional unit.

The environmental impact of the use of rolling bearings in trains is compared with the ideal case, i.e. bearings with no friction, and with no need for maintenance. In such a comparison it seems that the impact of using bearings is solely negative. The ideal case is however not realistic, and every decrease in environmental impact should therefore be seen as having a positive environmental impact.

3.1.3 System boundaries

In this study, the use-phase of train bearings involves the time the bearings are in operation on an EMU wheel axle and the processes for wheel axle refurbishment when needed. The environmental impact of the whole life cycle, from cradle to grave, for products used during the use-phase of the bearings is thus included, while production and recycling of bearings, and distribution of new and discarded bearings are not.

The main processes discussed in the study are production, operation, maintenance and transports of train bearings. For the maintenance process, there is a number of sub-processes called dismounting of wheel axle, detergent production, naphtha production, lubricating oil and grease production, local processes, and waste oil handling. Local processes denote electricity use of tools and machines at the refurbishment site. The use-phase of train bearings is illustrated in figure 5.

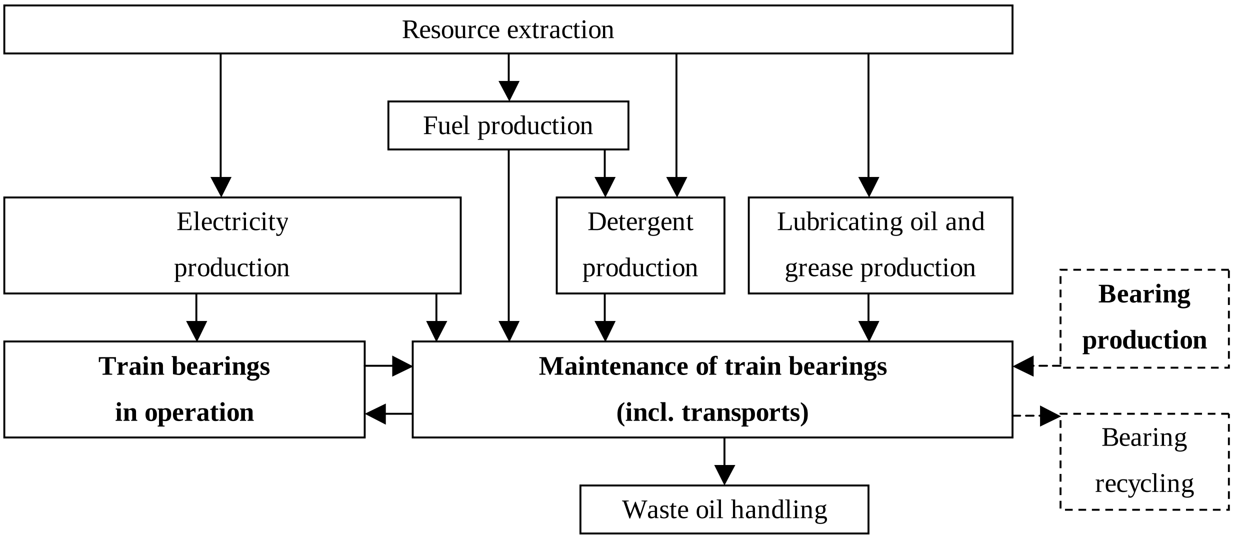

Figure 5: The use-phase of train bearings, where boxes represent the different processes and sub-processes, and arrows represent product flows. Bold type represents main processes. The dashed flows and processes are not included in the study.

3.1.3.1 Geographical boundaries

All the studied trains are in use in Sweden, where most of the maintenance is performed, too. The data used originates in the specific sub-processes employed at the actual sites in Sweden and at the TBU refurbishment site in Italy. The transport of the whole train to the wheel axle dismounting site is not included in the results, as the distance is depending on the actual operator and traffic route. A qualitative analysis of these transports is however included (section 3.3.3).

Data for detergents and oil products are general data for Europe and Northern Europe respectively, as they are based on the actual production conditions. The waste oil handling information applies to Swedish conditions. The influence of how and where the used electricity is produced is discussed in section 3.2.4.

3.1.3.2 Natural and technical boundaries

The operation and maintenance processes were mapped with regard to the specific sub-processes at the Swedish and Italian sites. However, specific data for those processes were not always available, and estimations made by the responsible staff, together with general data, had to be used as approximations.

The one environmental aspect considered for train bearings in operation is electricity use. Noise and vibration were not studied, and other environmental aspects of railway traffic operation were not regarded as being clearly related to the use of bearings.

Land, water and other types of resource use could not be assessed, due to lack of data (see section 3.1.4). The plastic bags and the re-usable wooden boxes used during transportation of TBUs are not included in the study. Neither is the electricity use of hydraulic tools and engraving equipment.

The environmental effects of industrial buildings, production of tools and machines, and the use of human labour are not included. The production of nuclear, wind and hydro power plants is however included in the inventory data used for electricity production, as recommended by IVL [Uppenberg et al, 2001].

3.1.3.3 Time-related boundaries

The study is intended to illustrate the present situation, and the qualitative and quantitative information for the main processes are from the year 2001 until today. However, the published data for the maintenance sub-processes detergent production, naphtha production, lubricating oil and grease production, and waste oil handling are from the past 5-15 years.

The lifetime of train bearings is not included in the study, as this primarily would affect the environmental impact of the production-phase in that a differing number of bearings would be needed to maintain the same function. It is thus included in the production-phase in the comparison with the operation, maintenance and transports processes (see section 3.3.3).

The lifetime of bearings is generally given as basic rating life (L_{10h}), which is “the life that 90 percent of a sufficiently large group of apparently identical bearings can be expected to attain or exceed” [SKF, 2003]. Calculations indicated a basic rating life of more than 200 000 hours (see section 3.2.2), i.e. 30 years with a daily running time of 18 hours. It is assumed that the lifetime of the bearings is of the same size as for the trains, and thus can be neglected (see discussion, section 4).

The maintenance process for the bearings in the Regina EMU is not definitive and may be changed during the coming years.

3.1.4 Data quality and acquisition

The data has been collected through visits and interviews, and through studies of earlier LCAs on detergents, oil products and waste oil handling. The TBU refurbishment process was studied through an SKF VHS presentation and the SKF instructions for mounting and maintenance (references and contact persons are found in the appendix).

Most data are estimates made by responsible personnel at the different sites, as there seldom is any information available, that is detailed enough for the purpose of an LCA. The estimates are combined with data from product data sheets and published LCA literature, to give a realistic approximation of the actual conditions. The electricity use for train bearings in operation was calculated with the computer program SKF Galaxy (see section 3.2.2).

The level of detail has been limited to the level of detail in the available references. This resulted in a focus on environmental impact related to emissions of polluting substances to air and water, and electricity use. Consequently, the impact of resource use is only analysed through the resulting emissions to air and water, i.e. during resource extraction.

Another consequence of the level of detail in the references is that detergents and oil products could not be analysed as specific brands and types, but the compositions had to be approximated with the general information available. The environmental impact of detergents and oil products should thus only be seen in relation to the other products and processes in the life cycle of train bearings, and not in relation to each other.

The data for production of bearings are taken from an LCA on the SKF Spherical Roller Bearing 24024 [Ekdahl, 2001], as described in chapter 2. The inventory results of that study were multiplied by a factor representing the mass ratio between the X1/X10 and the 24024 bearings, which is 2.66, to get an idea of the environmental impact of the production-phase compared to the operation, maintenance and transports processes. The number of bearings per functional unit (3 in X1 and 4 in X10) is also taken into consideration.

3.1.5 Choice of impact assessment method

The Life Cycle Impact Assessment (LCIA) step of an LCA is intended to illustrate the environmental impact of the studied processes. The inventory results are usually classified into certain impact categories, according to the type of potential environmental impact they may have, e.g. acidification or eutrophication (classification; see figure 6). Each material and substance in a category is then given a certain equivalence factor, reflecting the potential environmental impact compared to the other substances in the category, to recalculate the inventory results into impact equivalents (characterisation). The equivalents of each category can finally be added, to compare the potential environmental impact of different processes in the study. The total amount electricity used is often given as additional information.

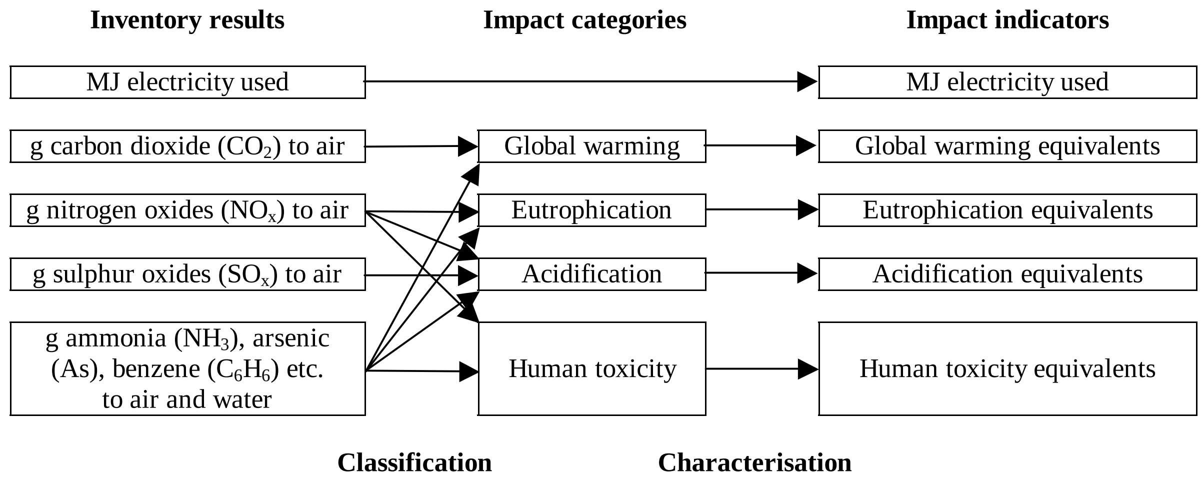

Figure 6: The Life Cycle Impact Assessment (LCIA) step of an LCA. In the figure a choice of possible impact categories is shown.

In the study the inventory results for electricity use and carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur oxides (SO_x) emissions to air are used directly as impact indicators, while classification and characterisation are utilized for the human toxicity impact category (see figure 7). Carbon dioxide emissions are a main contributor to the reinforcement of the greenhouse effect, emissions of nitrogen oxides may cause eutrophication, and both nitrogen oxides and sulphur oxides are contributors to acidification. The human toxicity is given as 1,4-dichlorobenzene equivalents, to denote the potential impact on human health of emissions to air and water [CML, 2002]. The environmental impact of electricity production is discussed in section 3.2.4.

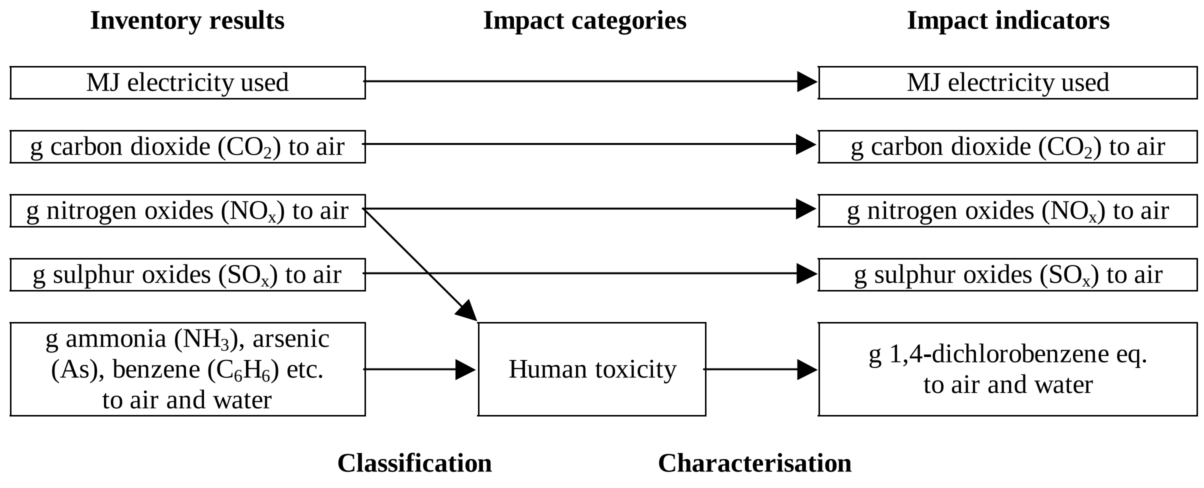

Figure 7: The impact assessment method used in the study.

3.2 Life Cycle Inventory Analysis (LCI)

This section starts with an overview of the environmental aspects of the use-phase for train bearings. After that follows a more comprehensive description of the processes, and of how the results were obtained. Central inventory results are presented in section 3.3, while detailed calculations, inventory data and references can be found in the appendix.

3.2.1 The use-phase of train bearings

When mounted on a X1 or X10, the axlebox with its one or two bearings is filled with grease and sealed, to keep the grease inside and water and dirt outside the box. Thus no lubrication is needed while the bearing is in operation, and the axlebox is only opened when the whole wheel axle is dismounted for maintenance. For Regina, the TBU is filled with grease and sealed at the SKF factory and no grease is added when the TBU and the axlebox are mounted on the axle.

If there is no leakage from the axlebox, the only environmental impact caused by train bearings in operation is related to noise, vibration and energy use because of friction between bearing parts. The consequences of the energy use depend on the energy source, which is electricity for all EMUs. The environmental impact of noise and vibration is not included in this study.

For maintenance of train bearings, the wheel axle is dismounted from the train car, and the axlebox and the bearings are dismounted from the axle. The different parts are cleaned, washed, refurbished, relubricated and finally remounted on the axle. The environmental impact of these activities, and the transports between them, is related to the use of electricity, detergents and oil products, and the discharge of greenhouse gases, toxic material and polluting substances.

Changed technical performance may also be of interest when investigating the environmental impact from the use of train bearings. Altered weight, size, maximum rotational speed, carrying capacity etc. may involve altered use and new fields of application that have consequences for the environment. These aspects are partly included in the study, and are further discussed in section 3.3.1.

3.2.2 Train bearings in operation

When the trains are in operation the wheel axles and the inner rings of the bearings are rotating with a velocity proportional to the train speed. Because of friction between the bearing components, heat is generated in the axlebox, and at the same time the air outside helps cooling the axlebox. The consequence of the friction is a certain loss of power, and it is influenced by the construction of the bearing, lubrication, radial and axial load, rotational speed etc. The cooling factor is depending on e.g. materials, wind speed and ambient temperature.

The calculations used in the study are performed in SKF Galaxy BeaTemp (version 3.1), a program that uses the equations published in the SKF General Catalogue [SKF, 1999a] to calculate the bearing temperature for which the generated heat is equal to the cooling. The bearing temperature, power loss and basic rating life are then given as outputs from the program. The equations used have been tried and verified by experimental results through several years of testing.

The exact conditions for the train bearings could not be modelled in Galaxy, so some of the parameters had to be approximated. To get a realistic picture of the cooling for the actual situation, these parameters were matched to experimental results on bearing temperature from a field experiment with a train similar to X10 [Blomberg, 1975]. It is assumed that the radial load is equally distributed over the bearings on each train car, and that no axial load is present. The calculations are based on the duty mass, and the complete results are presented in appendix 2. The mass of passengers is neglected, but corresponds to roughly 10 percent of the duty mass if the train is half-filled. The ambient temperature used in the calculations was 10 degrees centigrade.

The total efficiency of the electrical supply system is 81.8 percent for X1 and X10, and 84.5 percent for newly developed electric vehicles [Andersson, 1994], which would include Regina. The numbers can be explained by losses during transformation, and transmission of electricity to the trains.

3.2.3 Maintenance of train bearings

The maintenance interval is of great importance for the analysis of the total environmental impact from the use of train bearings. However, the real maintenance interval is difficult to estimate, as the wheel axles can be sent to refurbishment for various reasons, e.g. misuse, derailment, warm-running, reached recommended maintenance interval etc. There is no statistics on how often the bearings are sent to refurbishment just because of malfunction of the bearings themselves.

During a one-year period from October 23rd 2001, Citypendeln sent 196 of their 960 X1/X10 wheel axles to refurbishment, which represents 20 percent, or a 5-year maintenance interval. How many of the bearings that actually needed refurbishment is not known, but the same percentage is assumed. Together with a yearly running distance of 100 000-150 000 km for X1/X10 from TrainTech field measurements, this gives a maintenance interval of 500 000-750 000 km.

For the calculations a maintenance interval of 500 000 km is assumed for the bearings, which implies maintenance every fifth year if the EMUs are run 100 000 km per year. For the bearings in X1, X10 and Regina the recommended maintenance intervals are 1 200 000 km, 648 000 km and 1 000 000 km respectively, and for Regina a 4-year interval is recommended if the 1 000 000 km is not reached. These figures are based on evaluations of many factors, like climate, speed, lubrication and wheel axle and bearing construction, and do not reflect the performance of the bearings alone (for reference persons, see appendices A2-A5).

An overview of the maintenance process for train bearings is presented in figure 8.

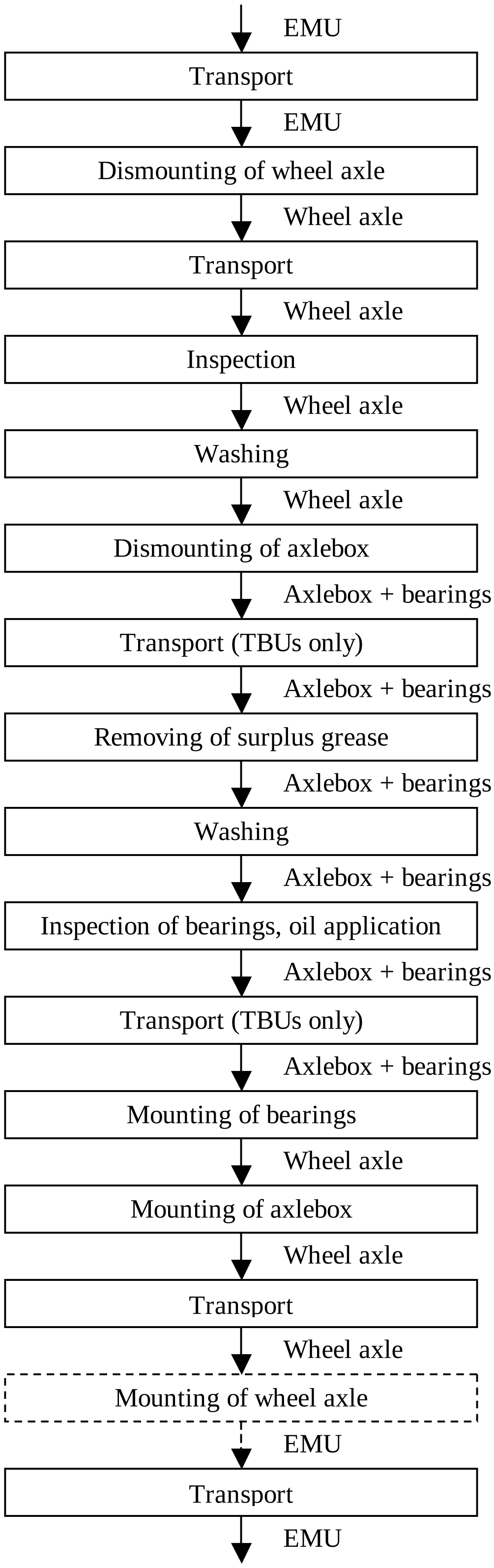

Figure 8: The maintenance process for train bearings. The mounting of the wheel axle is not included in the LCI, as another wheel axle is dismounted at the same occasion.

3.2.3.1 Dismounting of wheel axle

For Regina the dismounting of the wheel axles takes place at Bombardier Transportation in Västerås, and for X1 and half of the X10s it is done at Citypendeln in Älvsjö. (The process for the other half of the X10s is here approximated with the one at Citypendeln.) It is assumed that for each wheel axle 5 min of local electric forklift truck transports are used during the dismounting and refurbishment processes, which implicates an electricity use of 3.0 MJ.

To dismount the wheel axle from the EMU, it is first unfastened, and then the train cars are lifted from the axle by an electric lift. The energy needed for the lift is here approximated by the standard equation for potential energy:

$$E = mgh, \qquad (1)$$

where m is the mass of the EMU, g is the gravitational constant (in Sweden $g \approx 9.82$) and h is the height of the lift. It is assumed that two axles out of the eight are removed and that the mass of these axles can be neglected compared to the total mass of the EMU. As there are more wheel axles than needed for all EMUs in use today, the dismounted axle is directly replaced by a new or refurbished one. Thus only one lift of the train cars is included in the refurbishment process, and the inventory results for this lift are split up on two wheel axles. The results are presented in table 5.

Table 5: The electricity use for dismounting of a wheel axle and local electric forklift truck transports.

EMU	Electricity use, lifting (MJ)	Electricity use, local transports (MJ)	Electricity use, lifting + local tr. (MJ)
X1	0.46	3.0	3.46
X10	0.61	3.0	3.61
Regina	0.59	3.0	3.59

3.2.3.2 Wheel axle refurbishment

Firstly the wheel axle is washed, and then it is inspected and compared with the instructions given from the customer. If bearing refurbishment is needed, the axlebox is dismounted, surplus grease is removed and the different parts are washed with water and an alkaline washing detergent using a tunnel washing machine. For TBUs there is no grease to remove at this stage, but the TBUs are dismounted, packaged and sent to SKF for refurbishment. SRBs are dismounted using a special dismounting tool, which presses in oil between the bearing and the axle, and then the bearing can be removed. The SRBs are then cleaned in a naphtha bath, inspected and covered with a thin layer of oil for rust-proofing.

A certain share of the bearings are discarded and sent to recycling. For X1/X10 this share is approximately 25 percent, but for Regina the processes are too new to give a proper estimate. The discarding of bearings is not included in the study, as this is not related to the use-phase. However, it must be accounted for in the comparison with the production-phase (section 3.3.3).

The TBUs are disassembled at the SKF workshop using a hydraulic pressing tool, and the different parts are washed with water and an alkaline detergent, rinsed and drained. After inspection, each bearing is engraved with refurbishment information and then the TBUs are put together, greased, new seals are added and the pressing tool is used. After that the TBUs are packaged and sent back to the customer. (The packaging material is not included in the study.)

The axlebox parts and the axle tap are rust-proofed and the axlebox is remounted. The SRBs are heated to about 140ºC and shrinked onto the axle, while the TBUs are just pressed onto the axle tap with a hydraulic tool. The inventory results for the refurbishment process are shown in table 6 below.

Table 6: The inventory results for the refurbishment process. No naphtha is used for the Regina bearings, but more water and detergent is used instead. The amount of grease used for the TBUs in Regina is half the amount used for the SRBs in X1 and X10.

Inflows	**X1**	**X10**	**Regina**
Water (dm^3)	6.7	6.7	8.9
Electricity (MJ)	35.1	38.7	32.4
Detergent (kg)	0.28	0.28	0.38
Naphtha (kg)	1.6	1.6	-
Thin oils (kg)	0.20	0.20	0.20
Grease (kg)	1.6	1.6	0.80
Anti-rust agent (kg)	0.040	0.040	0.14
Total oil & grease (kg)	1.84	1.84	1.14

Outflows	**X1**	**X10**	**Regina**
Waste water (dm^3)	6.7	6.7	8.9
Oil sludge (kg)	0.24	0.24	0.34
Grease (kg)	1.6	1.6	0.8
Naphtha (kg)	1.6	1.6	-
Total waste oil (kg)	3.44	3.44	1.14

3.2.3.3 Detergent production

Except for the X1/X10 bearings, which today are cleaned with naphtha, all the components are washed with water and an alkaline washing detergent in tunnel washing machines. The properties for all water-based washing machines are here approximated with one standard machine for washing of railway parts, including electricity, detergent and water use, and waste water generation. The one detergent mix used in the calculations is an approximation of a standard alkaline detergent.

3.2.3.4 Oil products

The problem with inventory data for the production of refined oil products is that many products often are produced in the same process [Boustead, 1994a]. This implies a so-called allocation problem, where the emissions of one process have to be distributed on several products. In the reference used, this problem was handled by letting naphtha represent a typical refinery product [Boustead, 1993]. This is used as an approximation of all oil products in the study, i.e. naphtha, anti-rust agent, and lubricating oil and grease. The use of naphtha is however treated separated from the other products, as it is used for washing of the X1/X10 bearings, but not for the Regina bearings.

The information on waste oil handling used in the study is based on the conditions in southern Sweden, but is used as an approximation of general treatment of waste oil, also for Italian conditions. The transportation of the waste oil is not included in the study, as this would vary between different locations, and as no specific data were available.

3.2.3.5 Transports

To dismount the wheel axles, the whole train has to be taken to a workshop, where the train can be lifted. The detour distance for a train without passengers varies between different operators and traffic routes, and the related electricity use and environmental impact is assessed in a qualitative manner in chapter 3.3.3.

The dismounted wheel axles are transported by truck to the refurbishment sites. For the X1/X10 wheel axles all the maintenance sub-processes are carried out at the same location at TGOJ in Tillberga, and then they are returned to Citypendeln in Älvsjö by truck. The TBUs in Regina, though, are dismounted from the wheel axle at Lucchini in Surahammar and sent by truck via SKF, to a refurbishment site in Pinerolo in northern Italy. When refurbished they are returned to Lucchini and remounted on the axle, which is returned to Bombardier Transportation in Västerås. The transport distances, and the size and properties of the different trucks can be found in appendix 10.

3.2.4 Electricity production

The inventory results for electricity use are highly dependant on the electricity production system, as the mix of energy sources varies greatly between different suppliers and regions. In the actual cases the EMUs operated by SJ AB and X-Trafik AB (all Reginas and half of the X10s) are running on Bra miljöval (Eng. “Good Environmental Choice”) electricity, while those operated by Citypendeln (all X1s and half of the X10s) are running on the normal Swedish electricity mix. However, the studied bearings should not be connected with a certain electricity mix, so the three EMUs are analysed using the same three electricity mixes (see table 7 below). Coal is here representing a worst-case scenario for the environment, while Bra miljöval (approximately 100 percent hydro power) could be seen as a good alternative with respect to emission of greenhouse gases, pollution and waste problems. The emissions to air from the production of electricity are presented in figures 9 and 10.

Table 7: Different mixes for electricity production systems [Uppenberg et al, 2001].

	Coal (%)	Swedish mix 1999 (%)	Bra miljöval (%)
Hydro	0	48.20	100
Nuclear	0	44.30	0
Wind	0	0.23	0
Oil (CHP*)	0	1.33	0
Coal (CHP*)	0	2.43	0
Natural gas (CHP*)	0	0.47	0
Bio (CHP*)	0	2.81	0
Oil condensation	0	0.20	0
Coal	100	0	0

(* CHP stands for Co-generation of Heat and Power)

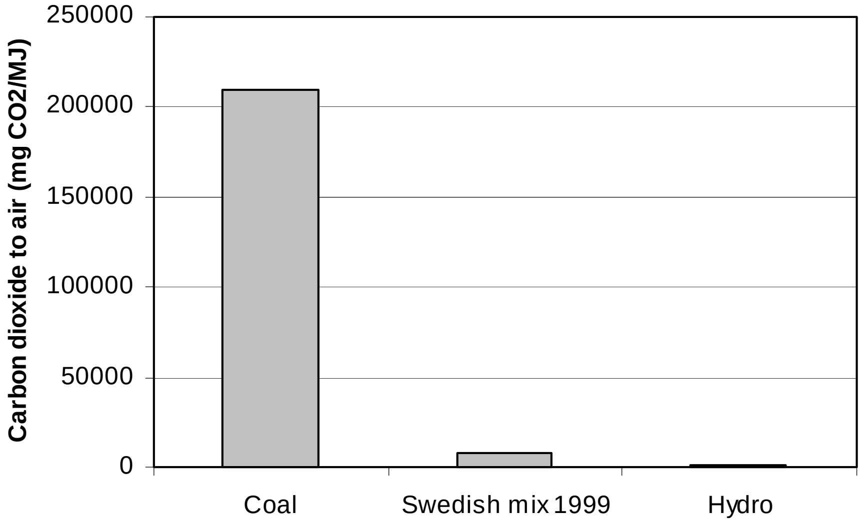

Figure 9: Carbon dioxide emissions to air from the production of different electricity mixes. The carbon dioxide coming from hydro power is mainly emitted during construction of the power plant. (Note that the emissions are related to 1 MJ of produced electricity, and not to the functional unit.)

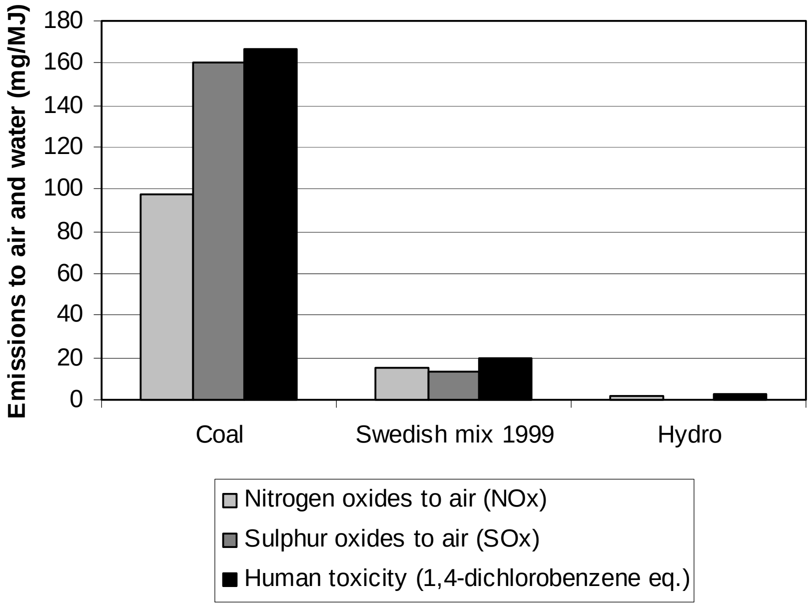

Figure 10: Emissions to air from the production of different electricity mixes. (Note that the emissions are related to 1 MJ of produced electricity, and not to the functional unit.)

We see that the emissions vary widely with respect to the actual mix, and accordingly the environmental impact of train bearings in operation is depending on the electricity mix used.

The problem with electricity production mixes also arises in the analysis of the different maintenance sub-processes. However, in some references the life cycle emissions from electricity production are already included in the inventory data, as a certain production mix has been used to calculate the emissions. Then the electricity use (in energy units) often is given as additional information, here called accounted electricity use. The other case, when the emissions of electricity production are not included in the inventory data, is called non-accounted.

3.2.5 Production of bearings

In the comparison with earlier results for the production-phase [Ekdahl, 2001], a lifetime of 20 years is used. This is based on the estimated maintenance interval 500 000 km, and the discarding rate 25 percent, as discussed in section 3.2.3 and 3.2.3.2.

3.3 Inventory results and assessment

3.3.1 Train bearings in operation

The total electricity use related to the bearings in X1, X10 and Regina for different speeds is presented in figure 11. (The results were obtained with SKF Galaxy, as explained in section 3.2.2.) We see that the electricity use for the bearings in X10 is more than 30 percent higher than for X1, which is slightly higher than for Regina. The friction seems to have a maximum at low speeds, but the reasons for this is not analysed in this study. For the analysis of the relations in environmental impact between production, operation, maintenance and transports the reference speed 80 km/h is used for all the EMUs (see section 3.3.3).

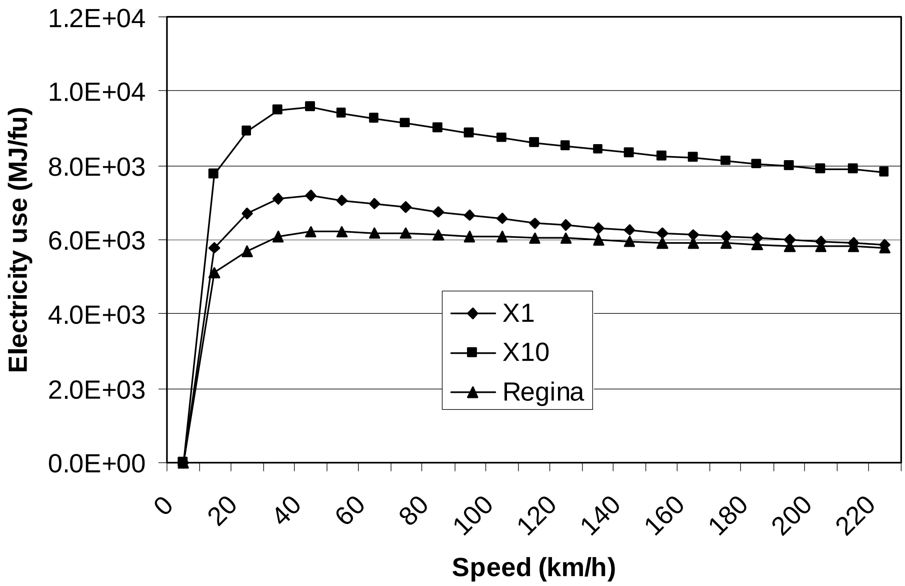

Figure 11: Electricity use related to the bearings in X1, X10 and Regina. For the reference speed 80 km/h the values are 6.7 GJ/fu, 9.0 GJ/fu, 6.2 GJ/fu for X1, X10 and Regina, respectively.

For train bearings in operation, all electricity use is non-accounted, and the related emissions per MJ produced electricity can be studied by looking at the effects of different electricity mixes (section 3.2.4).

For comparison, field measurements from TrainTech show that the electricity use is about 2.5 TJ per 100 000 km (7 kWh/km) for a whole X1/X10 EMU. The value for Regina is about 2 TJ (6 kWh/km). (See appendix 2 for references). If the result for the functional unit, shown in figure 11, is multiplied by the total number of wheel axles on one EMU, which is 8, we get roughly 50 GJ. This is the electricity use for all the bearings in one EMU, and it stands for at least 2 percent of the total electricity use for the whole train.

The difference in electricity use between X1 and X10 can only be related to the bearing radial load, as the other parameters for those (bearing model, lubrication, rotational speed etc.) are identical in the calculations. The bearing radial load is directly proportional to the duty mass of the EMUs, and to get a picture of the influence of the duty mass, the electricity use is divided by the average radial load for the bearings in each train. The result is presented in figure 12.

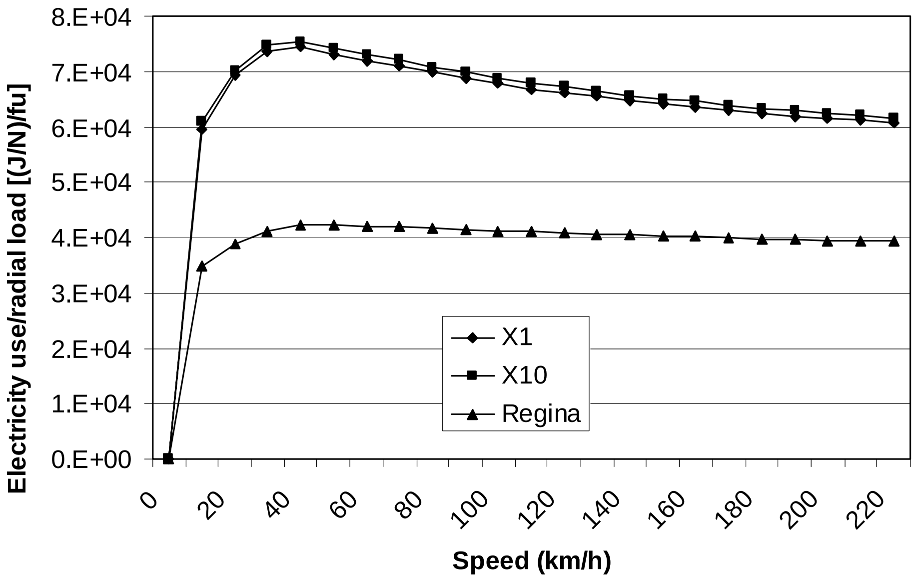

Figure 12: Electricity use divided by the average radial load for the bearings in X1, X10 and Regina. (The bearing radial load is not included in the functional unit.)

We see that the electricity use for the bearings in Regina is 30-40 percent lower than for X1 and X10, when divided by the radial load. The lower electricity use is however taken out in heavier trains, so that no major difference in electricity use can be seen between X1 and Regina in the preceding functional unit comparison (figure 11). This is not accounted for in the comparison with the production, maintenance and transports processes, as the bearing radial load is not included in the functional unit.

The figure also indicates that the maximum in electricity use for the speed 40-50 km/h is not that characteristic for the Regina bearings, as for those in X1 and X10.

It should be noted that the average number of bearings per wheel axle is 3 for X1 and 4 for X10. However, no conclusions about this can be drawn from the calculations in the study, as the duty mass is different for the two EMUs.

3.3.2 Maintenance of train bearings

To begin with, the inventory results of the maintenance process show that the non-accounted electricity use is dominating over the accounted use (see figure 13 below). Thus the non-accounted use can be taken as an approximation for the total electricity use when comparing with production, operation and transports (section 3.3.3). The electricity use for the different maintenance sub-processes is presented in figure 14.

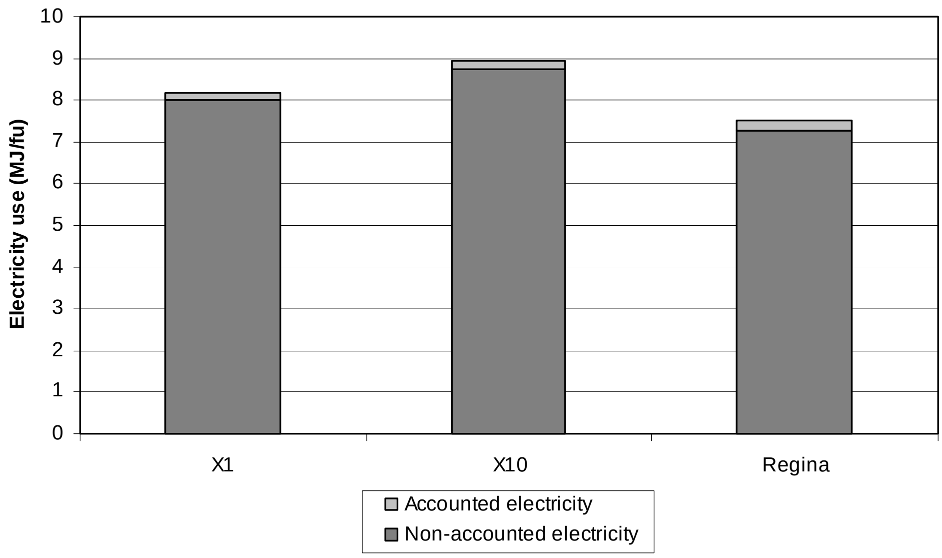

Figure 13: Accounted and non-accounted electricity use of the maintenance process. The non-accounted use can be taken as an approximation of the electricity use for the maintenance process in the comparison between the production, operation, maintenance and transport processes.

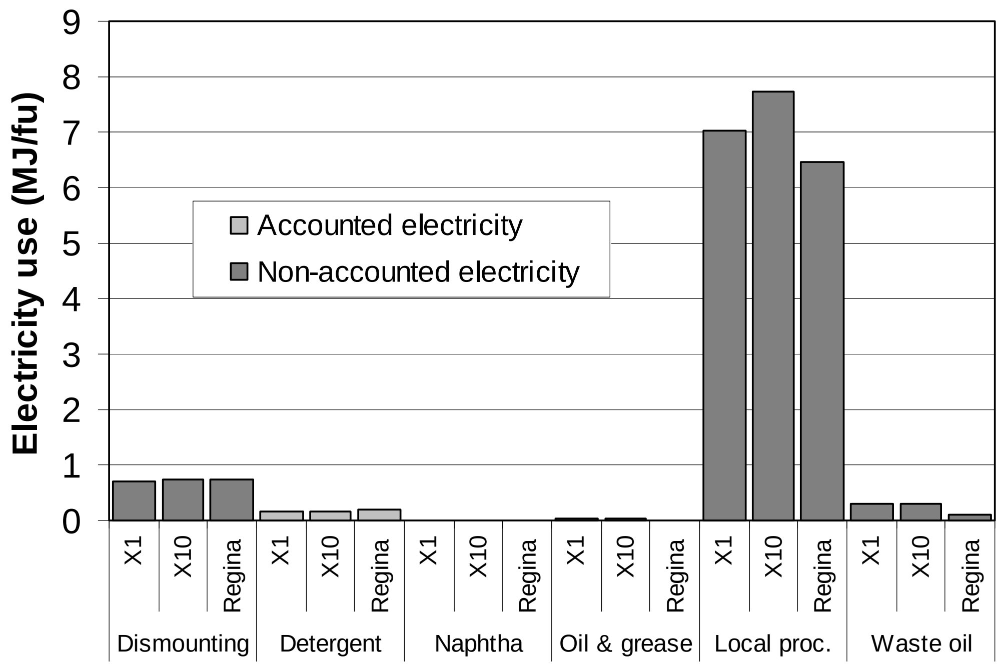

Figure 14: Accounted and non-accounted electricity use of the different maintenance sub-processes. The electricity use for local processes at the refurbishment site is dominating.

Comparing the electricity use for the maintenance sub-processes, we see that local processes at the refurbishment site are dominating. Approximately 1/3 is here used for heating the X1/X10 bearings (3 bearings in X1 and 4 in X10) and 2/3 are used for heating the washing water. For Regina the only local process is the heating of washing water. We can also see that the electricity use for detergent production is slightly higher for Regina, as more detergent is used instead of naphtha for washing. For waste oil handling the electricity use is lower for Regina, as no naphtha and less grease is treated.

Emissions to air from the maintenance sub-processes are presented in figures 15-17 below. Consequently, emissions deriving from accounted electricity use are included, while those from non-accounted electricity use are not.

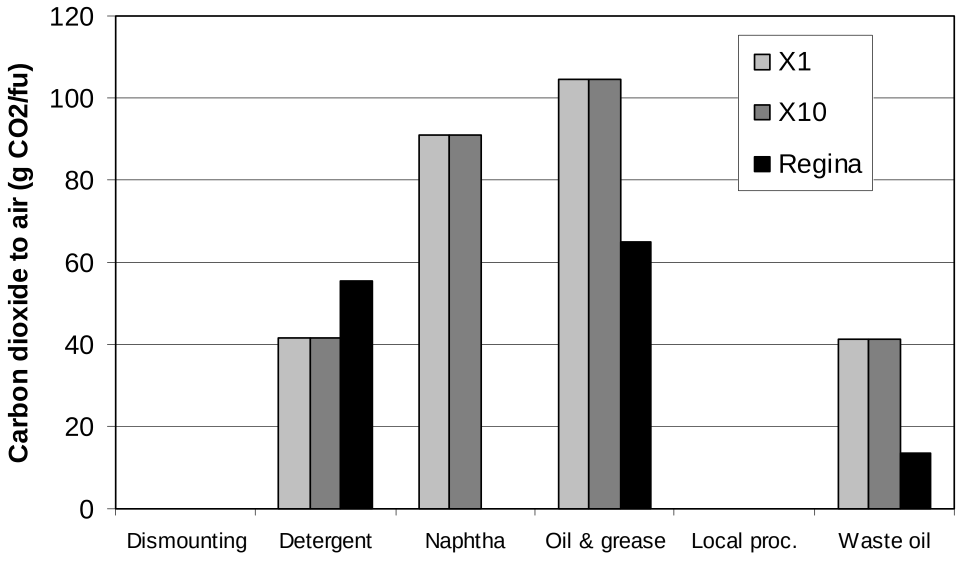

Figure 15: Carbon dioxide emissions to air from the maintenance sub-processes. Emissions from non-accounted electricity use are not included.

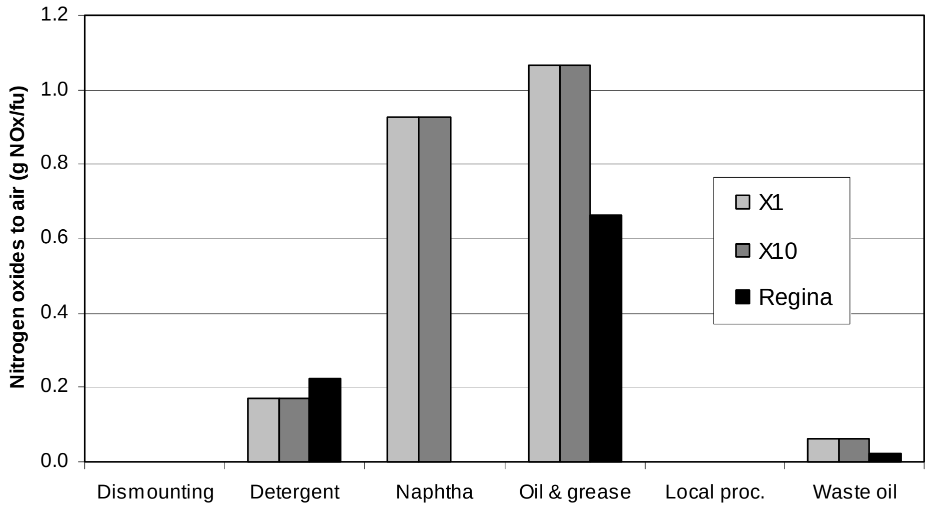

Figure 16: Nitrogen oxides emissions to air from the maintenance sub-processes. Emissions from non-accounted electricity use are not included.

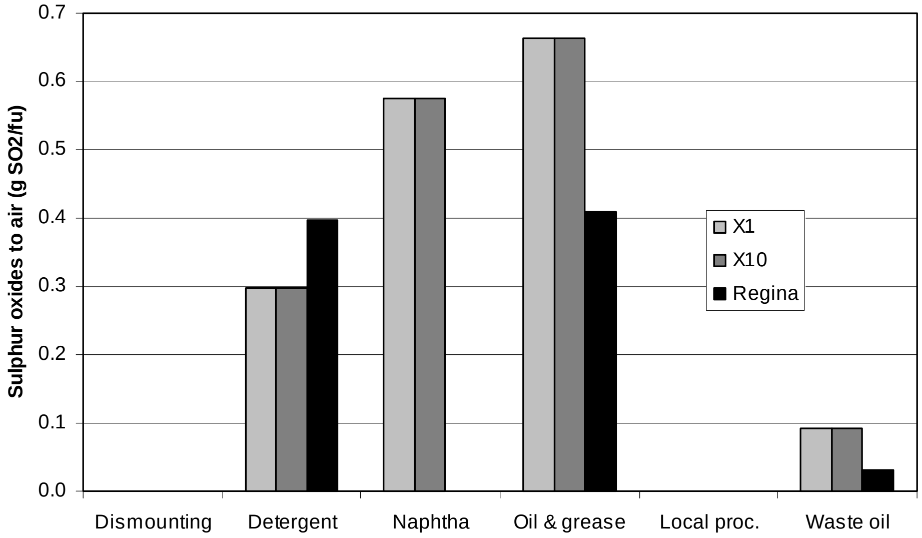

Figure 17: Sulphur oxides emissions to air from the maintenance sub-processes. Emissions from non-accounted electricity use are not included.

The trend seem to be the same for both carbon dioxide, nitrogen oxides and sulphur oxides, that naphtha and oil and grease production are the main contributors of emissions to air during the maintenance sub-processes. We see that the emissions for the Regina bearings are higher than for X1/X10 during detergent production, but lower during oil and grease production and waste oil handling, and zero during naphtha production. This is due to the use of water and detergent instead of naphtha for washing, and the smaller amount of grease used for the Regina bearings. The emissions to air and water, with respect to human toxicity, are analysed in figure 18 below.

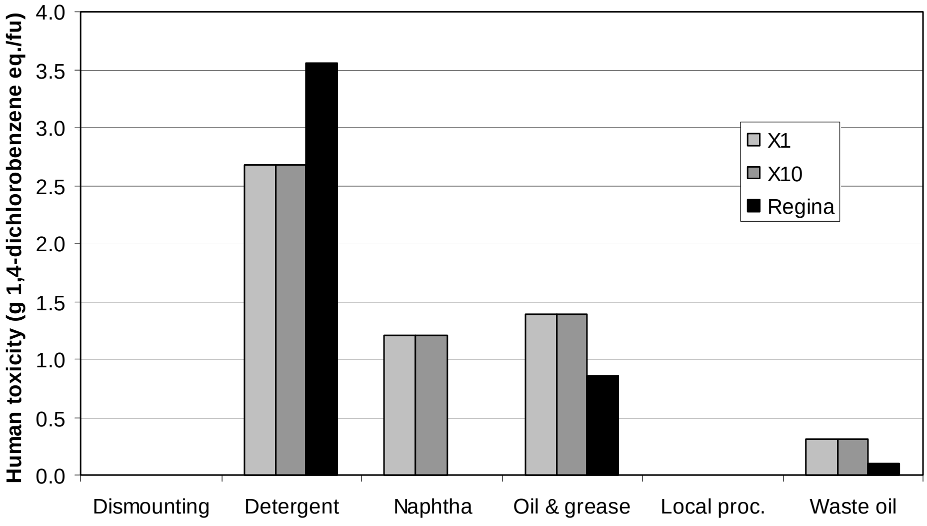

Figure 18: Human toxicity index for emissions to air and water from the maintenance sub-processes, given as 1,4-dichlorobenzene equivalents. Emissions from non-accounted electricity use are not included.

The human toxicity analysis shows a major contribution from detergent production for all the EMUs. Hence the higher use of detergent for the Regina bearings is of greater importance when it comes to human toxicity than it is for electricity use, carbon dioxide, nitrogen oxides and sulphur oxides emissions. Still the index is lower for the Regina bearings on naphtha, oil and grease production, and waste oil handling.

3.3.3 Production, operation, maintenance and transports

In the comparison of environmental impact between production, operation, maintenance and transports of train bearings, logarithmic scales have to be used to illustrate the relations (except figure 21). This means that one has to be careful when reading the diagrams, as one step on the y-scale indicates a 10-fold increase in data value. The reference speed used in the calculations is 80 km/h, and for both operation and maintenance the emissions of the non-accounted electricity are based on the Swedish electricity mix (see section 3.2.4). The already accounted electricity use of the maintenance process is not included as it is assumed to be negligible (see section 3.3.2). The results are presented in figures 19-24, where production data only applies to the bearings in X1 and X10.

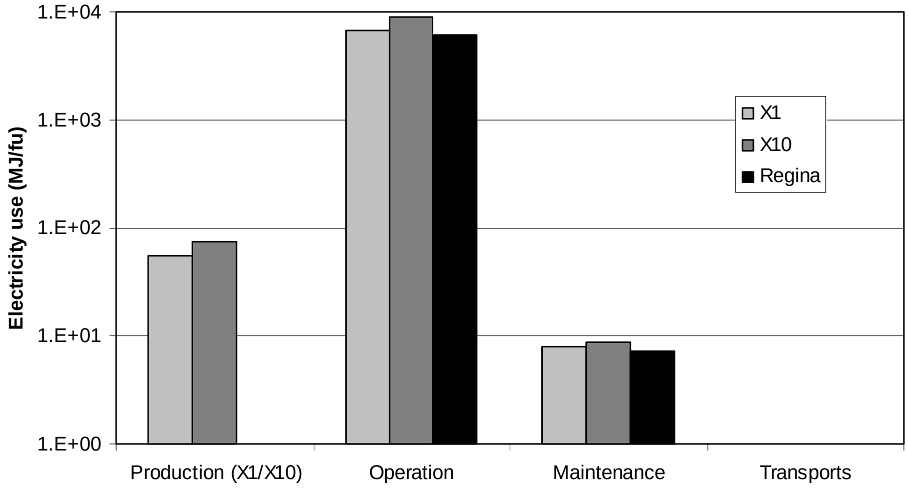

Figure 19: The electricity use for production, operation, maintenance and transports of train bearings. (Note the logarithmic scale! The difference in electricity use between the X10 and the Regina bearings is 2 000 times bigger during operation than during maintenance.)

The electricity use for train bearings in operation seems to be about 1 000 times higher than for maintenance, and for production it is almost 10 times higher than for maintenance. The electricity used for transporting the train to the wheel axle dismounting site is not shown in the figures, but if the electricity use for a whole train is about 20 MJ/km (6 kWh/km; see section 3.3.1), a 100 km detour would give an electricity use of 400 MJ/fu. A 500 km detour would give an electricity use of 2 GJ/fu, which is comparable to the use for operation (6-9 GJ/fu).

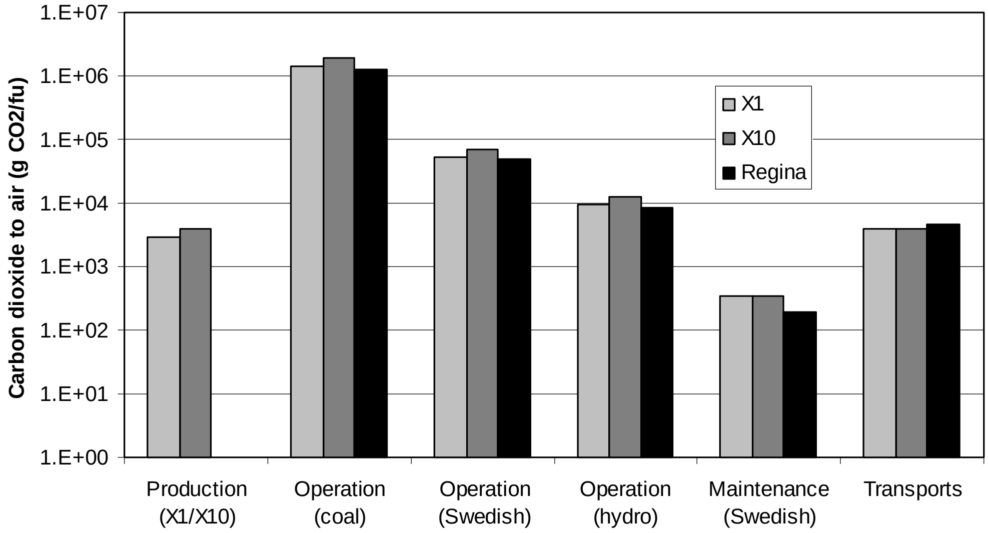

Figure 20: *Carbon dioxide emissions to air from the production, operation, maintenance and transports processes, respectively. Only one of the columns for operation, with a specific electricity production mix, is included in the use-phase of the bearings. (Note the logarithmic scale! The difference between X10 and Regina is about 50-100 times bigger during Swedish operation, than during maintenance and transports.)*

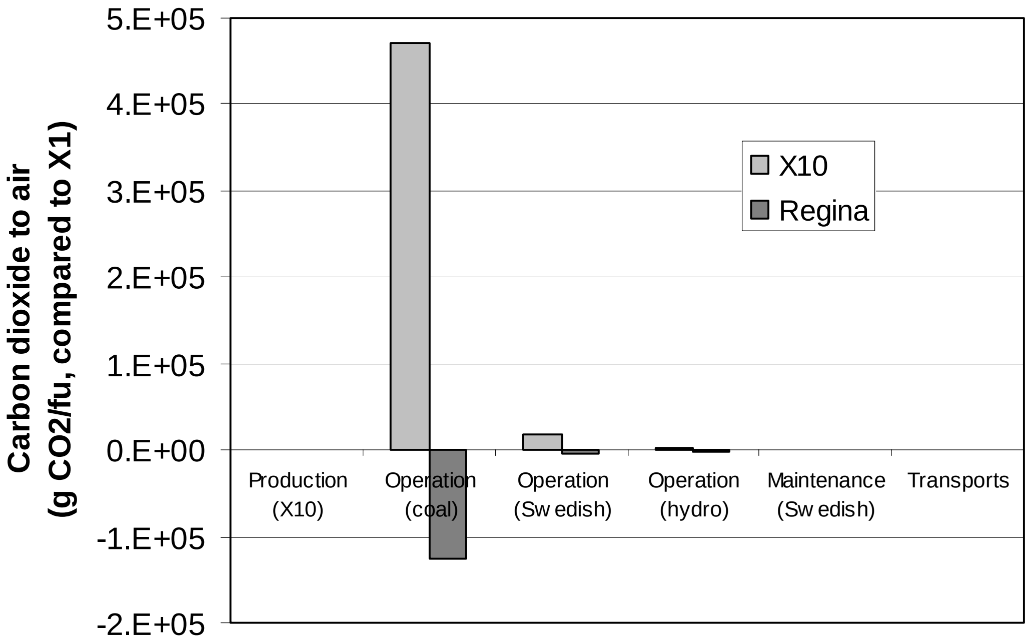

Figure 21: *Carbon dioxide emissions to air for X10 and Regina, compared to those from X1. Only one of the columns for operation, with a specific electricity production mix, is included in the use-phase of the bearings.*

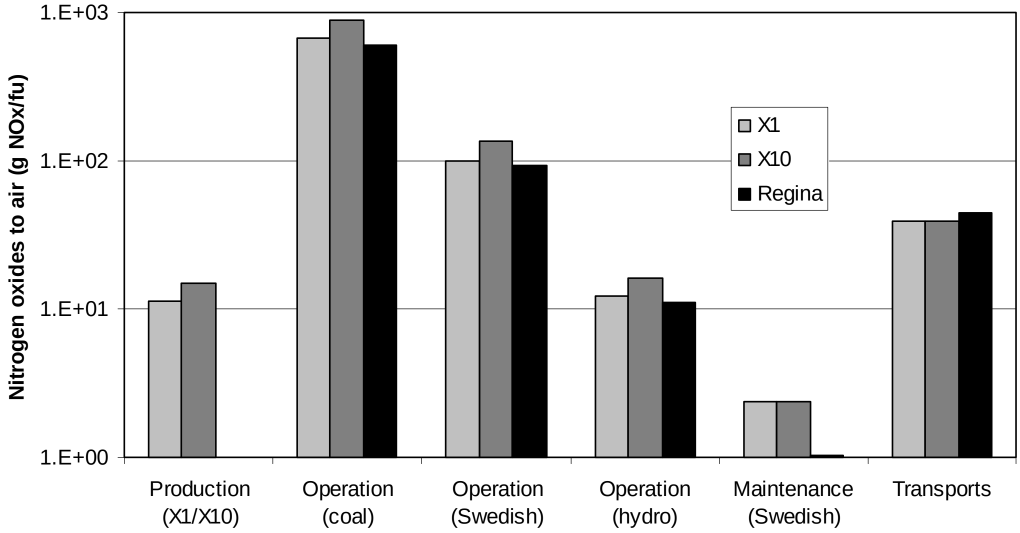

Figure 22: *Nitrogen oxides emissions to air from the production, operation, maintenance and transports processes, respectively. Only one operation process, with a specific electricity production mix, is included in the use-phase of the bearings. (Note the logarithmic scale! The difference between X10 and Regina is about 10 times bigger during Swedish operation, than during maintenance and transports.)*

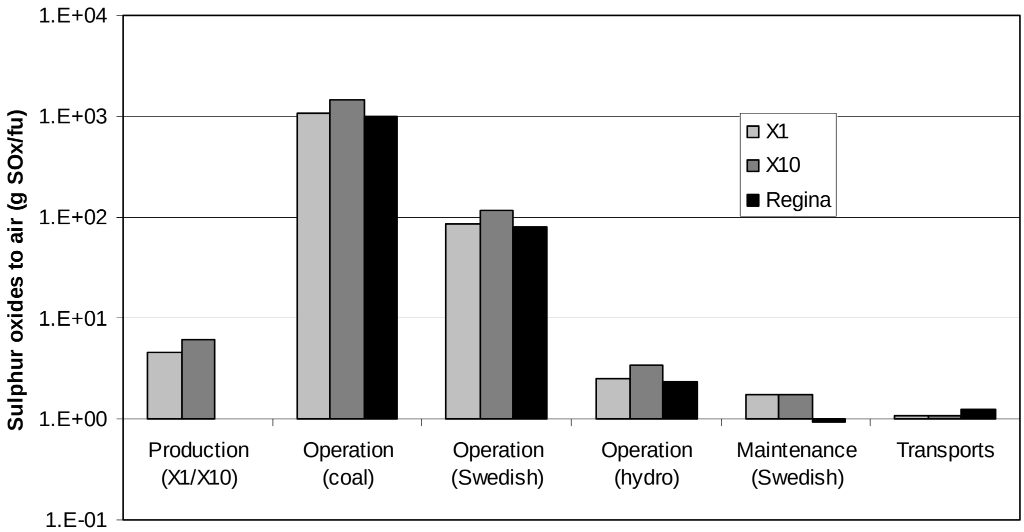

Figure 23: *Sulphur oxides emissions to air from the production, operation, maintenance and transports processes, respectively. Only one operation process, with a specific electricity production mix, is included in the use-phase of the bearings. (Note the logarithmic scale! The difference between X10 and Regina is more than 40 times bigger during Swedish operation, than during maintenance and transports.)*

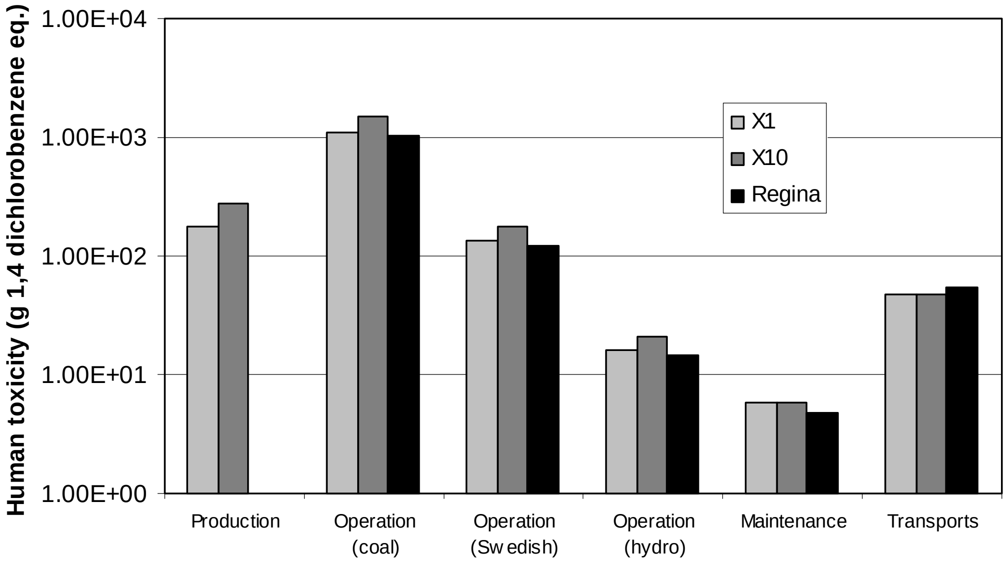

Figure 24: Human toxicity index for emissions to air and water from the production, operation, maintenance and transports processes, given as 1,4-dichlorobenzene equivalents. Only one operation process, with a specific electricity production mix, is included in the use-phase of the bearings. (Note the logarithmic scale! The difference between X10 and Regina is 10-50 times bigger during Swedish operation, than during maintenance and transports.)

We can see that the tendency is the same for all the presented emissions. Operation stands for emissions that are up to 1 000 times higher than for maintenance, depending on electricity mix and the studied substances. The emissions from transports are about 10 times higher than those from maintenance, and sometimes as high as those from operation. We also find that the emissions from the Regina transports are about 10 percent higher than for X1 and X10.

The emissions from production seem to be clearly higher than those from maintenance, and almost as high as the emissions from transports and train bearings in operation.

4 Discussion

The use of rolling bearings in trains could not be said to have a negative environmental impact, when compared to not using bearings. Every decrease in resource use and emission should therefore be seen as having positive environmental impact.

Not all the environmental aspects discussed in the study are strictly connected to bearing construction. Washing procedures and the location of refurbishment sites could for example be changed, as long as some quality requirements are satisfied.

There are a few questions, regarding the assumptions and limitations in the study, which have to be discussed:

- The lifetime of the bearings is not included in the use-phase, though it is closely connected to both the operation and maintenance processes. A longer lifetime would have an influence on the relation in environmental impact between the production-phase and the use-phase, as fewer bearings would have to be replaced with new ones during maintenance.

- The lifetime of the bearings is included in the comparison with the production-phase in section 3.3.3. This comparison, with a bearing similar to the one used in X1 and X10, is intended to give an idea of the relation in environmental impact between the production-phase and the use-phase, and the exact results should be used with care.

- The actual maintenance interval is of course an important factor when investigating the environmental impact of the use-phase. A 50-percent increase (or decrease) of the maintenance interval would for example halve (or double) the environmental impact of the maintenance and transports processes. This would not change the main conclusions of the study, though.

- The consequences of the choice of ambient temperature used in the friction calculations (10 degrees centigrade; see section 3.2.2) are not investigated. It is however known from SKF Galaxy that the power loss of the bearings generally decreases with rising temperature, and vice versa.

- The generalisation of treating all oil products as just “typical refinery products”, and the use of approximations and general data are weaknesses in the study, as the exact relations cannot be investigated. The used data should though be sufficient to show the approximate relations in environmental impact between the processes studied.

5 Conclusions

The conclusions of the study can be divided into primary and secondary conclusions, where the primary conclusions cover the most important contributors to the environmental impact of the use of rolling bearings in trains. The secondary conclusions are not that important, but can be of interest when studying different alternatives for maintenance.

Primary conclusions:

- The largest emissions of the use-phase for train bearings are released when the bearings are in operation. The emissions relation between operation and maintenance varies with the used electricity production mix, but the emissions from operation is up to 1 000 times higher.

- The electricity use for the bearings in X1 and Regina is almost the same, but for X10 it is up to 30 percent higher. When the bearing radial load, i.e. the duty mass of the trains, is considered, the Regina bearings show a 30-40 percent lower electricity use. It can therefore be said that the energy savings obtained with SKF rolling bearings has increased, as cited in the introduction (section 1.1).

- The environmental impact related to the transport of the trains to the wheel axle dismounting site can be of the same size as that from train bearings in operation if the detour is about 500 km or more.

- The bearings stand for about 2 percent of the electricity use during operation for the trains studied.

Secondary conclusions:

- During maintenance, most electricity is used for heating of washing water and heating of the X1/X10 bearings for mounting. For the Regina bearings no electricity is used for heating of the bearings.

- The emissions from the maintenance sub-processes naphtha production, oil and grease production and waste oil handling are noticeably lower for the Regina bearings. This is due to lower grease use, and the use of water and detergent for washing, instead of naphtha. Thus the electricity use for heating of washing water, and the emissions from detergent production are slightly higher than for the X1 and X10 bearings.

This study can be used as a motivation to perform more explicit investigations of the processes that contribute the most to the overall environmental impact of train bearings. For this there will probably be a need for more specific data than available for this study. Finally, to make use of the results of such studies, routines on how to include them in product development and everyday work, have to be worked out.

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Appendix

1 General information

X1/X10

Activity:	General information
Location:	SKF Sverige AB 415 50 GÖTEBORG Sweden Tel: +46 (0)31-337 10 00
Based on time period:	2002-09-03 - 2002-10-24
Inflow:	X1 or X10 EMU
Outflow:	X1 or X10 EMU
Reference(s)/contact person:	Fredrik Hallström E-mail: fredrik.hallstrom@skf.com Tel: +46 (0)31-337 10 12
Additional information:	

Recommended maintenance interval for X1: 1 200 000 km
Recommended maintenance interval for X10: 648 000 km

Regina

Activity:	General information
Location:	Bombardier Transportation 721 73 VÄSTERÅS Sweden Tel: +46 (0)21-31 70 00
Based on period:	2002-10-22, 2002-10-31
Inflow:	Regina EMU
Outflow:	Regina EMU
Reference(s)/contact person:	Bengt Uhlin E-mail: bengt.uhlin@se.transport.bombardier.com Tel: +46 (0)21-31 71 44 Glenn Holmström E-mail: glenn.holmstrom@se.transport.bombardier.com Tel: +46 (0)21-31 80 36
Additional information:	Qualitative information about the refurbishment process

Recommended maintenance interval for Regina: 1 000 000 km (or 4 years)

2 Train bearings in operation

Activity:	Energy use calculations
Location:	SKF Sverige AB 415 50 GÖTEBORG Sweden Tel: +46 (0)31-337 10 00
Based on time period:	2002-09-04 - 2002-12-12
Inflow:	X1 or X10 EMU
Outflow:	X1 or X10 EMU
Reference(s)/contact person:	Hans Wendeberg E-mail: hans.wendeberg@skf.com Tel: +46 (0)31-337 19 42
Additional information:	Consultations in SKF Galaxy BeaTemp 3.1

Activity:	Energy use and running distance
Location:	TrainTech Engineering Sweden AB Box 35171 11 SOLNA Sweden Tel: +46 (0)8-762 54 00
Based on time period:	2002-09-03 - 2002-10-24
Inflow:	X1 or X10 EMU
Outflow:	X1 or X10 EMU
Reference(s)/contact person:	Nils Jansson E-mail: nils.jansson@traintech.se Tel: +46 (0)8-762 54 00
Additional information:	

Activity:	Energy use
Location:	Bombardier Transportation 721 73 VÄSTERÅS Sweden Tel: +46 (0)21-31 70 00
Based on period:	2002-10-22, 2002-10-31
Inflow:	Regina EMU
Outflow:	Regina EMU
Reference(s)/contact person:	Bengt Uhlin E-mail: bengt.uhlin@se.transport.bombardier.com Tel: +46 (0)21-31 71 44
Additional information:	

Bearing radial load

	Radial load (N)	Load/fu (N)
Field study EMU	30000	120000
X1-A	30129	120516
X1-B	36334	72668
Whole X1	-	*96592*
X10-A	37113	148452
X10-B	26262	105048
Whole X10	-	*126750*
Whole Regina	*73650*	*147300*

Efficiency
[Andersson (1994)]

X1/X10: 0.818
Regina: 0.845

Input data for SKF Galaxy BeaTemp
With respect to wheel diameter etc.

Speed (km/h)	Speed (m/s)	Air velocity (m/s)	Rot. speed (r/min)	Rot. speed (r/min)	Rot. speed (r/min)	Bearing temp. (deg. C)
		(around axlebox)	(Field study EMU)	(X1/X10)	(Regina)	(From field study)
10	2.78	2.22	58.7	57.7	63.2	
20	5.56	4.44	117.4	115.3	126.3	
30	8.33	6.67	176.1	173.0	189.5	
40	11.11	8.89	234.7	230.7	252.6	
50	13.89	11.11	293.4	288.3	315.8	
60	16.67	13.33	352.1	346.0	378.9	
70	19.44	15.56	410.8	403.7	442.1	
80	22.22	17.78	469.5	461.3	505.3	
90	25.00	20.00	528.2	519.0	568.4	
100	27.78	22.22	586.9	576.6	631.6	
110	30.56	24.44	645.5	634.3	694.7	
120	33.33	26.67	704.2	692.0	757.9	
130	36.11	28.89	762.9	749.6	821.0	
140	38.89	31.11	821.6	807.3	884.2	
150	41.67	33.33	880.3	865.0	947.4	
160	44.44	35.56	939.0	922.6	1010.5	65.50
170	47.22	37.78	997.7	980.3	1073.7	
180	50.00	40.00	1056.3	1038.0	1136.8	
190	52.78	42.22	1115.0	1095.6	1200.0	75.67
200	55.56	44.44	1173.7	1153.3	1263.1	
210	58.33	46.67	1232.4	1211.0	1326.3	
220	61.11	48.89	1291.1	1268.6	1389.4	78.93

Power loss (W/bearing)
Calculated with SKF Galaxy BeaTemp

Speed (km/h)	X1-A	X1-B	X10-A	X10-B	Regina
0	0	0	0	0	0
10	43	45	46	42	60
20	100	104	104	98	134
30	160	165	166	157	214
40	216	222	223	212	292
50	265	273	274	261	365
60	313	322	323	308	436
70	361	371	372	356	508
80	*405*	*416*	*418*	*399*	*577*
90	449	461	463	442	645
100	492	505	507	484	713
110	533	547	549	525	780
120	577	592	594	568	849
130	618	634	636	608	914
140	657	675	677	647	979
150	697	715	718	686	1044
160	739	759	762	728	1113
170	777	798	801	766	1176
180	816	838	841	803	1240
190	854	877	880	841	1303
200	891	916	919	878	1366
210	932	958	962	918	1433
220	970	997	1000	955	1496

Power loss (W/axle)
Mean for A- and B-cars, and with respect to efficiency

Speed (km/h)	X1	X10	Regina
0	0	0	0
10	160	215	142
20	372	494	317
30	593	790	507
40	800	1064	691
50	982	1308	864
60	1159	1543	1032
70	1336	1780	1202
80	*1499*	*1998*	*1366*
90	1661	2213	1527
100	1820	2423	1688
110	1972	2626	1846
120	2134	2841	2009
130	2286	3042	2163
140	2432	3237	2317
150	2578	3433	2471
160	2735	3643	2634
170	2875	3831	2783
180	3020	4020	2935
190	3160	4208	3084
200	3298	4394	3233
210	3450	4597	3392
220	3590	4780	3541

Electricity use (MJ/fu)
Data for 80 km/h included in LCI

Speed (km/h)	X1	X10	Regina
0	0.00E+01	0.00E+01	0.00E+01
10	5.77E+03	7.75E+03	5.11E+03
20	6.69E+03	8.89E+03	5.71E+03
30	7.11E+03	9.48E+03	6.08E+03
40	7.20E+03	9.57E+03	6.22E+03
50	7.07E+03	9.42E+03	6.22E+03
60	6.95E+03	9.26E+03	6.19E+03
70	6.87E+03	9.15E+03	6.18E+03
80	*6.74E+03*	*8.99E+03*	*6.15E+03*
90	6.65E+03	8.85E+03	6.11E+03
100	6.55E+03	8.72E+03	6.08E+03
110	6.45E+03	8.59E+03	6.04E+03
120	6.40E+03	8.52E+03	6.03E+03
130	6.33E+03	8.42E+03	5.99E+03
140	6.25E+03	8.32E+03	5.96E+03
150	6.19E+03	8.24E+03	5.93E+03
160	6.15E+03	8.20E+03	5.93E+03
170	6.09E+03	8.11E+03	5.89E+03
180	6.04E+03	8.04E+03	5.87E+03
190	5.99E+03	7.97E+03	5.84E+03
200	5.94E+03	7.91E+03	5.82E+03
210	5.91E+03	7.88E+03	5.81E+03
220	5.88E+03	7.82E+03	5.79E+03

Electricity use/radial load [(J/N)/fu]
Not included in LCI

Speed (km/h)	X1	X10	Regina
0	0.00E+01	0.00E+01	0.00E+01
10	5.97E+04	6.11E+04	3.47E+04
20	6.93E+04	7.01E+04	3.88E+04
30	7.37E+04	7.48E+04	4.13E+04
40	7.45E+04	7.55E+04	4.22E+04
50	7.32E+04	7.43E+04	4.22E+04
60	7.20E+04	7.30E+04	4.20E+04
70	7.11E+04	7.22E+04	4.20E+04
80	*6.98E+04*	*7.09E+04*	*4.17E+04*
90	6.88E+04	6.98E+04	4.15E+04
100	6.78E+04	6.88E+04	4.12E+04
110	6.68E+04	6.78E+04	4.10E+04
120	6.63E+04	6.72E+04	4.09E+04
130	6.55E+04	6.65E+04	4.07E+04
140	6.47E+04	6.57E+04	4.05E+04
150	6.41E+04	6.50E+04	4.03E+04
160	6.37E+04	6.47E+04	4.02E+04
170	6.30E+04	6.40E+04	4.00E+04
180	6.25E+04	6.34E+04	3.98E+04
190	6.20E+04	6.29E+04	3.97E+04
200	6.15E+04	6.24E+04	3.95E+04
210	6.12E+04	6.22E+04	3.95E+04
220	6.08E+04	6.17E+04	3.93E+04

3 Dismounting of wheel axle

X1/X10

Activity:	Dismounting of wheel axle
Location:	Citypendeln Sverige AB Varuvägen 34 125 30 ÄLVSJÖ Sweden Tel: +46 (0)8-762 27 00
Based on time period:	2001-10-23 - 2002-10-22
Inflow:	X1 or X10 EMU
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Christer Carlsson E-mail: christer.carlsson@citypendeln.se Tel: +46 (0)8-762 48 78
Additional information:	

X1: mgh = 78.15E+03 x 9.82 x 1.20 / 2 = 0.46 MJ
X10: mgh = 103.26E+03 x 9.82 x 1.20 / 2 = 0.61 MJ

During the specified period Citypendeln sent 196 of their 960 X1/X10 wheel axles to refurbishment, which accounts for 20.4 percent. If this is true for the rest of the X10s, 318 out of the total 1560 X1/X10 wheel axles were sent to refurbishment during one year.

Regina

Activity:	Dismounting of wheel axle
Location:	Bombardier Transportation 721 73 VÄSTERÅS Sweden Tel: +46 (0)21-31 70 00
Based on period:	2002-10-15
Inflow:	Regina EMU
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Ove Rosenqvist E-mail: ove.rosenqvist@se.transport.bombardier.com Tel: +46 (0)21-31 80 40
Additional information:	

Regina: mgh = 120E+03 x 9.82 x 1.0 / 2 = 0.59 MJ

Local electric forklift truck transports

Activity:	Local electric forklift truck transports
Location:	BT Svenska AB Tredje Industrigatan Box 179 681 24 KRISTINEHAMN Tel: +46 (0)550-349 40
Based on period:	2002-11-14
Inflow:	Wheel axle with axleboxes
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Per Wärmlund E-mail: per.warmlund@bt-svenska.com Tel: +46 (0)550-315 41
Additional information:	

Data for Toyota 7FBMF-30:

750 Ah during 5 h use
16 kW traction motor
18 kW hydraulics
17 kW during 5 h
ca 10 kW real power

10 000 W x 5 min x 60 s/min = 3.0 MJ

Energy use

EMU	Dismounting (MJ)	Local transports (MJ)	Total (MJ)
X1	0.46	3	3.46
X10	0.61	3	3.61
Regina	0.59	3	3.59

4 Wheel axle refurbishment

Washing of railway parts

Activity:	Washing of railway parts
Location:	Teijo AB Regnvindsgatan 17 652 21 KARLSTAD Sweden Tel: +46 (0)54-85 00 39
Based on time period:	2002-12-12
Inflow:	Wheel axle or axle box parts
Outflow:	Wheel axle or axle box parts
Reference(s)/contact person:	Fredrik Widén E-mail: fredrik.widen@teijo.se Tel: +46 (0)54-85 00 39
Additional information:	

Washing machine
(1 washing cycle = 20 min)

Electricity use:	47 500 kWh/year = 3.6 MJ/kWh x 47 500 kWh/year = 171 000 MJ/year 171 000 MJ/year / (220 days/year x 8 h/day) = 97.16 MJ/h
Detergent use:	2 000 l/year / (220 days/year x 8 h/day) = 1.136 l/h which is 1.136 kg/h (est. density = 1kg/l)
Water use:	47 000 l/year / (220 days/year x 8 h/day) = 26.70 l/h which is 26.70 dm^3/h

2 axles at a time gives:	20 min / 2 = 10 min/ale
8 axleboxes at a time gives:	20 min / 4 = 5 min/pair
8 TBUs at a time gives:	20 min / 4 = 5 min/pair

X1/X10

Activity:	Wheel axle and bearing refurbishment
Location:	TGOJ Mälardalen Tillberga Box 19004 720 19 VÄSTERÅS Sweden Tel: +46 (0)21-10 22 00
Based on time period:	2001 and 2002-10-15
Inflow:	Wheel axle with axleboxes
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Ann-Kristin Castagna E-mail: annkristin.castagna@tgoj.se Tel: +46 (0)21-10 22 37
Additional information:	

Heating of SRBs:
(1 heating cycle = 15 min)

2 bearings at a time
Power: 8.0 kW
Electricity use (X1): 1.5 x 15 min x 60 s/min x 8000 W = 10.8 MJ/fu
Electricity use (X10): 2 x 15 min x 60 s/min x 8000 W = 14.4 MJ/fu

Washing of axles and axleboxes:

Time: (10 + 5) min/fu
Energy use: 0.25 h x 97.16 MJ/h = 24.29 MJ/fu
Detergent use: 0.25 h x 1.136 kg/h = 0.284 kg/fu
Water use: 0.25 h x 26.70 dm^3/h = 6.675 dm^3/fu

Inflows	Calculation	Value	Unit
Water	6.675 dm^3	6.675	dm^3
Electricity (X1)	(10.8 + 24.29) MJ = 35.09 MJ	35.09	MJ
Electricity (X10)	(14.4 + 24.29) MJ = 38.69 MJ	38.69	MJ
Detergent	0.284 kg	0.284	kg
Naphtha	4 x 0.4 kg = 1.6 kg	1.6	kg
Thin oils	2 x 0.1 kg = 0.2 kg		
Grease	2 x 0.8 kg = 1.6 kg		
Anti-rust agent	2 x 0.02 kg = 0.04 kg		
Total oil & grease	(0.2 + 1.6 + 0.04) kg = 1.84 kg	1.84	kg

Outflows	Calculation	Value	Unit
Waste water	6.675 dm^3	6.675	dm^3
Oil sludge	(0.2 + 0.04) kg = 0.24 kg		
Grease	1.6 kg		
Naphtha	1.6 kg		
Total waste oil	(0.24 + 1.6 + 1.6) kg = 3.44 kg	3.44	kg

Regina

Activity:	Wheel axle refurbishment
Location:	Lucchini Sweden AB Box 210 735 23 SURAHAMMAR Sweden Tel: +46 (0)220-347 00
Based on period:	2002-10-14
Inflow:	Wheel axle with axleboxes
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Christer Norgren E-mail: christer.norgren@lucchini.se Tel: +46 (0)220-347 23
Additional information:	

Washing of axles and axleboxes:

Time: (10 + 5) min/fu
Electricity use: 0.25 h x 97.16 MJ/h = 24.29 MJ/fu
Detergent use: 0.25 h x 1.136 kg/h = 0.284 kg/fu
Water use: 0.25 h x 26.70 dm^3/h = 6.675 dm^3/fu

Inflows	Calculation	Value	Unit
Water	6.675 dm^3	6.675	dm^3
Electricity	24.29 MJ	24.29	MJ
Detergent	0.284 kg	0.284	kg
Thin oils	2 x 0.05 kg = 0.10 kg		
Anti-rust agent	2 x 0.02 kg = 0.04 kg		
Total oil & grease	(0.10 + 0.04) kg = 0.14 kg	0.14	kg

Outflows	Calculation	Value	Unit
Waste water	6.675 dm^3	6.675	dm^3
Oil sludge	0.10 kg		
Total waste oil	0.10 kg	0.14	kg

TBU refurbishment

Activity:	TBU refurbishment
Location:	Konsultec SRL, Italy
Based on period:	2002
Inflow:	TBUs
Outflow:	TBUs
Reference(s)/contact person:	Lars Levin E-mail: lars.Levin@skf.com Tel: +46 (0)31-337 28 72 Fredrik Hallström E-mail: fredrik.hallstrom@skf.com Tel: +46 (0)31-337 10 12
Additional information:	Partly based on the VHS presentation Cartridge Bearing Refurbishment Service, SKF (U.K.) Limited - Railway Sales Unit

Washing of TBUs:

Time: 5 min/fu
Electricity use: (1/12) h x 97.16 MJ/h = 8.097 MJ/fu
Detergent use: (1/12) h x 1.136 kg/h = 0.0947 kg/fu
Water use: (1/12) h x 26.70 dm^3/h = 2.225 dm^3/fu

Inflows	Calculation	Value	Unit
Water	2.225 dm^3	2.225	dm^3
Electricity	8.097 MJ	8.097	MJ
Detergent	0.0947 kg	0.0947	kg
Thin oils	2 x 0.05 kg = 0.10 kg		
Grease	2 x (0.350 + 0.050) kg = 0.8 kg		
Anti-rust agent	2 x 0.05 kg = 0.10 kg		
Total oil & grease	(0.10 + 0.8 + 0.10) kg = 1 kg	1	kg

Outflows	Calculation	Value	Unit
Waste water	2.225 dm^3	2.225	dm^3
Oil sludge	(0.10 + 0.10) = 0.20 kg		
Grease	0.8 kg		
Total waste oil	(0.20 + 0.8) kg = 1 kg	1	kg

5 Electricity production

[Uppenberg et al, 2001]
Funtional unit: 1 MJ of produced electricity

			Oil	**Gasol**	**Coal**	**Natural gas (Denmark)**	**Natural gas (Norway)**
Resource use	Energy use	MJ	0.13	0.09	-	0.11	0.018
Emissions to air	Ammonia	mg	2	0	5.5	0	-
	Carbon dioxide	mg	146000	120000	210000	104000	101000
	Carbon monoxide	mg	32	21	92	17	18
	Methane	mg	0.97	3.8	2500	21	3.8
	Nitrogen oxides	mg	180	150	98	134	107
	Nitrous oxide	mg	0.95	0.89	3.4	1	0.88
	NMVOC	mg	27	57	4.6	6.2	1.9
	Particles	mg	2.7	1.8	59	0.57	0.26
	Sulphur oxides	mg	340	29	160	5.7	1
Rest products	Total	mg	5700	-	-	840	-

			Natural gas (Russia)	**Hydro**	**Wind**	**Nuclear**	**Swedish mix (1999)**
Resource use	Energy use	MJ	0.074	0.0037	0.029	0.061	0.032
Emissions to air	Ammonia	mg	-	0.0023	0.002	0.069	0.22
	Carbon dioxide	mg	114000	1400	1800	3100	7842
	Carbon monoxide	mg	17	1.9	14	2.3	18
	Methane	mg	107	1.55	1.8	12	49
	Nitrogen oxides	mg	114	1.8	5	9.7	15
	Nitrous oxide	mg	0.86	0.0064	0.008	0.033	0.71
	NMVOC	mg	1.9	0.35	1.2	1.6	2.9
	Particles	mg	0.29	0.23	1.4	2.8	2.5
	Sulphur oxides	mg	0.66	0.38	4.2	9.4	13
Rest products	Total	mg	-	1500	14000	27000	13000

Electricity production mixes

Production	**Marginal (coal)**	**Swedish mix (1999)**	**Bra miljöval (hydro)**
Hydro	0.00%	48.20%	100.00%
Nuclear	0.00%	44.30%	0.00%
Wind	0.00%	0.23%	0.00%
Oil (CHP*)	0.00%	1.33%	0.00%
Coal (CHP*)	0.00%	2.43%	0.00%
Natural gas (CHP*)	0.00%	0.47%	0.00%
Bio (CHP*)	0.00%	2.81%	0.00%
Oil condensation	0.00%	0.20%	0.00%
Coal	100.00%	0.00%	0.00%
Total	100.00%	99.97%	100.00%

* CHP stands for Co-generation of Heat and Power

LCI data for electricity production mixes
Functional unit: 1 MJ of produced electricity

			Coal	Swedish mix (1999)	Hydro	Human toxicity factor
Resource use	Energy use	MJ		0.032	0.0037	
Emissions to air	Ammonia (NH3)	mg	5.5	0.22	0.0023	0.1
	Carbon dioxide (CO2)	mg	210000	7842	1400	0
	Carbon monoxide (CO)	mg	92	18	1.9	0
	Methane (CH4)	mg	2500	49	1.55	0
	Nitrogen oxides (NOx)	mg	98	15	1.8	1.2
	Nitrous oxide (N2O)	mg	3.4	0.71	0.0064	0
	NMVOC	mg	4.6	2.9	0.35	0
	Particles	mg	59	2.5	0.23	0.82
	Sulphur oxides (SOx)	mg	160	13	0.38	0
	Human toxicity (1,4-dichlorobenzene eq.)	mg	166.53	20.072	2.34883	
Rest products	Total	mg		13000	1500	

6 Detergent production

Activity:	Detergent production
Location:	Henkel Norden AB Box 339 431 24 MÖLNDAL Sweden Tel: +46 (0)31-67 95 00
Based on time period:	2002-12-09
Inflow:	Chemical substances
Outflow:	Alkaline detergent
Reference(s)/contact person:	Anne Samuelsson E-mail: anne.samuelsson@henkel-stn.se Tel: +46 (0)31-67 95 26
Additional information:	

LCI data for detergent chemicals
Functional unit: 1000 kg of produced detergent
[Dall'Acqua et al, 1999; Boustead, 1994b]

	Substance	Unit	Detergent approximation
Waste generation	Total	kg	1.16E+02
Emissions to air	Ammonia (NH3)	g	7.58E+01
	Aromatic hydrocarbons	g	1.51E-00
	Benzene (C6H6)	g	1.06E-00
	Cadmium (Cd)	g	3.17E-02
	Carbon dioxide (CO2)	g	7.32E+05
	Carbon monoxide (CO)	g	1.45E+03
	Dust/particulates	g	1.89E+03
	Halogenated HC	g	1.47E-05
	Halon H1301	g	1.06E-02
	Hydrochloric acid (HCl)	g	5.00E+01
	Hydrofluoric acid (HF)	g	1.07E-00
	Lead (Pb)	g	8.00E-02
	Manganese (Mn)	g	8.92E-03
	Mercury (Hg)	g	3.84E-03
	Metals	g	7.44E-00
	Methane (CH4)	g	4.85E+02
	Nickel (Ni)	g	7.94E-01
	Nitrogen oxides (NOx) as NO2	g	2.97E+03
	Nitrous oxide (N2O)	g	4.01E-00
	NMVOC non-methane HC	g	1.22E+03
	PAH policycl. arom. HC	g	1.14E+03
	Radioactive substances	g	4.87E+04
	Sulphur oxides (SOx) as SO2	g	5.26E+03
	Zinc (Zn)	g	1.00E-01
Emissions to water	Waste water quantity	m^3	6.84E-00
	Acid (as H+)	g	4.73E+01
	Aluminium (Al)	g	1.58E+01
	Ammonium (NH4+)	g	4.02E+01
	AOX as Cl-	g	7.84E-03
	Aromatic HC	g	1.97E-00
	Arsenic (As)	g	3.33E-02
	Barium (Ba)	g	6.81E-00
	BOD	g	4.39E+01
	Cadmium (Cd)	g	6.10E-01
	Chloride (Cl-)	g	1.25E+05
	Chlorinated CH	g	2.60E-03
	Chromium (Cr)	g	3.99E-01

	COD	g	8.75E+01
	Copper (Cu)	g	8.20E-02
	Cyanide (CN-)	g	8.88E-03
	Dissolved solids	g	8.75E-00
	DOC	g	6.43E-01
	Fats/oils	g	6.07E+01
	Fluoride (F-)	g	1.07E+04
	Hydrocarbons	g	0.00E+01
	Inorg. salts and acids	g	7.38E+04
	Iron (Fe)	g	1.54E+01
	Lead (Pb)	g	9.08E-02
	Mercury (Hg)	g	1.76E-04
	Metals	g	3.00E+01
	Nickel (Ni)	g	8.63E-02
	Nitrate (NO3-)	g	1.66E-00
	Nitrogen org. bound	g	3.22E-01
	Nitrogen total	g	2.62E-00
	PAH policycl. arom. HC	g	2.90E-02
	Phenols	g	3.23E-01
	Phosphate (PO4 3-)	g	1.06E-00
	Radioactive substances	kBq	4.50E+02
	Silikates	g	1.44E+02
	Sodium ions	g	7.18E+02
	Sulphate (SO4 2-)	g	9.39E+02
	Sulphide (S 2-)	g	9.39E-01
	Suspended solids	g	4.35E+05
	TOC	g	6.12E+01
	Toluene (C7H8)	g	2.69E-01
	Zinc (Zn)	g	7.82E-00
Energy use	Feedstock	MJ	1.48E+03
	Electricity	MJ	2.80E+03
	Total delivered energy	MJ	8.49E+03

7 Naphtha production

LCI data for naphtha
Functional unit: 1000 kg of produced naphtha
[Boustead, 1993]

	Substance	Unit	Naphtha
Waste generation	Total		5.18
Emissions to air	Ammonia (NH3)	g	0
	Aromatic hydrocarbons	g	0
	Benzene (C6H6)	g	0
	Cadmium (Cd)	g	0
	Carbon dioxide (CO2)	g	284000
	Carbon monoxide (CO)	g	80
	Dust/particulates	g	340
	Halogenated HC	g	0
	Halon H1301	g	0
	Hydrochloric acid (HCl)	g	5
	Hydrofluoric acid (HF)	g	0
	Lead (Pb)	g	0
	Manganese (Mn)	g	0
	Mercury (Hg)	g	0
	Metals	g	1
	Methane (CH4)	g	0
	Nickel (Ni)	g	0
	Nitrogen oxides (NOx) as NO2	g	2900
	Nitrous oxide (N2O)	g	0
	NMVOC non-methane HC	g	2900
	PAH policycl. arom. HC	g	0
	Radioactive substances	g	0
	Sulphur oxides (SOx) as SO2	g	1800
	Zinc (Zn)	g	0
Emissions to water	Waste water quantity	m^3	0
	Acid (as H+)	g	30
	Aluminium (Al)	g	0
	Ammonium (NH4+)	g	1
	AOX as Cl-	g	0
	Aromatic HC	g	0
	Arsenic (As)	g	0
	Barium (Ba)	g	0
	BOD	g	5
	Cadmium (Cd)	g	0
	Chloride (Cl-)	g	10
	Chlorinated CH	g	0
	Chromium (Cr)	g	0
	COD	g	10
	Copper (Cu)	g	0
	Cyanide (CN-)	g	0
	Dissolved solids	g	0
	DOC	g	0
	Fats/oils	g	0
	Fluoride (F-)	g	0
	Hydrocarbons	g	20
	Inorg. salts and acids	g	0
	Iron (Fe)	g	0
	Lead (Pb)	g	0
	Mercury (Hg)	g	0
	Metals	g	5
	Nickel (Ni)	g	0
	Nitrate (NO3-)	g	1
	Nitrogen org. bound	g	0
	Nitrogen total	g	1
	PAH policycl. arom. HC	g	0

	Phenols	g	0
	Phosphate (PO4 3-)	g	0
	Radioactive substances	kBq	0
	Silikates	g	0
	Sodium ions	g	0
	Sulphate (SO4 2-)	g	0
	Sulphide (S 2-)	g	0
	Suspended solids	g	60
	TOC	g	0
	Toluene (C7H8)	g	0
	Zinc (Zn)	g	0
Energy use	Feedstock	MJ	45000
	Electricity	MJ	50
	Total delivered energy	MJ	4920

8 Oil and grease production

LCI data for oil products
Functional unit: 1000 kg of produced refinery products
[Boustead, 1993]

	Substance	Unit	Typical refinery products
Waste generation	Total		5.18
Emissions to air	Ammonia (NH3)	g	0
	Aromatic hydrocarbons	g	0
	Benzene (C6H6)	g	0
	Cadmium (Cd)	g	0
	Carbon dioxide (CO2)	g	284000
	Carbon monoxide (CO)	g	80
	Dust/particulates	g	340
	Halogenated HC	g	0
	Halon H1301	g	0
	Hydrochloric acid (HCl)	g	5
	Hydrofluoric acid (HF)	g	0
	Lead (Pb)	g	0
	Manganese (Mn)	g	0
	Mercury (Hg)	g	0
	Metals	g	1
	Methane (CH4)	g	0
	Nickel (Ni)	g	0
	Nitrogen oxides (NOx) as NO2	g	2900
	Nitrous oxide (N2O)	g	0
	NMVOC non-methane HC	g	2900
	PAH policycl. arom. HC	g	0
	Radioactive substances	g	0
	Sulphur oxides (SOx) as SO2	g	1800
	Zinc (Zn)	g	0
Emissions to water	Waste water quantity	m^3	0
	Acid (as H+)	g	30
	Aluminium (Al)	g	0
	Ammonium (NH4+)	g	1
	AOX as Cl-	g	0
	Aromatic HC	g	0
	Arsenic (As)	g	0
	Barium (Ba)	g	0
	BOD	g	5
	Cadmium (Cd)	g	0
	Chloride (Cl-)	g	10
	Chlorinated CH	g	0
	Chromium (Cr)	g	0
	COD	g	10
	Copper (Cu)	g	0
	Cyanide (CN-)	g	0
	Dissolved solids	g	0
	DOC	g	0
	Fats/oils	g	0
	Fluoride (F-)	g	0
	Hydrocarbons	g	20
	Inorg. salts and acids	g	0
	Iron (Fe)	g	0
	Lead (Pb)	g	0
	Mercury (Hg)	g	0
	Metals	g	5
	Nickel (Ni)	g	0
	Nitrate (NO3-)	g	1
	Nitrogen org. bound	g	0
	Nitrogen total	g	1

	PAH policycl. arom. HC	g	0
	Phenols	g	0
	Phosphate (PO4 3-)	g	0
	Radioactive substances	kBq	0
	Silikates	g	0
	Sodium ions	g	0
	Sulphate (SO4 2-)	g	0
	Sulphide (S 2-)	g	0
	Suspended solids	g	60
	TOC	g	0
	Toluene (C7H8)	g	0
	Zinc (Zn)	g	0
Energy use	Feedstock	MJ	45000
	Electricity	MJ	50
	Total delivered energy	MJ	4920

9 Waste oil handling

[Strandberg & Wik, 1999]

Inventory result for the oil treatment facility at Reci in Göteborg

Inflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	
De-greasing agent (1)	1.75E-00	m^3	Resource	Technosphere	7.80E-05	7.80E-05	m^3	
Electricity	1.87E+06	kWh	Resource	Technosphere	3.00E+02	3.00E+02	MJ	
Waste oil	*2.24E+04*	*ton*	*Resource*	*Technosphere*	*1.00E-00*	*1.00E-00*	*ton*	
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	**Destination**
HC	5.00E+06	g	Emission	Air	2.23E+02	2.23E+02	g	
Oil-contamined cistern water	1.38E+04	m^3	Residue	Technosphere	6.13E-01	6.13E-01	m^3	RECI water treatment
Oil-contamined surface water	1.10E+03	m^3	Residue	Technosphere	4.91E-02	4.91E-02	m^3	RECI water treatment
Oil sludge	2.36E+01	m^3	Waste	Technosphere	1.05E-03	1.05E-03	m^3	SAKAB
Scrap	1.50E+05	kg	Resource	Technosphere	6.69E-00	6.69E-00	kg	Sävenäs
Treated oil	9.45E+03	m^3	Resource	Technosphere	4.21E-01	4.21E-01	m^3	Halmstad

Inventory result for the water treatment facility at Reci in Göteborg

Inflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	
AlSO4	8.33E+03	kg	Resource	Technosphere	5.08E-02	3.36E-02	kg	
Electricity	2.29E+05	kWh	Resource	Technosphere	5.03E-00	3.33E-00	MJ	
Heat	1.06E+06	kWh	Resource	Technosphere	2.33E+01	1.54E+01	MJ	
H2SO4	1.21E+04	kg	Resource	Technosphere	7.36E-02	4.87E-02	kg	
Magnafloc LT27AG	7.75E+02	kg	Resource	Technosphere	4.73E-03	3.13E-03	kg	
NaOH	1.56E+04	kg	Resource	Technosphere	9.54E-02	6.31E-02	kg	
Oil-contamined water	*1.64E+05*	*m^3*	*Resource*	*Technosphere*	*1.00E-00*	*6.62E-01*	*m^3*	
Petrotec RI-54	2.00E+02	kg	Resource	Technosphere	1.22E-03	8.07E-04	kg	
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	**Destination**
Oil sludge	1.24E+01	m^3	Waste	Technosphere	7.56E-05	5.01E-05	m^3	SAKAB
Treated oil	4.94E+03	m^3	Co-product	Technosphere	3.02E-02	2.00E-02	m^3	Halmstad
HC	6.00E+06	g	Emission	Air	3.66E+01	2.42E+01	g	
AlSO4	8.33E+03	kg	Emission	Ocean	5.08E+01	3.36E+01	g	
Halon (AOX)	2.60E+04	g	Emission	Ocean	1.59E-01	1.05E-01	g	
Aromatics	3.00E+05	g	Emission	Ocean	1.83E-00	1.21E-00	g	
Cd	3.28E+02	g	Emission	Ocean	2.00E-03	1.32E-03	g	
COD	1.01E+08	g	Emission	Ocean	6.16E+02	4.08E+02	g	
Cr	8.03E+03	g	Emission	Ocean	4.90E-02	3.24E-02	g	
H2SO4	1.16E+04	kg	Emission	Ocean	7.06E+01	4.67E+01	g	
NaOH	1.56E+04	kg	Emission	Ocean	9.54E+01	6.31E+01	g	
Ni	1.64E+05	g	Emission	Ocean	1.00E-00	6.62E-01	g	
Oil	5.00E+05	g	Emission	Ocean	3.05E-00	2.02E-00	g	
Pb	1.64E+03	g	Emission	Ocean	1.00E-02	6.62E-03	g	
Phenol	1.50E+05	g	Emission	Ocean	9.15E-01	6.06E-01	g	
TEX (aliphatic)	2.00E+06	g	Emission	Ocean	1.22E+01	8.07E-00	g	
Treated water	1.59E+05	m^3	Main product	Technosphere	9.70E-01	6.42E-01	m^3	
Zn	1.64E+05	g	Emission	Ocean	1.00E-00	6.62E-01	g	

Inventory result for the oil treatment facility in Halmstad

Inflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	
Alkaline detergent	2.70E+03	l	Resource	Technosphere	6.67E-02	2.94E-02	l	
Alpoclar 200	1.00E+04	kg	Resource	Technosphere	2.48E-01	1.09E-01	kg	
De-greasing agent (2)	2.04E+03	kg	Resource	Technosphere	5.04E-02	2.22E-02	kg	
Electricity	2.88E+06	kWh	Resource	Technosphere	2.56E+02	1.13E+02	MJ	
Fuel oil (Eo4)	1.56E+03	m^3	Resource	Technosphere	3.85E-02	1.70E-02	m^3	
HCl (30 %)	9.05E+03	kg	Resource	Technosphere	2.24E-01	9.86E-02	kg	

HNO3	1.08E+03	kg	Resource	Technosphere	2.66E-02	1.17E-02	kg	
Mobil Term 605	2.08E+03	l	Resource	Technosphere	5.14E-02	2.27E-02	l	
NaOH	9.86E+04	kg	Resource	Technosphere	2.44E-00	1.07E-00	kg	
Phosphoric acid (75 %)	7.26E+03	kg	Resource	Technosphere	1.79E-01	7.91E-02	kg	
Pix 111	5.64E+04	kg	Resource	Technosphere	1.39E-00	6.14E-01	kg	
Sedipur CF 104	2.63E+02	kg	Resource	Technosphere	6.50E-03	2.87E-03	kg	
Sodiumhypochlorite	1.50E+02	l	Resource	Technosphere	3.71E-03	1.63E-03	l	
Waste oil (100 % oil)	*4.05E+04*	*m^3*	*Resource*	*Technosphere*	*1.00E-00*	*4.41E-01*	*m^3*	
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**	**Destination**
COD sludge	2.00E+01	kg	Waste	Technosphere	4.94E-04	2.18E-04	kg	
Converted fuel oil	3.66E+04	m^3	Product	Technosphere	9.04E-01	3.99E-01	m^3	Slite
Oil sludge	2.41E+02	m^3	Waste	Technosphere	5.95E-03	2.63E-03	m^3	SAKAB
Scrap	1.00E+05	kg	Waste	Technosphere	2.47E-00	1.09E-00	kg	Sävenäs
Water sludge	5.01E+02	m^3	Waste	Technosphere	1.24E-02	5.46E-03	m^3	RECI de-watering
Assay Al203	1.76E+03	kg	Emission	Ocean	4.34E+01	1.92E+01	g	
Cd	1.40E+01	g	Emission	Ocean	3.46E-04	1.53E-04	g	
Cl	1.74E+07	g	Emission	Ocean	4.29E+02	1.89E+02	g	
COD sludge	4.24E+07	g	Emission	Ocean	1.05E+03	4.62E+02	g	
Cr	2.60E+02	g	Emission	Ocean	6.42E-03	2.83E-03	g	
Dimetylaminoakrylat	2.63E+02	kg	Emission	Ocean	6.50E-00	2.87E-00	g	
Fe (III)	7.72E+06	g	Emission	Ocean	1.91E+02	8.41E+01	g	
HCl	2.71E+06	g	Emission	Ocean	6.71E+01	2.96E+01	g	
HNO3	1.08E+06	g	Emission	Ocean	2.66E+01	1.17E+01	g	
KOH	6.08E+02	l	Emission	Ocean	1.50E-02	6.63E-03	l	
Ni	7.12E+03	g	Emission	Ocean	1.76E-01	7.76E-02	g	
NTA solution (100 %)	5.18E+01	l	Emission	Ocean	1.28E-03	5.64E-04	l	
Oil sludge	8.96E+03	g	Emission	Ocean	2.21E-01	9.76E-02	g	
Oil in surface water	3.74E+05	g	Emission	Ocean	9.25E-00	4.08E-00	g	
Pb	7.00E+01	g	Emission	Ocean	1.73E-03	7.63E-04	g	
Phenol	4.16E+04	g	Emission	Ocean	1.03E-00	4.53E-01	g	
SO4	1.26E+05	g	Emission	Ocean	3.10E-00	1.37E-00	g	
Sodiumgluconate	1.49E+02	l	Emission	Ocean	3.68E-03	1.62E-03	l	
Sodiumhypochlorite	1.50E+02	l	Emission	Ocean	3.71E-03	1.63E-03	l	
Sodiumkapryl-aminodipropionate	3.38E+02	l	Emission	Ocean	8.35E-03	3.68E-03	l	
Sulphid	2.06E+03	g	Emission	Ocean	5.09E-02	2.24E-02	g	
Suspended material	3.12E+06	g	Emission	Ocean	7.70E+01	3.40E+01	g	
Tridecylalcohol-etoxilat	3.38E+02	l	Emission	Ocean	8.35E-03	3.68E-03	l	
Zn	2.09E+03	g	Emission	Ocean	5.16E-02	2.28E-02	g	
Ashes	4.25E+05	g	Emission	Air	1.05E+01	4.63E-00	g	
CO	8.10E+05	g	Emission	Air	2.00E+01	8.82E-00	g	
CO2	4.73E+06	kg	Emission	Air	1.17E+05	5.15E+04	g	
HC	1.87E+05	g	Emission	Air	4.62E-00	2.04E-00	g	
NOx	7.89E+06	g	Emission	Air	1.95E+02	8.60E+01	g	
Particles	1.82E+06	g	Emission	Air	4.50E+01	1.99E+01	g	
SO2	8.89E+06	g	Emission	Air	2.20E+02	9.68E+01	g	

Inventory result for waste treatment facility at SAKAB in Kumla

Inflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**
Lime	8.51E+03	kg	Resource	Technosphere	3.07E+01	1.15E-01	kg
Oil sludge	*2.77E+02*	*m^3*	*Resource*	*Technosphere*	*1.00E-00*	*3.73E-03*	*m^3*
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**
Electricity/heat	9.00E+02	kWh	Product	Technosphere	1.17E+01	4.36E-02	MJ
Slags & ashes	1.12E+04	kg	Waste	Technosphere	4.04E+01	1.51E-01	kg
Ashes	3.49E+01	g	Emission	Air	1.26E-01	4.70E-04	g
CO	6.48E+01	g	Emission	Air	2.34E-01	8.72E-04	g
CO2	4.13E+06	g	Emission	Air	1.49E+04	5.56E+01	g
HC	4.99E+01	g	Emission	Air	1.80E-01	6.72E-04	g
NOx	7.48E+02	g	Emission	Air	2.70E-00	1.01E-02	g
Particles	1.50E+02	g	Emission	Air	5.42E-01	2.02E-03	g
SO2	2.22E+06	g	Emission	Air	8.00E+03	2.98E+01	g

Inventory result for the de-watering facility at Reci Göteborg

Inflows	Amount/year	Unit	Category	Environment	Amount/ton	Amount/fu	Unit
Water sludge	*5.01E+02*	*m^3*	*Waste*	*Technosphere*	*1.00E-00*	*5.46E-03*	*m^3*
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**
Solid phase (sediment)	7.52E+01	m^3	Waste	Technosphere	1.50E-01	8.19E-04	m^3
Uncleaned water	4.26E+02	m^3	Residue	Technosphere	8.50E-01	4.64E-03	m^3

Inventory result for waste treatment at Sävenäs in Göteborg

Inflows	Amount/year	Unit	Category	Environment	Amount/ton	Amount/fu	Unit
Ammoniasolut. (25 %)	1.69E+06	kg	Resource	Technosphere	4.43E-00	3.45E-02	kg
Flocking-subst. polymer	5.27E+02	kg	Resource	Technosphere	1.38E-03	1.07E-05	kg
Fuel oil (Eo4)	7.09E+02	m^3	Resource	Technosphere	1.86E-03	1.45E-05	m^3
HCl (30 %)	4.61E+04	l	Resource	Technosphere	1.21E-01	9.40E-04	l
Levoxin/hydrazin	2.95E+03	kg	Resource	Technosphere	7.74E-03	6.01E-05	kg
Lime	2.71E+06	kg	Resource	Technosphere	7.11E-00	5.53E-02	kg
NaOH (100 %)	1.16E+04	l	Resource	Technosphere	3.05E-02	2.37E-04	l
Precipitationsub TMT15	2.56E+04	kg	Resource	Technosphere	6.71E-02	5.22E-04	kg
Slaked lime	2.56E+05	kg	Resource	Technosphere	6.71E-01	5.22E-03	kg
Trinatriumfosfat	1.40E+03	kg	Resource	Technosphere	3.67E-03	2.85E-05	kg
Waste	*3.81E+05*	*ton*	*Waste*	*Technosphere*	*1.00E-00*	*7.78E-03*	*ton*
Outflows	**Amount/year**	**Unit**	**Category**	**Environment**	**Amount/ton**	**Amount/fu**	**Unit**
Electricity	1.30E+05	kWh	Product	Technosphere	1.23E-00	9.54E-03	MJ
Heat	1.04E+06	kWh	Product	Technosphere	9.82E-00	7.63E-02	MJ
Solid waste	9.28E+07	kg	Waste	Technosphere	2.43E+02	1.89E-00	kg
As	8.00E+03	g	Emission	Air	2.10E-02	1.63E-04	g
Ashes	6.80E+06	g	Emission	Air	1.78E+01	1.39E-01	g
Be	1.00E+02	g	Emission	Air	2.62E-04	2.04E-06	g
Cd	6.00E+03	g	Emission	Air	1.57E-02	1.22E-04	g
CO	8.50E+04	g	Emission	Air	2.23E-01	1.73E-03	g
CO2	4.11E+08	kg	Emission	Air	1.08E+06	8.39E+03	g
Cr	7.00E+03	g	Emission	Air	1.84E-02	1.43E-04	g
Cu	2.80E+04	g	Emission	Air	7.34E-02	5.71E-04	g
Dioxin	1.43E-00	mg	Emission	Air	3.75E-09	2.92E-11	g
HCl	4.40E+07	g	Emission	Air	1.15E+02	8.97E-01	g
Hg	1.90E+04	g	Emission	Air	4.98E-02	3.87E-04	g
Ni	6.00E+03	g	Emission	Air	1.57E-02	1.22E-04	g
NOx	2.06E+08	g	Emission	Air	5.40E+02	4.20E-00	g
Pb	1.85E+05	g	Emission	Air	4.85E-01	3.77E-03	g
SO2	4.31E+08	g	Emission	Air	1.13E+03	8.79E-00	g
Zn	4.56E+05	g	Emission	Air	1.20E-00	9.30E-03	g
Cd	1.12E+06	mg	Emission	River	2.94E-03	2.28E-05	g
Cl	1.95E+09	g	Emission	River	5.12E+03	3.98E+01	g
Co	1.00E+06	mg	Emission	River	2.62E-03	2.04E-05	g
Dioxin	1.00E+01	mg	Emission	River	2.62E-08	2.04E-10	g
Hg	3.00E+04	mg	Emission	River	7.87E-05	6.12E-07	g
Ni	1.00E+06	mg	Emission	River	2.62E-03	2.04E-05	g
Pb	7.20E+05	mg	Emission	River	1.89E-03	1.47E-05	g
SO4	5.20E+07	g	Emission	River	1.36E+02	1.06E-00	g
Suspended solids	2.20E+06	g	Emission	River	5.77E-00	4.49E-02	g
Zn	7.60E+06	mg	Emission	River	1.99E-02	1.55E-04	g

Waste oil handling, total

Functional unit: 1000 kg of treated waste oil

Energy use	**Amount/fu**	**Unit**	
Electricity	4.16E+02	MJ	
Heat	1.53E+01	MJ	
Emissions to air	**Amount/fu**	**Unit**	
As	1.63E-04	g	
Ashes	4.77E-00	g	
Be	2.04E-06	g	
Cd	1.22E-04	g	
CO	8.83E-00	g	
CO2	6.00E+04	g	
Cr	1.43E-04	g	
Cu	5.71E-04	g	
Dioxin	2.92E-11	g	
HC	2.25E+02	g	
HCl	8.97E-01	g	
Hg	3.87E-04	g	
Ni	1.22E-04	g	
NOx	9.02E+01	g	
Particles	1.99E+01	g	
Pb	3.77E-03	g	
SO2	1.35E+02	g	
Zn	9.30E-03	g	
Emissions to water	**Amount/fu**	**Unit**	**Est. density**
AlSO4	3.36E+01	g	
Assay Al203	1.92E+01	g	
Halon (AOX)	1.05E-01	g	
Aromatics	1.21E-00	g	
Cd	1.50E-03	g	
Cl	2.29E+02	g	
Co	2.04E-05	g	
COD	8.70E+02	g	
Cr	3.53E-02	g	
Dimetylaminoakrylat	2.87E-00	g	
Dioxin	2.04E-10	g	
Fe (III)	8.41E+01	g	
H2SO4	4.67E+01	g	
HCl	2.96E+01	g	
Hg	6.12E-07	g	
HNO3	1.17E+01	g	
KOH	6.63E-03	l	1kg/l
NaOH	6.31E+01	g	
Ni	7.40E-01	g	
NTA solution (100 %)	5.64E-04	l	1kg/l
Oil	6.20E-00	g	
Pb	7.40E-03	g	
Phenol	1.06E-00	g	
SO4	2.43E-00	g	
Sodiumgluconate	1.62E-03	l	1kg/l
Sodiumhypochlorite	1.63E-03	l	1kg/l
Sodiumkaprylaminodipropionate	3.68E-03	l	1kg/l
Sulphid	2.24E-02	g	
Suspended material	3.40E+01	g	
TEX (aliphatic)	8.07E-00	g	
Tridecylalcoholetoxilat	3.68E-03	l	1kg/l
Zn	6.85E-01	g	
Waste generation	**Amount/fu**	**Unit**	**Est. density**
Uncleaned water	4.64E-03	m^3	
Solid waste	2.86E-00	kg	1000 kg/m^3

10 Transports

Load capacity and fuel consumption
[NTM, 2002]

	Weight		Fuel consumption	
Vehicle	**Load**	**Total**	**Without load**	**Full load**
	(tons)	(tons)	(l/100 km)	(l/100 km)
Small truck, distribution	8.5	14	20-25	25-30
Medium truck, regional	14	24	25-30	30-40
Large truck 1 (with trailer)	26	40	22-27	32-38
Large truck 2 (with trailer)	40	60	28-33	43-55

Energy contents for diesel (Mk1): 9.77 kWh/l = 35.172 MJ/l

Estimated fuel consumption (full load)
Calculated from previous table

Vehicle	Consumption (l/km)	Consumption (MJ/km)
Small truck, distribution	0.30	10.55
Medium truck, regional	0.40	14.07
Large truck 1 (with trailer)	0.38	13.37
Large truck 2 (with trailer)	0.55	19.34

LCI data for diesel (Mk1)
[Uppenberg et al, 2001]
Functional unit: 1 MJ of produced fuel

			Diesel (Mk1)
Resource use	Total energy use	MJ	0.06
Emissions to air	Ammonia	mg	-
	Carbon dioxide	mg	77000
	Carbon monoxide	mg	13
	Methane	mg	8
	Nitrogen oxides	mg	750
	Nitrous oxide	mg	3
	NMVOC	mg	44
	Particles	mg	12
	Sulphur oxides	mg	21
Efficiency			0.4

Transports for X1/X10

Activity:	Transports 1 & 2
Location:	-
Based on period:	2002-12-11
Inflow:	Wheel axle with TBUs
Outflow:	Wheel axle with TBUs
Reference(s)/contact person:	Christer Carlsson E-mail: christer.carlsson@citypendeln.se Tel: +46 (0)8-762 48 78
Additional information:	Distance calculated in Shell GeoStar http://www.shellgeostar.com/share (2002-12-11)

No.	From	To	Vehicle	Allocation	Distance (km)	Energy use (MJ/fu)
1	Citypendeln (Älvsjö)	TGOJ (Tillberga)	Small truck	10 axles per truck	123.1	129.89
2	TGOJ (Tillberga)	Citypendeln (Älvsjö)	Small truck	10 axles per truck	123.1	129.89
1-2	Citypendeln (Älvsjö)	Citypendeln (Älvsjö)	Small truck	10 axles per truck	246.2	259.78

Transports for Regina

Activity:	Transports no. 1, 14
Location:	-
Based on period:	2002-11-12
Inflow:	Wheel axle with axleboxes
Outflow:	Wheel axle with axleboxes
Reference(s)/contact person:	Ove Rosenqvist E-mail: ove.rosenqvist@se.transport.bombardier.com Tel: +46 (0)21-31 80 40
Additional information:	Distance calculated by: Shell GeoStar http://www.shellgeostar.com/share (2002-12-11)

Activity:	Transports no. 2-7, 8-13
Location:	-
Based on period:	2002-10-28
Inflow:	TBUs
Outflow:	TBUs
Reference(s)/contact person:	Stig Björkdahl E-mail: stig.bjorkdahl@skf.com Tel: +46 (0)31-337 20 03
Additional information:	Weight: 530 kg / 8 fu = 66.25 kg/fu

No.	From	To	Vehicle type	Allocation	Distance (km)	Energy use (MJ/fu)
1, 14	Bombardier (Västerås)	Lucchini (Surahammar)	Small truck	6 wheel axles load	25.2	44.31672
2, 13	Lucchini (Surahammar)	SKF (Göteborg)	Medium truck	14 tons total load	420	27.96174
3, 12	SKF (Göteborg)	Trelleborg	Large truck 1	20 tons total load	300	13.2818265
4, 11	Trelleborg	Travemünde	Car ferry	-	-	-
5, 10	Travemünde	Schweinfurt	Large truck 1	20 tons total load	575	25.45683413
6, 9	Schweinfurt	Airasca (Torino)	Large truck 1	20 tons total load	795	35.19684023
7, 8	Airasca (Torino)	Konsultec (Pinerolo)	Small truck	8.5 tons total load	11	0.904644529
1-7	Bombardier (Västerås)	Konsultec (Pinerolo)	Various	Various	2126.2	147.1186054
1-14	Bombardier (Västerås)	Bombardier (Västerås)	Various	Various	4252.4	294.2372108

Inventory results

Full load expected
[Uppenberg et al, 2001]

			X1/X10	Regina
Resource use	Total energy use	MJ	1.56E+01	1.77E+01
Emissions to air	Ammonia	g	-	-
	Carbon dioxide	g	2.00E+04	2.27E+04
	Carbon monoxide	g	3.38E-00	3.83E-00
	Methane	g	2.08E-00	2.35E-00
	Nitrogen oxides	g	1.95E+02	2.21E+02
	Nitrous oxide	g	7.79E-01	8.83E-01
	NMVOC	g	1.14E+01	1.29E+01
	Particles	g	3.12E-00	3.53E-00
	Sulphur oxides	g	5.46E-00	6.18E-00

11 LCI results

Functional unit distance: 100 000 km
Maintenance interval: 500 000 km
Discarding rate: 25%

X1

		Production (X1/X10)	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Electricity (Swedish)	Maintenance (Swedish)	Transports	Total (Swedish)
Energy use															
Feedstock	MJ						8.38E-02	1.44E+01	1.66E+01				3.10E+01		3.10E+01
Electricity (non-accounted)	MJ	5.63E+01	6.74E+03	6.74E+03	6.74E+03	6.92E-01				7.02E-00	2.86E-01	8.00E-00	8.00E-00		6.75E+03
Electricity (accounted)	MJ						1.59E-01	1.60E-02	1.84E-02				1.93E-01		1.93E-01
Emissions to air															
Ammonia (NH3)	g	1.58E-04	3.71E+01	1.48E-00	1.55E-02		4.30E-03					1.76E-03	6.06E-03		1.49E-00
Aromatic HC	g	2.29E-04					8.58E-05						8.58E-05		8.58E-05
Arsenic (As)	g	9.94E-05									1.12E-07		1.12E-07		1.12E-07
Benzene (C6H6)	g	6.90E-03					6.01E-05						6.01E-05		6.01E-05
Beryllium (Be)	g										1.40E-09		1.40E-09		1.40E-09
Cadmium (Cd)	g	9.38E-05					1.80E-06				8.42E-08		1.88E-06		1.88E-06
Carbon dioxide (CO2)	g	2.90E+03	1.42E+06	5.29E+04	9.44E+03		4.16E+01	9.09E+01	1.05E+02		4.13E+01	6.27E+01	3.41E+02	4.00E+03	5.72E+04
Carbon monoxide (CO)	g	1.79E+01	6.20E+02	1.21E+02	1.28E+01		8.25E-02	2.56E-02	2.94E-02		6.07E-03	1.44E-01	2.88E-01	6.75E-01	1.22E+02
Chromium (Cr)	g	2.57E-05									9.82E-08		9.82E-08		9.82E-08
Copper (Cu)	g	5.31E-04									3.93E-07		3.93E-07		3.93E-07
Dioxin	g	1.51E-08									2.01E-14		2.01E-14		2.01E-14
Dust/particulates	g		3.98E+02	1.69E+01	1.55E-00		1.07E-01	1.09E-01	1.25E-01		4.92E-03	2.00E-02	3.66E-01	6.23E-01	1.79E+01
Halogenated HC	g						8.33E-10						8.33E-10		8.33E-10
Halon H1301	g						6.02E-07						6.02E-07		6.02E-07
Hydrochloric acid (HCl)	g	8.26E-02					2.84E-03	1.60E-03	1.84E-03		6.17E-04		6.90E-03		6.90E-03
Hydrofluoric acid (HF)	g	4.51E-03					6.06E-05						6.06E-05		6.06E-05
Lead (Pb)	g	4.67E-04					4.54E-06				2.59E-06		7.14E-06		7.14E-06
Manganese (Mn)	g	1.44E-05					5.07E-07						5.07E-07		5.07E-07
Mercury (Hg)	g	1.21E-04					2.18E-07				2.67E-07		4.85E-07		4.85E-07
Metals	g						4.23E-04	3.20E-04	3.68E-04				1.11E-03		1.11E-03
Methane (CH4)	g	4.39E-00	1.69E+04	3.30E+02	1.05E+01		2.76E-02					3.92E-01	4.19E-01	4.16E-01	3.31E+02
Nickel (Ni)	g	1.60E-03					4.51E-05				8.42E-08		4.52E-05		4.52E-05
Nitrogen oxides (Nox) as NO2	g	1.14E+01	6.61E+02	1.01E+02	1.21E+01		1.69E-01	9.28E-01	1.07E-00		6.20E-02	1.20E-01	2.35E-00	3.90E+01	1.42E+02
Nitrous oxide (N2O)	g	8.98E-03	2.29E+01	4.79E-00	4.32E-02		2.28E-04					5.68E-03	5.91E-03	1.56E-01	4.95E-00
NMVOC non-methane HC	g	1.52E+01	3.10E+01	1.96E+01	2.36E-00		6.92E-02	9.28E-01	1.07E-00		1.55E-01	2.32E-02	2.24E-00	2.29E-00	2.41E+01
PAH policycl. arom. HC	g	2.21E-05					6.46E-02						6.46E-02		6.46E-02
Radioactive substances	g						2.77E-00						2.77E-00		2.77E-00
Sulphur oxides (Sox) as SO2	g	4.56E-00	1.08E+03	8.77E+01	2.56E-00		2.99E-01	5.76E-01	6.62E-01		9.32E-02	1.04E-01	1.73E-00	1.09E-00	9.05E+01
Zinc (Zn)	g	5.79E-03					5.70E-06				6.40E-06		1.21E-05		1.21E-05
Emissions to water															
Acid (as H+)	g	6.98E-05					2.68E-03	9.60E-03	1.10E-02				2.33E-02		2.33E-02
Aluminium (Al)	g						8.96E-04						8.96E-04		8.96E-04
Aluminium sulphate (AlSO4)	g										2.31E-02		2.31E-02		2.31E-02
Ammonium (NH4+)	g	2.56E-04					2.28E-03	3.20E-04	3.68E-04				2.97E-03		2.97E-03
AOX as Cl-	g						4.45E-07				7.22E-05		7.27E-05		7.27E-05
Aromatic HC	g						1.12E-04				8.33E-04		9.45E-04		9.45E-04
Arsenic (As)	g	4.71E-05					1.89E-06						1.89E-06		1.89E-06
Assay Al203	g										1.32E-02		1.32E-02		1.32E-02
Barium (Ba)	g						3.87E-04						3.87E-04		3.87E-04
BOD	g	4.79E-01					2.49E-03	1.60E-03	1.84E-03				5.93E-03		5.93E-03
Cadmium (Cd)	g	2.45E-05					3.46E-05				1.03E-06		3.57E-05		3.57E-05
Chloride (Cl-)	g						7.11E-00	3.20E-03	3.68E-03		1.58E-01		7.27E-00		7.27E-00
Chlorinated CH	g						1.48E-07						1.48E-07		1.48E-07
Chromium (Cr)	g	3.46E-04					2.26E-05				2.43E-05		4.69E-05		4.69E-05
Cobalt (Co)	g										1.40E-08		1.40E-08		1.40E-08
COD	g	1.30E-00					4.97E-03	3.20E-03	3.68E-03		5.98E-01		6.10E-01		6.10E-01
Copper (Cu)	g	6.30E-05					4.66E-06						4.66E-06		4.66E-06
Cyanide (CN-)	g	4.31E-05					5.04E-07						5.04E-07		5.04E-07
Dimethyl-aminoacrylate	g										1.97E-03		1.97E-03		1.97E-03
Dioxin	g										1.40E-13		1.40E-13		1.40E-13

Dissolved solids	g						4.97E-04						4.97E-04		4.97E-04
DOC	g						3.65E-05						3.65E-05		3.65E-05
Fats/oils	g	4.03E-01					3.45E-03				4.26E-03		7.71E-03		7.71E-03
Fluoride (F-)	g	2.57E-03					6.10E-01						6.10E-01		6.10E-01
Hydrocarbons (HC)	g							6.40E-03	7.36E-03				1.38E-02		1.38E-02
Hydrochloric acid (HCl)	g										2.04E-02		2.04E-02		2.04E-02
Inorg. salts and acids	g						4.19E-00						4.19E-00		4.19E-00
Iron (Fe)	g	2.66E-02					8.74E-04				5.79E-02		5.88E-02		5.88E-02
Lead (Pb)	g	1.88E-04					5.16E-06				5.09E-06		1.02E-05		1.02E-05
Mercury (Hg)	g						9.98E-09				4.21E-10		1.04E-08		1.04E-08
Metals	g						1.70E-03	1.60E-03	1.84E-03				5.14E-03		5.14E-03
Nickel (Ni)	g	1.73E-04					4.90E-06				5.09E-04		5.14E-04		5.14E-04
Nitrate (NO3-)	g	1.06E-04					9.43E-05	3.20E-04	3.68E-04				7.82E-04		7.82E-04
Nitric acid (HNO3)	g	7.86E-07									8.07E-03		8.07E-03		8.07E-03
Nitrogen org. bound	g						1.83E-05						1.83E-05		1.83E-05
Nitrogen total	g	8.18E-02					1.49E-04	3.20E-04	3.68E-04				8.37E-04		8.37E-04
NTA solution (100 %)	g										3.88E-04		3.88E-04		3.88E-04
PAH policycl. arom. HC	g						1.65E-06						1.65E-06		1.65E-06
Phenols	g	3.69E-06					1.84E-05				7.28E-04		7.47E-04		7.47E-04
Phosphate (PO4 3-)	g	1.37E-06					6.05E-05						6.05E-05		6.05E-05
Potassium hydroxide (KOH)	g										4.56E-03		4.56E-03		4.56E-03
Radioactive substances	kBq						2.55E-02						2.55E-02		2.55E-02
Silikates	g						8.15E-03						8.15E-03		8.15E-03
Sodium gluconate	g										1.12E-03		1.12E-03		1.12E-03
Sodium hydroxide (NaOH)	g										4.34E-02		4.34E-02		4.34E-02
Sodium hypchlorite	g										1.12E-03		1.12E-03		1.12E-03
Sodium ions	g						4.08E-02						4.08E-02		4.08E-02
Sodiumkapryl-aminodipropionate	g										2.53E-03		2.53E-03		2.53E-03
Sulphate (SO4 2-)	g						5.34E-02				1.67E-03		5.50E-02		5.50E-02
Sulphide (S 2-)	g						5.34E-05				1.54E-05		6.88E-05		6.88E-05
Sulphuric acid (H2SO4)	g										3.22E-02		3.22E-02		3.22E-02
Suspended solids	g						2.47E+01	1.92E-02	2.21E-02		2.34E-02		2.48E+01		2.48E+01
TEX (aliphatic)	g										5.56E-03		5.56E-03		5.56E-03
TOC	g						3.48E-03						3.48E-03		3.48E-03
Toluene (C7H8)	g						1.53E-05						1.53E-05		1.53E-05
Tridecylalcohol-etoxilate	g										2.53E-03		2.53E-03		2.53E-03
Zinc (Zn)	g	2.85E-04					4.44E-04				4.71E-04		9.15E-04		9.15E-04
Waste generation															
Waste water	m^3						3.89E-04			1.34E-03	3.19E-06		1.73E-03		1.73E-03
Solid waste	kg			8.77E+01	1.01E+01		6.57E-03	1.66E-03	1.91E-03		1.97E-03	1.04E-01	1.16E-01		8.78E+01

X10

		Production (X1/X10)	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Electricity (Swedish)	Maintenance (Swedish)	Transports	Total (Swedish)
Energy use															
Feedstock	MJ						8.38E-02	1.44E+01	1.66E+01				3.10E+01		3.10E+01
Electricity (non- accounted)	MJ	7.51E+01	8.99E+03	8.99E+03	8.99E+03	7.22E-01				7.74E-00	2.86E-01	8.75E-00	8.75E-00		9.00E+03
Electricity (accounted)	MJ						1.59E-01	1.60E-02	1.84E-02				1.93E-01		1.93E-01
Emissions to air															
Ammonia (NH3)	g	2.11E-04	4.94E+01	1.98E-00	2.07E-02		4.30E-03					1.92E-03	6.23E-03		1.98E-00
Aromatic HC	g	3.06E-04					8.58E-05						8.58E-05		8.58E-05
Arsenic (As)	g	1.32E-04									1.12E-07		1.12E-07		1.12E-07
Benzene (C6H6)	g	3.06E-02					6.01E-05						6.01E-05		6.01E-05
Beryllium (Be)	g										1.40E-09		1.40E-09		1.40E-09
Cadmium (Cd)	g	1.25E-04					1.80E-06				8.42E-08		1.88E-06		1.88E-06
Carbon dioxide (CO2)	g	3.86E+03	1.89E+06	7.05E+04	1.26E+04		4.16E+01	9.09E+01	1.05E+02		4.13E+01	6.86E+01	3.47E+02	4.00E+03	7.48E+04
Carbon monoxide (CO)	g	2.39E+01	8.27E+02	1.62E+02	1.71E+01		8.25E-02	2.56E-02	2.94E-02		6.07E-03	1.57E-01	3.01E-01	6.75E-01	1.63E+02
Chromium (Cr)	g	3.43E-05									9.82E-08		9.82E-08		9.82E-08
Copper (Cu)	g	7.08E-04									3.93E-07		3.93E-07		3.93E-07
Dioxin	g	2.01E-08									2.01E-14		2.01E-14		2.01E-14
Dust/particulates	g		5.30E+02	2.25E+01	2.07E-00		1.07E-01	1.09E-01	1.25E-01		4.92E-03	2.19E-02	3.68E-01	6.23E-01	2.35E+01
Halogenated HC	g						8.33E-10						8.33E-10		8.33E-10
Halon H1301	g						6.02E-07						6.02E-07		6.02E-07
Hydrochloricacid (HCl)	g	1.10E-01					2.84E-03	1.60E-03	1.84E-03		6.17E-04		6.90E-03		6.90E-03
Hydrofluoric acid (HF)	g	6.01E-03					6.06E-05						6.06E-05		6.06E-05
Lead (Pb)	g	6.22E-04					4.54E-06				2.59E-06		7.14E-06		7.14E-06
Manganese (Mn)	g	1.93E-05					5.07E-07						5.07E-07		5.07E-07
Mercury (Hg)	g	1.61E-04					2.18E-07				2.67E-07		4.85E-07		4.85E-07
Metals	g						4.23E-04	3.20E-04	3.68E-04				1.11E-03		1.11E-03
Methane (CH4)	g	5.85E-00	2.25E+04	4.40E+02	1.39E+01		2.76E-02					4.29E-01	4.56E-01	4.16E-01	4.41E+02
Nickel (Ni)	g	2.13E-03					4.51E-05				8.42E-08		4.52E-05		4.52E-05
Nitrogen oxides (NOx) as NO2	g	1.52E+01	8.81E+02	1.35E+02	1.62E+01		1.69E-01	9.28E-01	1.07E-00		6.20E-02	1.31E-01	2.36E-00	3.90E+01	1.76E+02

Nitrous oxide (N2O)	g	1.20E-02	3.06E+01	6.38E-00	5.75E-02		2.28E-04					6.21E-03	6.44E-03	1.56E-01	6.54E-00
NMVOC non-methane HC	g	2.03E+01	4.13E+01	2.61E+01	3.15E-00		6.92E-02	9.28E-01	1.07E-00		1.55E-01	2.54E-02	2.24E-00	2.29E-00	3.06E+01
PAH policycl. arom. HC	g	2.95E-05					6.46E-02						6.46E-02		6.46E-02
Radioactive substances	g						2.77E-00						2.77E-00		2.77E-00
Sulphur oxides (SOx) as SO2	g	6.09E-00	1.44E+03	1.17E+02	3.42E-00		2.99E-01	5.76E-01	6.62E-01		9.32E-02	1.14E-01	1.74E-00	1.09E-00	1.20E+02
Zinc (Zn)	g	7.71E-03					5.70E-06				6.40E-06		1.21E-05		1.21E-05
Emissions to water															
Acid (as H+)	g	9.31E-05					2.68E-03	9.60E-03	1.10E-02				2.33E-02		2.33E-02
Aluminium (Al)	g						8.96E-04						8.96E-04		8.96E-04
Aluminium sulphate (AlSO4)	g										2.31E-02		2.31E-02		2.31E-02
Ammonium (NH4+)	g	3.42E-04					2.28E-03	3.20E-04	3.68E-04				2.97E-03		2.97E-03
AOX as Cl-	g						4.45E-07				7.22E-05		7.27E-05		7.27E-05
Aromatic HC	g						1.12E-04				8.33E-04		9.45E-04		9.45E-04
Arsenic (As)	g	6.28E-05					1.89E-06						1.89E-06		1.89E-06
Assay Al203	g										1.32E-02		1.32E-02		1.32E-02
Barium (Ba)	g						3.87E-04						3.87E-04		3.87E-04
BOD	g	6.38E-01					2.49E-03	1.60E-03	1.84E-03				5.93E-03		5.93E-03
Cadmium (Cd)	g	3.26E-05					3.46E-05				1.03E-06		3.57E-05		3.57E-05
Chloride (Cl-)	g						7.11E-00	3.20E-03	3.68E-03		1.58E-01		7.27E-00		7.27E-00
Chlorinated CH	g						1.48E-07						1.48E-07		1.48E-07
Chromium (Cr)	g	4.61E-04					2.26E-05				2.43E-05		4.69E-05		4.69E-05
Cobalt (Co)	g										1.40E-08		1.40E-08		1.40E-08
COD	g	1.73E-00					4.97E-03	3.20E-03	3.68E-03		5.98E-01		6.10E-01		6.10E-01
Copper (Cu)	g	8.41E-05					4.66E-06						4.66E-06		4.66E-06
Cyanide (CN-)	g	5.75E-05					5.04E-07						5.04E-07		5.04E-07
Dimethyl-aminoacrylate	g										1.97E-03		1.97E-03		1.97E-03
Dioxin	g										1.40E-13		1.40E-13		1.40E-13
Dissolved solids	g						4.97E-04						4.97E-04		4.97E-04
DOC	g						3.65E-05						3.65E-05		3.65E-05
Fats/oils	g	5.37E-01					3.45E-03				4.26E-03		7.71E-03		7.71E-03
Fluoride (F-)	g	3.43E-03					6.10E-01						6.10E-01		6.10E-01
Hydrocarbons (HC)	g							6.40E-03	7.36E-03				1.38E-02		1.38E-02
Hydrochloric acid (HCl)	g										2.04E-02		2.04E-02		2.04E-02
Inorg. salts and acids	g						4.19E-00						4.19E-00		4.19E-00
Iron (Fe)	g	3.55E-02					8.74E-04				5.79E-02		5.88E-02		5.88E-02
Lead (Pb)	g	2.50E-04					5.16E-06				5.09E-06		1.02E-05		1.02E-05
Mercury (Hg)	g						9.98E-09				4.21E-10		1.04E-08		1.04E-08
Metals	g						1.70E-03	1.60E-03	1.84E-03				5.14E-03		5.14E-03
Nickel (Ni)	g	2.31E-04					4.90E-06				5.09E-04		5.14E-04		5.14E-04
Nitrate (NO3-)	g	1.42E-04					9.43E-05	3.20E-04	3.68E-04				7.82E-04		7.82E-04
Nitric acid (HNO3)	g	1.05E-06									8.07E-03		8.07E-03		8.07E-03
Nitrogen org. bound	g						1.83E-05						1.83E-05		1.83E-05
Nitrogen total	g	1.09E-01					1.49E-04	3.20E-04	3.68E-04				8.37E-04		8.37E-04
NTA solution (100 %)	g										3.88E-04		3.88E-04		3.88E-04
PAH policycl. arom. HC	g						1.65E-06						1.65E-06		1.65E-06
Phenols	g	4.92E-06					1.84E-05				7.28E-04		7.47E-04		7.47E-04
Phosphate (PO4 3-)	g	1.82E-06					6.05E-05						6.05E-05		6.05E-05
Potassium hydroxide (KOH)	g										4.56E-03		4.56E-03		4.56E-03
Radioactive substances	kBq						2.55E-02						2.55E-02		2.55E-02
Silikates	g						8.15E-03						8.15E-03		8.15E-03
Sodium gluconate	g										1.12E-03		1.12E-03		1.12E-03
Sodium hydroxide (NaOH)	g										4.34E-02		4.34E-02		4.34E-02
Sodium hypchlorite	g										1.12E-03		1.12E-03		1.12E-03
Sodium ions	g						4.08E-02						4.08E-02		4.08E-02
Sodiumkapryl-aminodipropionate	g										2.53E-03		2.53E-03		2.53E-03
Sulphate (SO4 2-)	g						5.34E-02				1.67E-03		5.50E-02		5.50E-02
Sulphide (S 2-)	g						5.34E-05				1.54E-05		6.88E-05		6.88E-05
Sulphuric acid (H2SO4)	g										3.22E-02		3.22E-02		3.22E-02
Suspended solids	g						2.47E+01	1.92E-02	2.21E-02		2.34E-02		2.48E+01		2.48E+01
TEX (aliphatic)	g										5.56E-03		5.56E-03		5.56E-03
TOC	g						3.48E-03						3.48E-03		3.48E-03
Toluene (C7H8)	g						1.53E-05						1.53E-05		1.53E-05
Tridecyl-alcoholetoxilate	g										2.53E-03		2.53E-03		2.53E-03
Zinc (Zn)	g	3.80E-04					4.44E-04				4.71E-04		9.15E-04		9.15E-04
Waste generation															
Waste water	m^3						3.89E-04			1.34E-03	3.19E-06		1.73E-03		1.73E-03
Solid waste	kg			1.17E+02	1.35E+01		6.57E-03	1.66E-03	1.91E-03		1.97E-03	1.14E-01	1.26E-01		1.17E+02

Regina

		Production (X1/X10)	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Electricity (Swedish)	Maintenance (Swedish)	Transports	Total (Swedish)
Energy use															
Feedstock	MJ						1.12E-01		1.03E+01				1.04E+01		1.04E+01
Electricity (non-accounted)	MJ		6.15E+03	6.15E+03	6.15E+03	7.18E-01				6.48E-00	9.49E-02	7.29E-00	7.29E-00		6.15E+03
Electricity (accounted)	MJ						2.12E-01		1.14E-02				2.23E-01		2.23E-01
Emissions to air															
Ammonia (NH3)	g		3.38E+01	1.35E-00	1.41E-02		5.74E-03					1.60E-03	7.34E-03		1.36E-00
Aromatic HC	g						1.14E-04						1.14E-04		1.14E-04
Arsenic (As)	g										3.72E-08		3.72E-08		3.72E-08
Benzene (C6H6)	g						8.01E-05						8.01E-05		8.01E-05
Beryllium (Be)	g										4.65E-10		4.65E-10		4.65E-10
Cadmium (Cd)	g						2.40E-06				2.79E-08		2.43E-06		2.43E-06
Carbon dioxide (CO2)	g		1.29E+06	4.82E+04	8.60E+03		5.55E+01		6.48E+01		1.37E+01	5.72E+01	1.91E+02	4.53E+03	5.29E+04
Carbon monoxide (CO)	g		5.65E+02	1.11E+02	1.17E+01		1.10E-01		1.82E-02		2.01E-03	1.31E-01	2.61E-01	7.65E-01	1.12E+02
Chromium (Cr)	g										3.25E-08		3.25E-08		3.25E-08
Copper (Cu)	g										1.30E-07		1.30E-07		1.30E-07
Dioxin	g										6.65E-15		6.65E-15		6.65E-15
Dust/particulates	g		3.63E+02	1.54E+01	1.41E-00		1.43E-01		7.75E-02		5.61E-03	1.82E-02	2.44E-01	7.06E-01	1.63E+01
Halogenated HC	g						1.11E-09						1.11E-09		1.11E-09
Halon H1301	g						8.02E-07						8.02E-07		8.02E-07
Hydrochloric acid (HCl)	g						3.79E-03		1.14E-03		2.05E-04		5.13E-03		5.13E-03
Hydrofluoric acid (HF)	g						8.08E-05						8.08E-05		8.08E-05
Lead (Pb)	g						6.06E-06				8.60E-07		6.92E-06		6.92E-06
Manganese (Mn)	g						6.75E-07						6.75E-07		6.75E-07
Mercury (Hg)	g						2.91E-07				8.83E-08		3.79E-07		3.79E-07
Metals	g						5.64E-04		2.28E-04				7.92E-04		7.92E-04
Methane (CH4)	g		1.54E+04	3.01E+02	9.53E-00		3.67E-02					3.57E-01	3.94E-01	4.71E-01	3.02E+02
Nickel (Ni)	g						6.01E-05				2.79E-08		6.01E-05		6.01E-05
Nitrogen oxides (NOx) as NO2	g		6.02E+02	9.22E+01	1.11E+01		2.25E-01		6.61E-01		2.06E-02	1.09E-01	1.02E-00	4.41E+01	1.37E+02
Nitrous oxide (N2O)	g		2.09E+01	4.36E-00	3.93E-02		3.04E-04					5.18E-03	5.48E-03	1.77E-01	4.55E-00
NMVOC non-methane HC	g		2.83E+01	1.78E+01	2.15E-00		9.23E-02		6.61E-01		5.13E-02	2.11E-02	8.26E-01	2.59E-00	2.12E+01
PAH policycl. arom. HC	g						8.62E-02						8.62E-02		8.62E-02
Radioactive substances	g						3.69E-00						3.69E-00		3.69E-00
Sulphur oxides (SOx) as SO2	g		9.83E+02	7.99E+01	2.34E-00		3.98E-01		4.10E-01		3.09E-02	9.48E-02	9.34E-01	1.24E-00	8.21E+01
Zinc (Zn)	g						7.60E-06				2.12E-06		9.72E-06		9.72E-06
Emissions to water															
Acid (as H+)	g						3.58E-03		6.84E-03				1.04E-02		1.04E-02
Aluminium (Al)	g						1.19E-03						1.19E-03		1.19E-03
Aluminium sulphate (AlSO4)	g										7.66E-03		7.66E-03		7.66E-03
Ammonium (NH4+)	g						3.05E-03		2.28E-04				3.27E-03		3.27E-03
AOX as Cl-	g						5.94E-07				2.39E-05		2.45E-05		2.45E-05
Aromatic HC	g						1.49E-04				2.76E-04		4.25E-04		4.25E-04
Arsenic (As)	g						2.52E-06						2.52E-06		2.52E-06
Assay Al203	g										4.37E-03		4.37E-03		4.37E-03
Barium (Ba)	g						5.16E-04						5.16E-04		5.16E-04
BOD	g						3.33E-03		1.14E-03				4.47E-03		4.47E-03
Cadmium (Cd)	g						4.62E-05				3.42E-07		4.65E-05		4.65E-05
Chloride (Cl-)	g						9.48E-00		2.28E-03		5.23E-02		9.54E-00		9.54E-00
Chlorinated CH	g						1.97E-07						1.97E-07		1.97E-07
Chromium (Cr)	g						3.02E-05				8.04E-06		3.82E-05		3.82E-05
Cobalt (Co)	g										4.65E-09		4.65E-09		4.65E-09
COD	g						6.63E-03		2.28E-03		1.98E-01		2.07E-01		2.07E-01
Copper (Cu)	g						6.21E-06						6.21E-06		6.21E-06
Cyanide (CN-)	g						6.72E-07						6.72E-07		6.72E-07
Dimethyl-aminoacrylate	g										6.53E-04		6.53E-04		6.53E-04
Dioxin	g										4.65E-14		4.65E-14		4.65E-14
Dissolved solids	g						6.63E-04						6.63E-04		6.63E-04
DOC	g						4.87E-05						4.87E-05		4.87E-05
Fats/oils	g						4.60E-03				1.41E-03		6.01E-03		6.01E-03
Fluoride (F-)	g						8.13E-01						8.13E-01		8.13E-01
Hydrocarbons (HC)	g								4.56E-03				4.56E-03		4.56E-03
Hydrochloric acid (HCl)	g										6.74E-03		6.74E-03		6.74E-03
Inorg. salts and acids	g						5.59E-00						5.59E-00		5.59E-00
Iron (Fe)	g						1.17E-03				1.92E-02		2.03E-02		2.03E-02
Lead (Pb)	g						6.88E-06				1.69E-06		8.56E-06		8.56E-06
Mercury (Hg)	g						1.33E-08				1.39E-10		1.34E-08		1.34E-08
Metals	g						2.27E-03		1.14E-03				3.41E-03		3.41E-03
Nickel (Ni)	g						6.54E-06				1.69E-04		1.75E-04		1.75E-04
Nitrate (NO3-)	g						1.26E-04		2.28E-04				3.54E-04		3.54E-04

Nitric acid (HNO3)	g										2.68E-03		2.68E-03		2.68E-03
Nitrogen org. bound	g						2.44E-05						2.44E-05		2.44E-05
Nitrogen total	g						1.99E-04		2.28E-04				4.27E-04		4.27E-04
NTA solution (100 %)	g										1.29E-04		1.29E-04		1.29E-04
PAH policycl. arom. HC	g						2.19E-06						2.19E-06		2.19E-06
Phenols	g						2.45E-05				2.41E-04		2.66E-04		2.66E-04
Phosphate (PO4 3-)	g						8.06E-05						8.06E-05		8.06E-05
Potassium hydroxide (KOH)	g										1.51E-03		1.51E-03		1.51E-03
Radioactive substances	kBq						3.41E-02						3.41E-02		3.41E-02
Silikates	g						1.09E-02						1.09E-02		1.09E-02
Sodium gluconate	g										3.70E-04		3.70E-04		3.70E-04
Sodium hydroxide (NaOH)	g										1.44E-02		1.44E-02		1.44E-02
Sodium hypchlorite	g										3.73E-04		3.73E-04		3.73E-04
Sodium ions	g						5.43E-02						5.43E-02		5.43E-02
Sodiumkapryl-aminodipropionate	g										8.40E-04		8.40E-04		8.40E-04
Sulphate (SO4 2-)	g						7.12E-02				5.54E-04		7.17E-02		7.17E-02
Sulphide (S 2-)	g						7.11E-05				5.12E-06		7.63E-05		7.63E-05
Sulphuric acid (H2SO4)	g										1.07E-02		1.07E-02		1.07E-02
Suspended solids	g						3.29E+01		1.37E-02		7.76E-03		3.29E+01		3.29E+01
TEX (aliphatic)	g										1.84E-03		1.84E-03		1.84E-03
TOC	g						4.64E-03						4.64E-03		4.64E-03
Toluene (C7H8)	g						2.04E-05						2.04E-05		2.04E-05
Tridecyl-alcoholetoxilate	g										8.40E-04		8.40E-04		8.40E-04
Zinc (Zn)	g						5.92E-04				1.56E-04		7.48E-04		7.48E-04
Waste generation															
Waste water	m^3						5.18E-04			6.68E-00	1.06E-06		6.68E-00		6.68E-00
Solid waste	kg			7.99E+01	9.22E-00		8.75E-03		1.18E-03		6.52E-04	9.48E-02	1.05E-01		8.00E+01

12 Human toxicity

[CML (2002)]
Problem oriented approach (CML, 1999)
HTP inf. (Huijbregts, 1999 & 2000)
1,4-dichlorobenzene eq.

X1

		Production	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Maintenance	Transports	Total	Human toxicity (recalc. factor)
Emissions to air															
Ammonia (NH3)	g	1.58E-05	3.71E-00	1.48E-01	1.55E-03		4.30E-04					6.06E-04		1.49E-01	1.000E-01
Aromatic HC	g														
Arsenic (As)	g	3.45E+01									3.90E-02	3.90E-02		3.90E-02	3.477E+05
Benzene (C6H6)	g	1.31E+01					1.14E-01					1.14E-01		1.14E-01	1.900E+03
Beryllium (Be)	g										3.18E-04	3.18E-04		3.18E-04	2.266E+05
Cadmium (Cd)	g	1.36E+01					2.61E-01				1.22E-02	2.73E-01		2.73E-01	1.450E+05
Carbon dioxide (CO2)	g														
Carbon monoxide (CO)	g														
Chromium (Cr)	g	1.66E-02									6.35E-05	6.35E-05		6.35E-05	6.468E+02
Copper (Cu)	g	2.28E-00									1.69E-03	1.69E-03		1.69E-03	4.295E+03
Dioxin	g	2.92E+01									3.88E-05	3.88E-05		3.88E-05	1.934E+09
Dust/particulates	g		3.26E+02	1.38E+01	1.27E-00		8.79E-02	8.92E-02	1.03E-01		4.04E-03	3.00E-01	5.11E-01	1.46E+01	8.200E-01
Halogenated HC	g														
Halon H1301	g														
Hydrochloric acid (HCl)	g	4.13E-02					1.42E-03	8.00E-04	9.20E-04		3.09E-04	3.45E-03		3.45E-03	5.000E-01
Hydrofluoric acid (HF)	g	1.29E+01					1.73E-01					1.73E-01		1.73E-01	2.851E+03
Lead (Pb)	g	2.18E-01					2.12E-03				1.21E-03	3.33E-03		3.33E-03	4.665E+02
Manganese (Mn)	g														
Mercury (Hg)	g	7.26E-01					1.31E-03				1.60E-03	2.91E-03		2.91E-03	6.008E+03
Metals	g														
Methane (CH4)	g														
Nickel (Ni)	g	5.59E+01					1.58E-00				2.95E-03	1.58E-00		1.58E-00	3.503E+04
Nitrogen oxides (NOx) as NO2	g	1.36E+01	7.93E+02	1.21E+02	1.46E+01		2.03E-01	1.11E-00	1.28E-00		7.44E-02	2.82E-00	4.68E+01	1.71E+02	1.200E-00
Nitrous oxide (N2O)	g														
NMVOC non-methane HC	g														
PAH policycl. arom. HC	g														
Radioactive substances	g														
Sulphur oxides (SOx) as SO2	g														
Zinc (Zn)	g	6.04E-01					5.95E-04				6.68E-04	1.26E-03		1.26E-03	1.044E+02
Emissions to water															
Acid (as H+)	g														
Aluminium (Al)	g														
Aluminium sulphate (AlSO4)	g														
Ammonium (NH4+)	g														
AOX as Cl-	g														
Aromatic HC	g														
Arsenic (As)	g	4.48E-02					1.80E-03					1.80E-03		1.80E-03	9.506E+02
Assay Al203	g														
Barium (Ba)	g						2.44E-01					2.44E-01		2.44E-01	6.305E+02
BOD	g														
Cadmium (Cd)	g	5.60E-04					7.93E-04				2.36E-05	8.16E-04		8.16E-04	2.289E+01
Chloride (Cl-)	g														
Chlorinated CH	g														
Chromium (Cr)	g	7.09E-04					4.65E-05				4.98E-05	9.63E-05		9.63E-05	2.052E-00
Cobalt (Co)	g										1.36E-06	1.36E-06		1.36E-06	9.670E+01
COD	g														
Copper (Cu)	g	8.44E-05					6.24E-06					6.24E-06		6.24E-06	1.339E-00
Cyanide (CN-)	g														
Dimethyl-aminoacrylate	g														
Dioxin	g										1.20E-04	1.20E-04		1.20E-04	8.583E+08
Dissolved solids	g														
DOC	g														
Fats/oils	g														
Fluoride (F-)	g														
Hydrocarbons (HC)	g														
Hydrochloric acid (HCl)	g														
Inorg. salts and acids	g														

Iron (Fe)	g														
Lead (Pb)	g	2.30E-03					6.32E-05				6.24E-05	1.26E-04		1.26E-04	1.226E+01
Mercury (Hg)	g						1.42E-05				6.00E-07	1.48E-05		1.48E-05	1.426E+03
Metals	g														
Nickel (Ni)	g	5.73E-02					1.62E-03				1.68E-01	1.70E-01		1.70E-01	3.311E+02
Nitrate (NO3-)	g														
Nitric acid (HNO3)	g														
Nitrogen org. bound	g														
Nitrogen total	g														
NTA solution (100 %)	g														
PAH policycl. arom. HC	g														
Phenols	g	1.81E-07					9.03E-07				3.58E-05	3.67E-05		3.67E-05	4.916E-02
Phosphate (PO4 3-)	g														
Potassium hydroxide (KOH)	g														
Radioactive substances	kBq														
Silikates	g														
Sodium gluconate	g														
Sodium hydroxide (NaOH)	g														
Sodium hypchlorite	g														
Sodium ions	g														
Sodiumkapryl-aminodipropionate	g														
Sulphate (SO4 2-)	g														
Sulphide (S 2-)	g														
Sulphuric acid (H2SO4)	g														
Suspended solids	g														
TEX (aliphatic)	g														
TOC	g														
Toluene (C7H8)	g						4.63E-06					4.63E-06		4.63E-06	3.028E-01
Tridecyl-alcoholetoxilate	g														
Zinc (Zn)	g	1.66E-04					2.59E-04				2.75E-04	5.34E-04		5.34E-04	5.839E-01
Total human toxicity	g	1.77E+02	1.12E+03	1.35E+02	1.58E+01		2.67E-00	1.20E-00	1.38E-00		3.08E-01	5.73E-00	4.73E+01	1.88E+02	

X10

		Production	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Maintenance	Transports	Total	Human toxicity (recalc. factor)
Emissions to air															
Ammonia (NH3)	g	2.11E-05	4.94E-00	1.98E-01	2.07E-03		4.30E-04					6.23E-04		1.98E-01	1.000E-01
Aromatic HC	g														
Arsenic (As)	g	4.61E+01									3.90E-02	3.90E-02		3.90E-02	3.477E+05
Benzene (C6H6)	g	5.81E+01					1.14E-01					1.14E-01		1.14E-01	1.900E+03
Beryllium (Be)	g										3.18E-04	3.18E-04		3.18E-04	2.266E+05
Cadmium (Cd)	g	1.81E+01					2.61E-01				1.22E-02	2.73E-01		2.73E-01	1.450E+05
Carbon dioxide (CO2)	g														
Carbon monoxide (CO)	g														
Chromium (Cr)	g	2.22E-02									6.35E-05	6.35E-05		6.35E-05	6.468E+02
Copper (Cu)	g	3.04E-00									1.69E-03	1.69E-03		1.69E-03	4.295E+03
Dioxin	g	3.89E+01									3.88E-05	3.88E-05		3.88E-05	1.934E+09
Dust/particulates	g		4.35E+02	1.84E+01	1.70E-00		8.79E-02	8.92E-02	1.03E-01		4.04E-03	3.02E-01	5.11E-01	1.92E+01	8.200E-01
Halogenated HC	g														
Halon H1301	g														
Hydrochloric acid (HCl)	g	5.51E-02					1.42E-03	8.00E-04	9.20E-04		3.09E-04	3.45E-03		3.45E-03	5.000E-01
Hydrofluoric acid (HF)	g	1.71E+01					1.73E-01					1.73E-01		1.73E-01	2.851E+03
Lead (Pb)	g	2.90E-01					2.12E-03				1.21E-03	3.33E-03		3.33E-03	4.665E+02
Manganese (Mn)	g														
Mercury (Hg)	g	9.68E-01					1.31E-03				1.60E-03	2.91E-03		2.91E-03	6.008E+03
Metals	g														
Methane (CH4)	g														
Nickel (Ni)	g	7.45E+01					1.58E-00				2.95E-03	1.58E-00		1.58E-00	3.503E+04
Nitrogen oxides (NOx) as NO2	g	1.82E+01	1.06E+03	1.62E+02	1.94E+01		2.03E-01	1.11E-00	1.28E-00		7.44E-02	2.83E-00	4.68E+01	2.11E+02	1.200E-00
Nitrous oxide (N2O)	g														
NMVOC non-methane HC	g														
PAH policycl. arom. HC	g														
Radioactive substances	g														
Sulphur oxides (SOx) as SO2	g														
Zinc (Zn)	g	8.05E-01					5.95E-04				6.68E-04	1.26E-03		1.26E-03	1.044E+02
Emissions to water															
Acid (as H+)	g														
Aluminium (Al)	g														

Aluminium sulphate (AlSO4)	g														
Ammonium (NH4+)	g														
AOX as Cl-	g														
Aromatic HC	g														
Arsenic (As)	g	5.97E-02					1.80E-03					1.80E-03		1.80E-03	9.506E+02
Assay Al203	g														
Barium (Ba)	g						2.44E-01					2.44E-01		2.44E-01	6.305E+02
BOD	g														
Cadmium (Cd)	g	7.46E-04					7.93E-04				2.36E-05	8.16E-04		8.16E-04	2.289E+01
Chloride (Cl-)	g														
Chlorinated CH	g														
Chromium (Cr)	g	9.45E-04					4.65E-05				4.98E-05	9.63E-05		9.63E-05	2.052E-00
Cobalt (Co)	g										1.36E-06	1.36E-06		1.36E-06	9.670E+01
COD	g														
Copper (Cu)	g	1.13E-04					6.24E-06					6.24E-06		6.24E-06	1.339E-00
Cyanide (CN-)	g														
Dimethyl-aminoacrylate	g														
Dioxin	g										1.20E-04	1.20E-04		1.20E-04	8.583E+08
Dissolved solids	g														
DOC	g														
Fats/oils	g														
Fluoride (F-)	g														
Hydrocarbons (HC)	g														
Hydrochloric acid (HCl)	g														
Inorg. salts and acids	g														
Iron (Fe)	g														
Lead (Pb)	g	3.07E-03					6.32E-05				6.24E-05	1.26E-04		1.26E-04	1.226E+01
Mercury (Hg)	g						1.42E-05				6.00E-07	1.48E-05		1.48E-05	1.426E+03
Metals	g														
Nickel (Ni)	g	7.64E-02					1.62E-03				1.68E-01	1.70E-01		1.70E-01	3.311E+02
Nitrate (NO3-)	g														
Nitric acid (HNO3)	g														
Nitrogen org. bound	g														
Nitrogen total	g														
NTA solution (100 %)	g														
PAH policycl. arom. HC	g														
Phenols	g	2.42E-07					9.03E-07				3.58E-05	3.67E-05		3.67E-05	4.916E-02
Phosphate (PO4 3-)	g														
Potassium hydroxide (KOH)	g														
Radioactive substances	kBq														
Silikates	g														
Sodium gluconate	g														
Sodium hydroxide (NaOH)	g														
Sodium hypchlorite	g														
Sodium ions	g														
Sodiumkapryl-aminodipropionate	g														
Sulphate (SO4 2-)	g														
Sulphide (S 2-)	g														
Sulphuric acid (H2SO4)	g														
Suspended solids	g														
TEX (aliphatic)	g														
TOC	g														
Toluene (C7H8)	g						4.63E-06					4.63E-06		4.63E-06	3.028E-01
Tridecyl-alcoholetoxilate	g														
Zinc (Zn)	g	2.22E-04					2.59E-04				2.75E-04	5.34E-04		5.34E-04	5.839E-01
Total human toxicity	g	2.76E+02	1.50E+03	1.80E+02	2.11E+01		2.67E-00	1.20E-00	1.38E-00		3.08E-01	5.74E-00	4.73E+01	2.33E+02	

Regina

		Production	Operation (coal)	Operation (Swedish)	Operation (hydro)	Dismounting	Detergent	Naphtha	Oil & grease	Local proc.	Waste oil	Maintenance	Transports	Total	Human toxicity (recalc. factor)
Emissions to air															
Ammonia (NH3)	g		3.38E-00	1.35E-01	1.41E-03		5.74E-04					7.34E-04		1.36E-01	1.000E-01
Aromatic HC	g														
Arsenic (As)	g										1.29E-02	1.29E-02		1.29E-02	3.477E+05
Benzene (C6H6)	g						1.52E-01					1.52E-01		1.52E-01	1.900E+03
Beryllium (Be)	g										1.05E-04	1.05E-04		1.05E-04	2.266E+05
Cadmium (Cd)	g						3.48E-01				4.04E-03	3.52E-01		3.52E-01	1.450E+05
Carbon dioxide (CO2)	g														
Carbon monoxide (CO)	g														
Chromium (Cr)	g										2.10E-05	2.10E-05		2.10E-05	6.468E+02
Copper (Cu)	g										5.59E-04	5.59E-04		5.59E-04	4.295E+03
Dioxin	g										1.29E-05	1.29E-05		1.29E-05	1.934E+09
Dust/particulates	g		2.97E+02	1.26E+01	1.16E-00		1.17E-01		6.36E-02		4.60E-03	2.00E-01	5.79E-01	1.34E+01	8.200E-01
Halogenated HC	g														
Halon H1301	g														
Hydrochloric acid (HCl)	g						1.89E-03		5.70E-04		1.02E-04	2.57E-03		2.57E-03	5.000E-01
Hydrofluoric acid (HF)	g						2.30E-01					2.30E-01		2.30E-01	2.851E+03
Lead (Pb)	g						2.83E-03				4.01E-04	3.23E-03		3.23E-03	4.665E+02
Manganese (Mn)	g														
Mercury (Hg)	g						1.75E-03				5.31E-04	2.28E-03		2.28E-03	6.008E+03
Metals	g														
Methane (CH4)	g														
Nickel (Ni)	g						2.11E-00				9.77E-04	2.11E-00		2.11E-00	3.503E+04
Nitrogen oxides (NOx) as NO2	g		7.23E+02	1.11E+02	1.33E+01		2.70E-01		7.93E-01		2.47E-02	1.22E-00	5.30E+01	1.65E+02	1.200E-00
Nitrous oxide (N2O)	g														
NMVOC non-methane HC	g														
PAH policycl. arom. HC	g														
Radioactive substances	g														
Sulphur oxides (SOx) as SO2	g														
Zinc (Zn)	g						7.94E-04				2.21E-04	1.01E-03		1.01E-03	1.044E+02
Emissions to water															
Acid (as H+)	g														
Aluminium (Al)	g														
Aluminium sulphate (AlSO4)	g														
Ammonium (NH4+)	g														
AOX as Cl-	g														
Aromatic HC	g														
Arsenic (As)	g						2.39E-03					2.39E-03		2.39E-03	9.506E+02
Assay Al203	g														
Barium (Ba)	g						3.25E-01					3.25E-01		3.25E-01	6.305E+02
BOD	g														
Cadmium (Cd)	g						1.06E-03				7.83E-06	1.07E-03		1.07E-03	2.289E+01
Chloride (Cl-)	g														
Chlorinated CH	g														
Chromium (Cr)	g						6.19E-05				1.65E-05	7.84E-05		7.84E-05	2.052E-00
Cobalt (Co)	g										4.49E-07	4.49E-07		4.49E-07	9.670E+01
COD	g														
Copper (Cu)	g						8.32E-06					8.32E-06		8.32E-06	1.339E-00
Cyanide (CN-)	g														
Dimethyl-aminoacrylate	g														
Dioxin	g										3.99E-05	3.99E-05		3.99E-05	8.583E+08
Dissolved solids	g														
DOC	g														
Fats/oils	g														
Fluoride (F-)	g														
Hydrocarbons (HC)	g														
Hydrochloric acid (HCl)	g														
Inorg. salts and acids	g														
Iron (Fe)	g														
Lead (Pb)	g						8.43E-05				2.07E-05	1.05E-04		1.05E-04	1.226E+01
Mercury (Hg)	g						1.90E-05				1.99E-07	1.92E-05		1.92E-05	1.426E+03
Metals	g														
Nickel (Ni)	g						2.16E-03				5.58E-02	5.80E-02		5.80E-02	3.311E+02
Nitrate (NO3-)	g														
Nitric acid (HNO3)	g														
Nitrogen org. bound	g														
Nitrogen total	g														
NTA solution (100 %)	g														

PAH policycl. arom. HC	g														
Phenols	g						1.20E-06				1.19E-05	1.31E-05		1.31E-05	4.916E-02
Phosphate (PO4 3-)	g														
Potassium hydroxide (KOH)	g														
Radioactive substances	kBq														
Silikates	g														
Sodium gluconate	g														
Sodium hydroxide (NaOH)	g														
Sodium hypchlorite	g														
Sodium ions	g														
Sodiumkapryl-aminodipropionate	g														
Sulphate (SO4 2-)	g														
Sulphide (S 2-)	g														
Sulphuric acid (H2SO4)	g														
Suspended solids	g														
TEX (aliphatic)	g														
TOC	g														
Toluene (C7H8)	g						6.17E-06					6.17E-06		6.17E-06	3.028E-01
Tridecylalcohol-etoxilate	g														
Zinc (Zn)	g						3.46E-04				9.12E-05	4.37E-04		4.37E-04	5.839E-01
Total human toxicity	g		1.02E+03	1.23E+02	1.44E+01		3.56E-00		8.58E-01		1.05E-01	4.67E-00	5.35E+01	1.82E+02	