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Transport Services

Data v2.0 (2007)

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Transport Services

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Summary

Freight transport occurs between nearly any two process steps of a product system and often is of major importance for a product life cycle. In addition, passenger transport services e.g. for business and service trips are of growing interest for Life Cycle Assessment studies. Comprehensive life cycle inventories (LCI) of various means of transport are available from Frischknecht (1996)and Maibach (1999). Within the framework of ecoinvent 2000 projects, these data have been extended, updated and harmonised.

The main objective of transport modelling in ecoinvent is to provide background data for transport services in order to complete a variety of product life cycles. Generic background data have been generated for four modes of transport (air-, rail-, road- and water transport) to account for environmental interventions due to the transportation between two process steps of a product system. The data represent average transport conditions in Switzerland and Europe.

In order to quantify environmental exchanges of transport services and relate transport datasets to other product life cycles, the environmental exchanges are related to the reference unit of one tonne kilometre [tkm]. A tonne kilometre is defined as the transport of one tonne of goods by a certain transport service over one kilometre. Passenger transport data is expressed in passenger kilometres [pkm].

Each mode of transport is further separated into sub-groups, referred to as transport services, using several criteria such as geographical operation (e.g., rail transport), vehicle size (e.g., road transport) and transported goods (e.g., water transport). Transport services are divided into several datasets, so-called transport components. In addition to vehicle operation (comprising vehicle travel and pre-combustion), infrastructure processes such as vehicle maintenance, manufacturing and disposal as well as transport infrastructure construction, operation and disposal are also modelled.

New and Updated Transport Datasets in ecoinvent v2.0

The ecoinvent data v2.0 contain new and updated life cycle inventories of transport systems based on fossil fuels and biofuels as well as life cycle inventories of electric railway transport systems. This report contains the inventories and documentation of fossil fuel-based and railway transport services, while biofuel-based transport services are documented in (Jungbluth et al. 2007).

Fossil fuel-based and railway transport services

Comprehensive life cycle inventories (LCI) for various transport services (road, rail, water and air) have been produced within the framework of ecoinvent v1.1 by Spielmann (2004). Within the framework of ecoinvent v2.0, data the focus is the extension and update of road transport datasets. In addition the figures for Swiss rail transport have been updated and some datasets representing the rail transport of coal in China and the USA have been added.

In the tables below the updated and new datasets are presented.

Tab. 1: Datasets for Freight Transport Services in Europe (RER)

Dataset name	Location	Category	Sub-Category	Unit	Status
operation, lorry 3.5-7.5t, EURO3	RER	transport systems	road	vkm	new
operation, lorry 3.5-7.5t, EURO4	RER	transport systems	road	vkm	new
operation, lorry 3.5-7.5t, EURO5	RER	transport systems	road	vkm	new
operation, lorry 7.5-16t, EURO3	RER	transport systems	road	vkm	new
operation, lorry 7.5-16t, EURO4	RER	transport systems	road	vkm	new
operation, lorry 7.5-16t, EURO5	RER	transport systems	road	vkm	new
operation, lorry 16-32t, EURO3	RER	transport systems	road	vkm	new
operation, lorry 16-32t, EURO4	RER	transport systems	road	vkm	new
operation, lorry 16-32t, EURO5	RER	transport systems	road	vkm	new
operation, lorry >32t, EURO3	RER	transport systems	road	vkm	new
operation, lorry >32t, EURO4	RER	transport systems	road	vkm	new
operation, lorry >32t, EURO5	RER	transport systems	road	vkm	new
transport, lorry 3.5-7.5t, EURO3	RER	transport systems	road	tkm	new
transport, lorry 3.5-7.5t, EURO4	RER	transport systems	road	tkm	new
transport, lorry 3.5-7.5t, EURO5	RER	transport systems	road	tkm	new
transport, lorry 7.5-16t, EURO3	RER	transport systems	road	tkm	new
transport, lorry 7.5-16t, EURO4	RER	transport systems	road	tkm	new
transport, lorry 7.5-16t, EURO5	RER	transport systems	road	tkm	new
transport, lorry 16-32t, EURO3	RER	transport systems	road	tkm	new
transport, lorry 16-32t, EURO4	RER	transport systems	road	tkm	new
transport, lorry 16-32t, EURO5	RER	transport systems	road	tkm	new
transport, lorry >32t, EURO3	RER	transport systems	road	tkm	new
transport, lorry >32t, EURO4	RER	transport systems	road	tkm	new
transport, lorry >32t, EURO5	RER	transport systems	road	tkm	new
operation, lorry 3.5-16t, fleet average	RER	transport systems	road	vkm	update
operation, lorry >16t, fleet average	RER	transport systems	road	vkm	update
transport, lorry 3.5-16t, fleet average	RER	transport systems	road	tkm	update
transport, lorry >16t, fleet average	RER	transport systems	road	tkm	update
operation, van < 3,5t	RER	transport systems	road	vkm	update
transport, van <3.5t	RER	transport systems	road	tkm	update

Tab. 2: Datasets for Freight Transport Services in Switzerland

Dataset name	Location	Category	Sub-Category	Unit	Status
operation, lorry 3.5-20t, fleet average	CH	transport systems	road	vkm	update
operation, lorry 3.5-20t, empty, fleet average	CH	transport systems	road	vkm	update
operation, lorry 3.5-20t, full, fleet average	CH	transport systems	road	vkm	update
operation, lorry 20-28t, fleet average	CH	transport systems	road	vkm	update
operation, lorry 20-28t, empty, fleet average	CH	transport systems	road	vkm	update
operation, lorry 20-28t, full, fleet average	CH	transport systems	road	vkm	update
operation, lorry >28t, fleet average	CH	transport systems	road	vkm	update
operation, lorry >28t, empty, fleet average	CH	transport systems	road	vkm	update
operation, lorry >28t, full, fleet average	CH	transport systems	road	vkm	update
transport, lorry 3.5-20t, fleet average	CH	transport systems	road	tkm	update
transport, lorry 20-28t, fleet average	CH	transport systems	road	tkm	update
transport, lorry >28t, fleet average	CH	transport systems	road	tkm	update
operation, van < 3,5t	CH	transport systems	road	vkm	update
transport, van <3.5t	CH	transport systems	road	tkm	update

Tab. 3: Datasets for Passenger Transport Services in Europe (RER)

Dataset name	Location	Category	Sub-Category	Unit	Status
operation, passenger car, diesel, fleet average	RER	transport systems	road	vkm	new
operation, passenger car, diesel, fleet average 2010	RER	transport systems	road	vkm	new
operation, passenger car, petrol, fleet average	RER	transport systems	road	vkm	new
operation, passenger car, petrol, fleet average 2010	RER	transport systems	road	vkm	new
transport, passenger car, diesel, fleet average	RER	transport systems	road	pkm	new
transport, passenger car, diesel, fleet average 2010	RER	transport systems	road	pkm	new
transport, passenger car, petrol, fleet average	RER	transport systems	road	pkm	new
transport, passenger car, petrol, fleet average 2010	RER	transport systems	road	pkm	new
operation, passenger car, fleet average	RER	transport systems	road	vkm	update
transport, passenger car	RER	transport systems	road	pkm	update

Tab. 4: Datasets for Passenger Transport Services in Switzerland

Dataset name	Location	Category	Sub-Category	Unit	Status
operation, passenger car, diesel, fleet average	CH	transport systems	road	vkm	new
operation, passenger car, petrol, fleet average	CH	transport systems	road	vkm	new
operation, passenger car, diesel, fleet average 2010	CH	transport systems	road	vkm	new
operation, passenger car, petrol, fleet average 2010	CH	transport systems	road	vkm	new
transport, passenger car, diesel, fleet average	CH	transport systems	road	pkm	new
transport, passenger car, petrol, fleet average	CH	transport systems	road	pkm	new
transport, passenger car, diesel, fleet average 2010	CH	transport systems	road	pkm	new
transport, passenger car, petrol, fleet average 2010	CH	transport systems	road	pkm	new
operation, passenger car, fleet average	CH	transport systems	road	vkm	update
transport, passenger car	CH	transport systems	road	pkm	update
operation, coach	CH	transport systems	road	vkm	update
operation, regular bus	CH	transport systems	road	vkm	update
transport, coach	CH	transport systems	road	pkm	update
transport, regular bus	CH	transport systems	road	pkm	update

Tab. 5: Dataset updates for Swiss rail transport

Dataset name	Location	Category	Sub-Category	Unit	Status
operation, long-distance train, SBB mix	CH	transport systems	rail	pkm	updated
operation, regional train, SBB mix	CH	transport systems	rail	pkm	updated
operation, freight train	CH	transport systems	rail	tkm	updated

Tab. 6: Dataset updates for rail coal transport in China and the USA

Name	Location	Category	SubCategory	unit	Staus
transport, coal freight, rail	CN	transport systems	rail	tkm	new
operation, coal freight train, electricity	CN	transport systems	rail	tkm	new
operation, coal freight train, diesel	CN	transport systems	rail	tkm	new
operation, coal freight train, steam	CN	transport systems	rail	tkm	new
transport, freight, rail, diesel	US	transport systems	rail	tkm	new

Biofuels

Additionally to the modelled transport systems documented in this report (updated and new datasets, Tab. 1 through Tab. 6), several transport systems based on biofuels were modelled within the framework of ecoinvent v2.0. The LCI of these biofuel-based transport systems are documented in chapters 20 and 21 in (Jungbluth et al. 2007). Tab. 7 and Tab. 8 only summarize these biofuel-based transport datasets.

Tab. 7: Biofuel-based transport system datasets documented in chapter 20 in (Jungbluth et al. 2007).

Name	Location	Category	SubCategory	unit	Status
operation, lorry 28t, rape methyl ester 100%	CH	transport systems	road	km	new
operation, passenger car, ethanol 5%	CH	transport systems	road	km	new
operation, passenger car, methane, 96 vol-%, from biogas	CH	transport systems	road	km	new
operation, passenger car, methanol	CH	transport systems	road	km	new
operation, passenger car, natural gas	CH	transport systems	road	km	new
operation, passenger car, rape seed methyl ester 5%	CH	transport systems	road	km	new
transport, lorry 28t, rape methyl ester 100%	CH	transport systems	road	tkm	new
transport, passenger car, ethanol 5%	CH	transport systems	road	pkm	new
transport, passenger car, methane, 96 vol-%, from biogas	CH	transport systems	road	pkm	new
transport, passenger car, methanol	CH	transport systems	road	pkm	new
transport, passenger car, natural gas	CH	transport systems	road	pkm	new
transport, passenger car, rape seed methyl ester 5%	CH	transport systems	road	pkm	new

Tab. 8: Biofuel-based transport system datasets documented in chapter 21 in (Jungbluth et al. 2007).

Name	Location	Category	SubCategory	unit	Status
operation, passenger car, petrol, 4% vol. ETBE with ethanol from biomass, EURO4	CH	transport systems	road	km	new
transport, passenger car, petrol, 4% vol. ETBE with ethanol from biomass, EURO4	CH	transport systems	road	pkm	new
operation, passenger car, petrol, 15% vol. ETBE with ethanol from biomass, EURO4	CH	transport systems	road	km	new
transport, passenger car, petrol, 15% vol. ETBE with ethanol from biomass, EURO4	CH	transport systems	road	pkm	new

Table of Content

1 Introduction

Transportation systems are linked with a wide range of environmental impacts at all geographical scales, from global warming to local air pollution and land use. Transport activities are consuming large quantities of energy, especially oil, and due to combustion processes in vehicle operation and fuel production, transport is a major source of numerous pollutants such as carbon dioxide, nitrogen oxide and hydrocarbons. In addition, construction and operation of transport infrastructures as well as vehicle production, maintenance and disposal consume resources and causes additional, so-called indirect, environmental impacts of transport activities.

The main objective of transport modelling in ecoinvent is to provide background data for transport services in order to complete a variety of product life cycles. Generic background data have been generated for four modes of transport (air-, rail-, road- and water transport) to account for environmental interventions due to the transportation between two process steps of a product system. The data represent average transport conditions in Switzerland and Europe.

For transport-focused LCA the presented generic datasets may have to be replaced with more specific data. In either case, whether transport processes are identified as sensitive for the overall outcome of a certain product life cycle or for transport specific comparisons, the modular model structure and transparent documentation of demand factors allows for an easy and transparent integration of more case-specific data for the selected transport components.

In order to quantify environmental exchanges of transport services and relate transport datasets to other product life cycles, the environmental exchanges are related to the reference unit of one tonne kilometre [tkm]. A tonne kilometre is defined as the transport of one tonne of goods by a certain transport service over one kilometre. Passenger transport data is expressed in passenger kilometres [pkm].

Each mode of transport is further separated into sub-groups, referred to as transport services, using several criteria such as geographical operation (e.g., rail transport), vehicle size (e.g., road transport) and transported goods (e.g., water transport). Transport services are divided into several datasets, so-called transport components. In addition to vehicle operation (comprising vehicle travel and pre-combustion), infrastructure processes such as vehicle maintenance, manufacturing and disposal as well as transport infrastructure construction, operation and disposal are also modelled.

2 Characteristics of Transport Services

2.1 Passenger Transport Services

In Figure 2-1 the development of the Swiss passenger transport performance is illustrated. The figure reveals the dominance of private motorised transport, due to the extensive use of private passenger cars.

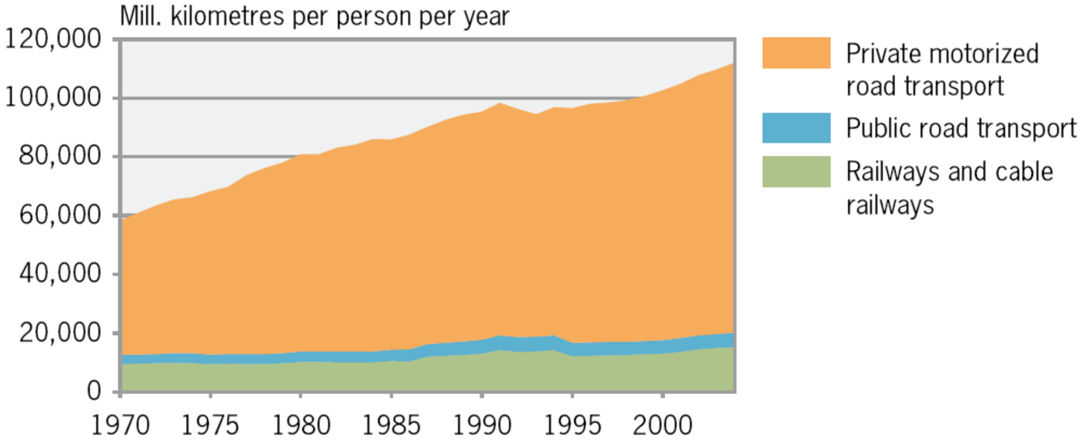


Figure 2-1: Passenger transport performance in Switzerland in the period from 1890 to 2004. Figure taken from BfS (2007).

In 2004, the Swiss passenger car fleet comprised 3'629 Mio vehicles. Newly registered cars in Switzerland are almost exclusively diesel and petrol vehicles. Alternative propulsion systems and fuels are currently negligible. For instance, in the first half of 2003, 131 compressed natural gas-vehicles have been newly registered (Carle 2005), corresponding to a share of less than 0.5% on the total number of new registrations in the same period.

In recent years there has been a considerable increase of diesel vehicles from about 5% in 1997 up to 25% in 2004 (see Figure 2-2). However, the share of diesel cars is still significantly below the average of diesel vehicles in Europe (almost 45%). For the year 2010, a further increase in the proportion of new vehicles up to 30% for the year 2010 is expected (Keller & Zbinden 2004).

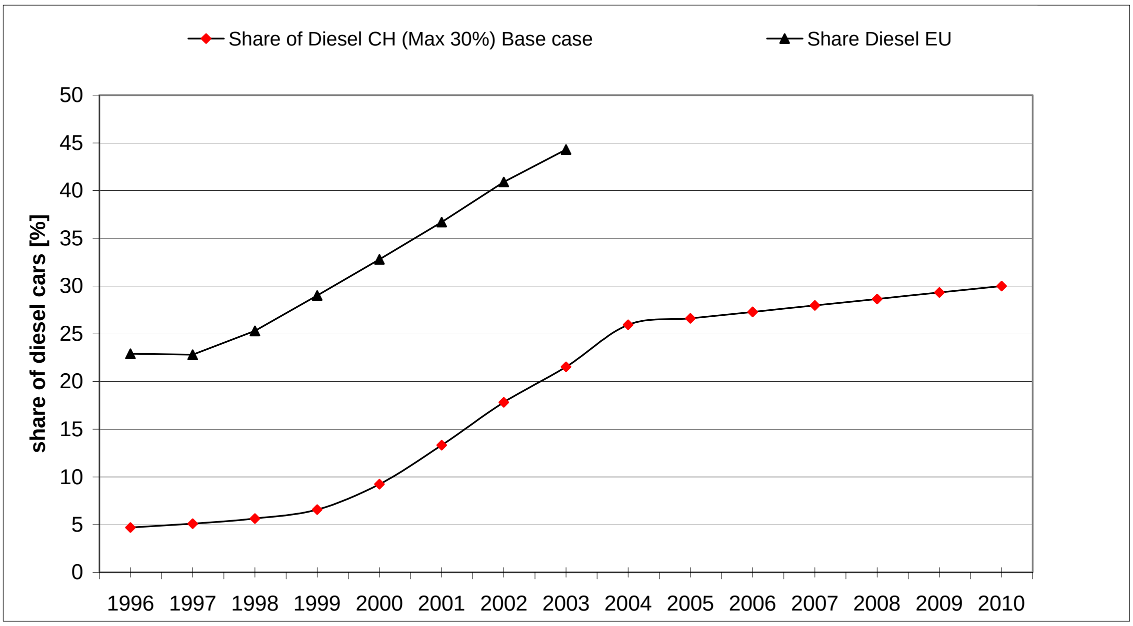


Figure 2-2: Development of the share of diesel passenger among newly registered cars from 1996 up to 2010. The Swiss figures from 2004 onward are extrapolations based on the assumption that in 2010 diesel passenger cars will have a share of 30%.

As far as fuel consumption – and directly coupled CO_2-emissions – are concerned, the average figures of newly registered cars in Switzerland are considerably higher than the European average (see Figure 2-3).

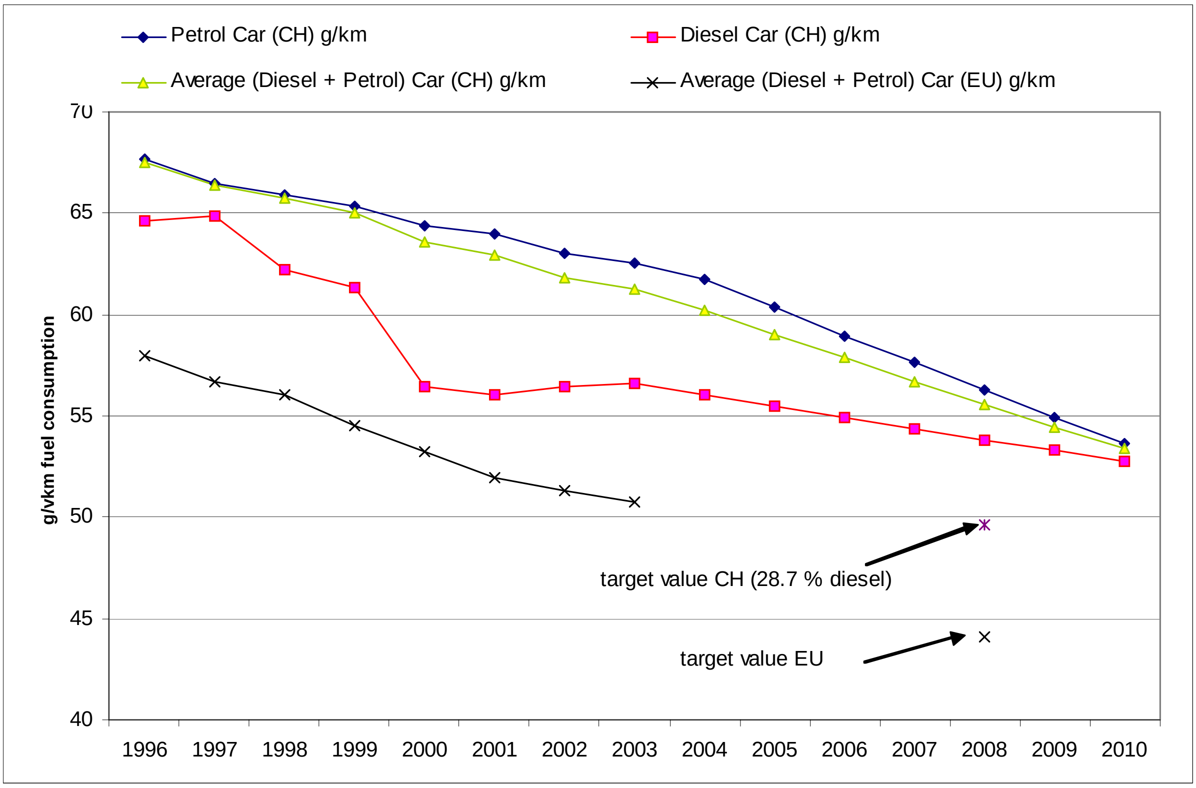


Figure 2-3: Development of fuel consumption in recent years. The figures from 2004 onward are extrapolations based on the assumption of a yearly reduction rate of 2%. (Spielmann & Althaus 2006)

The reasons for this are manifold, e.g. the low share of diesel vehicles and the high share of vehicles with higher engine capacity and power etc.. According to the target agreement between the Swiss association of car importers (auto-schweiz) and the Federal Department of the Environment, Transport, Energy and Communications a yearly reduction rate (2000 – 2008) of fuel consumption of 3% is required to match the target of 6.4 litres/100km in 2008 (auto-schweiz 2004). However, the average yearly reduction in the last eight years (1996-2004) was about 1.7%. This reduction rate is considerably below the target value.

In 2004, transport demand in the EU-25 (comprising motorised transport by passenger cars, powered twowheelers, buses and coaches, railways, subways, trams and metros, together with estimates for air and sea transport) was estimated to be 6 061 billion passenger-kilometres (pkm). This represented an increase of close to 18 % on 1995 figures (5 149 billion pkm) with car transport accounting for nearly three quarters of the daily travel demand of European citizens (Eurostat 2007). In 2005 there were 476 passenger cars for 1000 inhabitants – equating to about one car for every two inhabitants – compared with a 'motorisation rate' of 364 in 1990.

2.2 Freight Transport Services

In Switzerland, goods transport performance increased by 76% between 1980 and 2004 to reach around 26 billion tonne-kilometres. Whereas over half was carried by rail in 1980, by 2004 the railways share had dropped to 40%. This is mainly due to the fact that goods transport by road more than doubled over that period. In Figure 2-4 the development of the goods transport performance in Switzerland is presented.

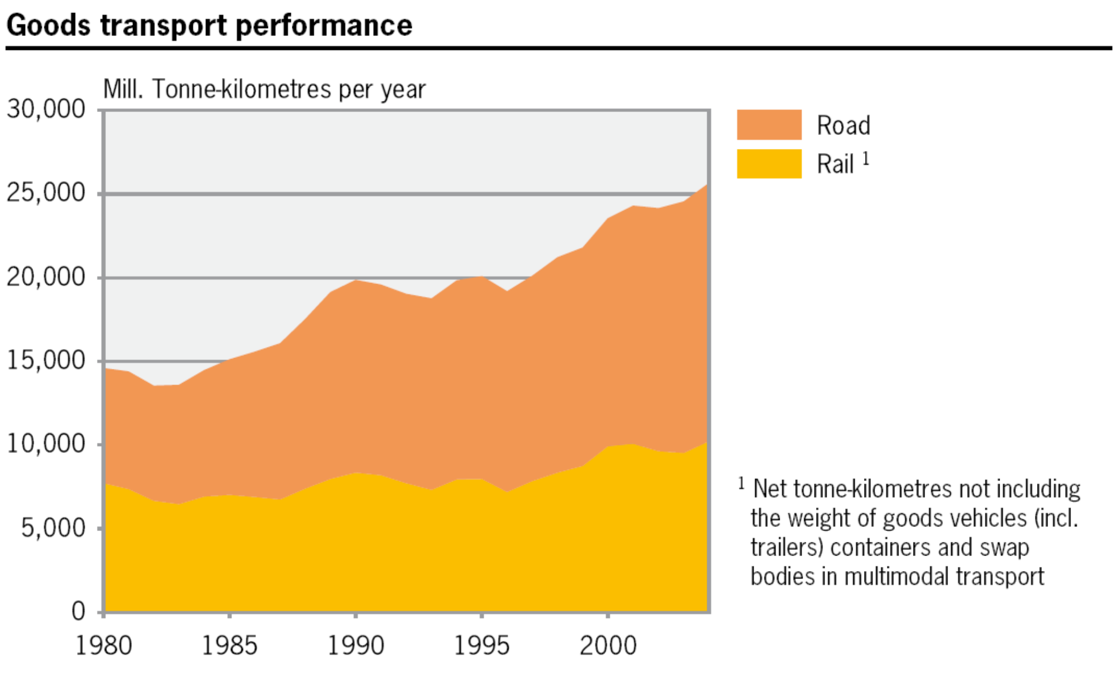


Figure 2-4: Goods transport performance in Switzerland in the period from 1890 to 2004. Figure taken from BfS (2007).

In Figure 2-5 the actually amount of transported goods on the Swiss road network are illustrated.

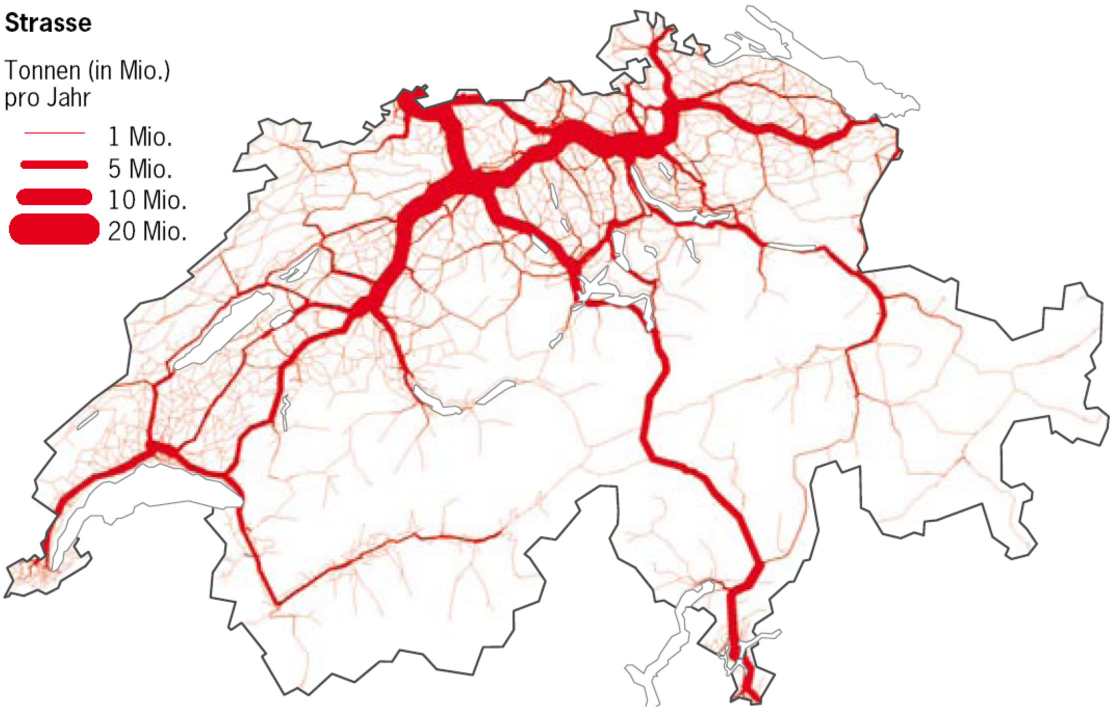


Figure 2-5: Goods traffic flows (Mio. tonnes) on Swiss roads. Figure taken from BfS (2007).

In Europe, many economies have experienced rapidly changing industrial structures in recent years. In general structural changes have further strengthened the already dominant role of service sectors. Increases in tonne-kilometres derive not from increasing volumes but from an increasing number of trips and longer distance per trip. Indeed modern manufacturing processes are characterised by international diversification, which requires the application of modern logistic concepts allowing for "just-in-time production", "day-to-day deliveries", etc. In addition to the transportation of intermediate products, the private householders' final demand is largely satisfied by goods manufactured abroad.

Consequently, in the EU-25, total freight transport performance (comprising road, rail, inland waterways, pipelines, intra-EU maritime and air transport) went up by 31 % between 1995 and 2005 from nearly 3 thousand billion tonne-kilometres (tkm) to reach 3 900 billion tkm (Eurostat 2007). As illustrated in Figure 2-6, this rise was largely attributable to road and sea transport, which accounted for 44% and 39% respectively of the total freight moved in 2005.

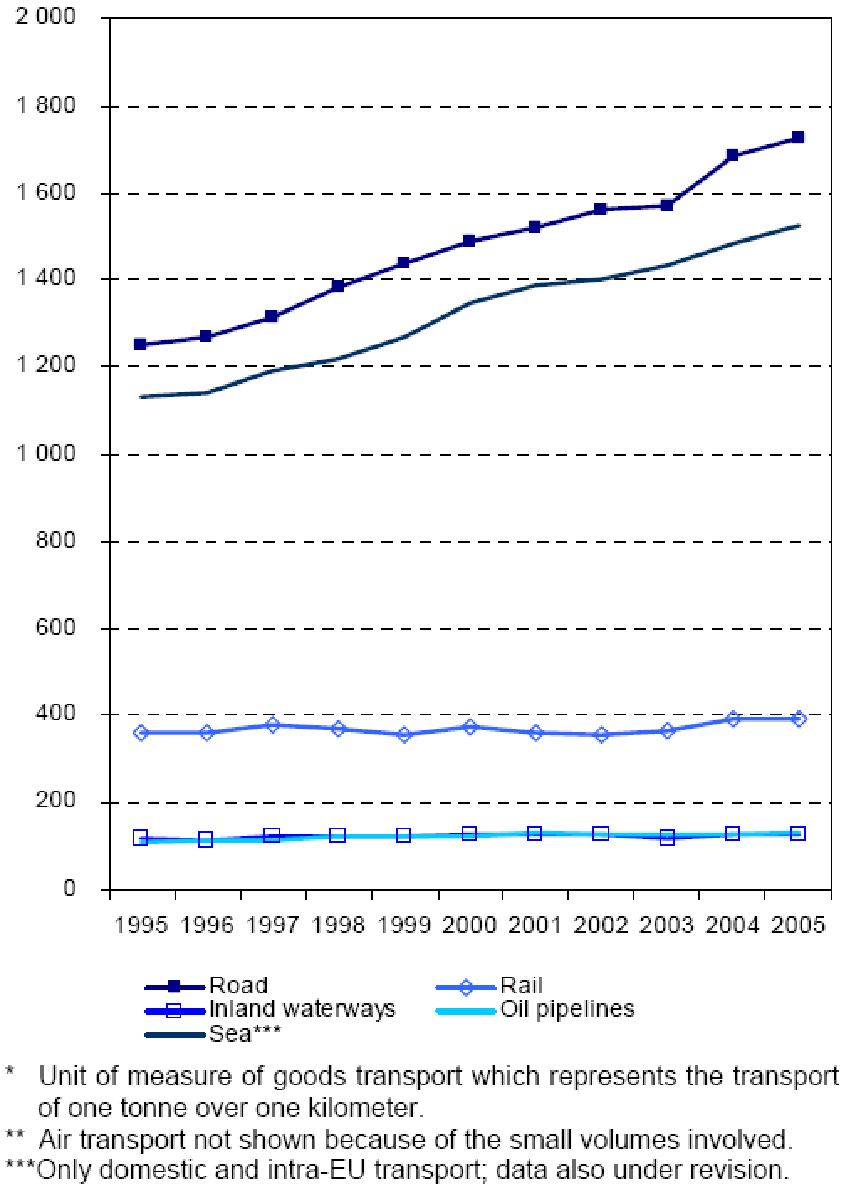
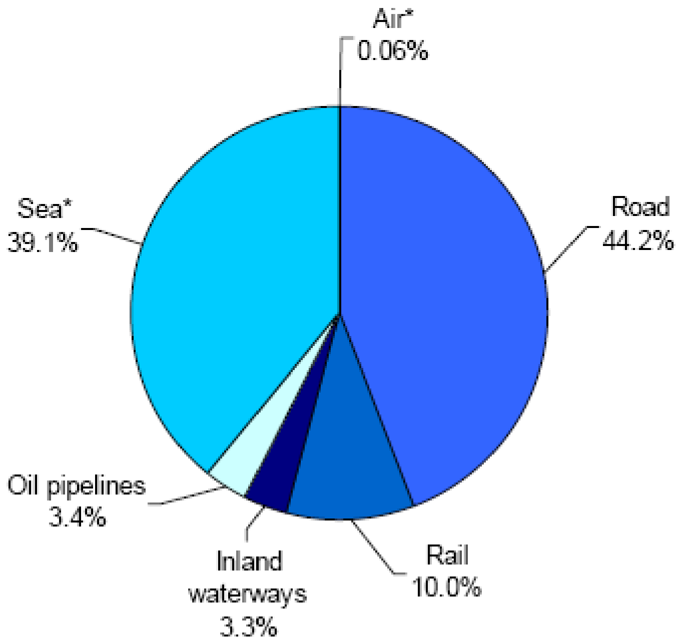


Figure 2-6: Modal split of freight transport performance. EU-25, 2005 (based on tkm) Figure taken from Eurostat (2007)

These increases led to changes in the modal split, i.e. the share of each transport mode in total freight transport. The progression of road freight between 1990 and 2005 is particularly notable in this respect: its 35% increase translated into a modal share that was 2 percentage points larger by 2005, reaching a modal share of over 44% (see Figure 2-7).



*Sea and air transport: only domestic and intra-EU transport; data under revision. Source: DG Energy and Transport

Figure 2-7: Evolution of freight transport (in billion tonne-kilometres performed*), by transport mode, EU-25, 1995-2005. Figure taken from Eurostat (2007)**

3 Use of Transport Services

3.1 Passenger Transport Services

Car transportation usually serves various purposes. In Table 3-1 the use of a passenger car by an average Swiss traveller allocated to four commonly distinguished travel purposes is summarised. In addition to car use, the travel time expenditures for various additional, frequently used transport modes are illustrated. The figures represent the daily travel time of an average Swiss traveller with various means of transportation with respect to four different travel purposes.

Table 3-1: Modal Split with respect to time for an average Swiss traveller (Spielmann et al. 2006)

		Commuting 1)	Leisure 2)	Shopping 3)	Business 4)	Total per Mode
Pedestriant	min/person	5.80	20.62	4.62	0.69	31.73
Bycicle	min/person	1.53	2.68	0.50	0.12	4.83
Car	min/person	10.83	18.02	5.96	3.56	38.37
Motorbike	min/person	0.35	0.39	0.10	0.07	0.91
Local Public Road Tran	min/person	2.62	1.88	0.88	0.29	5.67
Coach	min/person	0.08	0.43	0.00	0.03	0.54
Train	min/person	2.20	2.02	0.51	0.28	5.01
Aircraft	min/person	0.01	0.05	0.00	0.01	0.06
Others	min/person	1.22	2.30	0.23	1.12	4.87
Share of travel purpose	min/person	24.65	48.44	12.76	6.16	91.98

1: Commuting mobility has been derived by aggregating the original categories available from (ARE & SFSO 2000) and includes the following original categories: working trips (100%), education trips (100%) and escort and service trips (25%)

2: Leisure mobility includes leisure trips (100%) and escort and service trips (25%)

3: Shopping mobility includes shopping trips (100%) and escort and service trips (25%)

4: Business mobility includes business activities (100%), travelling on company business (100%) and escort and service trips (25%)

In terms of kilometric performance, an average of 37.3 kilometres travelled by Swiss citizens per day in 2005 is reported in BfS (2007). In Table 3-2, the shares of various used means of transport are shown.

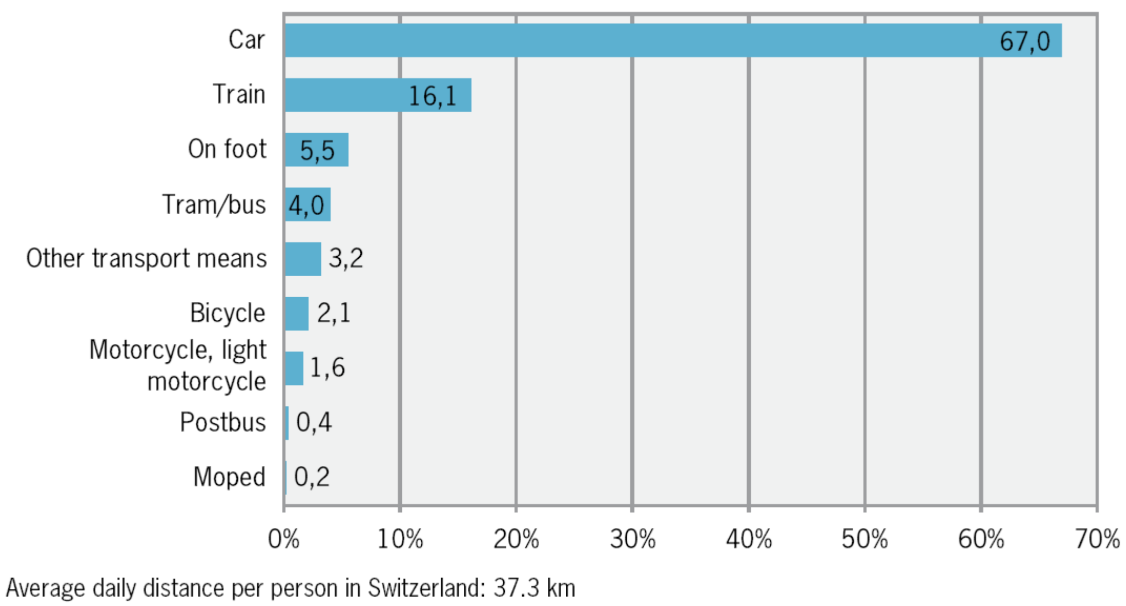


Table 3-2: Transport means choice (Proportion of average daily distance, 2005). Figure taken from BfS (2007).

For Europe in Eurostat (2007) an average of 36 kilometres travelled by EU citizens per day in 2004 is reported, including daily commute and other activities necessitating transport such as tourism. Car transport accounting for nearly three quarters of this total (26.5 km). This mode was followed, a long way behind, by buses/coaches and air transport (3 km each), railways (2 km), powered-two wheelers (1 km), trams and metros (0.5 km) and sea (0.3 km). It should be noted that non-motorised forms of transport are excluded from the analysis.

3.2 Freight Transport Services

Road freight performance reported by EU and Norwegian hauliers (excluding hauliers from Greece and Malta) in 2004 was 1 677 billion tonne-kilometres (Eurostat 2006). As illustrated in Figure 3-1 More than one third of this total was formed by goods of the NST/R classification 20-24, comprising vehicles and transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof, manufactures of metal, glass, glassware, ceramic products, leather, textiles, clothing, other manufactured articles, miscellaneous articles. Miscellaneous articles' and 'Leather, textile, clothing, other manufactured articles' comprised 16% and 10% respectively of total tonne-kilometres. Crude and manufactured minerals, building materials was the second largest group of goods with 17%, closely followed by foodstuffs and animal fodder with 16%.

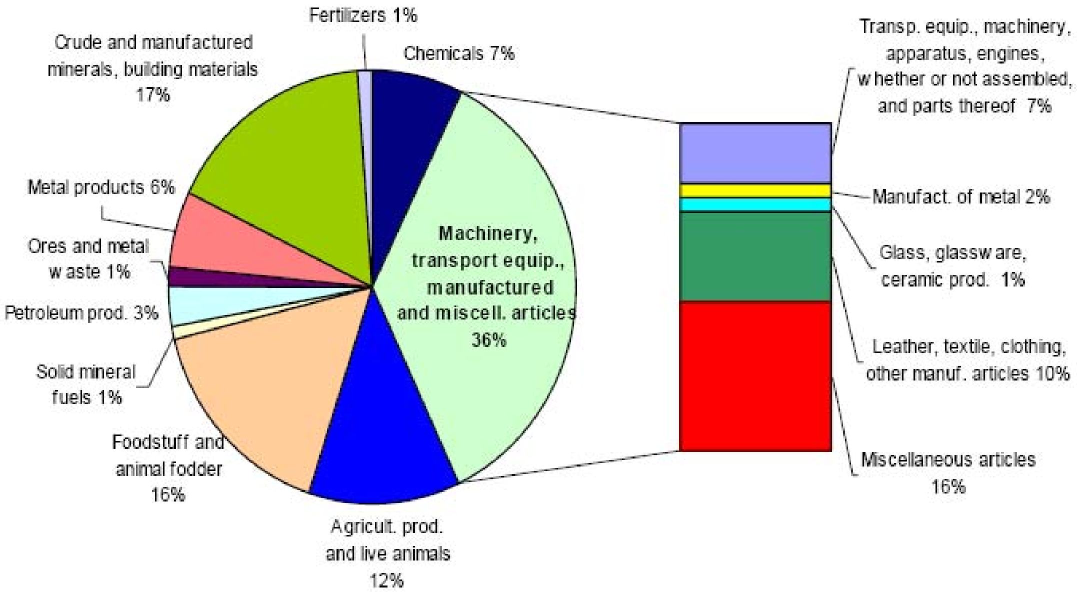


Figure 3-1: Total transport by type of goods, 2004 - % in tkm. Figure taken from Eurostat (2006)

As illustrated in Figure 3-2 the picture is however very different when considering tonnes carried, almost half of the 15.2 billion tonnes carried by road by hauliers registered in the EU25 and Norway in 2004 was Crude and manufactured minerals and building materials. (Eurostat 2006)

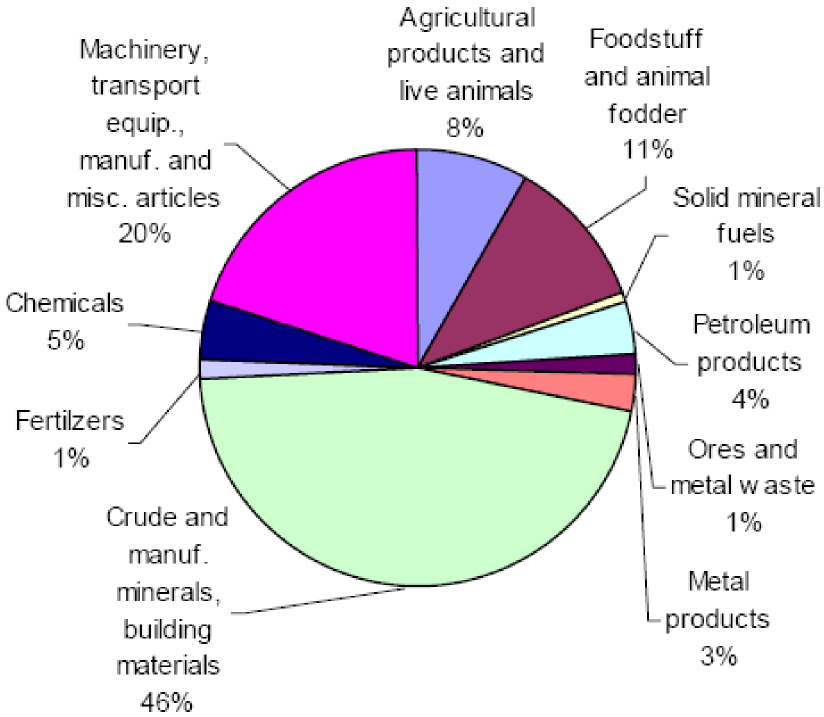


Figure 3-2: Total transport by type of goods, 2004 – % in tonnes. Figure taken from Eurostat (2006)

4.5% of the goods transported in 2004 were dangerous goods. Over half of these 75 billion tonne-kilometres were in the category 'Flammable liquids' (57%). Only two other categories recorded more than 10%: 'Gases, compressed, liquefied, dissolved under pressure' was second with 14%, followed by 'Corrosives' at 11%.

4 System Characterisation

4.1 Scope of the Project

In ecoinvent 2000 life cycle inventories for four means of goods and passenger transport are modelled:

- Road transportation
- Rail transportation
- Air transportation
- Water transportion

Each mode of transport is further separated into sub-groups, referred to as transport services, using several criteria such as geographical operation (e.g., rail transport), vehicle size (e.g., road transport) and transported goods (e.g., water transport).

4.2 Functional Unit

In order to relate transport modules to life cycles of other products and services the environmental interventions are related to the reference unit of one tonne kilometre [tkm]. A tonne kilometre is defined as: "unit of measure of goods transport, which represents the transport of one tonne of goods by a certain means of transportation over one kilometre". For passenger transportation, the reference unit of one passenger kilometre [pkm] has been applied.

4.3 Model Structure

Each mode of transport is further separated into sub-groups, referred to as transport services. In Figure 4-1, the general model structure is illustrated using the example of road freight transport. The modelled transport components (pi, i=1…7) are linked in a unit process (p_T) referred to in the database as "transport, transport service" (e.g. transport, lorry 16t). In order to link various transport components to the reference flow of one tonne kilometre (tkm), so-called demand factors d_j are determined. Cumulative LCI results for a transport service, per tkm are calculated as follows:

$$x_i^T = \sum_{j=1}^{n} \frac{x_i^j}{r(p_j)} \cdot d_j \quad (1)$$

where n denotes the number of transport components and $\mathbf{x}_i^j / \mathbf{r}(\mathbf{p}_j)$ indicate the cumulative interventions of a certain component related to its reference flow.

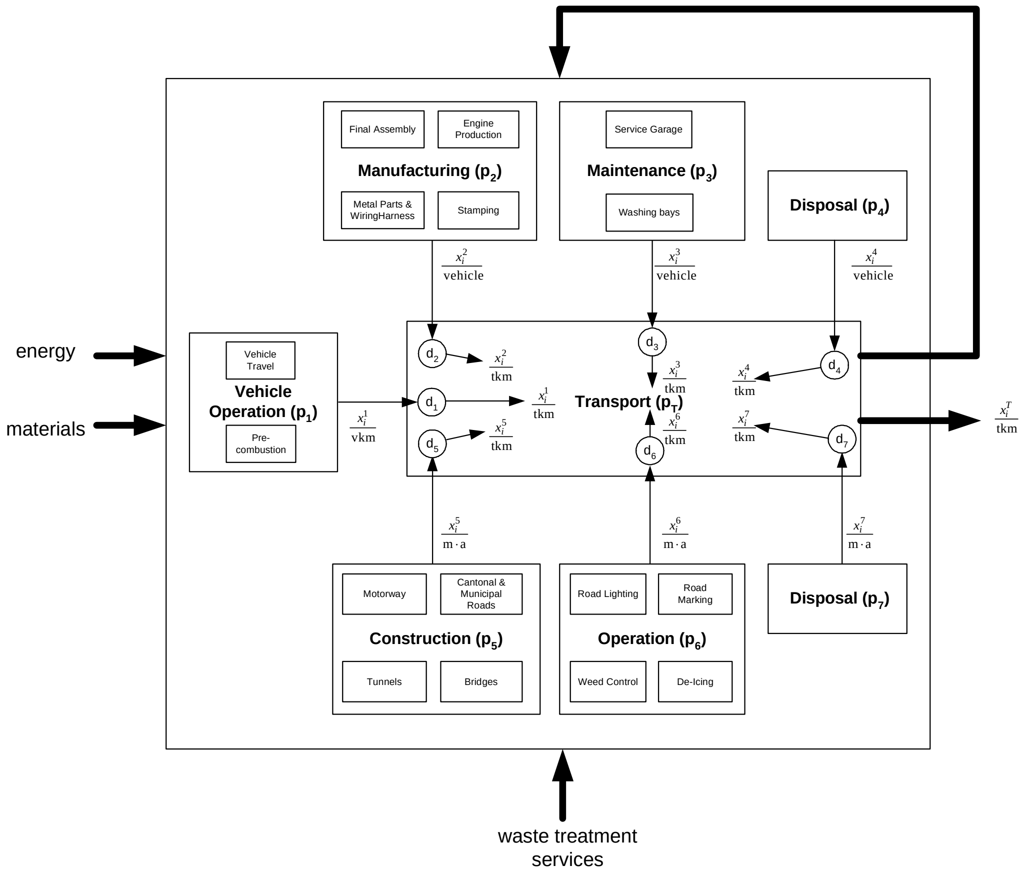


Figure 4-1: Principle model structure and transport components and their interrelationship (Spielmann & Scholz 2005)

In this report, transport components are frequently organised in three groups, as follows:

Vehicle Operation: The first component contains all processes that are directly connected with the operation of the vehicles. In this project the focus is on fuel consumption and airborne emissions. Particular attention has been paid to the issue of particulate emissions. The only interface to other ecoinvent modules are fuel supply, or in case of rail systems, electricity supply. For vehicle operation of rail- and road transportation we further distinguish average Swiss conditions and European conditions. The reference unit for operation is tonne kilometre [tkm] and in case of road transport vehicle kilometre [vkm]

Vehicle Fleet: Vehicle fleet comprises three components that are connected with the vehicle life cycle (excluding the operation) such as vehicle and part manufacture, vehicle maintenance and support as well as disposal of motor vehicles and parts. The data of the referring modules represent mainly European conditions. The reference unit for unit processes of this transport component is one vehicle [unit].

Transport Infrastructure: Transport infrastructure comprises three components addressing construction, operation and maintenance and disposal of the transport infrastructure. In contrast to the previous component the generated data predominately describes Swiss conditions. Land use data is recorded in the unit process “operation and maintenance”. Due to the fact that various elements of infrastructure are characterised by a different life span all data is calculated for one year. Thus the reference unit used for infrastructure modules is [m*a] or, in case of airports and ports [m^2*a].

4.4 Data Requirements and Assumptions

4.4.1 Temporal Scope

The figures for vehicle operation generally refer to the situation in 2000. For the infrastructure data however, such data was often not available. Thus, older data had to be employed, representing a situation somewhere in the last decade. For the new and updates road transport datasets, if not stated explicitly in the name of the datasets, the reference year is 2005.

A crucial assumption that has been made in this study, is to model all material or service inputs, which are situated in the past, with the current (2000) production and service standards. For instance, concrete, which has been used in the construction of airports in 1980, is represented by a state of the art production in 2000.

The description of infrastructure processes is generally limited to the amount of used bulk materials (such as steel, aluminium, copper, wood, rubber and synthetics) and energy consumption for manufacturing or construction activities. Furthermore, material and energy consumption due to maintenance activities and disposal of bulk materials are taken into account. For vehicles the disposal of bulk materials is also considered. For transport infrastructure, the disposal has neglected in most cases. Also, additional material and energy expenditures, e.g., for the production of machinery, have been neglected.

The allocation of infrastructure processes to the actual transport performance [tkm] is complex. In this study we use a static approach. First, the material and energy expenditures for the entire transport infrastructure network are determined and a certain life span for the infrastructure (or parts of the infrastructure) is assumed. Thus, an annual average consumption can be calculated. Furthermore, in order to link the infrastructure processes to the functional unit of one tonne kilometre [tkm] we assume that current (2000) performance figures also represent an average for the past and future situation.

4.4.2 Geographical Scope

The transport modules represent the Swiss conditions and/or European conditions. For rail and road transport infrastructure, data has only been collected for Switzerland and is assumed to represent European conditions as well.

Transport infrastructure is not solely used for goods transportation. Thus, allocation between passenger and goods transportation is unavoidable. In general, we use the gross tonne kilometre performance as allocation factor for infrastructure construction and maintenance. For infrastructure operation and maintenance, including land use, we employ the vehicle kilometric performance as allocation rule.

5 Life Cycle Inventories for Road Transportation

5.1 Classification of Emission Factors for Vehicle Operation

Vehicle operation contains all processes directly connected with the operation of the vehicles, i.e., tail pipe (exhaust) emissions and emissions due to tyre abrasion. In the context of ecoinvent, fuel consumption is also included.

According to the source of emissions and the approach employed, emissions determined in this report can be distinguished in into six groups.

- Group 1: Airborne exhaust emissions dependent on fuel consumption and composition (quality). The basis for the calculation of emission factors are so-called “emissions indices” (EI). The EI is defined as the mass of substance in grams per kilogram of fuel burned.
- Group 2: Airborne regulated exhaust pollutants
- Group 3: Hydrocarbon exhaust emission profiles, which are derived as a fraction of total NMHC emissions.
- Group 4: Other airborne exhaust emissions
- Group 5: Airborne non-exhaust abrasion particle emissions including fractions of heavy metals
- Group 6: Heavy metal emissions to soil and water due to tyre abrasion

In Table 5-1 and

Table 5-2 the include emissions for each group are summarised.

Table 5-1: Emissions included in each emission group (part 1)

Group	Emission/Pollutant	Remarks
1	Carbon Dioxide (CO_2)	Warm emissions. For passenger cars and vans, cold start emissions are accounted for, too. Value is directly derived from the fuel consumption, taken into account carbon fixed in CO emissions.
	Sulphur Dioxide	Warm emissions. For passenger cars and vans, cold start emissions are accounted for, too.
	Cadmium	Trace Elements in fuel.
	Copper	Trace Elements in fuel.
	Chromium	Trace Elements in fuel.
	Nickel	Trace Elements in fuel.
	Selenium	Trace Elements in fuel.
	Zinc	Trace Elements in fuel.
	Lead	Trace Elements in fuel.
	Mercury	Trace Elements in fuel.
	Chromium IV	assumption: 0.2% of the emitted Cr is emitted as Cr(IV)
2	Carbon Monoxide	Warm emissions. For passenger cars and vans, cold start emissions as well as evaporation are accounted for, too.
	Nitrogen Oxides (NO_x)	Including NO and NO_2. Given as NO_2 equivalent. Warm emissions. For cars and vans, cold start emissions are accounted for, too.
	Particulate Matter (PM)	Value corresponds to PM2.5. Coarse exhaust PM (PM10) is considered negligible, hence: PM2.5=PM10. Warm exhaust emissions. For cars and vans, cold start emissions are accounted for, too.
	Hydrocarbons (HC)	Total hydrocarbon emissions. Warm emissions. For cars and vans, cold start emissions as well as evaporation are accounted for, too.
3	Methane (CH_4)	Warm emissions. For passenger cars and vans, cold start emissions are accounted for, too.
	Toulene (C_7H_8)	Warm emissions. For cars and vans, cold start emissions as well as evaporation (for petrol engines) are accounted for, too.
	Benzene (C_6H_6)	Warm emissions. For cars and vans, cold start emissions as well as evaporation (for petrol engines) are accounted for, too.
	m,p,o Xylene (C_8H_{10})	Warm emissions. For cars and vans, cold start emissions as well as evaporation (for petrol engines) are accounted for, too.
	Formaldehyde (CH_2O)	Exhaust emissions, no further specification available.
	Acetaldehyde (CH_3CHO)	Exhaust emissions, no further specification available.
	NMHC	Total non methane hydrocarbon emissions. According to ecoinvent data requirements the final inventory data, excludes the fractions of toluene, benzene, xylene, formaldehyde and acetaldehyde.
4	Ammonia (NH_3)	Warm exhaust emissions.
	Nitrous Oxide (N_2O)	Warm exhaust emissions.
	PAHs	Benzo(a)pyrene. Warm exhaust emissions.

Table 5-2: Emissions included in each emission group (part 2)

5	**TSP-PM10**	**Including tyre wear, break wear and road surface abrasion emissions**
	PM10-PM2.5	**Including tyre wear, break wear and road surface abrasion emissions**
	PM2.5	**Including tyre wear, break wear and road surface abrasion emissions**
	Zinc	**Including tyre wear and break wear abrasion emissions**
	Cooper	**Including tyre wear and break wear abrasion emissions**
	Cadmium	**Including tyre wear and break wear abrasion emissions**
	Chrome	**Including tyre wear and break wear abrasion emissions**
	Nickel	**Including tyre wear and break wear abrasion emissions**
	Lead	**Including tyre wear and break wear abrasion emissions**
	Benzo(a)pyrene	**Including tyre wear and break wear abrasion emissions**
6	**Zinc, ion**	**Emissions to water based on tyre abrasion**
	Cooper, ion	**Emissions to water based on tyre abrasion**
	Cadmium, ion	**Emissions to water based on tyre abrasion**
	Chromium, ion	**Emissions to water based on tyre abrasion**
	Nickel, ion	**Emissions to water based on tyre abrasion**
	Lead	**Emissions to water based on tyre abrasion**
	Zinc	**Emissions to soil based on tyre abrasion**
	Cooper	**Emissions to soil based on tyre abrasion**
	Cadmium	**Emissions to soil based on tyre abrasion**
	Chrome	**Emissions to soil based on tyre abrasion**
	Nickel	**Emissions to soil based on tyre abrasion**
	Lead	**Emissions to soil based on tyre abrasion**

5.2 General Assumptions for Emission Factors

5.2.1 Group 1: Emissions Indices

Carbon dioxide and sulphur dioxide emissions are directly derived from the fuel consumption and carbon content or sulphur content of the used fuel, respectively.

For the determination of CO_2-emissions we employ a conversion factor of 3.172 kg_{CO2}/kg_{Fuel} (assuming a C-content of 86.5 w.% in both, diesel and petrol fuels (Jungbluth 2003)). The final value for the life cycle inventories is then derived by subtracting the carbon fixed in CO-emissions. For SO_2-emissions we assume a sulphur content of $50mg_S/kg_{fuel}$, i.e. $100mg_{SO2}/kg_{fuel}$ (ecoinvent fuel properties(Jungbluth 2003)). It should be noted, that in Keller (2004) different conversion factor are presented: 0.02 g_{SO2}/kg_{diesel} (0.001 w.%) and 0.016 g_{SO2}/kg_{petrol} (0.0008 w.%), for diesel powered cars and petrol powered cars, respectively.

Emission indices for heavy metal emissions due to trace elements in the fuels are presented in Table 5-3.

Table 5-3: Emission indices for heavy metal emissions

		Petrol	Diesel
		mg/kg	mg/kg
Cadmium [1)]	Cd	0.01	0.01
Copper [1)]	Cu	1.7	1.7
Chromium [1)]	Cr	0.05	0.05
Nickel [1)]	Ni	0.07	0.07
Selenium [1)]	Se	0.01	0.01
Zinc [1)]	Zn	1	1
Lead [2)]	Pb	2.E-03	1.10E-07
Mercury [2)]	Hg	7.E-05	2.E-05
Chromium IV [3)]	Cr(VI)	1.0E-04	1.0E-04

1: taken from EMEP/CORINAIR (2006)

2: derived from Jungbluth (2003)

3: underlying assumption: 0.2% of the emitted Cr is emitted as Cr(IV)

5.2.2 Group 2: Regulated Exhaust Pollutants

For the determination of combustion process-specific EURO-regulated exhaust emissions (HC, CO, NO_x and particles) Swiss figures are based on measurements carried out on chassis dynamometers using realistic driving patterns for Switzerland. These figures are different from the type approval cycles (de Haan & Keller 2004; de Haan & Keller 2004; Keller & Zbinden 2004). The employed figures include cold start emissions and for petrol vehicles emissions from vaporisation. In addition ageing effects of the catalytic converter are included. In order to convert cold start emissions per start and evaporation per stop to the reference unit of one vehicle kilometre, the values presented in Table 5-5 are used.

European data is derived from (TREMOVE 2007), which again is generated from various runs with COPERT (2006). The underlying methodology and major assumptions are presented in (EMEP/CORINAIR 2006).

5.2.3 Group 3: Hydrocarbon exhaust emission profiles

In Table 5-4 hydrocarbon exhaust emission profiles, which are derived as a fraction of total NMHC emissions are presented. Obviously, there are slight differences between the data obtained from EMEP/CORINAIR (2006) and Keller (2004). The latter is assumed to describe more precisely Swiss conditions and thus is applied for all Swiss transport datasets. In addition emission shares of formaldehyde and acetaldehyde available from EMEP/CORINAIR (2006) are applied to Swiss datasets. For the European transport datasets we use the data derived from EMEP/CORINAIR (2006).

Table 5-4: Hydrocarbon exhaust emission profiles, which are derived as a fraction of total NMHC emissions

		Diesel					Petrol			
Emission		HBEFA [1)]			CorineAir [2)]		HBEFA [1)]			CorineAir [2)]
		warm	start	evaporation	PC & LDV	HDV	warm	start	evaporation	Euro1 & on
Toulene	C_7H_8	0.29%	0.29%	0.00%	0.69%	0.01%	8.52%	9.93%	3.00%	10.98%
Benzene	C_6H_6	1.66%	1.14%	0.00%	1.98%	0.07%	11.82%	6.44%	0.80%	5.61%
m,p,o Xylene	C_8H_{10}	0.78%	0.78%	0.00%	1.38%	0.88%	7.05%	9.36%	1.00%	7.69%
Formaldehyde	CH_2O	n.a.	n.a.	n.a.	12.00%	8.40%	n.a.	n.a.	n.a.	1.70%
Acetaldehyde	CH_3CHO	n.a.	n.a.	n.a.	6.47%	4.57%	n.a.	n.a.	n.a.	0.75%

1: data derived from Keller (2004)

2: data as used in TREMOVE based on EMEP/CORINAIR (2006)

Table 5-5: Start/stop performances for the calculation of cold start and evaporation emissions of Swiss passenger cars and vans.

		PC		Van	
year		2005	2010	2005	2010
starts per year	Mio starts/a	3762	3892	199	205
kilometric performance	Mio vkm/a	53689	56537	4343	4635
starts per vkm	starts/vkm	0.070	0.069	0.046	0.044
trip length	vkm/start	14.27	14.53	21.82	22.61

5.2.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

Data for N_2O and NH_3 is directly available for Switzerland from Keller (2004). For Europe, TREMOVE (2007), merely delivers N_2O emissions. Thus, as a first approximation NH3 values from Keller (2004) are employed for Europe, too.

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions of diesel cars (0.7E-6 g/vkm for a direct injection concept) and petrol cars (0.4E-06g/vkm) are taken from EMEP/CORINAIR (2005). Whilst the uncertainty of the emission factor for diesel cars is reported to be low (0.3-1.0E-9 kg/vkm), the average emission factor presented for petrol concepts is fairly high (0.001-8.8E-09 kg/vkm). Thus we adjusted the uncertainty factor for the latter concept. For heavy duty vehicles we apply the best estimate 1.0E-06 g/vkm. The uncertainty range is assumed to be 0.02E-06 – 6.2E-06 g/vkm)

5.2.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions are based on assumptions and data presented in EMEP/CORINAIR (2003) Three categories of non-exhaust emissions are distinguished: tyre wear, break wear and road abrasion. In following parts, some basic information is given and the emission factors applied in ecoinvent v2.0 are presented. It should be noted, that the definition of particles in EMEP/CORINAIR (2003) differs from ecoinvent particle size classifications. Thus, the data has been adjusted to match ecoinvent methodology. Particle emissions with a diameter up to 100 µm may generally be considered as airborne emissions (TSP). Practically, particles larger than 100 µm have residence times of only seconds to minutes (depending on turbulence), and are generally considered as dustfall.

Tyre Wear Emitted Particles

Tyre wear material is emitted across the whole size range for airborne particles. Camatini (2001) collected debris from the road of a tyre proving ground. They found tyre debris agglomerated to particle sizes up to a few hundred micrometers. As stated above, such particles are not airborne and are of limited interest to air pollution, but they contribute the largest fraction by weight of total tyre wear. In ecoinvent, the heavy metal content of these emissions is accounted for as emission to water and soil (see emission group 7). In Table 5-6 the size distribution of tyre wear emitted particles is summarised. In Table 5-7 the resulting emission factors for tyre wear emitted particles according to ecoinvent classification are presented.

Table 5-6: Size distribution of tyre wear emitted particles

Particle size class	Mass fraction of TSP
TSP	1
PM10	0.6
PM2.5	0.42

Table 5-7: Emission factors for tyre wear emitted particles according to ecoinvent classification

	TSP-PM10	PM10-PM2.5	PM2.5	TSP
	g/vkm	g/vkm	g/vkm	g/vkm
Passenger Cars	0.0043	0.0037	0.0027	0.0107
Vans	0.0068	0.0059	0.0043	0.0169
Lorry	0.0180	0.0157	0.0113	0.0450

Brake Wear Emitted Particles

Brakes are used to decelerate a vehicle. There are two main brake system configurations in current use: disc brakes, in which flat brake pads are forced against a rotating metal disc, and drum brakes, in which curved pads are forced against the inner surface of a rotating cylinder (EMEP/CORINAIR 2003). Disc brakes tend to be used in smaller vehicles (passenger cars and motorcycles) and in the front wheels of light-duty trucks, whereas drum brakes tend to be used in heavier vehicles. Linings generally consist of four main components: binders, fibres, fillers, and friction. Various modified phenol-formaldehyde resins are used as the binders. Fibres can be classified as metallic, mineral, ceramic, or aramide, and include steel, copper, brass, potassium titanate, glass, asbestos, organic material, and Kevlar. Fillers tend to be low-cost materials such as barium and antimony sulphate, kaolinite clays, magnesium and chromium oxides, and metal powders. Friction modifiers can be of inorganic, organic, or metallic composition. Graphite is a major modifier used to influence friction, but other modifiers include cashew dust, ground rubber, and carbon black. In the past, brake pads included asbestos fibres, though these have now been totally removed from the European fleet.

In Table 5-8 the size distribution of brake wear emitted particles is summarised. In Table 5-9 the resulting emission factors for brake wear emitted particles according to ecoinvent classification is presented.

Table 5-8: Size distribution of brake wear emitted particles

Particle size class	Mass fraction of TSP
TSP	1
PM10	0.98
PM2.5	0.42

Table 5-9: Emission factors for brake wear emitted particles according to ecoinvent classification

	TSP-PM10	PM10-PM2.5	PM2.5	TSP
	g/vkm	g/vkm	g/vkm	g/vkm
Passenger Cars	0.0002	0.0043	0.0031	0.0075
Vans	0.0002	0.0067	0.0048	0.0117
Lorry	0.0006	0.0182	0.0132	0.0320

Particle Emissions from Road Surface

The wear rate of asphalt, at least in terms of airborne wear particles, is even more difficult to quantify than tyre and brake wear, partly because the complex chemical composition of bitumen, and partly because primary wear particles mix with road dust and suspended material. Therefore, the presented wear rates and particle emission rates for road surfaces are highly uncertain.

In Table 5-10 the size distribution of road surface emitted particles is summarised. In Table 5-11 the resulting emission factors for road surface emitted particles according to ecoinvent classification is presented.

Table 5-10: Size distribution of road surface emitted particles

Particle size class	Mass fraction of TSP
TSP	1
PM10	0.5
PM2.5	0.27

Table 5-11: Emission factors for road surface emitted particles according to ecoinvent classification

	TSP-PM10	PM10-PM2.5	PM2.5	TSP
Passenger Cars	0.0075	0.0055	0.0020	0.0150
Vans	0.0075	0.0055	0.0020	0.0150
Lorry	0.0380	0.0277	0.0103	0.0760

Total Non-Exhaust Particle Emissions

In Table 5-12 the total non exhaust particle emissions are summarised.

Table 5-12: Emission factors for road surface emitted particles according to ecoinvent classification

Particle size class		Passenger Car	Van	Lorry
TSP-PM10	g/vkm	0.012	0.014	0.057
PM10-PM2.5	g/vkm	0.013	0.018	0.062
PM2.5	g/vkm	0.008	0.011	0.035
TSP	g/vkm	0.033	0.044	0.153

Uncertainties

The emission factors provided in this section are based on EMEP/CORINAIR (2003). The data is reported to have been developed on the basis of information collected by literature review, and on wear rate experiments.

The emission factor values proposed in this Chapter have also been crosschecked with inventory activities and as a rule of thumb, an uncertainty in the order of ±50% is expected for tyre wear and brake wear. For road surface emissions uncertainties are expected to be significantly higher.

Heavy Metal Species Profile

Table 13 provides the speciation of tyre and brake wear into different elements. Data is available from BUWAL (2000) and (EMEP/CORINAIR 2003). For the latter, which is used for ecoinvent v2.0, several sources have been used to provide this speciation and for this reason, a mean value and the minimum and maximum values are shown. In several instances a large range is reported. This is obviously due to the variety of materials and sources used to manufacture tyre tread and brake linings, and a larger sample of materials needs to be studied. At present, due to the absence of such information the "mean" value is a non-weighted average of values given in different reports. For the latter, The latter is used in this research.

Table 5-13: Element specification of tyre and brake wear. Data used in ecoinvent is EMEP/CORINAIR (2003)

		Buwal [1]	CorineAir [2]					
Species		Tyre Wear	Tyre Wear			Break Wear		
		Mean	Mean	Min	Max	Mean	Min	Max
		%	ppm	ppm	ppm	ppm	ppm	ppm
Zinc oxide	ZnO	1.00%						
Zinc	Zn	-	7343	430	13494	8676	270	21800
Cooper	Cu	0.020%	174	1.8	490	51112	370	142000
Cadmium	Cd	0.001%	2.6	0.3	5	13.2	2.7	29.9
Chrome	Cr	0.009%	12.4	0.4	30	699	115	1200
Nickel	Ni	0.008%	33.6	0.9	50	463	133	850
Lead	Pb	0.005%	107	1	160	3126	50	6594

1: BUWAL (2000)

2: data available from EMEP/CORINAIR (2003)

5.2.6 Group 7: Emissions to soil and water

As stated above only a fraction of the tyre abrasion is emitted to air. The remaining fraction is assumed to be emitted to soil and water close to roads or is fixed in the roadway. As far as heavy metals fixed in the roadway are concerned, we assume that they finally will enter the natural environment due to road cleaning activities or rainfall. Since no further information on the share of emissions to soil and water (e.g. canalisation) is readily available we assume that 50% of the abrasion, which is not emitted to air, is emitted to soil and another 50% is emitted to water. In Table 5-14 the resulting abrasions figures and underlying assumptions are summarised.

Table 5-14: Non-airborne tyre wear losses

		passenger car	van	lorry 16t	lorry 28t	lorry 40t
Performance vehicle	vkm/v	150000	235000	540000	540000	540000
Life span tyre set	a	3	3	-	-	-
	km	45000	45000	75000	75000	75000
Weight tyre	kg	8	8	47.5	47.5	47.5
Losses	%	15.00%	15.00%	20.00%	20.00%	20.00%
Abrasion per tyre	kg	1.2	1.2	9.5	9.5	9.5
Number of tyres per vehicle		4	4	6	12	14
Number of tyres per vehicle lifet time		13.33	20.89	43.20	86.40	100.80
Total abrasion	g/vkm	0.11	0.11	0.76	1.52	1.77
Airborne emissions	g/vkm	0.0332	0.0436	0.1530	0.1530	0.1530
Remaining Losses	g/vkm	0.07	0.06	0.61	1.37	1.62

5.3 Life Cycle Inventories for the Operation of Swiss Passenger Cars (Average Fleet)

Since 1996 the European emission limits for newly registered road vehicles (Euro standards) also became effective in Switzerland. Euro3 and Euro4 came into force in January 2001 and January 2006, respectively. In Table 5-15 the technology composition of the Swiss average fleet for the years 2005 and 2010 are presented, differentiated with respect to engine type.

Table 5-15: Performance weighted technology composition (Keller & Zbinden 2004)

Fuel Type	**Vehicle Technology**	**2005**	**2010**
		%	**%**
Petrol	Conventional (no Cat)	1	0
	GCat < 91	4	1
	Euro1	18	5
	Euro2	28	14
	Euro3	18	13
	Euro4	15	39
Diesel	Conventional (no Cat)	0	0
	FAV1 (Swiss Regulation)	1	0
	Euro2	3	2
	Euro3	10	7
	Euro4	3	18

5.3.1 Group 1: Fuel Consumption and Fuel Dependent Emissions

In Table 5-16 and Table 5-17fuel consumption and fuel dependent emissions are summarised.

Table 5-16: Fuel Consumption and fuel dependent emissions of diesel powered passenger cars for the years 2005 and 2010.

	PC 2005 Diesel			**PC 2010 Diesel**		
Emission/Pollutant	**warm emissions**	**cold start emissions**	**total**	**warm emissions**	**cold start emissions**	**total**
	g/vkm	**g/vkm**	**g/vkm**	**g/vkm**	**g/vkm**	**g/vkm**
Fuel Consumption	58.0	3.2	61.3	55.1	3.1	58.1
Carbon Dioxide (CO2) 1)	184.0	10.3	194.3	174.7	9.7	184.4
Sulphur Dioxide	5.8E-03	3.2E-04	6.1E-03	5.5E-03	3.1E-04	5.8E-03
Cadmium	5.8E-04		5.8E-04	5.5E-04		5.5E-04
Copper	3.1E-01		3.1E-01	3.0E-01		3.0E-01
Chromium	2.9E-07		2.9E-07	2.8E-07		2.8E-07
Nickel	4.1E-08		4.1E-08	3.9E-08		3.9E-08
Selenium	3.1E-06		3.1E-06	3.0E-06		3.0E-06
Zinc	2.9E-10		2.9E-10	2.8E-10		2.8E-10
Lead	4.5E-18		4.5E-18	4.2E-18		4.2E-18
Mercury	6.3E-14		6.3E-14	5.9E-14		5.9E-14
Chromium IV	5.8E-10		5.8E-10	5.5E-10		5.5E-10

1: The presented figures are not yet corrected with respect to CO-emissions.

Table 5-17: Fuel Consumption and fuel dependent emissions of petrol powered passenger cars for the years 2005 and 2010.

Emission/Pollutant	warm emissions	cold start emissions	evaporation	total	warm emissions	cold start emissions	evaporation	total
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Fuel Consumption	64.8	3.1		67.9	62.0	3.0		65.0
Carbon Dioxide (CO2) 1)	205.4	9.9	0.0	215.3	196.6	9.5	0.0	206.1
Sulphur Dioxide	6.5E-03	3.1E-04	0.0E+00	6.8E-03	6.2E-03	3.0E-04	0.0E+00	6.5E-03
Cadmium	6.5E-07			6.5E-07	6.2E-07			6.2E-07
Copper	1.1E-04			1.1E-04	1.1E-04			1.1E-04
Chromium	3.2E-06			3.2E-06	3.1E-06			3.1E-06
Nickel	4.5E-06			4.5E-06	4.3E-06			4.3E-06
Zinc	6.5E-05			6.5E-05	6.2E-05			6.2E-05
Lead	7.1E-12			7.1E-12	6.8E-12			6.8E-12
Selenium	6.5E-07			6.5E-07	6.2E-07			6.2E-07
Mercury	1.3E-09			1.3E-09	1.2E-09			1.2E-09
Chromium IV	6.5E-09			6.5E-09	6.2E-09			6.2E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

5.3.2 Group 2: Regulated Emissions

The presented figures are based on Keller (2004) and are derived from real world test-bench cycles. The obtained emission factors are directly based on bag data obtained from these real world driving cycles, or on linear combinations of the results of these cycles. These figures differ from emission quantities derived from the type approval cycles (NEDC).

In Table 5-18 and Table 5-19 the quantities of Euro-regulated exhaust emissions for diesel and petrol powered engines are summarised.

Table 5-18: Emission factors of Euro-regulated exhaust emissions for diesel powered passenger cars (Swiss fleet average). Data is differentiated with respect to warm emissions and cold start emissions. Ageing effects of catalytic converter are accounted for.

	PC 2005 Diesel			PC 2010 Diesel		
Emission/Pollutant	warm emissions	cold start emissions	total	warm emissions	cold start emissions	total
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Carbon Monoxide	1.7E-01	1.1E-01	2.8E-01	1.4E-01	1.1E-01	2.5E-01
Nitrogen Oxides (NOx)	4.9E-01	9.0E-03	5.0E-01	3.8E-01	7.7E-03	3.9E-01
Particulate Matter (PM)	3.6E-02	4.5E-03	4.0E-02	2.0E-02	2.7E-03	2.2E-02
Hydrocarbons (HC)	4.0E-02	1.6E-02	5.6E-02	3.5E-02	1.5E-02	5.0E-02

Table 5-19: Emission factors of Euro-regulated exhaust emissions for petrol powered passenger cars (Swiss fleet average). Data is differentiated with respect to warm emissions, cold start emissions, evaporation of hydrocarbons. Ageing effects of catalytic converter are accounted for.

	PC 2005 Petrol				PC 2010 Petrol			
Emission/Pollutant	warm emissions	cold start em.	evaporation	total	warm emissions	cold start em.	evaporation	total
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Carbon Monoxide	1.1E+00	2.2E+00		3.4E+00	7.9E-01	1.5E+00		2.3E+00
Nitrogen Oxides (NOx)	2.3E-01	5.1E-02		2.8E-01	1.3E-01	3.3E-02		1.7E-01
Particulate Matter (PM)	0.0E+00	0.0E+00		0.0E+00	0.0E+00	0.0E+00		0.0E+00
Hydrocarbons (HC)	5.9E-02	1.3E-01	3.1E-02	2.2E-01	3.0E-02	7.9E-02	2.2E-02	1.3E-01

5.3.3 Group 3: Hydrocarbon exhaust emission profiles

The presented figures (see Table 5-20 and Table 5-21) for NMHC, benzene, toluene and xylene are based on Keller (2004). In addition emission shares of formaldehyde and acetaldehyde available from EMEP/CORINAIR (2006) are applied to Swiss datasets.

Table 5-20: Specific hydrocarbon exhaust emissions for diesel powered passenger cars (Swiss average Fleet). NMHC values are not yet corrected according to ecoinvent methodology.

	PC 2005 Diesel			PC 2010 Diesel		
Emission/Pollutant	warm emissions	cold start emissions	total	warm emissions	cold start emissions	total
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Methane (CH4)	9.6E-04	3.9E-04	1.4E-03	8.4E-04	3.6E-04	1.2E-03
Toulene (C7H8)	1.3E-04	4.9E-05	1.8E-04	1.1E-04	4.5E-05	1.6E-04
Benzene (C6H6)	6.7E-04	1.9E-04	8.6E-04	5.8E-04	1.8E-04	7.6E-04
m,p,o Xylene (C8H10)	3.2E-04	1.3E-04	4.5E-04	2.8E-04	1.2E-04	4.0E-04
Formaldehyde (CH2O)	4.7E-03		4.7E-03	4.1E-03		4.1E-03
Acetaldehyde (CH3CHO)	2.5E-03		2.5E-03	2.2E-03		2.2E-03
NMHC	3.9E-02	1.6E-02	5.5E-02	3.4E-02	1.5E-02	4.9E-02

Table 5-21: Specific hydrocarbon exhaust emissions for petrol powered passenger cars (Swiss average Fleet). et). NMHC values are not yet corrected according to ecoinvent methodology.

	PC 2005 Petrol				PC 2010 Petrol			
Emission/Pollutant	**warm emissions**	**cold start em.**	**evaporation**	**total**	**warm emissions**	**cold start em.**	**evaporation**	**total**
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Methane (CH4)	4.2E-03	7.5E-03		1.2E-02	2.2E-03	4.5E-03		6.7E-03
Toulene (C7H8)	5.7E-03	1.4E-02	9.3E-04	2.1E-02	2.9E-03	8.4E-03	6.6E-04	1.2E-02
Benzene (C6H6)	6.4E-03	8.8E-03	2.5E-04	1.5E-02	3.3E-03	5.3E-03	1.8E-04	8.8E-03
m,p,o Xylene (C8H10)	4.7E-03	1.3E-02	3.1E-04	1.8E-02	2.4E-03	7.9E-03	2.2E-04	1.0E-02
Formaldehyde (CH2O)	9.3E-04			9.3E-04	4.7E-04			4.7E-04
Acetaldehyde (CH3CHO)	4.1E-04			4.1E-04	2.1E-04			2.1E-04
NMHC	5.5E-02	1.2E-01	3.1E-02	2.1E-01	2.8E-02	7.5E-02	2.2E-02	1.2E-01

5.3.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

Data for N_2O and NH_3 is directly available for Switzerland from Keller (2004).

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions for diesel cars (0.7E-6 g/vkm for a direct injection concept) and petrol cars (0.4E-06g/vkm) are taken from EMEP/CORINAIR (2005). Whilst the uncertainty of the emission factor for diesel cars is reported to be low (0.3-1.0E-9 kg/vkm), the average emission factor presented for petrol concepts is fairly high (0.001-8.8E-09 kg/vkm).

5.3.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions and heavy metal trace elements are presented in section 5.2.5.

5.3.6 Group 6: Emissions to soil and water

Emission factors are based on the assumption described in section 5.2.6. The resulting figures are summarised in Table 5-22 and Table 5-23.

5.3.7 Life Cycle Inventory Input Tables

In Table 5-22 and Table 5-23 the complete life cycle inventory input table are presented. In addition, in Table 5-24 the average Swiss passenger car is presented based on an assumed petrol performance share of 83.4% and 73.01% for the years 2005 and 2010, respectively.

Table 5-22: Life Cycle Inventory Input table for the operation of Swiss diesel passenger cars (fleet average).

	401	InputGroup	OutputGroup	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	operation, passenger car, diesel, fleet average	operation, passenger car, diesel, fleet average 2010	Uncertainty	StandardDeviation95%	GeneralComment
	662			Location						CH	CH			
	493			InfrastructureProcess						0	0			
	403			Unit						vkm	vkm			
		-	0	operation, passenger car, diesel, fleet average	CH	-	-	0	vkm	1.00E+0				
		-	0	operation, passenger car, diesel, fleet average 2010	CH	-	-	0	vkm		1.00E+0			
technosphere		5	-	diesel, low-sulphur, at regional storage	CH	-	-	0	kg	6.13E-2	5.81E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions
fuel dependent airborne emissions		-	4	Carbon dioxide, fossil	-	air	unspecified	-	kg	0.1939	0.1840	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
		-	4	Sulfur dioxide	-	air	unspecified	-	kg	6.13E-6	5.81E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)		-	4	Cadmium	-	air	unspecified	-	kg	7.07E-10	6.78E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Copper	-	air	unspecified	-	kg	4.84E-7	4.79E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Chromium	-	air	unspecified	-	kg	8.28E-9	8.13E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Nickel	-	air	unspecified	-	kg	7.89E-9	7.69E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Zinc	-	air	unspecified	-	kg	2.02E-7	1.99E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Lead	-	air	unspecified	-	kg	2.46E-8	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Selenium	-	air	unspecified	-	kg	5.80E-10	5.51E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Mercury	-	air	unspecified	-	kg	1.16E-12	1.10E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Chromium VI	-	air	unspecified	-	kg	5.80E-12	5.51E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions		-	4	Carbon monoxide, fossil	-	air	unspecified	-	kg	2.80E-4	2.47E-4	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
		-	4	Nitrogen oxides	-	air	unspecified	-	kg	5.01E-4	3.89E-4	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion		-	4	Particulates, < 2.5 um	-	air	unspecified	-	kg	4.82E-5	3.02E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion		-	4	Particulates, > 10 um	-	air	unspecified	-	kg	1.19E-5	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
		-	4	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	1.35E-5	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons		-	4	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	4.50E-5	4.00E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Methane, fossil	-	air	unspecified	-	kg	1.35E-6	1.20E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Benzene	-	air	unspecified	-	kg	1.77E-7	1.57E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Toluene	-	air	unspecified	-	kg	8.60E-7	7.59E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Xylene	-	air	unspecified	-	kg	4.49E-7	4.00E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Formaldehyde	-	air	unspecified	-	kg	4.69E-6	4.09E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
		-	4	Acetaldehyde	-	air	unspecified	-	kg	2.53E-6	2.21E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others		-	4	Ammonia	-	air	unspecified	-	kg	1.00E-6	1.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	Dinitrogen monoxide	-	air	unspecified	-	kg	5.10E-6	5.51E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	4.00E-10	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water		-	4	Zinc, ion	-	water	unspecified	-	kg	2.70E-7	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper, ion	-	water	unspecified	-	kg	6.39E-9	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium, ion	-	water	unspecified	-	kg	9.55E-11	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium, ion	-	water	unspecified	-	kg	4.55E-10	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel, ion	-	water	unspecified	-	kg	1.23E-9	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	water	unspecified	-	kg	3.93E-9	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil		-	4	Zinc	-	soil	unspecified	-	kg	2.70E-7	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper	-	soil	unspecified	-	kg	6.39E-9	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium	-	soil	unspecified	-	kg	9.55E-11	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium	-	soil	unspecified	-	kg	4.55E-10	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel	-	soil	unspecified	-	kg	1.23E-9	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	soil	unspecified	-	kg	3.93E-9	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat		-	4	Heat, waste	-	air	unspecified	-	MJ	2.76E+0	2.62E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-23: Life Cycle Inventory Input table for the operation of Swiss petrol passenger cars (fleet average).

	401	InputGroup	OutputGroup	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	operation, passenger car, petrol, fleet average	operation, passenger car, petrol, fleet average 2010	Uncertainty	StandardDeviation95%	GeneralComment
	662			Location						CH	CH			
	493			InfrastructureProcess						0	0			
	403			Unit						vkm	vkm			
		-	0	operation, passenger car, petrol, fleet average	CH	-	-	0	vkm	1.00E+0				
		-	0	operation, passenger car, petrol, fleet average 2010	CH	-	-	0	vkm		1.00E+0			
technosphere		5	-	petrol, low-sulphur, at regional storage	CH	-	-	0	kg	6.79E-2	6.50E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions
fuel dependent airborne emissions		-	4	Carbon dioxide, fossil	-	air	unspecified	-	kg	0.2100	0.2024	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
		-	4	Sulfur dioxide	-	air	unspecified	-	kg	6.79E-6	6.50E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)		-	4	Cadmium	-	air	unspecified	-	kg	7.74E-10	7.47E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Copper	-	air	unspecified	-	kg	4.95E-7	4.91E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Chromium	-	air	unspecified	-	kg	8.61E-9	8.47E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Nickel	-	air	unspecified	-	kg	8.37E-9	8.17E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Zinc	-	air	unspecified	-	kg	2.08E-7	2.06E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Lead	-	air	unspecified	-	kg	2.46E-8	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Selenium	-	air	unspecified	-	kg	6.48E-10	6.20E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Mercury	-	air	unspecified	-	kg	1.30E-12	1.24E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Chromium VI	-	air	unspecified	-	kg	6.48E-12	6.20E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions		-	4	Carbon monoxide, fossil	-	air	unspecified	-	kg	3.35E-3	2.33E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
		-	4	Nitrogen oxides	-	air	unspecified	-	kg	2.84E-4	1.66E-4	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion		-	4	Particulates, < 2.5 um	-	air	unspecified	-	kg	7.81E-6	7.81E-6	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion		-	4	Particulates, > 10 um	-	air	unspecified	-	kg	1.19E-5	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
		-	4	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	1.35E-5	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons		-	4	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	1.43E-4	8.38E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Methane, fossil	-	air	unspecified	-	kg	1.17E-5	6.65E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Benzene	-	air	unspecified	-	kg	2.06E-5	1.19E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Toluene	-	air	unspecified	-	kg	1.54E-5	8.78E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Xylene	-	air	unspecified	-	kg	1.81E-5	1.05E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Formaldehyde	-	air	unspecified	-	kg	9.32E-7	2.12E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
		-	4	Acetaldehyde	-	air	unspecified	-	kg	4.11E-7	9.35E-7	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others		-	4	Ammonia	-	air	unspecified	-	kg	2.78E-5	2.56E-5	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	Dinitrogen monoxide	-	air	unspecified	-	kg	6.54E-6	3.55E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	7.00E-10	7.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water		-	4	Zinc, ion	-	water	unspecified	-	kg	2.70E-7	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper, ion	-	water	unspecified	-	kg	6.39E-9	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium, ion	-	water	unspecified	-	kg	9.55E-11	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium, ion	-	water	unspecified	-	kg	4.55E-10	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel, ion	-	water	unspecified	-	kg	1.23E-9	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	water	unspecified	-	kg	3.93E-9	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil		-	4	Zinc	-	soil	unspecified	-	kg	2.70E-7	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper	-	soil	unspecified	-	kg	6.39E-9	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium	-	soil	unspecified	-	kg	9.55E-11	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium	-	soil	unspecified	-	kg	4.55E-10	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel	-	soil	unspecified	-	kg	1.23E-9	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	soil	unspecified	-	kg	3.93E-9	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat		-	4	Heat, waste	-	air	unspecified	-	MJ	3.06E+0	2.93E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-24: Life Cycle Inventory Input table for the operation of Swiss passenger cars (fleet average including diesel and petrol cars).

	401	InputGroup	OutputGroup	Name	Location	InfrastructureProcess	Unit	operation, passenger car	UncertaintyType	StandardDeviation95%	GeneralComment
	662			Location				CH			
	493			InfrastructureProcess				0			
	403			Unit				km			
		-	0	operation, passenger car	CH	0	km	1.00E+0			
technosphere		5	-	petrol, low-sulphur, at regional storage	CH	0	kg	5.66E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
technosphere		5	-	diesel, low-sulphur, at regional storage	CH	0	kg	1.02E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
fuel dependent airborne emissions		-	4	Carbon dioxide, fossil	-	-	kg	0.2073	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
		-	4	Sulfur dioxide	-	-	kg	6.68E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)		-	4	Cadmium	-	-	kg	7.63E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Copper	-	-	kg	4.93E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Chromium	-	-	kg	8.56E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Nickel	-	-	kg	8.29E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Zinc	-	-	kg	2.07E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Lead	-	-	kg	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
		-	4	Selenium	-	-	kg	6.36E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Mercury	-	-	kg	1.27E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
		-	4	Chromium VI	-	-	kg	6.36E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions		-	4	Carbon monoxide, fossil	-	-	kg	2.84E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
		-	4	Nitrogen oxides	-	-	kg	3.20E-4	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion		-	4	Particulates, < 2.5 um	-	-	kg	1.45E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion		-	4	Particulates, > 10 um	-	-	kg	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
		-	4	Particulates, > 2.5 um, and < 10um	-	-	kg	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons		-	4	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.27E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Methane, fossil	-	-	kg	1.00E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Benzene	-	-	kg	1.72E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Toluene	-	-	kg	1.30E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Xylene	-	-	kg	1.52E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
		-	4	Formaldehyde	-	-	kg	1.56E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
		-	4	Acetaldehyde	-	-	kg	7.63E-7	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others		-	4	Ammonia	-	-	kg	2.33E-5	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	Dinitrogen monoxide	-	-	kg	6.30E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
		-	4	PAH, polycyclic aromatic hydrocarbons	-	-	kg	6.50E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water		-	4	Zinc, ion	-	-	kg	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper, ion	-	-	kg	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium, ion	-	-	kg	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium, ion	-	-	kg	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel, ion	-	-	kg	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	-	kg	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil		-	4	Zinc	-	-	kg	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Copper	-	-	kg	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Cadmium	-	-	kg	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Chromium	-	-	kg	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Nickel	-	-	kg	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
		-	4	Lead	-	-	kg	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat		-	4	Heat, waste	-	-	MJ	4.59E-1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

5.4 Life Cycle Inventories for the Operation of Diesel Buses in Switzerland

Regular buses and coaches have to comply with EURO-regulations standards for Heavy-Duty-Vehicles. In Table 5-25 the technology composition of the Swiss average fleets for the years 2005 are presented.

Table 5-25: Performance (vkm) weighted technology composition of bus and coach transport in Switzerland (Keller & Zbinden 2004)

Bus Type	Vehicle Technology	2005
		%
Regular Bus	Bus 80th	24
	Euro1	11
	Euro2	36
	Euro3	27
	Euro4	1
Coach	Bus 70th	2
	Bus 80th	16
	Euro1	18
	Euro2	37
	Euro3	25
	Euro4	1

5.4.1 Group 1: Fuel Consumption and Fuel Dependent Emissions

In Table 5-26: fuel consumption and fuel dependent emissions of Swiss diesel buses are summarised.

Table 5-26: Fuel Consumption and fuel dependent emissions of the average Swiss Regular Bus and Coach

Emission/Pollutant	Regular bus	Coach
	g/vkm	g/vkm
Fuel Consumption	349.8	252.5
Carbon Dioxide (CO2) 1)	1109.6	801.0
Sulphur Dioxide	3.5E-02	2.5E-02
Cadmium	3.5E-06	2.5E-06
Copper	5.9E-04	4.3E-04
Chromium	1.7E-05	1.3E-05
Nickel	2.4E-05	1.8E-05
Zinc	3.5E-04	2.5E-04
Lead	3.8E-11	2.8E-11
Selenium	3.5E-06	2.5E-06
Mercury	7.0E-09	5.1E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

5.4.2 Group 2: Regulated Emissions

The presented figures are based on Keller (2004). In Table 5-27 the quantities of Euro-regulated exhaust emissions for diesel buses as are summarised.

Table 5-27: Emission factors of Euro-regulated exhaust emissions for diesel powered regular buses and coaches (Swiss fleet average). Ageing effects of catalytic converter are accounted for.

Emission/Pollutant	Regular bus	Coach
	g/vkm	g/vkm
Carbon Monoxide	3.2E+00	1.4E+00
Nitrogen Oxides (NOx)	1.3E+01	8.7E+00
Particulate Matter (PM)	4.1E-01	2.2E-01
Hydrocarbons (HC)	9.4E-01	4.5E-01

5.4.3 Group 3: Hydrocarbon exhaust emission profiles

The presented figures for NMHC, benzene, toluene and xylene are based on Keller (2004). In addition emission shares of formaldehyde and acetaldehyde available from EMEP/CORINAIR (2006) are applied to Swiss datasets.

Table 5-28: Specific hydrocarbon exhaust emissions for diesel powered regular buses and coaches (Swiss fleet average). NMHC values are not yet corrected according to ecoinvent methodology.

	Regular bus	Coach
Emission/Pollutant	g/vkm	g/vkm
Hydrocarbons (HC)	9.4E-01	4.5E-01
NMHC	9.2E-01	4.4E-01
Methane (CH4)	2.3E-02	1.1E-02
Toulene (C7H8)	3.0E-03	1.4E-03
Benzene (C6H6)	1.6E-02	7.5E-03
m,p,o Xylene (C8H10)	7.5E-03	3.6E-03
Formaldehyde (CH2O)	7.7E-02	3.7E-02
Acetaldehyde (CH3CHO)	4.2E-02	2.0E-02

5.4.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

Data for N_2O and NH_3 is directly available for Switzerland from Keller (2004).

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions for diesel heavy duty vehicles are taken from EMEP/CORINAIR (2005).

5.4.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions and heavy metal trace elements are presented in section 5.2.5.

5.4.6 Group 6: Emissions to soil and water

Emission factors are based on the assumption described in section 5.2.6. The resulting figures are summarised in Table 5-37.

5.4.7 Life Cycle Inventory Input Tables

In Table 5-37 the complete life cycle inventory input table for the operation of diesel powered regular buses and coaches (Swiss fleet average) are presented.

Table 5-29: Life Cycle Inventory Input table for the operation of diesel powered regular buses and coaches (Swiss fleet average)

	Name	Location	InfrastructureProcess	Unit	operation, regular bus	UncertaintyType	StandardDeviation95%	GeneralComment	operation, coach	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH				CH			
	InfrastructureProcess				0				0			
	Unit				vkm				vkm			
	operation, regular bus	CH	0	vkm	1.00E+0							
	operation, coach	CH	0	vkm					1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	3.50E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)	2.53E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	1.1045	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption	0.7987	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	3.50E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption	2.53E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	3.71E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	2.74E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	9.86E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	8.20E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	2.33E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	1.84E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	2.95E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	2.27E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	7.45E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	6.48E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	3.50E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel	2.53E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	7.00E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel	5.05E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	3.50E-11	1	5.42	(4,5,5,1,1,5); own calculation	2.53E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	3.21E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions	1.44E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	1.28E-2	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions	8.72E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	4.44E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.	2.59E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	7.49E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).	3.60E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	2.25E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).	1.08E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	3.00E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).	1.44E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	1.57E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).	7.53E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	7.51E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).	3.61E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	7.70E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)	3.70E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	4.19E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)	2.01E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	1.32E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)	1.32E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	5.02E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	5.02E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	1.19E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	1.19E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	1.78E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	1.78E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	8.48E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	8.48E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	2.30E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	2.30E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	7.31E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	5.02E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	5.02E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	1.19E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	1.19E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	1.78E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	1.78E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	8.48E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	8.48E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	2.30E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	2.30E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition	7.31E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	1.58E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.	1.14E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

5.5 Life Cycle Inventories for the Operation of Road Freight Transportation in Switzerland

Lorries and vans in Switzerland have to comply with EURO-regulations standards for Heavy-Duty-Vehicles and Light-Duty-Vehicles, respectively. In Table 5-30 the technology composition of the Swiss average fleets for the year 2005 are presented.

Table 5-30: Performance weighted technology composition of heavy duty vehicles (lorries) and light duty vehicle (vans) in Switzerland (Swiss average fleet). Light Duty Vehicles are further differentiated with respect to fuel type (diesel and petrol). The presented figures sum up to 102% due to rounding errors.

Vehicle Technology	Heavy Duty Vehicles	Light Duty Vehicles (petrol)	Light Duty Vehicles (diesel)
HDV 80th	10	-	-
LDV Conventional	-	3	5
LDV (petrol) G-Cat (<1991)	-	2	
Euro1	8	12	8
Euro2	24	11	22
Euro3	54	8	29
Euro4			-
Total	100	38	64

5.5.1 Group 1: Fuel Consumption and Fuel Dependent Emissions

In Table 5-31: and Table 5-32: fuel consumption and fuel dependent emissions for truck transport and van transport, respectively are summarised.

Table 5-31: Fuel Consumption and fuel dependent emissions of truck transport.

Emission/Pollutant	3.5-20t average	20-28t average	>28t average	3.5-20t empty	20-28t empty	>28t empty	3.5-20t full	20-28t full	>28t full
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Fuel Consumption	1.8E+02	2.5E+02	2.8E+02	1.6E+02	2.0E+02	2.2E+02	2.0E+02	3.0E+02	3.6E+02
Carbon Dioxide (CO2) [1)]	571.6	779.3	891.3	498.1	620.2	694.6	634.6	941.3	1141.8
Sulphur Dioxide	1.8E-02	2.5E-02	2.8E-02	1.6E-02	2.0E-02	2.2E-02	2.0E-02	3.0E-02	3.6E-02
Cadmium	1.8E-06	2.5E-06	2.8E-06	1.6E-06	2.0E-06	2.2E-06	2.0E-06	3.0E-06	3.6E-06
Copper	3.1E-04	4.2E-04	4.8E-04	2.7E-04	3.3E-04	3.7E-04	3.4E-04	5.0E-04	6.1E-04
Chromium	9.0E-06	1.2E-05	1.4E-05	7.9E-06	9.8E-06	1.1E-05	1.0E-05	1.5E-05	1.8E-05
Nickel	1.3E-05	1.7E-05	2.0E-05	1.1E-05	1.4E-05	1.5E-05	1.4E-05	2.1E-05	2.5E-05
Zinc	1.8E-04	2.5E-04	2.8E-04	1.6E-04	2.0E-04	2.2E-04	2.0E-04	3.0E-04	3.6E-04
Lead	2.0E-11	2.7E-11	3.1E-11	1.7E-11	2.2E-11	2.4E-11	2.2E-11	3.3E-11	4.0E-11
Selenium	1.8E-06	2.5E-06	2.8E-06	1.6E-06	2.0E-06	2.2E-06	2.0E-06	3.0E-06	3.6E-06
Mercury	3.6E-09	4.9E-09	5.6E-09	3.1E-09	3.9E-09	4.4E-09	4.0E-09	5.9E-09	7.2E-09
Chromium IV	1.8E-08	2.5E-08	2.8E-08	1.6E-08	2.0E-08	2.2E-08	2.0E-08	3.0E-08	3.6E-08

1: The presented figures are not yet corrected with respect to CO-emissions.

Table 5-32: Fuel Consumption and fuel dependent emissions of van transport.

Emission/Pollutant	warm emissions	cold start emissions	total
	g/vkm	g/vkm	g/vkm
Fuel Consumption	83.5	4.1	87.5
Carbon Dioxide (CO_2) [1)]	264.8	12.9	277.7
Sulphur Dioxide	8.3E-03	4.1E-04	8.8E-03
Cadmium	8.3E-07		8.3E-07
Copper	1.4E-04		1.4E-04
Chromium	4.2E-06		4.2E-06
Nickel	5.8E-06		5.8E-06
Zinc	8.3E-05		8.3E-05
Lead	9.2E-12		9.2E-12
Selenium	8.3E-07		8.3E-07
Mercury	1.7E-09		1.7E-09
Chromium IV	8.3E-09		8.3E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

5.5.2 Group 2: Regulated Emissions

In Table 5-33: and Table 5-34: the quantities of Euro-regulated exhaust emissions for truck transport and van transport, respectively are summarised. The presented figures are based on Keller (2004) and are derived from real world test-bench cycles.

Table 5-33: Emission factors of Euro-regulated exhaust emissions for diesel powered lorries (Swiss fleet average).

Emission/Pollutant	3.5-20t average	20-28t average	>28t average	3.5-20t empty	20-28t empty	>28t empty	3.5-20t full	20-28t full	>28t full
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
Carbon Monoxide	1.4E+00	1.6E+00	1.7E+00	1.2E+00	1.4E+00	1.4E+00	1.4E+00	1.8E+00	2.0E+00
Nitrogen Oxides (NOx)	6.1E+00	8.1E+00	8.8E+00	5.3E+00	6.4E+00	6.9E+00	6.7E+00	9.6E+00	1.1E+01
Particulate Matter (PM)	1.8E-01	2.2E-01	2.0E-01	1.6E-01	1.9E-01	1.7E-01	1.9E-01	2.4E-01	2.3E-01
Hydrocarbons (HC)	4.4E-01	4.6E-01	4.4E-01	4.0E-01	4.2E-01	4.0E-01	4.3E-01	4.5E-01	4.5E-01

Table 5-34: Emission factors of Euro-regulated exhaust emissions for vans (Swiss fleet average).

Emission/Pollutant	warm emissions	cold start emissions	total
	g/vkm	g/vkm	g/vkm
Carbon Monoxide	2.7E+00	2.0E+00	4.7E+00
Nitrogen Oxides (NOx)	1.0E+00	1.1E-01	1.1E+00
Particulate Matter (PM)	7.0E-02	1.8E-03	7.2E-02
Hydrocarbons (HC)	1.5E-01	1.3E-01	2.8E-01

5.5.3 Group 3: Hydrocarbon exhaust emission profiles

The presented figures for NMHC, benzene, toluene and xylene are based on Keller (2004). In addition emission shares of formaldehyde and acetaldehyde available from EMEP/CORINAIR (2006) are applied to Swiss datasets.

Table 5-35: Specific hydrocarbon exhaust emissions for diesel powered lorries. NMHC values are not yet corrected according to ecoinvent methodology.

Emission/Pollutant	3.5-20t average	20-28t average	>28t average	3.5-20t empty	20-28t empty	>28t empty	3.5-20t full	20-28t full	>28t full
	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm	g/vkm
NMHC	4.3E-01	4.4E-01	4.3E-01	3.9E-01	4.1E-01	3.9E-01	4.2E-01	4.4E-01	4.4E-01
Methane (CH4)	1.1E-02	1.1E-02	1.0E-02	9.6E-03	1.0E-02	9.6E-03	1.0E-02	1.1E-02	1.1E-02
Toulene (C7H8)	1.4E-03	1.5E-03	1.4E-03	1.3E-03	1.3E-03	1.3E-03	1.4E-03	1.4E-03	1.4E-03
Benzene (C6H6)	7.4E-03	7.6E-03	7.3E-03	6.6E-03	7.0E-03	6.7E-03	7.2E-03	7.6E-03	7.5E-03
m,p,o Xylene (C8H10)	3.5E-03	3.6E-03	3.5E-03	3.2E-03	3.4E-03	3.2E-03	3.5E-03	3.6E-03	3.6E-03
Formaldehyde (CH2O)	3.6E-02	3.7E-02	3.6E-02	3.3E-02	3.4E-02	3.3E-02	3.5E-02	3.7E-02	3.7E-02
Acetaldehyde (CH3CHO)	2.0E-02	2.0E-02	1.9E-02	1.8E-02	1.9E-02	1.8E-02	1.9E-02	2.0E-02	2.0E-02

Table 5-36: Specific hydrocarbon exhaust emissions for vans (Swiss average Fleet). NMHC values are not yet corrected according to ecoinvent methodology. Evaporation emissions are exclusively from petrol powered vans (37.2% of total fleet performance).

Emission/Pollutant	warm emissions	cold start emissions	evaporation	total
	g/vkm	g/vkm	g/vkm	g/vkm
NMHC	1.4E-01	1.2E-01	2.7E-02	2.9E-01
Methane (CH4)	9.5E-03	7.8E-03		1.7E-02
Toulene (C7H8)	1.1E-02	1.3E-02	8.2E-04	2.5E-02
Benzene (C6H6)	1.4E-02	7.7E-03	2.2E-04	2.2E-02
m,p,o Xylene (C8H10)	9.4E-03	1.2E-02	2.7E-04	2.2E-02
Formaldehyde (CH2O)	1.7E-02			1.7E-02
Acetaldehyde (CH3CHO)	8.9E-03			8.9E-03

5.5.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

Data for N_2O and NH_3 is directly available for Switzerland from Keller (2004) (see section 5.2.4)

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions for diesel lorries are 1E-6 g/vkm.

5.5.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions and heavy metal trace elements are presented in section 5.2.5.

5.5.6 Group 6: Emissions to soil and water

Emission factors are based on the assumption described in section 5.2.6. The resulting figures are presented in section 5.5.7.

5.5.7 Life Cycle Inventory Input Tables

In this part, life cycle inventory tables for “operation, lorry, xx” and “operation, van, xx” datasets are shown.

Table 5-37: Life Cycle Inventory Input table for the operation of Swiss lorries, fleet average and average load.

	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	operation, lorry 3.5-20t, fleet average	operation, lorry 20-28t, fleet average	operation, lorry >28t, fleet average	UncertaintyType	StandardDeviation95%	GeneralComment
	Location						CH	CH	CH			
	InfrastructureProcess						0	0	0			
	Unit						vkm	vkm	vkm			
	operation, lorry 3.5-20t, fleet average	CH	-	-	0	vkm	1.00E+0					
	operation, lorry 20-28t, fleet average	CH	-	-	0	vkm		1.00E+0				
	operation, lorry >28t, fleet average	CH	-	-	0	vkm			1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	-	-	0	kg	1.80E-1	2.46E-1	2.81E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA).
fuel dependent airborne emissions	Carbon dioxide, fossil	-	air	unspecified	-	kg	0.5695	0.7767	0.8886	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	air	unspecified	-	kg	1.80E-5	2.46E-5	2.81E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	air	unspecified	-	kg	2.02E-9	2.67E-9	3.03E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	air	unspecified	-	kg	6.98E-7	8.09E-7	8.69E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	air	unspecified	-	kg	1.48E-8	1.81E-8	1.98E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	air	unspecified	-	kg	1.76E-8	2.22E-8	2.47E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	air	unspecified	-	kg	5.76E-7	6.41E-7	6.76E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	air	unspecified	-	kg	2.83E-8	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	air	unspecified	-	kg	1.80E-9	2.46E-9	2.81E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	air	unspecified	-	kg	3.60E-12	4.91E-12	5.62E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	air	unspecified	-	kg	1.80E-11	2.46E-11	2.81E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	air	unspecified	-	kg	1.36E-3	1.62E-3	1.73E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	air	unspecified	-	kg	6.13E-3	8.12E-3	8.78E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	air	unspecified	-	kg	2.16E-4	2.55E-4	2.36E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	air	unspecified	-	kg	5.66E-5	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	6.16E-5	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	3.53E-4	3.63E-4	3.48E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	air	unspecified	-	kg	1.06E-5	1.09E-5	1.05E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	air	unspecified	-	kg	1.42E-6	1.46E-6	1.40E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	air	unspecified	-	kg	7.40E-6	7.60E-6	7.29E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	air	unspecified	-	kg	3.54E-6	3.64E-6	3.49E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	air	unspecified	-	kg	3.63E-5	3.73E-5	3.58E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	air	unspecified	-	kg	1.98E-5	2.03E-5	1.95E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	air	unspecified	-	kg	5.00E-6	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	air	unspecified	-	kg	9.52E-6	9.48E-6	8.83E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	1.00E-9	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	water	unspecified	-	kg	5.02E-6	5.02E-6	5.02E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	water	unspecified	-	kg	1.19E-7	1.19E-7	1.19E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	water	unspecified	-	kg	1.78E-9	1.78E-9	1.78E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	water	unspecified	-	kg	8.48E-9	8.48E-9	8.48E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	water	unspecified	-	kg	2.30E-8	2.30E-8	2.30E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	water	unspecified	-	kg	7.31E-8	7.31E-8	7.31E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	soil	unspecified	-	kg	5.02E-6	5.02E-6	5.02E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	soil	unspecified	-	kg	1.19E-7	1.19E-7	1.19E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	soil	unspecified	-	kg	1.78E-9	1.78E-9	1.78E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	soil	unspecified	-	kg	8.48E-9	8.48E-9	8.48E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	soil	unspecified	-	kg	2.30E-8	2.30E-8	2.30E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	soil	unspecified	-	kg	7.31E-8	7.31E-8	7.31E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	air	unspecified	-	MJ	8.13E+0	1.11E+1	1.27E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-38: Life Cycle Inventory Input table for the operation of Swiss lorries, empty vehicle (fleet average)

	Name	Location	InfrastructureProcess	Unit	operation, lorry 3.5-20t, empty, fleet average	operation, lorry 20-28t, empty, fleet average	operation, lorry >28t, empty, fleet average	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH			
	InfrastructureProcess				0	0	0			
	Unit				vkm	vkm	vkm			
	operation, lorry 3.5-20t, empty, fleet average	CH	0	vkm	1.00E+0					
	operation, lorry 20-28t, empty, fleet average	CH	0	vkm		1.00E+0				
	operation, lorry >28t, empty, fleet average	CH	0	vkm			1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	1.57E-1	1.96E-1	2.19E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA).
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.4962	0.6180	0.6923	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	1.57E-5	1.96E-5	2.19E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	1.79E-9	2.17E-9	2.41E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	6.58E-7	7.24E-7	7.63E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	1.37E-8	1.56E-8	1.67E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	1.60E-8	1.87E-8	2.03E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	5.53E-7	5.91E-7	6.14E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	1.57E-9	1.96E-9	2.19E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	3.14E-12	3.91E-12	4.38E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	1.57E-11	1.96E-11	2.19E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.18E-3	1.38E-3	1.44E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	5.28E-3	6.39E-3	6.88E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	1.93E-4	2.24E-4	2.08E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.17E-4	3.35E-4	3.19E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	9.55E-6	1.01E-5	9.60E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	1.27E-6	1.34E-6	1.28E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	6.65E-6	7.01E-6	6.68E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	3.18E-6	3.36E-6	3.20E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	3.26E-5	3.44E-5	3.28E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	1.78E-5	1.87E-5	1.78E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	9.52E-6	9.48E-6	8.83E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.00E-9	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	5.02E-6	5.02E-6	5.02E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	1.78E-9	1.78E-9	1.78E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	2.30E-8	2.30E-8	2.30E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	5.02E-6	5.02E-6	5.02E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	1.78E-9	1.78E-9	1.78E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	2.30E-8	2.30E-8	2.30E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	7.08E+0	8.82E+0	9.88E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-39: Life Cycle Inventory Input table for the operation of Swiss lorries, fully loaded vehicle (fleet average)

	Name	Location	InfrastructureProcess	Unit	operation, lorry 3.5-20t, full, fleet average	operation, lorry 20-28t, full, fleet average	operation, lorry >28t, full, fleet average	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH			
	InfrastructureProcess				0	0	0			
	Unit				vkm	vkm	vkm			
	operation, lorry 3.5-20t, full, fleet average	CH	0	vkm	1.00E+0					
	operation, lorry 20-28t, full, fleet average	CH	0	vkm		1.00E+0				
	operation, lorry >28t, full, fleet average	CH	0	vkm			1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	2.00E-1	2.97E-1	3.60E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA).
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.6323	0.9385	1.1387	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	2.00E-5	2.97E-5	3.60E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	2.22E-9	3.18E-9	3.82E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	7.31E-7	8.96E-7	1.00E-6	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	1.58E-8	2.06E-8	2.38E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	1.90E-8	2.58E-8	3.02E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	5.96E-7	6.92E-7	7.55E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	2.00E-9	2.97E-9	3.60E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	4.00E-12	5.94E-12	7.20E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	2.00E-11	2.97E-11	3.60E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.43E-3	1.76E-3	1.97E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	6.75E-3	9.59E-3	1.08E-2	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	2.22E-4	2.75E-4	2.65E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.45E-4	3.61E-4	3.60E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	1.04E-5	1.09E-5	1.08E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	1.38E-6	1.45E-6	1.45E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	7.23E-6	7.56E-6	7.55E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	3.46E-6	3.62E-6	3.62E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	3.55E-5	3.71E-5	3.71E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	1.93E-5	2.02E-5	2.02E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	9.52E-6	9.48E-6	8.83E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.00E-9	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	5.02E-6	5.02E-6	5.02E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	1.78E-9	1.78E-9	1.78E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	2.30E-8	2.30E-8	2.30E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	5.02E-6	5.02E-6	5.02E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	1.78E-9	1.78E-9	1.78E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	2.30E-8	2.30E-8	2.30E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	9.02E+0	1.34E+1	1.62E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-40: Life Cycle Inventory Input table for the operation of Swiss vans (fleet average).

	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	operation, van < 3,5t	UncertaintyType	StandardDeviation95%	GeneralComment
	Location						CH			
	InfrastructureProcess						0			
	Unit						km			
	operation, van < 3,5t	CH	-	-	0	km	1.00E+0			
technosphere	petrol, low-sulphur, at regional storage	CH	-	-	0	kg	3.26E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA), assuming a share of 37.2% for petrol
	diesel, low-sulphur, at regional storage	CH	-	-	0	kg	5.50E-2	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions
fuel dependent airborne emissions	Carbon dioxide, fossil	-	air	unspecified	-	kg	0.2704	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	air	unspecified	-	kg	8.75E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	air	unspecified	-	kg	1.03E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	air	unspecified	-	kg	7.43E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	air	unspecified	-	kg	1.26E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	air	unspecified	-	kg	1.18E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	air	unspecified	-	kg	3.09E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	air	unspecified	-	kg	3.84E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	air	unspecified	-	kg	8.35E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	air	unspecified	-	kg	1.67E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	air	unspecified	-	kg	8.35E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	air	unspecified	-	kg	4.67E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	air	unspecified	-	kg	1.14E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	air	unspecified	-	kg	1.29E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	air	unspecified	-	kg	1.45E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	1.80E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	1.77E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Methane, fossil	-	air	unspecified	-	kg	1.73E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Benzene	-	air	unspecified	-	kg	2.50E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Toluene	-	air	unspecified	-	kg	2.17E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Xylene	-	air	unspecified	-	kg	2.19E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Formaldehyde	-	air	unspecified	-	kg	1.66E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	air	unspecified	-	kg	8.95E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	air	unspecified	-	kg	1.08E-5	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	air	unspecified	-	kg	5.89E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	water	unspecified	-	kg	2.32E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	water	unspecified	-	kg	5.49E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	water	unspecified	-	kg	8.20E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	water	unspecified	-	kg	3.91E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	water	unspecified	-	kg	1.06E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	water	unspecified	-	kg	3.37E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	soil	unspecified	-	kg	2.32E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	soil	unspecified	-	kg	5.49E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	soil	unspecified	-	kg	8.20E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	soil	unspecified	-	kg	3.91E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	soil	unspecified	-	kg	1.06E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	soil	unspecified	-	kg	3.37E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	air	unspecified	-	MJ	2.48E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

5.6 Life Cycle Inventories for the Operation of European Passenger Cars (Average Fleet)

The passenger emissions shown in this section are representative for the European passenger car data-sets. The underlying technology mixes are presented in table Table 5-41.

Table 5-41: Performance weighted (vkm-performance in the year 2005) technology composition of petrol and diesel passenger cars differentiated with respect to car size. Data is derived from TREMOVE (2007).

Fuel Type	Vehicle Technology	Big Car +2.0 l	Medium Car 1.4-2.0 l	Small Car -1.4l
		%	%	%
Petrol	**Conventional**	**0**	**2**	**4**
	Euro1	**11**	**11**	**12**
	Euro2	**15**	**19**	**16**
	Euro3	**29**	**30**	**28**
	Euro4	**44**	**38**	**38**
Diesel	**Conventional**	**2**	**1**	
	Euro1	**4**	**3**	
	Euro2	**8**	**11**	
	Euro3	**31**	**32**	**29**
	Euro4	**55**	**53**	**71**

5.6.1 Group 1: Fuel Consumption and Fuel Dependent Emissions

Fuel consumption is directly taken from TREMOVE (2007). The presented emission factors are based on the emission indices as outlined in 5.2.1.

Table 5-42: Fuel Consumption and fuel dependent emissions of diesel powered passenger cars for the years 2005 and 2010. The average fleet car is based on the following shares: 2005: 21.7%, 74.5% and 3.8% for big vehicles medium vehicles and small vehicles, respectively. 2010: 20.3%, 72.4% and 7.3% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2005	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2010
Fuel Consumption	78	57	43	61	71	53	41	56
Carbon Dioxide (CO2) [1)]	247	181	136	193	226	168	129	177
Sulphur Dioxide	7.8E-03	5.7E-03	4.3E-03	6.1E-03	7.1E-03	5.3E-03	4.1E-03	5.6E-03
Cadmium	7.8E-07	5.7E-07	4.3E-07	6.1E-07	7.1E-07	5.3E-07	4.1E-07	5.6E-07
Copper	1.3E-04	9.7E-05	7.3E-05	1.0E-04	1.2E-04	9.0E-05	6.9E-05	9.5E-05
Chromium	3.9E-06	2.8E-06	2.1E-06	3.0E-06	3.6E-06	2.6E-06	2.0E-06	2.8E-06
Nickel	5.5E-06	4.0E-06	3.0E-06	4.3E-06	5.0E-06	3.7E-06	2.9E-06	3.9E-06
Zinc	7.8E-05	5.7E-05	4.3E-05	6.1E-05	7.1E-05	5.3E-05	4.1E-05	5.6E-05
Lead	8.6E-12	6.3E-12	4.7E-12	6.7E-12	7.9E-12	5.8E-12	4.5E-12	6.1E-12
Selenium	7.8E-07	5.7E-07	4.3E-07	6.1E-07	7.1E-07	5.3E-07	4.1E-07	5.6E-07
Mercury	1.6E-09	1.1E-09	8.6E-10	1.2E-09	1.4E-09	1.1E-09	8.1E-10	1.1E-09
Chromium IV	7.8E-09	5.7E-09	4.3E-09	6.1E-09	7.1E-09	5.3E-09	4.1E-09	5.6E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

Table 5-43: Fuel consumption and fuel dependent emissions of petrol powered passenger cars for the years 2005 and 2010. The average fleet car is based on the following shares: 2005: 9%, 38% and 52% for big vehicles medium vehicles and small vehicles, respectively. In 2010: 9.8%, 37.8% and 52.5% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2005	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2010
Fuel Consumption	84	68	59	60	79	63	54	52
Carbon Dioxide (CO2) [1)]	267	216	187	190	250	201	173	166
Sulphur Dioxide	8.4E-03	6.8E-03	5.9E-03	6.0E-03	7.9E-03	6.3E-03	5.4E-03	5.2E-03
Cadmium	8.4E-07	6.8E-07	5.9E-07	6.0E-07	7.9E-07	6.3E-07	5.4E-07	5.2E-07
Copper	1.4E-04	1.2E-04	1.0E-04	1.0E-04	1.3E-04	1.1E-04	9.3E-05	8.9E-05
Chromium	4.2E-06	3.4E-06	2.9E-06	3.0E-06	3.9E-06	3.2E-06	2.7E-06	2.6E-06
Nickel	5.9E-06	4.8E-06	4.1E-06	4.2E-06	5.5E-06	4.4E-06	3.8E-06	3.7E-06
Zinc	8.4E-05	6.8E-05	5.9E-05	6.0E-05	7.9E-05	6.3E-05	5.4E-05	5.2E-05
Lead	9.3E-12	7.5E-12	6.5E-12	6.6E-12	8.7E-12	7.0E-12	6.0E-12	5.7E-12
Selenium	8.4E-07	6.8E-07	5.9E-07	6.0E-07	7.9E-07	6.3E-07	5.4E-07	5.2E-07
Mercury	1.7E-09	1.4E-09	1.2E-09	1.2E-09	1.6E-09	1.3E-09	1.1E-09	1.0E-09
Chromium IV	8.4E-09	6.8E-09	5.9E-09	6.0E-09	7.9E-09	6.3E-09	5.4E-09	5.2E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

5.6.2 Group 2: Regulated Emissions

In Table 5-44: and Table 5-45 the quantities of Euro-regulated exhaust emissions for diesel and petrol powered engines, respectively are summarised. The presented figures are derived from TREMOVE (2007).

Table 5-44: Emission factors of Euro-regulated exhaust emissions for diesel powered passenger cars (European fleet average). The average fleet car is based on the following shares: 2005: 21.7%, 74.5% and 3.8% for big vehicles medium vehicles and small vehicles, respectively. 2010: 20.3%, 72.4% and 7.3% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2005	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2010
Carbon Monoxide	1.8E-01	1.6E-01	7.9E-02	1.6E-01	1.0E-01	9.7E-02	6.8E-02	9.6E-02
Nitrogen Oxides (NOx)	7.2E-01	6.9E-01	7.4E-01	7.0E-01	5.3E-01	5.3E-01	4.8E-01	5.2E-01
Particulate Matter (PM)	5.9E-02	4.8E-02	3.5E-02	5.0E-02	3.4E-02	3.1E-02	2.4E-02	3.1E-02
Hydrocarbons (HC)	6.2E-02	3.0E-02	1.9E-02	3.7E-02	4.5E-02	2.2E-02	1.9E-02	2.7E-02

Table 5-45: Emission factors of Euro-regulated exhaust emissions for petrol powered passenger cars (European fleet average). The average fleet car is based on the following shares: 2005: 9%, 38% and 52% for big vehicles medium vehicles and small vehicles, respectively. In 2010: 9.8%, 37.8% and 52.5% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2005	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2010
Carbon Monoxide	2.6E+00	3.7E+00	5.1E+00	1.6E+00	1.3E+00	1.9E+00	2.7E+00	2.2E+00
Nitrogen Oxides (NOx)	4.4E-01	5.3E-01	5.8E-01	4.5E-01	1.9E-01	2.4E-01	2.8E-01	2.6E-01
Particulate Matter (PM)	1.7E-03	1.7E-03	1.7E-03	1.5E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
Hydrocarbons (HC)	3.2E-01	5.1E-01	6.8E-01	4.2E-01	1.4E-01	2.2E-01	3.0E-01	2.6E-01

5.6.3 Group 3: Hydrocarbon exhaust emission profiles

The presented figures (see Table 5-46 and Table 5-47) are based on EMEP/CORINAIR (2006).

Table 5-46: Specific hydrocarbon exhaust emissions for diesel powered passenger cars (European fleet average). NMHC values are not yet corrected according to ecoinvent methodology. The average fleet car is based on the following shares: 2005: 21.7%, 74.5% and 3.8% for big vehicles medium vehicles and small vehicles, respectively. 2010: 20.3%, 72.4% and 7.3% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2005	big diesel car +2,0 l	medium diesel car 1,4-2,0 l	small diesel car -1.4 l	Diesel Average Fleet 2010
NMHC	5.8E-02	2.7E-02	1.8E-02	3.4E-02	4.3E-02	2.1E-02	1.9E-02	2.6E-02
Methane (CH4)	3.4E-03	2.7E-03	9.7E-04	2.7E-03	1.2E-03	1.0E-03	2.9E-04	1.0E-03
Toulene (C7H8)	4.0E-04	1.9E-04	1.2E-04	2.3E-04	3.0E-04	1.5E-04	1.3E-04	1.8E-04
Benzene (C6H6)	1.1E-03	5.4E-04	3.5E-04	6.7E-04	8.6E-04	4.2E-04	3.7E-04	5.1E-04
m,p,o Xylene (C8H10)	8.0E-04	3.8E-04	2.4E-04	4.7E-04	6.0E-04	2.9E-04	2.6E-04	3.5E-04
Formaldehyde (CH2O)	7.0E-03	3.3E-03	2.1E-03	4.0E-03	5.2E-03	2.6E-03	2.2E-03	3.1E-03
Acetaldehyde (CH3CHO)	3.7E-03	1.8E-03	1.1E-03	2.2E-03	2.8E-03	1.4E-03	1.2E-03	1.7E-03

Table 5-47: Specific hydrocarbon exhaust emissions for petrol powered passenger cars (European fleet average). NMHC values are not yet corrected according to ecoinvent methodology. The average fleet car is based on the following shares: 2005: 9%, 38% and 52% for big vehicles medium vehicles and small vehicles, respectively. In 2010: 9.8%, 37.8% and 52.5% for big vehicles medium vehicles and small vehicles, respectively.

Emission/Pollutant	2005				2010			
	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2005	big gasoline car +2,0 l	medium gasoline car 1,4-2,0 l	small gasoline car -1,4 l	Petrol Average Fleet 2010
NMHC	2.9E-01	4.8E-01	6.4E-01	4.0E-01	1.1E-01	2.0E-01	2.8E-01	2.3E-01
Methane (CH4)	2.3E-02	2.6E-02	3.2E-02	1.2E-02	2.2E-02	2.2E-02	2.5E-02	2.4E-02
Toulene (C7H8)	3.2E-02	5.3E-02	7.1E-02	4.4E-02	1.2E-02	2.2E-02	3.0E-02	2.6E-02
Benzene (C6H6)	1.7E-02	2.7E-02	3.6E-02	2.2E-02	6.4E-03	1.1E-02	1.6E-02	1.3E-02
m,p,o Xylene (C8H10)	2.3E-02	3.7E-02	4.9E-02	3.0E-02	8.7E-03	1.5E-02	2.1E-02	1.8E-02
Formaldehyde (CH2O)	5.0E-03	8.2E-03	1.1E-02	6.7E-03	1.9E-03	3.4E-03	4.7E-03	3.9E-03
Acetaldehyde (CH3CHO)	2.2E-03	3.6E-03	4.8E-03	3.0E-03	8.5E-04	1.5E-03	2.1E-03	1.7E-03

5.6.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

N_2O emissions are derived from TREMOVE (2007). For NH_3 emissions, Swiss values from Keller (2004) are employed as a first approximation, (see 5.2.4).

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions for diesel cars (0.7E-6 g/vkm for a direct injection concept) and petrol cars (0.4E-06g/vkm) are taken from EMEP/CORINAIR (2005). Whilst the uncertainty of the emission factor for diesel cars is reported to be low (0.3-1.0E-9 kg/vkm), the average emission factor presented for petrol concepts is fairly high (0.001-8.8E-09 kg/vkm).

5.6.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions and heavy metal trace elements are presented in section 5.2.5.

5.6.6 Group 7: Emissions to soil and water

Emission factors are based on the assumption described in section 5.2.6. The resulting figures are summarised in section 5.6.7.

5.6.7 Life Cycle Inventory Input Tables

In Table 5-48 and Table 5-49 the complete life cycle inventory input table are presented. In addition, in the average European passenger car is presented based on an assumed petrol performance share of 67%.

Table 5-48: Life Cycle Inventory Input table for the operation of European diesel passenger cars (fleet average).

	Name	Location	InfrastructureProcess	Unit	operation, passenger car, diesel, fleet average	operation, passenger car, diesel, fleet average 2010	Uncertainty	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				0	0			
	Unit				vkm	vkm			
	operation, passenger car, diesel, fleet average	RER	0	vkm	1.00E+0				
	operation, passenger car, diesel, fleet average 2010	RER	0	vkm		1.00E+0			
technosphere	petrol, low-sulphur, at regional storage	CH	0	kg	0	0	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	6.10E-2	5.58E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.1932	0.1769	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	6.10E-6	5.58E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	7.37E-10	6.85E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	4.89E-7	4.80E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	8.42E-9	8.17E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	8.10E-9	7.74E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	2.05E-7	1.99E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.46E-8	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	5.70E-10	5.58E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	1.14E-12	1.12E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	5.70E-12	5.58E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.57E-4	9.59E-5	1	5.00	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
	Nitrogen oxides	-	-	kg	7.00E-4	5.23E-4	1	1.50	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	5.80E-5	3.90E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	1.19E-5	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.35E-5	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.34E-5	1.88E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Methane, fossil	-	-	kg	2.72E-6	1.02E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Benzene	-	-	kg	2.33E-7	1.77E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Toluene	-	-	kg	6.68E-7	5.08E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Xylene	-	-	kg	4.65E-7	3.54E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Formaldehyde	-	-	kg	4.05E-6	3.08E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	2.18E-6	1.66E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.10E-6	5.10E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	7.27E-6	8.27E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	4.00E-10	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	2.70E-7	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	6.39E-9	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	9.55E-11	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	4.55E-10	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	1.23E-9	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	2.70E-7	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	6.39E-9	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	9.55E-11	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	4.55E-10	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	1.23E-9	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	2.75E+0	2.52E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-49: Life Cycle Inventory Input table for the operation of European petrol passenger cars (fleet average).

	Name	Location	InfrastructureProcess	Unit	operation, passenger car, petrol, fleet average	operation, passenger car, petrol, fleet average 2010	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				0	0			
	Unit				vkm	vkm			
	operation, passenger car, petrol, fleet average	RER	0	vkm	1.00E+0				
	operation, passenger car, petrol, fleet average 2010	RER	0	vkm		1.00E+0			
technosphere	petrol, low-sulphur, at regional storage	CH	0	kg	6.00E-2	6.02E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	0	0	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.1877	0.1875	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	6.00E-6	6.02E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	7.27E-10	7.29E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	4.87E-7	4.88E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	8.38E-9	8.39E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	8.03E-9	8.05E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	2.04E-7	2.04E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.46E-8	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	6.00E-10	6.02E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	1.20E-12	1.20E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	6.00E-12	6.02E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.64E-3	2.22E-3	1	5.00	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
	Nitrogen oxides	-	-	kg	4.49E-4	2.58E-4	1	1.50	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	9.30E-6	9.20E-6	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	1.19E-5	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.35E-5	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.78E-4	1.46E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Methane, fossil	-	-	kg	1.20E-5	2.38E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Benzene	-	-	kg	4.35E-5	2.55E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Toluene	-	-	kg	2.22E-5	1.30E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Xylene	-	-	kg	3.05E-5	1.79E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Formaldehyde	-	-	kg	6.74E-6	3.95E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	2.97E-6	1.74E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	2.78E-5	2.56E-5	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	1.18E-5	5.38E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	7.00E-10	7.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	2.70E-7	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	6.39E-9	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	9.55E-11	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	4.55E-10	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	1.23E-9	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	2.70E-7	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	6.39E-9	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	9.55E-11	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	4.55E-10	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	1.23E-9	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	0	0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-50: Life Cycle Inventory Input table for the operation of European passenger cars (fleet average including diesel and petrol cars)).

	Name	Location	InfrastructureProcess	Unit	operation, passenger car	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER			
	InfrastructureProcess				0			
	Unit				km			
	operation, passenger car, petrol, fleet average	RER	0	vkm				
	operation, passenger car, petrol, fleet average 2010	RER	0	vkm				
technosphere	petrol, low-sulphur, at regional storage	CH	0	kg	4.01E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	2.02E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.1914	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	6.03E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	7.30E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	4.88E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	8.39E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	8.05E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	2.04E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.46E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	6.03E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	1.21E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	6.03E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.15E-3	1	5.00	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
	Nitrogen oxides	-	-	kg	5.32E-4	1	1.50	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	2.54E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	1.19E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	1.35E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.94E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Methane, fossil	-	-	kg	8.89E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Benzene	-	-	kg	2.92E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Toluene	-	-	kg	1.51E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Xylene	-	-	kg	2.05E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Formaldehyde	-	-	kg	5.85E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	2.71E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	2.03E-5	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	1.03E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	6.01E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	2.70E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	6.39E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	9.55E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	4.55E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	1.23E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	2.70E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	6.39E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	9.55E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	4.55E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	1.23E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	9.11E-1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

5.7 Life Cycle Inventories for the Operation of Road Freight Transport in Europe

In this section, the data and underlying assumptions used for the datasets of lorry transport and van transport in Europe are presented. Lorry transport is further differentiated with respect to vehicle weight and emission technology standard (EURO-standard). The share of diesel vans in 2005 is assumed to be 81%.

5.7.1 Group 1: Fuel Consumption and Fuel Dependent Emissions

Fuel consumption is directly taken from TREMOVE (2007). The presented emission factors (Table 5-51) are based on the emission indices as outlined in 5.2.1.

Table 5-51: Fuel Consumption and fuel dependent emissions of truck transport.

Emission/Pollutant	3.5-7.5t				7.5-16t				16-32t				> 32t			
	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005
Fuel Consumption	143.4	135.3	137.5	144.4	218.8	196.1	199.2	221.7	210.4	187.0	189.9	212.5	288.5	244.0	248.0	292.4
Carbon Dioxide (CO2) [1)]	454.8	429.1	436.2	457.9	693.9	622.0	632.0	703.4	667.2	593.0	602.4	674.2	915.3	774.0	786.8	927.5
Sulphur Dioxide	1.4E-02	1.4E-02	1.4E-02	1.4E-02	2.2E-02	2.0E-02	2.0E-02	2.2E-02	2.1E-02	1.9E-02	1.9E-02	2.1E-02	2.9E-02	2.4E-02	2.5E-02	2.9E-02
Cadmium	1.4E-06	1.4E-06	1.4E-06	1.4E-06	2.2E-06	2.0E-06	2.0E-06	2.2E-06	2.1E-06	1.9E-06	1.9E-06	2.1E-06	2.9E-06	2.4E-06	2.5E-06	2.9E-06
Copper	2.4E-04	2.3E-04	2.3E-04	2.5E-04	3.7E-04	3.3E-04	3.4E-04	3.8E-04	3.6E-04	3.2E-04	3.2E-04	3.6E-04	4.9E-04	4.1E-04	4.2E-04	5.0E-04
Chromium	7.2E-06	6.8E-06	6.9E-06	7.2E-06	1.1E-05	9.8E-06	1.0E-05	1.1E-05	1.1E-05	9.3E-06	9.5E-06	1.1E-05	1.4E-05	1.2E-05	1.2E-05	1.5E-05
Nickel	1.0E-05	9.5E-06	9.6E-06	1.0E-05	1.5E-05	1.4E-05	1.4E-05	1.6E-05	1.5E-05	1.3E-05	1.3E-05	1.5E-05	2.0E-05	1.7E-05	1.7E-05	2.0E-05
Zinc	1.4E-04	1.4E-04	1.4E-04	1.4E-04	2.2E-04	2.0E-04	2.0E-04	2.2E-04	2.1E-04	1.9E-04	1.9E-04	2.1E-04	2.9E-04	2.4E-04	2.5E-04	2.9E-04
Lead	1.6E-11	1.5E-11	1.5E-11	1.6E-11	2.4E-11	2.2E-11	2.2E-11	2.4E-11	2.3E-11	2.1E-11	2.1E-11	2.3E-11	3.2E-11	2.7E-11	2.7E-11	3.2E-11
Selenium	1.4E-06	1.4E-06	1.4E-06	1.4E-06	2.2E-06	2.0E-06	2.0E-06	2.2E-06	2.1E-06	1.9E-06	1.9E-06	2.1E-06	2.9E-06	2.4E-06	2.5E-06	2.9E-06
Mercury	2.9E-09	2.7E-09	2.8E-09	2.9E-09	4.4E-09	3.9E-09	4.0E-09	4.4E-09	4.2E-09	3.7E-09	3.8E-09	4.3E-09	5.8E-09	4.9E-09	5.0E-09	5.8E-09
Chromium IV	1.4E-08	1.4E-08	1.4E-08	1.4E-08	2.2E-08	2.0E-08	2.0E-08	2.2E-08	2.1E-08	1.9E-08	1.9E-08	2.1E-08	2.9E-08	2.4E-08	2.5E-08	2.9E-08

1: The presented figures are not yet corrected with respect to CO-emissions.

Table 5-52: Fuel Consumption and fuel dependent emissions of van transport. The share of diesel vans is 81%.

Emission/Pollutant			
	light duty vehicle diesel	light duty vehicle gasoline	Van Average Fleet 2005
Fuel Consumption	70	93	74
Carbon Dioxide (CO2) [1)]	222	295	236
Sulphur Dioxide	7.0E-03	9.3E-03	7.4E-03
Cadmium	7.0E-07	9.3E-07	7.4E-07
Copper	1.2E-04	1.6E-04	1.3E-04
Chromium	3.5E-06	4.6E-06	3.7E-06
Nickel	4.9E-06	6.5E-06	5.2E-06
Zinc	7.0E-05	9.3E-05	7.4E-05
Lead	7.7E-12	1.0E-11	8.2E-12
Selenium	7.0E-07	9.3E-07	7.4E-07
Mercury	1.4E-09	1.9E-09	1.5E-09
Chromium IV	7.0E-09	9.3E-09	7.4E-09

1: The presented figures are not yet corrected with respect to CO-emissions.

5.7.2 Group 2: Regulated Emissions

In Table 5-33: the quantities of Euro-regulated exhaust emissions are summarised. The presented values are derived from TREMOVE (2007).

Table 5-53: Emission factors of Euro-regulated exhaust emissions for diesel powered lorries.

Emission/Pollutant	3.5-7.5t				7.5-16t				16-32t				> 32t			
	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005
Carbon Monoxide	9.2E-01	5.2E-02	4.1E-02	1.1E+00	1.3E+00	7.9E-02	7.9E-02	1.5E+00	1.3E+00	4.3E-02	4.3E-02	1.5E+00	1.6E+00	6.5E-02	5.5E-02	1.9E+00
Nitrogen Oxides (NOx)	3.7	2.3	1.3	4.8	6.0	3.6	2.1	7.1	5.7	3.4	2.0	7.2	7.9	4.6	2.7	9.7
Particulate Matter (PM)	8.5E-02	9.5E-03	9.8E-03	1.3E-01	9.5E-02	2.5E-02	2.5E-02	1.9E-01	7.4E-02	2.1E-02	2.1E-02	1.7E-01	1.2E-01	2.6E-02	2.6E-02	2.4E-01
Hydrocarbons (HC)	7.2E-02	3.5E-03	3.9E-03	2.5E-01	1.9E-01	8.4E-03	9.1E-03	3.5E-01	1.1E-01	6.7E-03	6.7E-03	2.5E-01	2.5E-01	4.7E-03	4.8E-03	2.9E-01

Table 5-54: Emission factors of Euro-regulated exhaust emissions for vans (European fleet average).

Emission/Pollutant			
	light duty vehicle diesel	light duty vehicle gasoline	Van Average Fleet 2005
Carbon Monoxide	5.4E-01	9.3E+00	2.2E+00
Nitrogen Oxides (NOx)	1.1E+00	1.1E+00	1.1E+00
Particulate Matter (PM)	1.2E-01	1.7E-03	9.6E-02
Hydrocarbons (HC)	1.3E-01	7.9E-01	2.5E-01

5.7.3 Group 3: Hydrocarbon exhaust emission profiles

The presented figures in Table 5-55 and Table 5-56 are based on EMEP/CORINAIR (2006).

Table 5-55: Specific hydrocarbon exhaust emissions for diesel powered lorries. NMHC values are not yet corrected according to ecoinvent methodology.

Emission/Pollutant	3.5-7.5t				7.5-16t				16-32t				> 32t			
	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005	EURO3	EURO4	EURO5	Fleet Av. 2005
NMHC	4.7E-02	1.8E-03	2.6E-03	2.2E-01	1.7E-01	6.9E-03	6.9E-03	3.3E-01	3.0E-02	1.8E-03	1.8E-03	1.7E-01	1.7E-01	3.6E-04	3.7E-04	2.1E-01
Methane (CH4)	2.5E-02	2.0E-03	2.0E-03	2.5E-02	2.5E-02	2.0E-03	1.9E-03	2.5E-02	7.8E-02	5.0E-03	5.0E-03	7.8E-02	7.6E-02	4.6E-03	4.6E-03	7.5E-02
Toulene (C7H8)	4.7E-06	1.8E-07	2.6E-07	2.2E-05	1.7E-05	6.9E-07	6.9E-07	3.3E-05	3.0E-06	1.8E-07	1.8E-07	1.7E-05	1.7E-05	3.6E-08	3.7E-08	2.1E-05
Benzene (C6H6)	3.3E-05	1.3E-06	1.8E-06	1.6E-04	1.2E-04	4.8E-06	4.8E-06	2.3E-04	2.1E-05	1.3E-06	1.3E-06	1.2E-04	1.2E-04	2.5E-07	2.6E-07	1.5E-04
m,p,o Xylene (C8H10)	4.2E-04	1.6E-05	2.3E-05	2.0E-03	1.5E-03	6.0E-05	6.0E-05	2.9E-03	2.6E-04	1.6E-05	1.6E-05	1.5E-03	1.5E-03	3.2E-06	3.2E-06	1.9E-03
Formaldehyde (CH2O)	4.0E-03	1.5E-04	2.2E-04	1.9E-02	1.4E-02	5.8E-04	5.8E-04	2.7E-02	2.5E-03	1.5E-04	1.5E-04	1.5E-02	1.5E-02	3.0E-05	3.1E-05	1.8E-02
Acetaldehyde (CH3CHO)	2.2E-03	8.4E-05	1.2E-04	1.0E-02	7.7E-03	3.1E-04	3.1E-04	1.5E-02	1.4E-03	8.3E-05	8.2E-05	8.0E-03	7.9E-03	1.6E-05	1.7E-05	9.6E-03

Table 5-56: Specific hydrocarbon exhaust emissions for vans (European fleet average). NMHC values are not yet corrected according to ecoinvent methodology.

Emission/Pollutant			
	light duty vehicle diesel	light duty vehicle gasoline	Van Average Fleet 2005
NMHC	1.3E-01	7.6E-01	2.5E-01
Methane (CH4)	4.7E-03	2.0E-02	7.6E-03
Toulene (C7H8)	8.7E-04	8.4E-02	1.7E-03
Benzene (C6H6)	2.5E-03	4.3E-02	4.9E-03
m,p,o Xylene (C8H10)	1.7E-03	5.9E-02	3.4E-03
Formaldehyde (CH2O)	1.5E-02	1.3E-02	3.0E-02
Acetaldehyde (CH3CHO)	8.2E-03	5.7E-03	1.6E-02

5.7.4 Group 4: Other exhaust emissions

Nitrous Oxides (N_2O) and Ammonia (NH_3)

N_2O emissions are derived from TREMOVE (2007). For NH_3 emissions Swiss values from Keller (2004) are employed as a first approximation.

PAHs

Polycyclic Aromatic Hydrocarbons (PAHs) emissions for diesel lorries are 1E-6 g/vkm.

5.7.5 Group 5: Non-exhaust abrasion particle emissions including fractions of heavy metals

The emission factors for non exhaust abrasion particle emissions and heavy metal trace elements are presented in section 5.7.7.

5.7.6 Group 7: Emissions to soil and water

Emission factors are based on the assumption described in section 5.2.6. The resulting figures are summarised in section 5.7.7.

5.7.7 Life Cycle Inventory Input Tables

In this part, life cycle inventory tables for “operation, lorry, xx” and “operation, van, xx” datasets are shown.

Table 5-57: Life Cycle Inventory Input table for the operation of European lorries, fleet average.

	Name	Location	InfrastructureProcess	Unit	operation, lorry 3.5-16t, fleet average	operation, lorry >16t, fleet average	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				0	0			
	Unit				vkm	vkm			
	operation, lorry 3.5-16t, fleet average	RER	0	vkm	1.00E+0				
	operation, lorry >16t, fleet average	RER	0	vkm		1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	1.66E-1	2.49E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.5243	0.7882	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	1.66E-5	2.49E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	1.87E-9	2.71E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	6.73E-7	8.15E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	1.41E-8	1.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	1.66E-8	2.24E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	5.61E-7	6.45E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	1.66E-9	2.49E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	3.32E-12	4.99E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	1.66E-11	2.49E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.18E-3	1.64E-3	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	5.46E-3	8.36E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	1.82E-4	2.38E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.16E-4	1.64E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	2.50E-5	7.67E-5	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	2.51E-8	1.91E-8	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	1.76E-7	1.34E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	2.21E-6	1.68E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	2.11E-5	1.60E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	1.15E-5	8.73E-6	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	3.00E-5	3.00E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	2.23E-6	5.45E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	5.28E-8	1.29E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	7.89E-10	1.93E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	3.76E-9	9.20E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	1.02E-8	2.49E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.25E-8	7.94E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	2.23E-6	5.45E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	5.28E-8	1.29E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	7.89E-10	1.93E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	3.76E-9	9.20E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	1.02E-8	2.49E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.25E-8	7.94E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	7.48E+0	1.12E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-58: Life Cycle Inventory Input table for the operation of European lorries (3.5-7.5t and 7.5-16t) (Euro-Class-Specific).

	Name	Location	InfrastructureProcess	Unit	operation, lorry 3.5-7.5t, EURO3	operation, lorry 3.5-7.5t, EURO4	operation, lorry 3.5-7.5t, EURO5	operation, lorry 7.5-16t, EURO3	operation, lorry 7.5-16t, EURO4	operation, lorry 7.5-16t, EURO5	Uncertainty	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER	RER	RER			
	InfrastructureProcess				0	0	0	0	0	0			
	Unit				vkm	vkm	vkm	vkm	vkm	vkm			
	operation, lorry 3.5-7.5t, EURO3	RER	0	vkm	1.00E+0								
	operation, lorry 3.5-7.5t, EURO4	RER	0	vkm		1.00E+0							
	operation, lorry 3.5-7.5t, EURO5	RER	0	vkm			1.00E+0						
	operation, lorry 7.5-16t, EURO3	RER	0	vkm				1.00E+0					
	operation, lorry 7.5-16t, EURO4	RER	0	vkm					1.00E+0				
	operation, lorry 7.5-16t, EURO5	RER	0	vkm						1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	1.43E-1	1.35E-1	1.38E-1	2.19E-1	1.96E-1	1.99E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.4534	0.4290	0.4361	0.6919	0.6218	0.6319	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	1.43E-5	1.35E-5	1.38E-5	2.19E-5	1.96E-5	1.99E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	1.65E-9	1.57E-9	1.59E-9	2.40E-9	2.18E-9	2.21E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	6.35E-7	6.21E-7	6.25E-7	7.63E-7	7.25E-7	7.30E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	1.30E-8	1.26E-8	1.27E-8	1.67E-8	1.56E-8	1.58E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	1.50E-8	1.45E-8	1.46E-8	2.03E-8	1.87E-8	1.89E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	5.39E-7	5.31E-7	5.33E-7	6.14E-7	5.92E-7	5.95E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	2.83E-8	2.83E-8	2.83E-8	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	1.43E-9	1.35E-9	1.38E-9	2.19E-9	1.96E-9	1.99E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	2.87E-12	2.71E-12	2.75E-12	4.38E-12	3.92E-12	3.98E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	1.43E-11	1.35E-11	1.38E-11	2.19E-11	1.96E-11	1.99E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	9.22E-4	5.15E-5	4.05E-5	1.29E-3	7.85E-5	7.92E-5	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	3.72E-3	2.28E-3	1.34E-3	6.00E-3	3.57E-3	2.11E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	1.20E-4	4.43E-5	4.46E-5	1.30E-4	5.93E-5	5.95E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	5.66E-5	5.66E-5	5.66E-5	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	6.16E-5	6.16E-5	6.16E-5	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	4.07E-5	1.58E-6	2.25E-6	1.45E-4	5.91E-6	5.90E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	2.52E-5	1.96E-6	1.96E-6	2.53E-5	1.98E-6	1.90E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	4.73E-9	1.83E-10	2.61E-10	1.69E-8	6.86E-10	6.86E-10	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	3.31E-8	1.28E-9	1.83E-9	1.18E-7	4.80E-9	4.80E-9	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	4.16E-7	1.61E-8	2.30E-8	1.49E-6	6.04E-8	6.03E-8	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	3.97E-6	1.54E-7	2.20E-7	1.42E-5	5.76E-7	5.76E-7	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	2.16E-6	8.36E-8	1.19E-7	7.73E-6	3.14E-7	3.13E-7	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	5.00E-6	5.00E-6	5.00E-6	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	3.00E-5	2.99E-5	2.97E-5	3.00E-5	2.99E-5	3.01E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	2.23E-6	2.23E-6	2.23E-6	2.23E-6	2.23E-6	2.23E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	5.28E-8	5.28E-8	5.28E-8	5.28E-8	5.28E-8	5.28E-8	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	7.89E-10	7.89E-10	7.89E-10	7.89E-10	7.89E-10	7.89E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	3.76E-9	3.76E-9	3.76E-9	3.76E-9	3.76E-9	3.76E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.25E-8	3.25E-8	3.25E-8	3.25E-8	3.25E-8	3.25E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	2.23E-6	2.23E-6	2.23E-6	2.23E-6	2.23E-6	2.23E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	5.28E-8	5.28E-8	5.28E-8	5.28E-8	5.28E-8	5.28E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	7.89E-10	7.89E-10	7.89E-10	7.89E-10	7.89E-10	7.89E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	3.76E-9	3.76E-9	3.76E-9	3.76E-9	3.76E-9	3.76E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1.02E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	3.25E-8	3.25E-8	3.25E-8	3.25E-8	3.25E-8	3.25E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	6.47E+0	6.10E+0	6.20E+0	9.87E+0	8.84E+0	8.99E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-59: Life Cycle Inventory Input table for the operation of European lorries (16-32t and > 32t) (Euro-Class-Specific)

	Name	Location	InfrastructureProcess	Unit	operation, lorry 16-32t, EURO3	operation, lorry 16-32t, EURO4	operation, lorry 16-32t, EURO5	operation, lorry >32t, EURO3	operation, lorry >32t, EURO4	operation, lorry >32t, EURO5	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER	RER	RER			
	InfrastructureProcess				0	0	0	0	0	0			
	Unit				vkm	vkm	vkm	vkm	vkm	vkm			
	operation, lorry 16-32t, EURO3	RER	0	vkm	1.00E+0								
	operation, lorry 16-32t, EURO4	RER	0	vkm		1.00E+0							
	operation, lorry 16-32t, EURO5	RER	0	vkm			1.00E+0						
	operation, lorry >32t, EURO3	RER	0	vkm				1.00E+0					
	operation, lorry >32t, EURO4	RER	0	vkm					1.00E+0				
	operation, lorry >32t, EURO5	RER	0	vkm						1.00E+0			
technosphere	diesel, low-sulphur, at regional storage	CH	0	kg	2.10E-1	1.87E-1	1.90E-1	2.89E-1	2.44E-1	2.48E-1	1	1.05	(1,1,1,1,1,1); derived from Swiss database on road transport emissions (HBEFA)
fuel dependent airborne emissions	Carbon dioxide, fossil	-	-	kg	0.6653	0.5930	0.6023	0.9128	0.7739	0.7867	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	-	kg	2.10E-5	1.87E-5	1.90E-5	2.89E-5	2.44E-5	2.48E-5	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	-	kg	2.32E-9	2.09E-9	2.12E-9	3.10E-9	2.66E-9	2.70E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	-	kg	7.49E-7	7.09E-7	7.14E-7	8.82E-7	8.06E-7	8.13E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	-	kg	1.63E-8	1.51E-8	1.53E-8	2.02E-8	1.80E-8	1.82E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	-	kg	1.97E-8	1.81E-8	1.83E-8	2.52E-8	2.21E-8	2.23E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	-	kg	6.06E-7	5.82E-7	5.85E-7	6.84E-7	6.40E-7	6.44E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	-	kg	2.83E-8	2.83E-8	2.83E-8	2.83E-8	2.83E-8	2.83E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	-	kg	2.10E-9	1.87E-9	1.90E-9	2.89E-9	2.44E-9	2.48E-9	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	-	kg	4.21E-12	3.74E-12	3.80E-12	5.77E-12	4.88E-12	4.96E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	-	kg	2.10E-11	1.87E-11	1.90E-11	2.89E-11	2.44E-11	2.48E-11	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	-	kg	1.26E-3	4.29E-5	4.28E-5	1.58E-3	6.48E-5	5.53E-5	1	5.00	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
	Nitrogen oxides	-	-	kg	5.74E-3	3.36E-3	1.98E-3	7.93E-3	4.58E-3	2.68E-3	1	1.50	(1,1,1,1,1,2); derived from Swiss database on road transport emissions
Exhaust and Abrasion	Particulates, < 2.5 um	-	-	kg	1.09E-4	5.57E-5	5.62E-5	1.58E-4	6.06E-5	6.09E-5	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	-	kg	5.66E-5	5.66E-5	5.66E-5	5.66E-5	5.66E-5	5.66E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	-	kg	6.16E-5	6.16E-5	6.16E-5	6.16E-5	6.16E-5	6.16E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.59E-5	1.56E-6	1.54E-6	1.49E-4	3.10E-7	3.17E-7	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Methane, fossil	-	-	kg	7.85E-5	5.02E-6	5.02E-6	7.56E-5	4.60E-6	4.62E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Benzene	-	-	kg	3.01E-9	1.82E-10	1.79E-10	1.73E-8	3.60E-11	3.68E-11	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Toluene	-	-	kg	2.11E-8	1.27E-9	1.26E-9	1.21E-7	2.52E-10	2.58E-10	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Xylene	-	-	kg	2.65E-7	1.60E-8	1.58E-8	1.52E-6	3.17E-9	3.24E-9	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA).
	Formaldehyde	-	-	kg	2.53E-6	1.53E-7	1.51E-7	1.45E-5	3.02E-8	3.09E-8	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	-	kg	1.38E-6	8.31E-8	8.20E-8	7.89E-6	1.64E-8	1.68E-8	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	-	kg	5.00E-6	5.00E-6	5.00E-6	5.00E-6	5.00E-6	5.00E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	-	kg	3.00E-5	3.00E-5	2.99E-5	3.00E-5	3.00E-5	3.00E-5	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1.00E-9	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	-	kg	5.02E-6	5.02E-6	5.02E-6	5.95E-6	5.95E-6	5.95E-6	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1.41E-7	1.41E-7	1.41E-7	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	-	kg	1.78E-9	1.78E-9	1.78E-9	2.11E-9	2.11E-9	2.11E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1.00E-8	1.00E-8	1.00E-8	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	-	kg	2.30E-8	2.30E-8	2.30E-8	2.72E-8	2.72E-8	2.72E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	8.67E-8	8.67E-8	8.67E-8	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	-	kg	5.02E-6	5.02E-6	5.02E-6	5.95E-6	5.95E-6	5.95E-6	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	-	kg	1.19E-7	1.19E-7	1.19E-7	1.41E-7	1.41E-7	1.41E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	-	kg	1.78E-9	1.78E-9	1.78E-9	2.11E-9	2.11E-9	2.11E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	-	kg	8.48E-9	8.48E-9	8.48E-9	1.00E-8	1.00E-8	1.00E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	-	kg	2.30E-8	2.30E-8	2.30E-8	2.72E-8	2.72E-8	2.72E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	-	kg	7.31E-8	7.31E-8	7.31E-8	8.67E-8	8.67E-8	8.67E-8	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	-	MJ	9.49E+0	8.43E+0	8.57E+0	1.30E+1	1.10E+1	1.12E+1	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

Table 5-60: Life Cycle Inventory Input table for the operation of European vans, fleet average.

	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	operation, van < 3,5t	UncertaintyType	StandardDeviation95%	GeneralComment
	Location						RER			
	InfrastructureProcess						0			
	Unit						vkm			
	operation, van < 3,5t	RER	-	-	0	vkm	1.00E+0			
technosphere	petrol, low-sulphur, at regional storage	CH	-	-	0	kg	1.40E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
technosphere	diesel, low-sulphur, at regional storage	CH	-	-	0	kg	6.04E-2	1	1.05	(1,1,1,1,1,1); derived from TREMOVE database v2.44c
fuel dependent airborne emissions	Carbon dioxide, fossil	-	air	unspecified	-	kg	0.2326	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
	Sulfur dioxide	-	air	unspecified	-	kg	7.44E-6	1	1.07	(2,1,1,1,1,1); own calculations, based on fuel consumption
Heavy metals (fuel dependent & abrasion)	Cadmium	-	air	unspecified	-	kg	9.42E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Copper	-	air	unspecified	-	kg	7.27E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Chromium	-	air	unspecified	-	kg	1.21E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Nickel	-	air	unspecified	-	kg	1.12E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Zinc	-	air	unspecified	-	kg	3.00E-7	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Lead	-	air	unspecified	-	kg	3.84E-8	1	5.42	(4,5,5,1,1,5); trace elements in fuel and abrasion of tyres
	Selenium	-	air	unspecified	-	kg	9.28E-10	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Mercury	-	air	unspecified	-	kg	1.86E-12	1	5.42	(4,5,5,1,1,5); trace elements in fuel
	Chromium VI	-	air	unspecified	-	kg	9.28E-12	1	5.42	(4,5,5,1,1,5); own calculation
Process specific airborne emissions	Carbon monoxide, fossil	-	air	unspecified	-	kg	2.19E-3	1	5.00	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
	Nitrogen oxides	-	air	unspecified	-	kg	1.13E-3	1	1.50	(1,1,1,1,1,2); derived from TREMOVE database v2.44c
Exhaust and Abrasion	Particulates, < 2.5 um	-	air	unspecified	-	kg	1.07E-4	1	3.01	(1,1,3,3,1,2); includes exhaust- and abrasions emissions.
Particle Abrasion	Particulates, > 10 um	-	air	unspecified	-	kg	1.45E-5	1	1.52	(1,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
	Particulates, > 2.5 um, and < 10um	-	air	unspecified	-	kg	1.80E-5	1	2.03	(3,3,3,3,1,2); abrasions emissions (tyre wear, break wear, road surface)
Hydrocarbons	NMVOC, non-methane volatile organic compounds, unspecified origin	-	air	unspecified	-	kg	1.84E-4	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Methane, fossil	-	air	unspecified	-	kg	7.58E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Benzene	-	air	unspecified	-	kg	1.70E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Toluene	-	air	unspecified	-	kg	4.89E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Xylene	-	air	unspecified	-	kg	3.40E-6	1	1.50	(1,1,1,1,1,2); derived from HC values; split available from Swiss database on road transport emissions (HBEFA). Quantity includes evaporation for petrol cars.
	Formaldehyde	-	air	unspecified	-	kg	2.96E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
	Acetaldehyde	-	air	unspecified	-	kg	1.60E-5	1	1.51	(2,3,2,1,1,2); derived from NMHC values; split available from European Road Transport Emission database (Copert)
Others	Ammonia	-	air	unspecified	-	kg	5.10E-6	1	1.24	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	Dinitrogen monoxide	-	air	unspecified	-	kg	9.33E-6	1	1.53	(2,3,1,1,1,4); derived from Swiss database on road transport emissions (HBEFA)
	PAH, polycyclic aromatic hydrocarbons	-	air	unspecified	-	kg	4.00E-10	1	12.01	(2,3,1,1,1,2); rough estimate, derived from from European Road Transport Emission database (Copert)
Emissions to water	Zinc, ion	-	water	unspecified	-	kg	2.32E-7	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper, ion	-	water	unspecified	-	kg	5.49E-9	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium, ion	-	water	unspecified	-	kg	8.20E-11	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium, ion	-	water	unspecified	-	kg	3.91E-10	1	3.55	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel, ion	-	water	unspecified	-	kg	1.06E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	water	unspecified	-	kg	3.37E-9	1	5.63	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Emissions to soil	Zinc	-	soil	unspecified	-	kg	2.32E-7	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Copper	-	soil	unspecified	-	kg	5.49E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Cadmium	-	soil	unspecified	-	kg	8.20E-11	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Chromium	-	soil	unspecified	-	kg	3.91E-10	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Nickel	-	soil	unspecified	-	kg	1.06E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
	Lead	-	soil	unspecified	-	kg	3.37E-9	1	2.11	(5,5,5,1,1,5); abrasion of tyres, quantity derived from tyre composition
Heat	Heat, waste	-	air	unspecified	-	MJ	3.36E+0	1	1.22	(2,1,1,1,1,5); own calculation; based on HHV.

5.8 Operation of Trolley-Buses and Trams

5.8.1 Electricity consumption

The total electricity consumption of trolley buses and trams operating in Switzerland is available from the Swiss transport statistic Bundesamt für Statistik (BfS) (2000). In Table 5-61 these figures and the resulting specific electricity consumption are presented.

Table 5-61: Specific electricity consumption of tram and trolley buses

	Unit	Trolley bus	Tram
Total electricity consumption	kWh/a	8.94E+07	1.21E+08
Specific energy consumption per vkm	kWh/vkm	3.04	4.55
Specific energy consumption per pkm	kWh/pkm	0.12	0.09

5.8.2 Other Emissions

For trolley buses no direct emissions due to combustion occur. However, emissions due to tyre, brake and road abrasion are accounted for. For Tram transport abrasions tyre and brake emissions are taking into account.

5.8.3 Life Cycle Inventory Input Data

The below tables summarise the input data for the datasets operation tram and operation trolley bus.

Table 5-62: Life cycle inventory table of operation of an average Swiss tram

	Name	Location	Infra	Unit	*operation, tram*	Uncertainty Type	StandardDeviation 95%	GeneralComment
	Location				***CH***			
	InfrastructureProcess				***0***			
	Unit				***vkm***			
product	operation, tram	CH	0	vkm	1.00E+0			
technosphere	electricity, medium voltage, at grid	CH	0	kWh	4.75E+0	1	1.05	data dreived top down, using national transport statistic data (vkm performance and total energy consumption)
emissions to air	Particulates, > 10 um	-	-	kg	4.56E-4	1	2.00	own estimates based on recent PM 10 studies; estimated basic uncertainty = 2.
	Particulates, > 2.5 um, and < 10um	-	-	kg	8.13E-4	1	2.00	own estimates based on recent PM 10 studies; estimated basic uncertainty = 2.
	Heat, waste	-	-	MJ	1.71E+1	1	1.05	(2,1,1,1,1,1); standard value
emmissions to soil	Iron	-	-	kg	6.74E-4	1	2.00	own estimates based on recent PM 10 studies; estimated basic uncertainty = 2.

Table 5-63: Life cycle inventory table of operation of an average Swiss trolley bus

Explanations	Name	Location	Infrastructure-Process	Unit	operation, trolleybus
	Location				CH
	InfrastructureProcess				0
	Unit				vkm
Outputs	operation, trolleybus	CH	0	vkm	1.00E+0
Technosphere	electricity, medium voltage, at grid	CH	0	kWh	3.04E+0
air, high population density	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a			kg	1.25E-5
	Particulates, > 10 um			kg	4.24E-4
	Particulates, > 2.5 um, and < 10um			kg	7.08E-5
	Particulates, < 2.5 um			kg	3.00E-5
	Lead			kg	2.10E-8
	Cadmium			kg	4.21E-9
	Copper			kg	6.31E-8
	Chromium			kg	3.79E-8
	Nickel			kg	3.37E-8
	Zinc			kg	3.38E-6
	Chromium VI			kg	7.57E-11
	Heat, waste			MJ	1.09E+1
soil, industrial	Lead			kg	2.20E-8
	Cadmium			kg	4.40E-9
	Copper			kg	6.59E-8
	Chromium			kg	3.96E-8
	Nickel			kg	3.52E-8
	Zinc			kg	3.53E-6
water, river	Lead			kg	2.20E-8
	Cadmium, ion			kg	4.40E-9
	Copper, ion			kg	6.59E-8
	Chromium, ion			kg	3.96E-8
	Nickel, ion			kg	3.52E-8
	Zinc, ion			kg	3.53E-6

5.9 Goods Transportation Vehicle Fleet

In this section, exchanges and environmental interventions due to vehicle manufacturing, maintenance and disposal are addressed. These environmental interventions are related to one vehicle unit.

In order to relate these interventions to the functional unit of 1 tkm, kilometric and transport performance per average vehicle must be determined. The figures used in this study are presented in Table 5-64.

Table 5-64: Reference figures for an average van and various lorry classes

Reference figure	unit	<3.5	16t	28t	40t
Kilometric performance per vehicle [1)]	km/vehicle	2.35E+05	5.40E+05	5.40E+05	5.40E+05
Average load	t/vehicle	0.30	2.93	5.82	9.68
Transport performance per vehicle	tkm/vehicle	7.05E+04	1.58E+06	3.14E+06	5.23E+06

1: taken from Maibach et al. (1999)

In addition, expenditures for the infrastructure of a road vehicle plant have been estimated and linked to vehicle manufacturing.

5.9.1 Vehicle Manufacturing

Material Composition of goods transportation road vehicles

Based on the material composition of a Volvo truck, (available from product declaration Volvo Truck Corporation (2004),. assumptions about the material composition are made and illustrated in Table 5-72.

Energy Consumption and Airborne Emissions in Vehicle Manufacturing

The figures presented here are used for all lorry (Heavy-Duty vehicle) classes regardless of vehicle weight category. The manufacturing of vans (light duty vehicles) is modelled with data from the production of passenger car manufacturing, as presented in chapter 5.10.

Energy expenditures for stationary combustion processes are available from environmental reports of a German lorry manufacturer MAN Nutzfahrzeuge AG (2000)andMAN Nutzfahrzeuge AG (2000). The data is available for various manufacturing sites performing different tasks in the manufacturing chain. The total value used in this study comprises stamping processes, metal part and wiring harness manufacturing, engine production and testing as well as the final assembly. In Table 5-65 the total yearly fuel and electricity consumption for this plant is summarised. The consumption per vehicle unit is calculated based on a vehicle output of 22918 vehicles, including 1855 “completely knocked down” vehicles for export to overseas countries.

Table 5-65: Specific energy consumption for the production of a Heavy-Duty vehicle (own calculations, based on MAN Nutzfahrzeuge AG (2000; MAN Nutzfahrzeuge AG (2002))

	unit	**total**	final assembly	engine production	metal parts & wiring harness	stamping
natural gas	MJ/lorry	**3.40E+04**	2.68E+04	5.81E+03	5.71E+02	8.28E+02
electricity	kwh/lorry	**4.74E+03**	3.35E+03	1.01E+03	1.17E+02	2.66E+02
light fuel oil	MJ/lorry	**9.06E+02**	1.53E+02	1.49E+02	1.08E+00	6.03E+02
diesel	kg/lorry	**1.87E+02**	1.11E+02	7.40E+01	2.48E-01	1.31E+00

We further assume that diesel is used for engine testing and the operation of fork-lifters. The latter is modeled as building machine. In Table 5-66 the assumed share used in this study is presented.

Table 5-66: Diesel use in lorry manufacturing (own calculations)

	unit	**Total**	final assembly	engine production	metal parts & wiring harness	stamping
diesel, burned in building machine	kg/vehicle	2.01E+01	1.11E+01	7.40E+00	2.48E-01	1.31E+00
engine test (lorry 28t operation empty)	kg/vehicle	1.67E+02	1.00E+02	6.66E+01	0	0

Based on the diesel consumption for engine testing, direct environmental emissions to air are calculated, employing the emission profile of a lorry 28t empty. NMVOC emission also include emissions of solvents (7.2 kg/lorry) used in manufacturing (95% in the final assembly).

Water Consumption in Vehicle Manufacturing

About 95% of the consumed tap water and groundwater are used in the final assembly of vehicles (own calculations based on MAN Nutzfahrzeuge AG (2002)). In Table 5-67 the water in- and output flows for the assembly plant are summarised.

Table 5-67: Water Input-Output balance MAN Nutzfahrzeuge AG (2000)

Input	unit		Output	
Drinking water	m3/a	3.63E+05	Surface waters	2.64E+05
Ground water 1)	m3/a	1.50E+06	Municipal waste water	3.65E+05
Rainfall 2)	m3/a	1.00E+06	Infiltration	1.73E+06
			Evaporation	5.00E+05
Total Input	**m3/a**	**2.86E+06**	**Total out**	**2.86E+06**

1: ground water is exclusively used as cooling water

2:currently rainwater is not used

About 45’000 m^3 of the drinking water are used for the production of de-ionised water. De-ioinsed water is used for painting processes. For the production of de-ionised water both, reverse-osmosis (20%) and ion-exchanger (80%)[1] are used.

About 65’000 m^3 of the water output are treated at the plant; 60’000 m3 are neutralised using FE(III) Cl-precipitation and the remaining 5000 m^3 are treated with ultra filtration.

Among the water leaving the plant, about 50,000 m^3 are contaminated. In Table 5-68 the contaminations are summarised. In this study for the calculation of the resulting environmental exchanges a particular module has been generated: “treatment lorry production effluent, to wastewater treatment, class 1” (see Doka (2003))

[1] Oral communication Susanne Stühler, MAN Nutzfahrzeuge Aktiengesellschaft.

Table 5-68: Composition of untreated wastewater to sewage

Pollutant	unit	
Chlorine (Cl)	kg/m3	1.14E-04
Nickel (Ni)	kg/m3	2.70E-04
Lead (Pb)	kg/m3	4.40E-05
Zinc (Zn)	kg/m3	4.84E-04

The consumption per vehicle unit is calculated, based on a vehicle output of 22918 vehicles, including 1855 "completely knocked down" vehicles for export to overseas countries.

For automotive stamping, a Chemical Oxygen Demand (COD) is reported MAN Nutzfahrzeuge AG (2002) with 12800 kg/year resulting in a specific COD of 0.126 kg/vehicle. Values for the, Biological Oxygen Demand (BOD5), Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC) are calculated according to ecoinvent quality guidelines Frischknecht et al. (2003).

Other Aspects of Vehicle Manufacturing

For rail- and road transport of materials, we employed standard distances as documented in Frischknecht & Jungbluth (2003) to account for environmental interventions due to essential transport services in the vehicle production. In Table 5-75 and Table 5-76 exchanges and environmental interventions, respectively, due to the manufacturing of one vehicle are presented.

5.9.2 Infrastructure Road Vehicle Plant

This module comprises land use and exchanges for the construction of buildings, roads and parking comprising various production within the vehicle manufacturing chain (metal part and wiring harness manufacturing and final assembly). The data input is established on own calculations based on figures obtained from MAN Nutzfahrzeuge AG (2000) documented in Table 5-69.

Table 5-69: Land occupation for road vehicle manufacturing

Land Use	unit	**total**	final assembly	metal parts & wiring harness
Sealed (industrial area) 1)	m2	8.83E+05	8.58E+05	2.49E+04
Sealed and built up (industrial area, built up)	m2	2.67E+05	2.58E+05	9.40E+03
Unsealed (vegetation)	m2	1.49E+05	1.36E+05	1.39E+04

1: Including built up area

In Table 5-74 the specific land use is presented assuming a total life span of the infrastructure of 50 years.

For material and energy consumption due to the construction and disposal of buildings on a factory site, no specific data was available. In consequence, we employed the generic modules as available from Kellenberger et al. (2003). We further assume that 70% of the built up area is occupied with building halls and 30% are used for office buildings (multi storey buildings) with an assumed height between the floors of 2.7m Kellenberger et al. (2003) and further assume an average of 5 floors. The remaining sealed area is modelled as road and parking infrastructure employing the module "roads, company, internal".

5.9.3 Vehicle Maintenance

For the determination of maintenance expenditures figures as reported in Frischknecht et al. (1996) are employed.

The foundations for the calculations are “Selbstkosten des Gütertransportes” ASTAG (1991) and personal information from a lorry manufacturer (IVECO). The determined data are representative for non-urban use of the vehicles and a yearly traffic performance of 70000 vkm/a (van 30000 km/a). The kilometric performance of the tyres depends on the number of axes and the number of starts and stops. In Table 5-70 the maintenance parts and materials are summarised. For the latter, the original data in Frischknecht et al. (1996), however, is documented in mass expenditures per transport performance. In order to determine the expenditures per vehicle unit we use the figures as presented in Table 5-64. For vans and lorries, 7.7 and 7.8 maintenance performances, respectively, are accounted for.

Table 5-70: Maintenance components and materials per 70000 km lorry and 30000 km van

Components/ materials	unit	van	16 t	28 t	40 t
Oil	kg	18	72	72	100
Grease	kg	8	29	36	50
Oil filter [1)]	unit	3.6	4	4	4
Air filter [2)]	unit	0.9	4	4	4
Exhaust pipe [3)]	unit	0.3	0.3	0.3	0.3
Break block [4)]	unit	1.4	0.6	0.6	0.6
Tyres [6)]	unit	31	43	86	100

1: 100 g paper and 900 g steel

2: 1 kg paper

3: lorry 40 t = 40 kg, 28t = 30kg; van = 10kg

4: 100% steel

6: figures are for the entire vehicle life span (share in steel: 17%)

The input value for lead (battery) has been calculated assuming two batteries – with a total weight of 108 kg – per truck. Based on Dietrich (1999) we assume a share of lead, H2SO4 and plastic of 68.2% 25.8% and 6%, respectively.

For the energy consumption due to maintenance activities, data from Maibach et al. (1999) have been employed. These figures are summarised in Table 5-71 and include energy expenditures of heating and lighting of service garages as well as energy expenditures for washing bays.

Table 5-71: Specific energy consumption [kg/vehicle unit] for maintenance activities of heavy and light duty vehicles

	Unit	Van	16 t	28 t	40 t
Electricity, low voltage	MJ/unit	1.32E+04	1.58E+04	1.58E+04	1.58E+04
Light fuel oil	MJ/unit	4.72E+04	5.67E+04	5.67E+04	5.67E+04

In Table 5-75 the exchanges due to the maintenance of one vehicle are presented.

5.9.4 Vehicle Disposal

For the disposal of vehicle we merely have taken into account the bulk material used in the vehicle and make a number of assumptions as follows:

- Steel, aluminium and copper are fully recycled and thus we make a cut off allocation

- 50% of all used tyres are used as a secondary fuel in Swiss cement works. Consequently we make a cut of allocation and merely take into account an average transport performance. We assume an average transport distance of 150 km from garage to cement works and an average weight of 30 kg per lorry tyre and 10 kg per light dusty vehicle, respectively. It should be beared in mind that about 30% of used tyres are exported BUWAL (2000).
- for the remaining materials a complete disposal is assumed.

5.9.5 Life Cycle Inventory Input Data

Table 5-72: Life cycle inventory table of vehicle manufacturing. Part 1: exchanges with the technosphere.

Explanations	Name	Location	Infrastructure-Process	Unit	lorry 16t	lorry 28t	lorry 40t
	Location				RER	RER	RER
	InfrastructureProcess				1	1	1
	Unit				unit	unit	unit
Outputs	lorry 16t	RER	1	unit	1		
	lorry 28t	RER	1	unit		1	
	lorry 40t	RER	1	unit			1
Technosphere	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	1.89E-1	1.89E-1	1.89E-1
	nitric acid, 50% in H2O, at plant	RER	0	kg	9.85E-2	9.85E-2	9.85E-2
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	3.81E-1	3.81E-1	3.81E-1
	sulphuric acid, liquid, at plant	RER	0	kg	2.79E+1	2.79E+1	2.79E+1
	acetic acid, 98% in H2O, at plant	RER	0	kg	6.60E-2	6.60E-2	6.60E-2
	lubricating oil, at plant	RER	0	kg	6.21E+1	1.00E+2	1.56E+2
	propylene glycol, liquid, at plant	RER	0	kg	2.20E+1	3.59E+1	5.63E+1
	lime, hydrated, packed, at plant	CH	0	kg	3.10E-1	3.10E-1	3.10E-1
	electronics for control units	RER	0	kg	3.00E+1	4.90E+1	7.68E+1
	diesel, burned in building machine	GLO	0	MJ	2.01E+1	2.01E+1	2.01E+1
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	4.74E+3	4.74E+3	4.74E+3
	flat glass, uncoated, at plant	RER	0	kg	4.50E+1	7.34E+1	1.15E+2
	rock wool, packed, at plant	CH	0	kg	1.00E+1	1.63E+1	2.56E+1
	aluminium, production mix, at plant	RER	0	kg	2.15E+2	3.51E+2	5.50E+2
	brass, at plant	CH	0	kg	2.00E+1	3.26E+1	5.12E+1
	cast iron, at plant	RER	0	kg	1.45E+3	1.80E+3	2.31E+3
	chromium steel 18/8, at plant	RER	0	kg	5.00E+0	8.16E+0	1.28E+1
	copper, at regional storage	RER	0	kg	3.00E+1	4.90E+1	7.68E+1
	lead, at regional storage	RER	0	kg	7.36E+1	7.36E+1	7.36E+1
	pig iron, at plant	GLO	0	kg	1.63E+3	2.94E+3	3.62E+3
	reinforcing steel, at plant	RER	0	kg	2.26E+3	3.97E+3	6.74E+3
	steel, low-alloyed, at plant	RER	0	kg	1.14E+1	1.99E+1	3.38E+1
	section bar rolling, steel	RER	0	kg	1.63E+3	2.94E+3	3.62E+3
	sheet rolling, steel	RER	0	kg	4.18E+2	6.82E+2	1.07E+3
	wire drawing, copper	RER	0	kg	3.00E+1	4.90E+1	7.68E+1
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	3.40E+4	3.40E+4	3.40E+4
	bitumen, at refinery	RER	0	kg	1.00E+1	1.63E+1	2.56E+1
	diesel, at regional storage	RER	0	kg	1.67E+2	1.67E+2	1.67E+2
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	9.06E+2	9.06E+2	9.06E+2
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	4.00E+1	6.53E+1	1.02E+2
	polyethylene, HDPE, granulate, at plant	RER	0	kg	2.30E+2	3.75E+2	5.89E+2
	synthetic rubber, at plant	RER	0	kg	3.75E+2	6.12E+2	9.60E+2
	road vehicle plant	RER	1	unit	8.73E-7	8.73E-7	4.36E-7
	transport, lorry 32t	RER	0	tkm	6.45E+2	1.05E+3	1.55E+3
	transport, freight, rail	RER	0	tkm	1.38E+3	2.25E+3	3.32E+3
	treatment, lorry production effluent, to wastewater treatment, class 1	CH	0	m3	2.18E+0	2.18E+0	2.18E+0
	treatment, sewage, to wastewater treatment, class 1	CH	0	m3	1.59E+1	1.59E+1	1.59E+1
	tap water, at user	RER	0	kg	1.64E+4	1.64E+4	1.64E+4
resource, in water	Water, well, in ground			m3	6.95E+1	6.95E+1	6.95E+1

Table 5-73: Life cycle inventory table of vehicle manufacturing. Part 2: exchanges with the environment.

Explanations	Name	Location	Infrastructure-Process	Unit	lorry 16t	lorry 28t	lorry 40t
	Location				RER	RER	RER
	InfrastructureProcess				1	1	1
	Unit				unit	unit	unit
Outputs	lorry 16t	RER	1	unit	1		
	lorry 28t	RER	1	unit		1	
	lorry 40t	RER	1	unit			1
air, unspecified	Ammonia			kg	2.23E-2	2.23E-2	2.23E-2
	Benzene			kg	1.31E-2	1.31E-2	1.31E-2
	Cadmium			kg	1.73E-6	1.73E-6	1.73E-6
	Carbon dioxide, fossil			kg	6.33E+2	6.33E+2	6.33E+2
	Carbon monoxide, fossil			kg	9.73E-1	9.73E-1	9.73E-1
	Chromium			kg	2.93E-4	2.93E-4	2.93E-4
	Copper			kg	2.93E-4	2.93E-4	2.93E-4
	Dinitrogen monoxide			kg	2.23E-2	2.23E-2	2.23E-2
	Heat, waste			MJ	1.71E+4	1.71E+4	1.71E+4
	Lead			kg	1.90E-8	1.90E-8	1.90E-8
	Mercury			kg	3.45E-9	3.45E-9	3.45E-9
	Methane, fossil			kg	1.65E-2	1.65E-2	1.65E-2
	Nickel			kg	1.21E-5	1.21E-5	1.21E-5
	Nitrogen oxides			kg	6.00E+0	6.00E+0	6.00E+0
	NMVOC, non-methane volatile organic compounds, unspecified origin			kg	7.87E+0	7.87E+0	7.87E+0
	Particulates, < 2.5 um			kg	2.54E-1	2.54E-1	2.54E-1
	Particulates, > 10 um			kg	1.09E-2	1.09E-2	1.09E-2
	Particulates, > 2.5 um, and < 10um			kg	2.12E-2	2.12E-2	2.12E-2
	Selenium			kg	1.73E-6	1.73E-6	1.73E-6
	Sulfur dioxide			kg	1.20E-1	1.20E-1	1.20E-1
	Toluene			kg	5.51E-3	5.51E-3	5.51E-3
	Xylene			kg	5.51E-3	5.51E-3	5.51E-3
	Zinc			kg	1.73E-4	1.73E-4	1.73E-4
water, unspecified	BOD5, Biological Oxygen Demand			kg	1.26E-1	1.26E-1	1.26E-1
	COD, Chemical Oxygen Demand			kg	1.26E-1	1.26E-1	1.26E-1
	DOC, Dissolved Organic Carbon			kg	5.51E-2	5.51E-2	5.51E-2
	TOC, Total Organic Carbon			kg	5.51E-2	5.51E-2	5.51E-2

Table 5-74: Life cycle inventory table of road vehicle plant

	Name	Location	Unit	road vehicle plant	Uncertainty Type	Standard Deviation95 %	GeneralComment
product	road vehicle plant	RER	unit	1.00E+0			
technosphere	building, hall	CH	m2	2.40E+5	1	3.35	(4,4,3,3,2,5); environmental report and own calculations
	building, multi-storey	RER	m3	3.61E+5	1	3.35	(4,4,3,3,2,5); environmental report and own calculations
	roads, company, internal	CH	m2a	3.08E+7	1	3.35	(4,4,3,3,2,5); environmental report and own calculations
land use	Occupation, industrial area	-	m2a	3.08E+7	1	1.56	(1,4,1,1,1,1); environmental report and own calculations
	Occupation, industrial area, built up	-	m2a	1.34E+7	1	1.56	(1,4,1,1,1,1); environmental report and own calculations
	Occupation, industrial area, vegetation	-	m2a	7.47E+6	1	1.56	(1,4,1,1,1,1); environmental report and own calculations
	Transformation, from unknown	-	m2	1.03E+6	1	2.05	(1,4,1,1,1,1); environmental report and own calculations
	Transformation, to industrial area	-	m2	6.16E+5	1	2.05	(1,4,1,1,1,1); environmental report and own calculations
	Transformation, to industrial area, built up	-	m2	2.67E+5	1	2.05	(1,4,1,1,1,1); environmental report and own calculations
	Transformation, to industrial area, vegetation	-	m2	1.49E+5	1	2.05	(1,4,1,1,1,1); environmental report and own calculations

Table 5-75: Life cycle inventory table of vehicle maintenance.

Explanations	Name	Location	Infrastructure-Process	Unit	maintenance, lorry 16t	maintenance, lorry 28t	maintenance, lorry 40t
	Location				CH	CH	CH
	InfrastructureProcess				1	1	1
	Unit				unit	unit	unit
Outputs	maintenance, lorry 16t	CH	1	unit	1.00E+0		
	maintenance, lorry 28t	CH	1	unit		1.00E+0	
	maintenance, lorry 40t	CH	1	unit			1.00E+0
Technosphere	lubricating oil, at plant	RER	0	kg	7.80E+2	8.32E+2	1.17E+3
	electricity, low voltage, at grid	CH	0	kWh	4.43E+3	4.43E+3	4.43E+3
	lead, at regional storage	RER	0	kg	2.10E+2	2.10E+2	2.10E+2
	reinforcing steel, at plant	RER	0	kg	5.75E+2	1.06E+3	1.24E+3
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	5.67E+4	5.67E+4	5.67E+4
	paper, woodfree, uncoated, at regional storage	RER	0	kg	3.50E+1	3.50E+1	3.50E+1
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.42E+2	1.42E+2	1.42E+2
	synthetic rubber, at plant	RER	0	kg	1.10E+3	2.11E+3	4.21E+3
	transport, lorry 28t	CH	0	tkm	2.03E+2	2.80E+2	4.11E+2
	transport, freight, rail	CH	0	tkm	8.11E+2	1.12E+3	1.64E+3
	sulphuric acid, liquid, at plant	RER	0	kg	7.97E+1	7.97E+1	7.97E+1

Table 5-76: Life cycle inventory table of vehicle disposal

	Name	Location	Unit	disposal, lorry 16t	disposal, lorry 28t	disposal, lorry 40t	UncertaintyType	StandardDeviation95%	GeneralComment
product	disposal, lorry 16t	CH	unit	1.00E+0					
	disposal, lorry 28t	CH	unit		1.00E+0				
	disposal, lorry 40t	CH	unit			1.00E+0			
disposal	disposal, plastics, mixture, 15.3% water, to r	CH	kg	2.30E+2	3.75E+2	5.89E+2	1	1.16	(3,4,1,3,1,1); material composition
	transport, lorry 28t	CH	tkm	1.94E+2	3.87E+2	4.50E+2	1	2.03	(3,4,1,3,1,1); transport of tyres, data based on oral communication.
	disposal, glass, 0% water, to municipal inci	CH	kg	4.50E+1	7.34E+1	1.15E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.
	disposal, emulsion paint, 0% water, to muni	CH	kg	4.00E+1	6.53E+1	1.02E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.
	disposal, zinc in car shredder residue, 0% w	CH	kg	2.00E+1	3.26E+1	5.12E+1	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.
	disposal, used mineral oil, 10% water, to ha	CH	kg	2.52E+1	2.71E+1	3.78E+1	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.

Data Quality and Uncertainty

If not stated explicitly, for the representation of uncertainties a lognormal distribution has been applied. The standard deviation comprises a basic uncertainty and further uncertainties generated with the pedigree matrix Frischknecht et al. (2003). The scores of the different data quality indicators are given in the above tables.

Manufacturing of vehicles

In order to estimate the material consumption, the material composition of average lorries have been employed. The composition is easy to determine and we assume that the data quality is good. For some materials, however, only general information was available, such as plastic used, or “other metals”. In such cases we made simple assumptions, for instance, in a first estimation all unknown plastic is accounted for as polyethylene. It should be beared in mind that the share of waste materials is not accounted for.

The data for the manufacturing of vehicles merely represents several sites of a German lorry manufacturer including sites in Austria and the Czech Republic. Thus, the geographical and also technological representativeness is considered as sufficient. The quality of the actual figures is considered as good; however, further uncertainties arise, when referring the data to one vehicle

Infrastructure road vehicle plant

Most data concerning the production-building hall are estimations and hence the modules are of poor overall quality. The data for the multi-storey building are based on two specific buildings, one in Switzerland and one in Germany. The usage of this average for a module with the validity for Western Europe has a very high uncertainty. Also, the share of two types of buildings (hall and multi-storey building) is based on own estimates. Furthermore, machinery used in the manufacturing has not been accounted for. Thus, these data may not be used when having a high importance in a certain context, however, for this study the significance is considered as fairly low. Land use data is based on data from one environmental report and thus geographical and also technological representativeness is considered as low.

Maintenance

The figures determined for maintenance must be considered as rough estimates and thus of low data quality.

Disposal

For the disposal of vehicles, only bulk materials of the vehicles have been taken into account. For these materials, however, the data quality is good. Furthermore, it should be beared in mind that the disposal modules merely reflect Swiss disposal conditions. In consequence, the uncertainty at stake is rather a methodological uncertainty, i.e. uncertainties arise due to a lack of knowledge.

5.10 Passenger Car Vehicle Fleet

5.10.1 Vehicle Manufacturing

For the expenditures and environmental interventions due to the manufacturing of passenger cars, we employed data from a recent lifecycle inventory analysis of the “Golf A4, 1.4 l Otto” Schweimer & Levin (2002). In Table 5-77 the life cycle inventory for manufacturing of a passenger car and an average delivery van are presented. Infrastructure expenditures are accounted for by employing the road vehicle plant module as documented in the previous section. Emissions to air, apart from NMVOC emissions, are assumed to result from stationary combustion processes and are accounted for by employing the referring ecoinvent unit processes. Manufacturing values for vans are partly based on data available from Frischknecht (1996) and Maibach (1999)and complemented with modified values from passenger car maintenances. The data has been taken from the super ordinate plan for “Golf A4 Technosphere”. The fraction of plastics is characterised by a great variety of products, however, not for all these products LCI-data is available in the ecoinvent database. In consequence, products for which no LCI data have been available are classified as polyethylene.

5.10.2 Vehicle Maintenance

For passenger cars, maintenance values are also taken from the super ordinate plan. Maintenance values for vans are partly based on data available from Frischknecht (1996) and Maibach (1999) and complemented with modified values from passenger car maintenances. In Table 5-78 the life cycle inventory for maintenance of a passenger car and an average delivery van is presented.

5.10.3 Vehicle Disposal

For the disposal of vehicles we merely have taken into account the bulk material used in the vehicle and make a number of assumptions as follows:

- steel, aluminium and copper are fully recycled and thus we make a cut off allocation;
- 50% of all used tyres are used as a secondary fuel in Swiss cement works. Consequently we make a cut of allocation and merely take into account an average transport of 150 km per used tyres to the cement works. It should be bared in mind that about 30% of used tyres are exported BUWAL (2000);
- for the remaining materials disposal is addressed in referring disposal modules as summarised in the below table;

In Table 5-77 the life cycle inventory for passenger car manufacturing is presented. Moreover, the data for an average delivery van is given.

5.10.4 Life Cycle Inventory Input Data

Table 5-77: Life cycle inventory table of manufacturing of passenger cars and vans

	Name	Location	Infra	Unit	passenger	UncertaintyType	StandardDeviation95 %	GeneralComment	van <3.5t	UncertaintyType	StandardDeviation95 %	GeneralComment
product	passenger car	RER	1	unit	1.00E+0							
	van <3.5t	RER	1	unit					1.00E+0			
technosphere	steel, low-alloyed, at plant	RER	0	kg	9.90E+1	1	1.20	LCI of a VW Golf	1.04E+3	1	1.20	literatur study
	reinforcing steel, at plant	RER	0	kg	8.91E+2	1	1.20	LCI of a VW Golf	1.17E+2	1	1.20	literature study
	sheet rolling, steel	RER	0	kg	5.41E+2	1	1.20	LCI of a VW Golf	8.10E+2	1	1.20	literature study
	section bar rolling, steel	RER	0	kg	2.03E+2	1	1.20	LCI of a VW Golf	3.47E+2	1	1.20	literature study
	wire drawing, copper	RER	0	kg	1.01E+1	1	1.20	LCI of a VW Golf	1.22E+3	1	1.20	literature study
	copper, at regional storage	RER	0	kg	1.01E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	2.70E+1	1	1.17	(2,3,2,1,1,3); literature study
	chromium, at regional storage	RER	0	kg	2.40E+0	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	2.40E+0	1	1.17	(2,3,2,1,1,3); LCI of a VW Golf
	nickel, 99.5%, at plant	GLO	0	kg	1.40E+0	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	1.40E+0	1	1.17	(2,3,2,1,1,3); literature study
	aluminium, production mix, at plant	RER	0	kg	5.18E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	8.40E+1	1	1.17	(2,3,2,1,1,3); literature study
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.02E+2	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	2.70E+1	1	1.17	(2,3,2,1,1,3); literature study
	polypropylene, granulate, at plant	RER	0	kg	4.90E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	4.90E+1	1	1.17	(2,3,2,1,1,3); LCI of a VW Golf
	polyvinylchloride, at regional storage	RER	0	kg	1.60E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	1.60E+1	1	1.17	(2,3,2,1,1,3); LCI of a VW Golf
	synthetic rubber, at plant	RER	0	kg	4.41E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	7.20E+1	1	1.17	(2,3,2,1,1,3); literature study
	flat glass, uncoated, at plant	RER	0	kg	3.01E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	4.50E+1	1	1.17	(2,3,2,1,1,3); literature study
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	4.16E+0	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	1.20E+1	1	1.17	(2,3,2,1,1,3); literature study
	platinum, at regional storage	GLO	0	kg	1.60E-3	1	1.24	(1,4,1,3,1,1); literature studies	1.60E-3	1	1.17	(2,3,2,1,1,3); literature study
	palladium, at regional storage	GLO	0	kg	3.00E-4	1	1.24	(1,4,1,3,1,1); literature studies	3.00E-4	1	1.17	(2,3,2,1,1,3); literature study
	zinc for coating, at regional storage	RER	0	kg	5.89E+0	1	1.24	own calculations based on LCI of a VW Golf		1	1.17	(2,3,2,1,1,3); literature study
	heat, natural gas, at industrial furnace >100kW	RER	0	MJ	2.22E+3	1	1.24	(1,4,1,3,1,1); literature studies	2.22E+3	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	2.14E+3	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	2.14E+3	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	6.30E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	6.30E+1	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	tap water, at user	RER	0	kg	3.22E+3	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	3.22E+3	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	lead, at regional storage	RER	0	kg	1.30E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	1.30E+1	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	ethylene, average, at plant	RER	0	kg	1.85E+1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	1.85E+1	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	ethylene glycol, at plant	RER	0	kg	4.80E+0	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	4.80E+0	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	sulphuric acid, liquid, at plant	RER	0	kg	8.00E-1	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	8.00E-1	1	1.22	(2,4,1,1,2,1); LCI of a VW Golf
	transport, lorry 32t	RER	0	tkm	5.30E+1	1	2.06	(1,4,1,3,1,1); LCI of a VW Golf	5.30E+1	1	2.06	(2,4,1,3,1,1); LCI of a VW Golf
	transport, freight, rail	RER	0	tkm	5.30E+2	1	2.06	(1,4,1,3,1,1); LCI of a VW Golf	5.30E+2	1	2.06	(2,4,1,3,,); LCI of a VW Golf
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin			kg	4.80E+0	1	1.58	(1,4,1,3,1,1); LCI of a VW Golf	4.80E+0	1	1.58	(2,4,1,3,1,1); LCI of a VW Golf
	Heat, waste			MJ	7.70E+3	1	1.24	(1,4,1,3,1,1); LCI of a VW Golf	7.70E+3	1	1.24	(2,4,1,3,1,1); LCI of a VW Golf
emissions to water	COD, Chemical Oxygen Demand			kg	1.93E-1	1	1.58	(1,4,1,3,1,1); LCI of a VW Golf	1.93E-1	1	1.58	(2,4,1,3,1,1); LCI of a VW Golf
	BOD5, Biological Oxygen Demand			kg	2.60E-2	1	1.58	(1,4,1,3,1,1); LCI of a VW Golf	2.60E-2	1	1.58	(2,4,1,3,1,1); LCI of a VW Golf
	Phosphate			kg	1.00E-3	1	1.58	(1,4,1,3,1,1); LCI of a VW Golf	1.00E-3	1	1.58	(2,4,1,3,1,1); LCI of a VW Golf
technosphere	road vehicle plant	RER	1	unit	2.91E-7	1	3.28	(5,4,3,1,1,1); environmental report and own calculations	2.91E-7	1	3.28	(5,4,3,1,1,1); environmental report and own calculations

Table 5-78: Life cycle inventory table of maintenance of passenger car vehicles and vans.

	Name	Location	Unit	maintenance, van < 3.5t	UncertaintyType	StandardDeviation95%	GeneralComment	maintenance passenger car	UncertaintyType	StandardDeviation95%	GeneralComment
	maintenance, van < 3.5t	RER	unit	1.00E+0							
	maintenance, passenger car	RER	unit					1.00E+0			
technosphere	steel, low-alloyed, at plant	RER	kg	2.20E+1	1	1.00	(3,4,2,1,1,4); oral communication and own calculations	1.10E+1	1	1.24	(1,4,1,3,1,1); LCI of one car
	copper, at regional storage	RER	kg	3.00E-1	1	1.86	(4,5,3,3,1,5); LCI of one passenger car	3.00E-1	1	1.24	(1,4,1,3,1,1); LCI of one car
	polyethylene, HDPE, granulate, at plant	RER	kg	1.00E+1	1	1.86	(4,5,3,3,1,5); oral communication and own calculations	5.00E+0	1	1.24	(1,4,1,3,1,1); LCI of one car
	polypropylene, granulate, at plant	RER	kg	1.20E+1	1	1.86	(4,5,3,3,1,5); oral communication and own calculations	6.00E+0	1	1.24	(1,4,1,3,1,1); LCI of one car
	synthetic rubber, at plant	RER	kg	2.33E+2	1	1.86	(4,5,3,3,1,5); oral communication and own calculations	1.16E+2	1	1.24	(1,4,1,3,1,1); LCI of one car
	electricity, low voltage, production UCTE, at grid	UCTE	kWh	8.47E+3	1	1.86	(4,5,3,3,1,5); oral communication and own calculations	5.83E+2	1	1.24	(1,4,1,3,1,1); LCI of one car
	lead, at regional storage	RER	kg	1.30E+1	1	1.86	(4,5,3,3,1,5); oral communication and own calculations	2.50E+1	1	1.24	(1,4,1,3,1,1); LCI of one car
	ethylene, average, at plant	RER	kg	3.80E+1	1	1.86	(4,5,3,3,1,5); LCI of one passenger car	3.80E+1	1	1.24	(1,4,1,3,1,1); LCI of one car
	ethylene glycol, at plant	RER	kg	2.00E+0	1	1.86	(4,5,3,3,1,5); LCI of one passenger car	2.00E+0	1	1.24	(1,4,1,3,1,1); LCI of one car
	sulphuric acid, liquid, at plant	RER	kg	1.40E+0	1	1.86	(4,5,3,3,1,5); LCI of one passenger car	1.40E+0	1	1.24	(1,4,1,3,1,1); LCI of one car
	transport, lorry 32t	RER	tkm	3.18E+1	1	2.30	(4,5,3,3,1,na); standard transport distance	2.96E+1	1	2.11	(4,4,1,3,1,na); standard transport distance
	transport, freight, rail	RER	tkm	6.37E+1	1	2.30	(4,5,3,3,1,na); standard transport distance	5.93E+1	1	2.11	(4,4,1,3,1,na); standard transport distance
	Heat, waste		MJ	3.05E+4	1	1.60	(4,5,3,3,1,na); LCI of one passenger car	2.10E+3	1	1.32	(4,4,1,3,1,na); standard value

Table 5-79: Life cycle inventory table of disposal of passenger cars and vans.

	Name	Location	Unit	disposal, van < 3.5t	disposal, passenger car	UncertaintyType	StandardDeviation95 %	General Comment
product	maintenance, van < 3.5t	RER	unit					
	maintenance, passenger car	RER	unit					
disposal	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	kg	2.70E+1	6.50E+1	1	1.15	(3,4,1,1,1,1); material composition
	transport, lorry 28t	CH	tkm	4.65E+1	3.26E+1	1	2.03	(3,4,1,1,1,1); oral communication
	disposal, glass, 0% water, to municipal incineration	CH	kg	4.50E+1	3.01E+1	1	1.15	(3,4,1,1,1,1); material composition
	disposal, emulsion paint remains, 0% water, to hazardous waste incineration	CH	kg	1.20E+1	1.00E+2	1	1.15	(3,4,1,1,1,1); material composition
	disposal, zinc in car shredder residue, 0% water, to municipal incineration	CH	kg	1.44E+1	5.89E+0	1	1.15	(3,4,1,1,1,1); material composition

Data Quality and Uncertainties

Passenger Cars

Whilst the reliability of the production and maintenance data of the vehicle for itself is high, the selected vehicle type is merely representative for a small amount of passenger car vehicle market. The technological representativeness is unknown. Thus, in total, we consider the quality of the data as sufficient.

Vans

For vans, no specific manufacturing nor maintenance data is available. The data presented in this study must be considered as rough estimates.

5.11 Public Road Transportation Vehicle Fleet

In this section, exchanges and environmental interventions due to vehicle manufacturing, maintenance and disposal are addressed. These environmental interventions are related to one vehicle unit.

In order to relate these interventions to the functional unit of 1 tkm, kilometric and transport performance per average vehicle must be determined. The figures used in this study are presented in Table 5-64.

Table 5-80: Reference figures for an average van and various lorry classes

Reference figure	unit	Coach	Regular bus	Trolley Bus	Tram
Average Life Span	a/v	12.5 [1)]	12.5 [1)]	17 [2)]	30 [1)]
Kilometric performance per vehicle (over total life span)	km	1'000'000 [3)]	1'000'000 [3)]	1'416'666	1.12E06 [1)]
Average load [3)]	p/vehicle	21.1	12.3	26.0	52.8
Transport performance per vehicle	pkm/vehicle	11'300'000	6'640'000	19'867'050	59'100'000

1: taken from Maibach et al. (1999)

2: oral communication city of Lugarno

3: Volvo Truck Corporation (2004)

In addition, expenditures for the infrastructure of a road vehicle plant have been estimated and linked to vehicle manufacturing.

5.11.1 Vehicle Manufacturing

Material Composition of goods transportation road vehicles

Buses and trams appear in many different guises. Passenger capacity, floor height, layout, comfort level, interior design – everything can be tailored to suit individual needs. The material composition of the modelled bus in this research is based on the material composition of a Volvo bus, (available from product declaration Volvo Truck Corporation (2004)). Assumptions about the material composition are made and illustrated in Table 5-83. The material composition of a tram is obtained from Maibach et al. (1999). In Table 5-87 the life cycle inventory input data and direct emissions are summarised.

Energy Consumption and Emissions in Vehicle Manufacturing

Energy figures and environmental interventions for bus manufacturing are assumed to be the same as for the manufacturing of lorries (see section 5.9.1). The figures presented here are used for all buses regardless of vehicle type. Manufacturing expenditures and interventions for a tram are obtained from Maibach et al. (1999). However, we assume that 50% of the heating energy is based on natural gas and 50% is based on light fuel oil.

5.11.2 Vehicle Maintenance

Energy consumption for the operation of service garages as well as direct emissions of VOCs are taking into account. The resulting figures are summarised in Table 5-81 and

Table 5-81: Maintenance expenditures and emissions of buses

	Unit	Specific consumption bus maintenance [1)]	Unit	Specific consumption bus maintenance [3)]
Electricity [1)]	KWh/a	700000	KWh/bus*a)	5426
Natural gas [1)]	MJ/a	833000	MJ/(bus*a)	3230 [4)]
Light fuel oil	MJ/a	-	MJ/(bus*a)	3230 [4)]
Water consumption [1)]	m^3/a	5000	m^3/(bus*a)	39
Lubricating oil [1)]	Kg/a	8500	Kg/(bus*a)	66
Cooling agent [1)]	Kg/a	130	Kg/(bus*a)	1
VOC [2)]	Kg/a	4000	Kg/(bus*a)	7.03 [5)]

1: figures derived from Service garages in Berne. (bus maintenance)

2: figures derived from service garages in Zurich (bus and tram maintenance)

3: the presented figures are employed for coaches, regular buses and trolley buses

4: for heating energy we assume a split of 50% natural gas and 50% light fuel oil.

5: allocation between buses and trams is performed using the vkm-performance.

Table 5-82: Maintenance expenditures and emissions of trams

	Unit	Specific consumption bus maintenance [1)]	Unit	Specific consumption bus maintenance [3)]
Electricity [2)]	KWh/a	2860000	KWh/tram*a)	5426
Natural gas [2)]	MJ/a	1259403	MJ/(tram*a)	2580000 [4)]
Light fuel oil [2)]	MJ/a	3900205	MJ/(tram*a)	2580000 [4)]
Water consumption [1)]	m^3/a	5000	m^3/(tram*a)	39
Sand [2)]	Kg/a	300000	Kg/(tram*a)	3488
VOC [2)]	Kg/a	4000	Kg/(tram*a)	8.02 [5)]

1: figures derived from Service garages in Berne. (bus maintenance)

2: figures derived from service garages in Zurich (bus and tram maintenance)

3: the presented figures represent a tram comprising 1 traction vehicle and 0.5 trailer.

4: for heating energy we assume a split of 50% natural gas and 50% light fuel oil.

5: allocation between buses and trams is performed using the vkm-performance.

5.11.3 Vehicle Disposal

For the disposal of vehicles we merely have taken into account the bulk material used in the vehicle and make a number of assumptions as follows:

- Steel, aluminium and copper are fully recycled and thus we make a cut-off allocation
- 50% of all used bus tyres are used as a secondary fuel in Swiss cement works. Consequently we make a cut of allocation and merely take into account an average transport performance. We assume an average transport distance of 150 km from garage to cement works and an average weight of 30 kg per bus tyre. It should be beared in mind that about 30% of used tyres are exported BUWAL (2000);
- for the remaining materials a complete disposal is assumed.

5.11.4 Life Cycle Inventory Input Data

Table 5-83: Input data for bus manufacturing Part 1: exchanges with the technosphere

	Name	Location	Infra	Unit	bus	Uncertainty Type	Standard Deviation 95%	GeneralComment
	Location				RER			
	InfrastructureProcess				1			
	Unit				unit			
product	bus	RER	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	4.54E+3	1	1.12	Based on the material composition of a Volovo FH as available from product declaration. No information about the share of unalloyed and low alloyed steel is available. Assumption: 99.5% of used steel is unalloyed.
	steel, low-alloyed, at plant	RER	0	kg	2.28E+1	1	10.0	Based on the material composition of a Volovo FH as available from product declaration. No information about the share of unalloyed and low alloyed steel is available. Assumption: 0.5% of used steel is low alloyed.
	sheet rolling, steel	RER	0	kg	5.68E+2	1	1.12	Based on the material composition of a Volovo FH as available from product declaration.
	cast iron, at plant	RER	0	kg	103E+3	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	section bar rolling, steel	RER	0	kg	5.02E+2	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	pig iron, at plant	GLO	0	kg	5.02E+2	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	chromium steel 18/8, at plant	RER	0	kg	6.90E+2	1	2.0	Based on the material composition of a Volovo FH as available from product declaration.
	aluminium, production mix, at plant	RER	0	kg	167E+3	1	2.0	Based on the material composition of a Volovo FH as available from product declaration.
	copper, at regional storage	RER	0	kg	109E+2	1	2.0	Based on the material composition of a Volovo FH as available from product declaration.
	wire drawing, copper	RER	0	kg	109E+2	1	2.0	Based on the material composition of a Volovo FH as available from product declaration.
	polyethylene, HDPE, granulate, at plant	RER	0	kg	5.53E+2	1	2.0	Based on the material composition of a Volovo FH as available from product declaration.
	synthetic rubber, at plant	RER	0	kg	4.05E+2	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	flat glass, coated, at plant	RER	0	kg	4.90E+2	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	tempering, flat glass	RER	0	kg	4.90E+2	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	3.00E+1	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	brass, at plant	CH	0	kg	3.00E+0	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	refrigerant R134a, at plant	RER	0	kg	2.00E+0	1	1.15	Based on the material composition of a Volovo FH as available from product declaration.
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	3.40E+4	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	electricity, low voltage, at grid	CH	0	kWh	-	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	4.74E+3	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	9.06E+2	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	diesel, burned in building machine	GLO	0	MJ	2.01E+1	1	3.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	diesel, at regional storage	RER	0	kg	167E+2	1	3.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	tap water, at user	RER	0	kg	164E+4	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Water, well, in ground		-	m3	6.95E+1	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	lubricating oil, at plant	RER	0	kg	8.01E+1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	3.81E-1	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	lime, hydrated, packed, at plant	CH	0	kg	3.10E-1	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company. For Ca(OH)2, 50% H2O is assumed.
	acetic acid, 98% in H2O, at plant	RER	0	kg	6.60E-2	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	nitric acid, 50% in H2O, at plant	RER	0	kg	9.85E-2	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	189E-1	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	lead, at regional storage	RER	0	kg	9.00E+1	1	1.12	Lead used in battery; based on the material composition of a Volovo FH. Data available from product declaration.
	sulphuric acid, liquid, at plant	RER	0	kg	3.40E+1	1	1.12	H2SO4 used in battery; based on the material composition of a Volovo FH. Data available from product declaration.
	rock wool, packed, at plant	CH	0	kg	3.96E+2	1	1.12	Based on the material composition of a Volovo FH as available from product declaration.
	propylene glycol, liquid, at plant	RER	0	kg	2.60E+1	1	1.12	Based on the material composition of a Volovo FH as available from product declaration.
	bitumen, at refinery	RER	0	kg	5.40E+1	1	1.12	Based on the material composition of a Volovo FH as available from product declaration.
	electronics for control units	RER	0	kg	-	1	1.12	Based on the material composition of a Volovo FH as available from product declaration.
	transport, lorry 32t	RER	0	tkm	106E+3	1	2.1	standard transport distance
	transport, freight, rail	RER	0	tkm	2.46E+3	1	2.1	standard transport distance
	treatment, sewage, to wastewater treatment, class 1	CH	0	m3	159E+1	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	treatment, lorry production effluent, to wastewater treatment, class 1	CH	0	m3	2.18E+0	1	1.12	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company.
	road vehicle plant	RER	1	unit	8.73E-7	1	3.0	Based on the yearly production in 2000 and a life span of 50 yrs. Both, the yearly production and life span are uncertain.

Table 5-84: Input data for bus manufacturing. Part 2: exchanges with the environment

	Name	Location	Infra	Unit	bus	Uncertainty Type	Standard Deviation 95%	GeneralComment
	Location				RER			
	InfrastructureProcess				1			
	Unit				unit			
product	bus	RER	1	unit	1.00E+0			
emissions to air	Benzene			kg	1.31E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Methane, fossil			kg	1.65E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Carbon monoxide, fossil			kg	9.73E-1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Carbon dioxide, fossil			kg	6.33E+2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Dinitrogen monoxide			kg	2.23E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Ammonia			kg	2.23E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	NMVOC, non-methane volatile organic compounds, unspecified origin			kg	7.87E+0	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Nitrogen oxides			kg	6.00E+0	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Sulfur dioxide			kg	1.20E-1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Toluene			kg	5.51E-3	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Xylene			kg	5.51E-3	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Particulates, > 10 um			kg	1.09E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Particulates, > 2.5 um, and < 10um			kg	2.12E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Particulates, < 2.5 um			kg	2.54E-1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Lead			kg	1.90E-8	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Cadmium			kg	1.73E-6	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Copper			kg	2.93E-4	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Chromium			kg	2.93E-4	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Nickel			kg	1.21E-5	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Selenium			kg	1.73E-6	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Zinc			kg	1.73E-4	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Mercury			kg	3.45E-9	1	5.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts.
	Heat, waste			MJ	1.71E+4	1	1.2	(1,4,1,1,1,1); standard values
emissions to water	COD, Chemical Oxygen Demand			kg	1.26E-1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company.
	BOD5, Biological Oxygen Demand			kg	1.26E-1	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company. Value calculated from COD value assuming BOD5=COD.
	TOC, Total Organic Carbon			kg	5.51E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company. Value calculated from COD value assuming TOC=DOC=COD*14/32.
	DOC, Dissolved Organic Carbon			kg	5.51E-2	1	2.0	Data represent MAN production sites in Germany and comprises: final truck assembly, engine manufacturing, manufacturing of metal parts. Data available from environmental reports of the company. Value calculated from COD value assuming TOC=DOC=COD*14/32.

Table 5-85: Life cycle inventory input data for bus maintenance

	Name	Location	Infra	Unit	maintenance, bus	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				*CH*			
	InfrastructureProcess				*1*			
	Unit				*unit*			
product	maintenance, bus	CH	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	5.50E+1	1	2.00	Literature studies. Original data is derived from expert estimates and comprising steel used in tyres and oil filters, brake shoes, exhaust.
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.40E+0	1	2.00	Literature studies. Original data is derived from expert estimates.
	synthetic rubber, at plant	RER	0	kg	1.33E+2	1	2.00	Literature studies. Original data is derived from expert estimates.
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	4.04E+4	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	electricity, low voltage, at grid	CH	0	kWh	6.78E+4	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	light fuel oil, burned in industrial furnace 1MW, non	RER	0	MJ	4.04E+4	1	1.80	Literature studies. Original data is derived from expert estimates.
	tap water, at user	CH	0	kg	4.84E+5	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	lubricating oil, at plant	RER	0	kg	8.24E+2	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	lead, at regional storage	RER	0	kg	1.79E+1	1	1.80	Literature studies. Original data is derived from expert estimates.
	paper, woodfree, uncoated, at regional storage	RER	0	kg	3.15E+0	1	2.00	Literature studies. Original data is derived from expert estimates.
	transport, freight, rail	CH	0	tkm	2.07E+2	1	2.09	standard transport distances
	Heat, waste			MJ	2.44E+5	1	1.80	standard calculation
disposal	disposal, used mineral oil, 10% water, to hazardous	CH	0	kg	8.24E+2	1	2.00	own calculation based on maintenance input data.
disposal	disposal, plastics, mixture, 15.3% water, to municipa	CH	0	kg	5.50E+1	1	2.00	own calculation based on maintenance input data.
disposal	treatment, sewage, to wastewater treatment, class	CH	0	m3	4.84E+2	1	2.00	own calculation based on maintenance input data.
	transport, lorry 28t	CH	0	tkm	5.17E+1	1	2.09	standard transport distances

Table 5-86: Life cycle inventory input data for bus disposal

	Name	Location	Infra	Unit	disposal, bus	Uncertainty Type	Standard Deviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1.00E+0			
	Unit				unit			
product	disposal, bus	CH	1	unit	1.00E+0			
disposal	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	5.53E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a bus
	transport, lorry 28t	CH	0	tkm	1.41E+1	1	2.03	(3,4,1,3,1,1); transport of tyres, data based on oral communication.
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	1.15E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a bus
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	1.20E+1	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a bus
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	2.52E+1	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a bus

Table 5-87: Life cycle inventory input data for tram manufacturing

	Name	Location	Infra	Unit	tram	Uncertainty Type	Standard Deviation 95%	GeneralComment
	Location				***RER***			
	InfrastructureProcess				***1***			
	Unit				***unit***			
product	tram	RER	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	1.67E+4	1	1.5	Literature data
	aluminium, production mix, at plant	RER	0	kg	5.88E+2	1	2.0	Literature data
	copper, at regional storage	RER	0	kg	1.46E+3	1	2.0	Literature data
	polyethylene, HDPE, granulate, at plant	RER	0	kg	8.50E+2	1	2.0	Literature data
	synthetic rubber, at plant	RER	0	kg	1.96E+2	1	2.0	Literature data
	flat glass, uncoated, at plant	RER	0	kg	7.63E+2	1	1.5	Literature data
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	3.71E+2	1	2.0	Literature data
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	2.42E+4	1	3.0	Literature data, very rough estimate
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	1.74E+5	1	3.0	Literature data, very rough estimate
	lead, at regional storage	RER	0	kg	6.41E+1	1	2.0	Literature data
	transport, lorry 32t	RER	0	tkm	2.09E+3	1	2.1	standard transport distances
	transport, freight, rail	RER	0	tkm	4.64E+3	1	2.1	standard transport distances

Table 5-88: Life cycle inventory input data for tram maintenance

	Name	Location	Infra	Unit	maintenance, tram	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				*CH*			
	InfrastructureProcess				*1*			
	Unit				*unit*			
product	maintenance, tram	CH	1	unit	1.00E+0			
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	2.26E+5	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	electricity, medium voltage, at grid	CH	0	kWh	1.88E+5	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	light fuel oil, burned in industrial furnace 1MW, non	RER	0	MJ	2.26E+5	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	tap water, at user	CH	0	kg	1.16E+6	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	sand, at mine	CH	0	kg	1.05E+5	1	1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	transport, freight, rail	CH	0	tkm	2.09E+4	1	2.09	standard transport distances
	treatment, sewage, to wastewater treatment, class	CH	0	m3	1.16E+3	1	1.80	calculated from the used tap water
	transport, lorry 28t	CH	0	tkm	5.23E+3	1	2.09	standard transport distances
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin			kg	3.02E+2		1.80	Derived from yearly consumption of service garages from public transport companies in Switzerland.
	Heat, waste			MJ	6.76E+5	1	2.00	standard calculation

Table 5-89: Life cycle inventory input data for tram disposal

	Name	Location	Unit	disposal, tram	Uncertainty Type	Standard Deviation95%	GeneralComment
disposal	disposal, tram	CH	unit	1.00E+0			
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	kg	8.50E+2	1	1.16	(3,4,1,3,1,1); material composition
	transport, lorry 28t	CH	tkm	1.98E+1	1	2.10	standard transport distances for disposal processes
	disposal, glass, 0% water, to municipal incineration	CH	kg	7.63E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.
	disposal, emulsion paint, 0% water, to municipal incineration	CH	kg	3.71E+2	1	1.16	(3,4,1,3,1,1); Data is derived from material composition of a lorry.

5.12 Road Infrastructure

In order to account for environmental interventions due to construction, renewal, operation and maintenance of road infrastructure generic data for the Swiss road infrastructure is employed; i.e. environmental interventions and technological specifications for 1m of an average Swiss road comprising motorways, cantonal- and municipal roads are determined. Due to the fact that various road infrastructure elements are characterised by different life spans, all environmental exchanges refer to one meter year [m*a]. For instance, a bridge with a life span of 50 years is accounted for twice. In this study, road infrastructure data is organised in three infrastructure sub-modules, as illustrated in Figure 5-1.

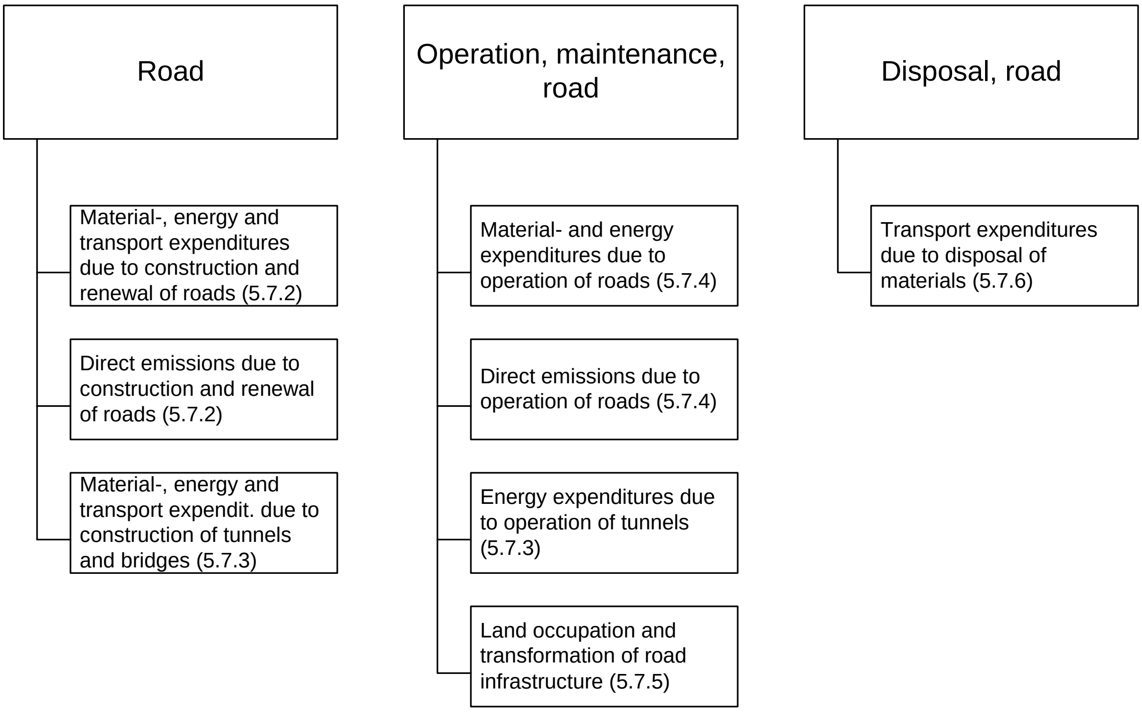


Figure 5-1: Road infrastructure modules as used in this project. The figures in bracket indicate the section in which the description for theses aspects can be found.

The sub-module “road” contains both expenditures and interventions due to road, tunnel and bridge construction, as well as renewal of different road layers as illustrated in

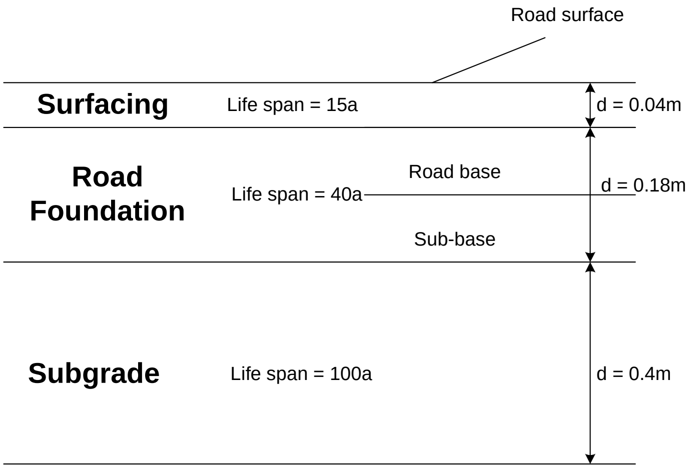


Figure 5-2. In contrast, the sub-module “operation, maintenance road” accounts for activities required to guarantee a safe use of the road network (e.g. lighting and de-icing of roads). Furthermore, land occupation and transformation are included.

The data generation is not straightforward, since roads of the same category can differ significantly and the commonly used road classifications express the functionality of a road rather than its construction or geometrical features. Furthermore, in Switzerland, two classifications are frequently used:

1. motorways, cantonal- and municipal roads, or
2. motorways, 1st class roads, 2nd class roads, 3rd class roads.

In the literature used for this study, both types of classification are used, however an official key for transforming the data is lacking. In Table 5-90 the basic characteristics according to these two classifications of the Swiss road network are summarised. For further calculations we assume a total length of the Swiss Road network of 71114 km Bundesamt für Statistik (BfS) (2000).

Table 5-90: Basic characteristics of the Swiss road transport network

	Length	Width	Average Swiss road [4)]	Share bitumen roads	Share concrete roads
Unit	km	m	m	km	km
Motorways [1)]	1638	23	0.02	1488	150
1. Class road [2)]	9000	7	0.13	9000	0
2. Class road [2)]	33400	5.7	0.47	33400	0
3. Class road [2)]	27100	4.4	0.38	27100	0
Cantonal road [3)]	18176	7.5	-	18176	0
Municipal road [3)]	51397	6	-	51397	0
Tunnels [5)]	161	-	-	-	-
Bridges [5)]	261	-	-	-	-

1: Data of length is derived from Bundesamt für Statistik (BfS) (2000) and data for the width is based on oral communication with H. Lindemann, IVT, ETH Zürich.

2: Classification and data used for the calculation of expenditures due to construction, renewal, and maintenance of roads. The data is derived from Maibach et al. (1999).

3: Classification and data used for the calculation of land use. Data of length is derived from Bundesamt für Statistik (BfS) (2000) and data for the width is based on oral communication with H. Lindemann, IVT, ETH Zürich.

4: Contribution of different road types to an average Swiss road.

5: Statistical data only available for motorways.

5.12.1 Road Construction and Road Renewal

Road construction and road renewal are accounted for in the module “road”. Figure 5-2 illustrates the different road layers distinguished in this project.

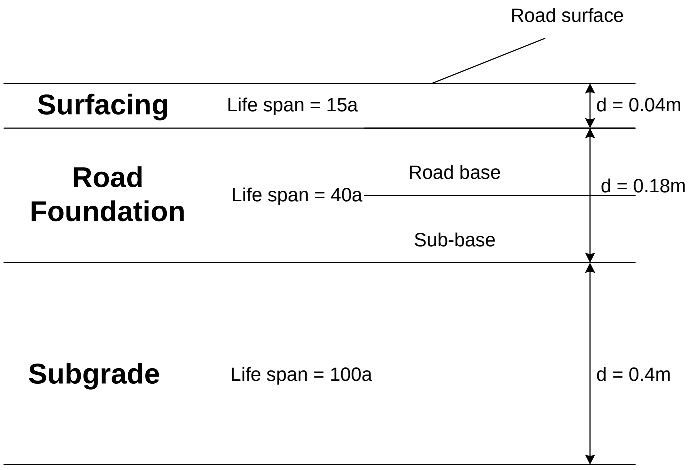


Figure 5-2: Layers of national roads in Switzerland

The figures presented in this section are based on inventories generated by Maibach et al. (1999). Due to the fact that different layers of a road are characterised by various life spans, the data is presented for 1 meter of road and 1 year. Different road types have been distinguished; namely motorway (Nationalstrassen) and three different classes (1st class road, 2nd class road and 3rd class road) of the Swiss Road network. For all categories, layers and materials are recorded, according to their life span. In Table 5-91 the assumptions made for the further calculations are summarised.

Table 5-91: Assumption for bulk materials and layers for bitumen roads per meter of road and year Maibach et al. (1999)

Material per m road	Surfacing			Road foundation			Subgrade			Total		
life span [years]	15			40			100			100		
Component	Width	Bitumen	Gravel	Width	Bitumen	Gravel	Width	Bitumen	Gravel	Width	Bitumen	Gravel
Share		6%	94%		5%	95%		0%	100%			
Unit	m	t/m	t/m	m	t/m	t/m	m	t/m	t/m	m	t/m	t/m
Motorway	0.04	0.132	1.98	0.18	0.48	9.05	0.4	0	21.2	0.62	2.0712	56.853
1. class street	0.04	0.04	0.61	0.15	0.12	2.31	0.4	0	6.48	0.59	0.564	16.281
2. class street	0.03	0.02	0.37	0.13	0.08	1.61	0.4	0	5.21	0.56	0.332	11.677
3. class street	0.03	0.02	0.28	0.1	0.05	0.96	0.35	0	3.53	0.48	0.257	7.778

Furthermore, as presented in Table 5-90 about 10% of the Swiss motorways are constructed with a concrete surfacing. In Table 5-92 the assumption for bulk materials and layers for concrete motorways are summarised.

Table 5-92: Assumption for bulk materials and layers for bitumen roads per meter of road and year Maibach et al. (1999)

Material per m road	Surfacing		Subgrade	
life span [years]	30		100	
Component	Width	Concrete	Width	Gravel
Unit	m	t/m	m	t/m
Motorway	0.22	11.13	0.4	18.40

Material Consumption

For the calculation of material expenditures per m bitumen road, recycling rates have been estimated. For the road foundation, a recycling rate of 50% has been assumed. For the surfacing and for the subgrade no recycling has been assumed. The subgrade will be removed after 100 years and the street must be completely re-constructed. For concrete roads, no recycling is assumed.

If we apply these assumptions to the material requirements presented in Table 5-91 and Table 5-92 we obtain the desired material expenditures per m road and year. In Table 5-93 the resulting figures are summarised.

Table 5-93: Material consumption for the construction and renewal of Swiss roads

	Unit	Motorway	1st class road	2nd class road	3rd class road	Average Swiss road
Concrete	kg/(m*a)	37.1	-	-	-	0.85
Bitumen	kg/(m*a)	15.4	4.83	3.11	2.14	3.24
Gravel, crushed	kg/(m*a)	470	146	105	70.9	105.60

Energy and Construction Processes

The figures for energy- and construction processes are derived from different sources, and are documented in Table 5-94.

Table 5-94: Energy- and construction processes for the construction and renewal of Swiss roads

	Unit	Motorway	1st class road	2nd class road	3rd class road	Average Swiss road
Electricity, medium voltage [1)]	MJ/(m*a)	98.7	10.6	2.18	2.18	5.47
Diesel, burned in building machine [2)]	MJ/(m*a)	192	60	33	23	36.27
Excavation, skid-steer loader [3)]	m3/(m*a)	2	0.2	0.15	0.1	0.18
Transport, lorry 28t [4)]	tkm/(m*a)	16.01	4.57	3.26	2.21	3.51

1: Maibach et al. (1999)

2: Frischknecht et al. (1996)

3: Stiller (1993)

4: The figures represent a vehicle with a payload of 14.5 t. An average distance between construction site and material origin of 30 km has been accounted for. Leuenberger & Spittel (2001).

NMVOC-Emissions

VOC emissions in road construction originate from the use of bitumen. Significant emissions of VOC emissions result from paving works in particular from the use of bitumen solvents for road surface treatments. Bitumen emulsions are characterised by a small solvent content less than 5g/kg. The yearly mass load in Switzerland is estimated with 3.6%. Hot spray bituminous binders contribute approximately 1.6% of the yearly bitumen consumption for road construction in Switzerland and are characterised by a fairly high solvent content: 90-140 g/kg bitumen Stolz (2001). Moreover, during thermic processes of solvent free bitumen VOC emissions occur. These emissions significantly change with the processing temperature and the bitumen type used. In this study, we employ an emission factor of 12kg NMVOC/t bitumen available from BUWAL (1995). In Table 5-95 the resulting figures for the different road types are summarised.

Table 5-95: NMVOC emissions due to road construction

	Unit	Motorway	1st class road	2nd class road	3rd class road	Average Swiss road
NMVOC emissions	Kg/(m*a)	0.19	0.058	0.037	0.026	0.04

Particulate Matter

Data of particulate emissions from mechanical processes and activities on road construction sites are available from Stolz (2001). The size distribution has been adjusted to comply with the size distribution used in this project. In Table 5-96 the resulting data is summarised.

Table 5-96: Particulate emissions due to loading and tipping of lorries

	Material	Unit	Large particles	Coarse particles
			>10μm	**2.5-10μm**
Loading	Gravel	g/t	-	0.05
Tipping	Gravel	g/t	7	1.8
	Cement [1)]	g/t	82	20
Loading	Gravel	g/(m*a)		5.28E-03
Tipping	Gravel	g/(m*a)	7.39E-01	1.90E-01
	Cement [1)]	g/(m*a)	5.32E-01	1.30E-01

1: The amount of cement is derived from the ratio cement/bitumen as used in road construction in Switzerland. In Stolz (2001) it is reported as 2:1; i.e. the amount of cement used is twice as high as the amount of used bitumen.

5.12.2 Tunnel and Bridge Construction

Tunnel Construction

In the above data the expenditure for tunnel and bridge construction has not yet been included.

The data for construction and operation of tunnels are based on data of specific motorway tunnel projects Maibach et al. (1999). In Table 5-97 the construction expenditures for tunnels per road kilometre and a life span of 100a as well as the expenditures for tunnel operation are summarised. The expenditures for operation are limited to energy consumption for lighting and ventilation of an average tunnel. The transport figures are calculated according to Leuenberger & Spittel (2001). The expenditures for the road are not included, since we assume no significant differences to an ordinary road.

Table 5-97: Construction and operation expenditure for an average motorway tunnel pipe (one track) in Switzerland

Construction		Unit	Tunnel [m*a] [1)]
Materials	Concrete	kg/(m*a)	400
	Steel un-alloyed	kg/(m*a)	13.5
	Steel, low-alloyed	kg/(m*a)	1.58
Construction Processes	Electricity, medium voltage	MJ/(m*a)	500
	Transport, lorry 28t [2)]	tkm/(m*a)	72.45
	Disposal of tunnel excavation	kg/(m*a)	2000
Operation	Electricity, medium voltage	MJ/(m*a)	8650

1: The data has been calculated for a life span of 100a Maibach et al. (1999). Expenditures for the construction of road in the tunnel are excluded.

2: For all materials and tunnel excavation, a kilometric transport performance of 30 km Leuenberger & Spittel (2001) has been assumed in the calculation of the required transport service.

In 1998, 161.7 km tunnel are in operation on a total motorway network of 1638 km Bundesamt für Statistik (BfS) (2000), resulting in a share of 98m tunnel on an average motorway of 1km length. Frischknecht (1996) stated that 52 km of the 115 km motorway tunnel have two pipes. In this project we assume that 50% of the tunnels have two pipes, resulting in a total length of pipes of 147m per kilometre road. For the remaining road types, no data from the national transport statistics are available and we employ the estimates available from Frischknecht et al. (1996) as presented in Table 5-98.

In Table 5-98 the road type specific and average tunnel construction and operation expenditures are demonstrated. These figures are added to the figures for road construction and operation, resulting in the total expenditures for road construction and road operation, respectively.

Table 5-98: Construction and operation expenditures tunnels on different Swiss road types and an average Swiss road

	Unit	**Motorway**	**1st class road**	**2nd class road**	**3rd class road**	**Average Swiss road**
Tunnel share	m/km	147	6.7	0.7	0.7	3.71
Construction						
Concrete	kg/(m*a)	58.80	2.68	0.28	0.28	1.93
Steel un-alloyed	kg/(m*a)	1.98	0.09	0.01	0.01	0.07
Steel, low-alloyed	kg/(m*a)	0.23	0.01	0.001	0.001	0.01
Electricity, medium voltage	MJ/(m*a)	73.50	3.35	0.35	0.35	2.41
Transport, lorry 28t	tkm/(m*a)	10.65	0.49	0.051	0.051	0.35
Disposal of tunnel excavation	kg/(m*a)	294.00	13.40	1.40	1.40	9.66
Operation						
Electricity, medium voltage	MJ/(m*a)	1271.55	57.96	6.06	6.06	41.76

Bridge Construction

For material expenditures due to bridge construction data for rail bridges is available from von Rozycki et al. (2003) and displayed in Table 5-99. Due to the lack of similar data for roads, these data is applied for road bridges, too.

Statistical data for the length of bridges, is merely available for Swiss Motorways. In the year 1998 the length of bridges is estimated being 264 km [2]. 25% of these bridges are motorway fly-over and are accounted for as road/rail bridges. The remaining 75% are taken into account as glen bridges. Per km motorway, 160 m bridges are accounted for in this project. For cantonal and municipal roads we employ the assumptions made for the share of tunnels of the other road types, 10.1 m/km and 1.1 m/km for 1. class roads and 2./3. class roads, respectively.

Table 5-99: Material expenditures for the construction of bridges

	Absolute material consumption		Life span	Specific material consumption	
Material	Concrete	Steel		Concrete	Steel
Unit	t/km Bridge	t/km Bridge	Years	kg/(m*a) Bridge	kg/(m*a) Bridge
Glen bridges	55000	3000	100	550	30
Road/railway bridges	89000	4900	50	3560	196
Average bridge this project				1302.5	71.5

In Table 5-105 the exchanges of road construction including construction of bridges and tunnels are summarised.

5.12.3 Operation and Maintenance of Roads

The inventory for road maintenance and operation are limited to the activities as follows:

- de-icing,
- weed control,

[2] oral communication with Mr. W. Schuler, Astra, May 2003.

- marking lines, and
- energy consumption for road lighting.

De-Icing

For the determination of the use of salt and gravel for icy roads on highways and 1.class roads, data from a recent Austrian study Wresowar & Sieghardt (2000) have been used. These figures represent an average yearly consumption calculated from the yearly consumption between 1986 and 1996. According to this study, 103’000 t/a salt (96% NaCl and 4% Ca2Cl) and 98’880 t/a gravel have been used on roads in Austria. The study further contains figures for the average yearly salt consumption per km motorway track and km 1st class road (Bundes-und Schnellstrassen). On a motorway, 5.7 t/a salt have been dispersed on one lane of 1 km length. On 1.class roads, 3t/a for one lane of the same length have been used. If we assume 4 lanes for a highway and two lanes for a 1.Class road, we obtain the figures presented in Table 5-101. For the remaining road types, we employed the figures given in Maibach (1999).

Weed Control

In Switzerland, the use of herbicides for weed control is restricted to weed control of embankments of motorways and cantonal roads. Two active agents are approved to use: Glyphosat and Glufosinat. The actual use of herbicides differs significantly in the different Swiss Cantons. Also, some Cantons (Basel and Basel Land) do not use herbicides at all. Since it was impossible to perform a survey of all 26 Swiss Cantons, we made some assumptions to estimate the use of herbicides. The estimates concerning the amount of spend herbicides may be considered as a worst-case scenario. In order to determine the use of herbicides per m road assumptions as follows have been applied:

- The predominately used herbicide in Switzerland is Glyphosat. As a first estimate we assume that all used herbicides are Glyphosat.
- The concentration of the active agent is 360g Glyphosat/l. Anonymous (2002)
- The dispersed amount per hectare depends on the treated plant (2-10 l/ha) Anonymous (2002). In this study we assume the maxim allowed amount for roadside treatments of 8 l/ha or 2880 g Glyphosat/ha.
- 25 cm per meter of each roadside are treated per year. This results in 0.5 m^2 per metre cantonal road per year and 1 m^2 per meter motorway per year.

In Table 5-100 the resulting figures are summarised

Table 5-100: Herbicide use for weed control on Swiss roads

		Motorway	Cantonal road	Municipal road	Average Swiss road
Share	%	2.30	25.52	72.18	100.00
Glyphosat	kg/m	2.88E-04	1.44E-04	0	3.68E-05

Road Marking

For the use of paints for road marking, no current figures are available. In Frischknecht et al. (1996), a yearly consumption of 4000-5000 t paint have been reported, based on an extrapolation of figures for the Canton Aargau. Based on a survey of 17 companies in the paint sector in 1993, a current annual use of 2500 – 4000 t per year has been estimated [3]. According to this survey the share of solvent containing paints was about 40%. In the 2000 the share is estimated to be about 35%[3]. Thus, we can assume a yearly dispersion of 1000-1500t of solvent containing paints. The solvent content of currently used paints in road marking is between 23% and 25%[4]. For this study we employ data for a worst-case scenario, assuming a yearly dispersion of 1500 t of solvent containing paint with a solvent share of 25%. If we further assume that the entire amount of solvents is released as NMVOC emissions, we obtain a yearly load of 375 t NMVOC due to road marking. Thus, per m road 5.27E-03 kg NMVOC is emitted in Switzerland.

Energy Consumption for Road Lighting

In Frischknecht et al. (1996) a consumption of 400 GWh for road lighting has been estimated, based on statistical figures for public lighting Anonymous (1993). Currently, in Zurich, the energy consumption for road lighting is reported with19 GWh electricity, which is approximately 0.8 % of the total electricity consumption in the supply area of the electric power stations of the Canton Zurich EKZ (2003). In the Canton Zurich exclusively gas discharge lamps are in operation, which are characterised by a low energy consumption and high light efficiency. Thus, the total share of electricity consumption in Switzerland is estimated slightly higher to be about 1% of the total final Swiss electricity consumption [5]. For the year 2000 the total final electricity consumption is reported with 52373 GWh BFE (2003). In consequence, 523 GWh are used for road lighting, resulting in a specific electricity consumption of 7.4 kWh/m*a. The latter figure is used in this study.

In Table 5-101 the expenditures for road maintenance and operation are summarised.

Table 5-101: Expenditures and environmental expenditures for road operation and maintenance

	Unit	Motorway	1.class	2.class	3.class	Swiss Average Road
Sodium chloride	kg/(m*a)	22.8	6	1.67	1.3	**2.56E+00**
Gravel	kg/(m*a)	-	2.85	2.29	1.77	**2.11E+00**
Transport PC [1)]	pkm/(m*a)	13.8	1.23	0.38	0.38	**7.97E-01**
Electricity, medium voltage	kWh/(m*a)	6.79E-01	1.14E+00	3.43E+00	2.15E+00	**7.40E+00**
Glyphosat (agent)	kg(m*a)	2.88E-04	7.20E-05	7.20E-05	0.00E+00	**3.68E-05**
Paint solvent free	kg(m*a)	3.23E-03	5.40E-03	1.63E-02	1.02E-02	**3.52E-02**
Paint containing solvent	kg(m*a)	1.94E-03	3.24E-03	9.79E-03	6.13E-03	**2.11E-02**
NMVOC	kg(m*a)	4.84E-04	8.09E-04	2.45E-03	1.53E-03	**5.27E-03**
Chloride	kg(m*a)	13.68	3.6	1.002	0.78	**1.54E+00**
Sodium	kg/(m*a)	9.12	2.4	0.668	0.52	**1.03E+00**

1: Maibach et al. (1999)

5.12.4 Land Use

According to Frischknecht et al. (2003) a distinction between land transformation and land occupation is required. Whilst transformation directly changes the ecological quality of land, occupation post-

[3] oral communication Felix Mutter, chief executive director of the VSLF (Fachverband der schweizerischen Lack-, Farben- und Druckfarben-Industrie)

[4] Oral communication Mr. Paulus, basler lacke.

[5] Oral communication with a person in charge for road lighting of the Elektrizitätswerke des Kantons Zürich (EKZ)

pones changes of the ecological quality. For transport related land cover types we further distinguish between area actually used for the operation of vehicles (paved area) and embankments.

Land Occupation

Occupation refers to the time period for which the land is unavailable for other activities. The occupation intervention is expressed in terms of land use type, area and time. The unit is therefore square metres *year.

The data employed for the road traffic area is based on a comprehensive assessment of land occupation due to Swiss traffic infrastructure in Hüsler et al. (1989). These data has been modified according to recent changes in the Swiss Road network Bundesamt für Statistik (BfS) (2000). In Table 5-102 the original data and the figures used in this project are summarised. In order to determine the changes in the road network we assumed that the width of the roads remains the same.

Table 5-102: Swiss road network area

	Occupation road network	Occupation road embankment	Changes in Swiss road network from 1985-1998 in	Occupation Road Network used in this project	Occupation Road Embankment (used in this project)
Unit	km^2	km^2	%	km^2	km^2
Source	Hüsler et al. (1989)/	Hüsler et al. (1989)	Bundesamt für Statistik (BfS) (2000)	Own calculations	Own calculations
Reference year	1985	1985	1998	1998	1998
Motorways (Nationalstrassen)	39.5	17.0	18.352601	46.8	20.3
Cantonal and municipal roads (Kantonsstrassen und Gemeindestrassen)	418.3	80.0	-0.044538	418.1	79.7
Total Occupation	457.8	97		464.9	100.0

In Table 5-103 the specific land use for the various used vehicle classes used in this project are summarised. For the determination of European land use no data was readily available, Thus, as a first estimate, we employed the Swiss figures as presented in Table 5-102.

Table 5-103: Specific land occupation as used in this study.

	Unit	Road Network occupation	Road embankment occupation
Total land occupation	m2/m	6.43	1.36

Land Transformation

For transformation (the change of land use to be allocated to a certain user or user type) the situation is more difficult, mainly due to data variability. The yearly change in land use for a certain user may change considerably, as land use change is not a continuous process, but very much determined by political decisions and economic constraints and opportunities. Thus, to assess transformation for a generic database, the yearly trend has been determined based on a number of consecutive years, from

1985 to 1998. The total changes of the Swiss road network between 1985 and 1998 are presented in Table 5-102 The yearly changes can be easily achieved by dividing these figures by the number of years. As already outlined in Table 5-102 in Switzerland between 1985 and 1998 there has been a significant increase of motorways, whilst a slight cutback of cantonal and municipal roads has taken place. The figures presented in Table 5-104 account for the net-transformation; i.e. the cutback area has been subtracted from the area of the added motorways. Information of the initial use of road infrastructure land is not available, nor information on the use after cutback has been taken place. In Table 5-104 the resulting figures are presented.

Table 5-104: Specific land transformation as used in this study

	Unit	Road network transformation	Road embankment transformation
Total land occupation	m2/m	7.64E-03	3.37E-03

For the determination of European land transformation due to road construction no data was readily available. Thus, as a first estimate, we employed the Swiss figures as presented in Table 5-102.

5.12.5 Road Disposal

In Switzerland, approximately 1.5 Mio tonnes of asphalt and 1.3 Mio tonnes result from yearly road excavation Bundesamt für Konjunkturfragen (1991). 20% of the asphalt are recycled and reused. The remaining amount of asphalt is used as recycling gravel in subgrade layers, and only a small amount is disposed. Road excavation is used as a substitute for gravel for various applications Stolz (2001). Thus, as a first estimate we assume a complete reuse and recycling of road materials and merely account for excavation with a skid-steer loader (assuming a density of 1.5t /m^3) and a transport over a distance of 20 kilometres of 80% of the excavation to recycling plants. The resulting figures are summarised in table Table 5-107.

5.12.6 Life Cycle Inventory Input Data

Table 5-105: Life cycle inventory input data for road construction including tunnel and bridge construction.

	Name	Location	Unit	*road*	Uncertainty Type	Standard Deviation 95%	GeneralComment
product	road	CH	ma	1.00E+0			
technosphere	concrete, exacting, with de-icing salt contact, at plant	CH	m3	1.05E+1	1	1.27E+0	(3,3,3,1,1,5); literature studies and own calculations
	bitumen, at refinery	CH	kg	3.24E+0	1	1.27E+0	(3,3,3,1,1,5); literature studies and own calculations
	gravel, crushed, at mine	CH	kg	1.06E+2	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	electricity, medium voltage, at grid	CH	kWh	6.13E-1	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	diesel, burned in building machine	GLO	MJ	3.63E+1	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	excavation, skid-steer loader	RER	m3	1.80E-1	1	2.12	(3,3,3,1,1,5); literature studies and own calculations
	transport, lorry 28t	CH	tkm	3.86E+0	1	2.12	(3,3,3,1,1,5); literature studies and own calculations
	steel, low-alloyed, at plant	RER	kg	8.96E-2	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	reinforcing steel, at plant	RER	kg	1.32E+0	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	3.89E-2	1	1.62	(4,3,2,1,1,5); literature studies and own calculations
	Particulates, > 10 um	-	kg	1.27E-3	1	2.08	(3,3,2,5,1,5); literature studies and own calculations
	Particulates, > 2.5 um, and < 10um	-	kg	3.25E-4	1	2.09	(3,3,3,5,1,5); literature studies and own calculations
	Heat, waste		MJ	2.21E+0	1	1.07	standard uncertainty
disposal	disposal, inert waste, 5% water, to inert material landfill	CH	kg	9.66E+0	1	1.27	(3,3,3,1,1,5); literature studies and own calculations

Table 5-106: Life cycle inventory table for road operation including land use.

	Name	Location	Unit	*operation, maintenance, road*	Uncertainty Type	Standard Deviation95%	GeneralComment
product	operation, maintenance, road	CH	ma	1.00E+0			
technosphere	gravel, crushed, at mine	CH	kg	2.11E+0	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	electricity, medium voltage, at grid	CH	kWh	1.91E+1	1	1.27	(3,3,3,1,1,5); literature studies and own calculations
	sodium chloride, powder, at plant	RER	kg	2.56E+0	1	1.09	(2,3,1,1,1,1); de-icing salt study and own calculations
	glyphosate, at regional storehouse	CH	kg	3.68E-5	1	1.09	(2,3,1,1,1,1); oral communication and own calculations
	alkyd paint, white, 60% in H2O, at plant	RER	kg	3.52E-2	1	1.09	(2,3,1,1,1,1); oral communication and own calculations
	alkyd paint, white, 60% in solvent, at plant	RER	kg	2.11E-2	1	1.09	(2,3,1,1,1,1); oral communication and own calculations
	transport, passenger car	CH	pkm	7.97E-1	1	2.08	(3,3,3,1,1,5); literature studies and own calculations
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	5.27E-3	1	1.62	(4,3,2,1,1,5); literature studies and own calculations
	Heat, waste		MJ	6.87E+1	1	1.11	(3,1,1,1,1,1); standard heat waste
emissions to soil	Chloride		kg	1.54E+0	1	1.52	(3,3,1,3,1,1); de-icing salt study and own calculations
	Sodium, ion	-	kg	1.03E+0	1	1.52	(3,3,1,3,1,1); de-icing salt study and own calculations
	Glyphosate		kg	3.68E-5	1	1.24	(3,3,1,3,1,1); oral communication and own calculations
land use	Occupation, traffic area, road embankment	-	m2a	1.36E+0	1	1.51	(2,2,1,1,na,1); literature studies and own calculations
	Occupation, traffic area, road network	-	m2a	6.43E+0	1	1.51	(2,2,1,1,na,2); literature studies and own calculations
	Transformation, from unknown	-	m2	1.10E-2	1	2.01	(2,2,1,1,na,3); literature studies and own calculations
	Transformation, to traffic area, road network	-	m2	7.64E-3	1	2.02	(2,2,1,1,na,4); literature studies and own calculations
	Transformation, to traffic area, road embankment	-	m2	3.37E-3	1	2.05	(2,2,1,1,na,5); literature studies and own calculations

Table 5-107: Life cycle inventory table for road disposal.

	Name	Location	Unit	*disposal, road*	Uncertainty Type	Standard Deviation95%	GeneralComment
product	disposal, road	RER	ma	1.00E+0			
technosphere	excavation, skid-steer loader	RER	m3	6.20E-2	1.00E+0	2.12	(3,3,3,1,1,5); literature studies and own calculations
	transport, lorry 28t	CH	tkm	3.90E-1	1.00E+0	2.12	(3,3,3,1,1,5); literature studies and own calculations

Data Quality and Uncertainties

Road Construction

For the basis data, such as material consumption and energy consumption in road construction the data is of sufficient quality. The issue of NMVOC emissions from road construction is still in its infancies and no reliable data is available yet. Thus the data quality is low. The uncertainty of the data will increase if we use these data to calculate European average environmental interventions. For instance the share of tunnels per km road is likely to be lower in other European countries.

Road Operation

Most of the data in this section is based on straightforward assumptions and thus shall be considered as qualified estimates.

Land Use

The data for land occupation is based on an extensive study, of the land use of transport infrastructure in Switzerland. The data has been updated with current infrastructure data. The quality is expected to be good.

For land transformation, we simply compared the changes of the Swiss road network in the last 13 years and calculated the average. The selection of the interval is somehow arbitrarily, and we may obtain different figures if we change the period of time considered. The figures, however, represent the Swiss conditions and thus are of average quality as far as Switzerland is concerned.

5.13 Tram Infrastructure

5.13.1 Characteristics of Tram infrastructure

Table 5-108: Key characteristics of tram infrastructure

	Total length 1)	One track 1)	Double track 1)	Double track this project 2)
Unit	m	m	m	m
On road	110152			
Off road	63827			
Total	173979	11390	162590	168300

1: (BfS, 2000)

2: own calculations: single tracks are transformed to double tracks by dividing the single track length by two.

Tram infrastructure is exclusively used for tram passenger transport. Allocation of tram-infrastructure to roads has been neglected due its irrelevant contribution.

The calculation of the infrastructure demand is straightforward, employing the figures as illustrated in Table 5-109.

Table 5-109: Key performance figures of tram transportation in Switzerland

Aspect	Unit	
Yearly kilometric performance (total Swiss)	Mio. vkm	26.551
Yearly transport performance	Mio. pkm	1402.968
Average load 2)	passengers	33

1: (BfS, 2000)

2: calculated from pkm and vkm performance

Thus, in this project we assume a infrastructure demand of 1.20E-04 m*a/pkm.

5.13.2 Track Construction and Renewal

The module track construction and renewal accounts for double track concrete stretch (width = 6.5m) and a bitumen layer of 3 cm on top Maibach et al. (1999). In addition, steel expenditures for railway tracks and bracing are included. Alternative constructions of tram-infrastructure (e.g. green stretches) are not accounted for. The life span is estimated at 15 years. In Table 5-111 resulting expenditures and interventions are summarised.

5.13.3 Operation and Maintenance of Tram Infrastructure

The inventory for operation and maintenance of tram infrastructure is limited to the energy consumption for signals (79.5 kWh/m*a) and land use.

For the operation of signals a electricity consumption of 79.5 kWh/m*a is accounted for Maibach et al. (1999).

Figures for Land occupation and transformation are derived employing the assumptions as summarised in

Table 5-110: Land use of tram infrastructure

	Tram infrastructure length	Width	Total occupied area	Total transformed area [1]	Specific occupied area	Specific transformed area [1]
Unit	m	m	m^2*a	m^2	m^2*a/m	m^2/m
	168’300	6.5	1’093’950	10’939	6.5	0.065

1: assuming a life span of 100 years for rail infrastructure

5.13.4 Tram Infrastructure Disposal

Similar as for road disposal (see section) we assume a complete reuse and recycling of infrastructure materials. Consequently we merely account transport of the materials over a distance of 20 km. The resulting figures are summarised in Table 5-113.

5.13.5 Life Cycle Inventory Input Data

Table 5-111: Life cycle inventory input data for construction and renewal of tram infrastructure

	Name	Location	Infra	Unit	*tram track*	Uncertainty Type	Standard Deviation 95%	GeneralComment
	Location				***CH***			
	InfrastructureProcess				***1***			
	Unit				***ma***			
product	tram track	CH	1	ma	1.00E+0			
technosphere	concrete, exacting, with de-icing salt contact, at plant	CH	0	m3	1.11E-1	1	1.27	(3,3,3,1,1,5); literature studies
	bitumen, at refinery	CH	0	kg	1.20E+0	1	1.27	(3,3,3,1,1,5); literature studies
	gravel, crushed, at mine	CH	0	kg	2.35E+1	1	1.27	(3,3,3,1,1,5); literature studies
	diesel, burned in building machine	GLO	0	MJ	3.90E+2	1	1.27	(3,3,3,1,1,5); literature studies
	excavation, skid-steer loader	RER	0	m3	3.00E-1	1	2.08	(3,3,3,1,1,5); literature studies
	transport, lorry 28t	CH	0	tkm	1.41E+1	1	2.09	(4,5,na,na,na,na); literature studies
	steel, low-alloyed, at plant	RER	0	kg	1.21E+1	1	1.27	(3,3,3,1,1,5); literature studies
	reinforcing steel, at plant	RER	0	kg	8.58E-2	1	1.27	(3,3,3,1,1,5); literature studies
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.24E+0	1	1.62	(4,3,2,1,1,5); literature studies

Table 5-112: Life cycle inventory input data for operation of tram infrastructure

	Name	Location	Infra	Unit	*operation, tram track*	Uncertainty Type	Standard Deviation95%	GeneralComment
	Location				***CH***			
	InfrastructureProcess				***1***			
	Unit				***ma***			
product	operation, tram track	CH	1	ma	1.00E+0			
technosphere	electricity, medium voltage, at grid	CH	0	kWh	7.95E+1	1	1.27	(3,3,3,1,1,5); literature studies
	Heat, waste		0	MJ	2.86E+2	1	1.27	(3,3,3,1,1,5); literature studies
land use	Occupation, traffic area, road network	-	-	m2a	6.50E+0	1	1.51	(2,2,1,1,na,2); literature studies
	Transformation, from unknown	-	-	m2	6.50E-3	1	2.01	(2,2,1,1,na,3); literature studies
	Transformation, to traffic area, road network	-	-	m2	6.50E-3	1	2.02	(2,2,1,1,na,4); literature studies

Table 5-113: Life cycle inventory input data for disposal of tram infrastructure

	Name	Location	Unit	*disposal, tram track*	Uncertainty Type	Standard Deviation95%	GeneralComment
	Location			***CH***			
	InfrastructureProcess			***1***			
	Unit			***ma***			
product	disposal, tram track	CH	ma	1.00E+0			
	transport, lorry 28t	CH	tkm	5.39E+0	1.00E+0	2.28	(4,5,na,na,na,na); standard transport distance

5.14 Road Transport

Transport datasets are related to the reference unit of one passenger kilometre [pkm] or one tonne kilometre [tkm], for passenger or freight transport, respectively. The environmental interventions due to vehicle transport are modelled by linking the environmental interventions due to vehicle operation with impacts due to vehicle manufacturing, vehicle maintenance, vehicle disposal, road construction, operation and maintenance of roads and road disposal. So-called demand factors are used to link the transport service components to the functional unit of one passenger kilometre [pkm] or one tonne kilometre [tkm] (Spielmann & Scholz 2005).

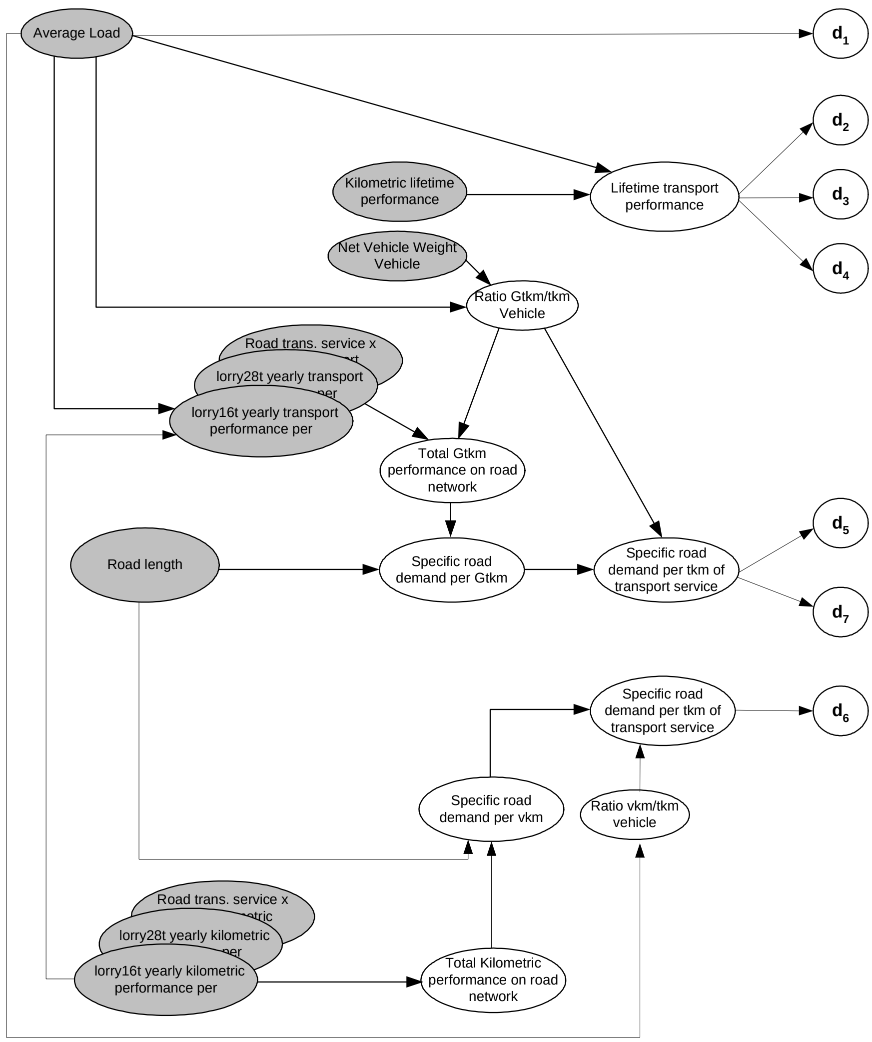


Figure 5-3: Schematic illustration of information and factors essential for the determination of different demand factors. The grey fields present information available from statistics and literature. The white fields represent factors based on own calculations. (Spielmann & Scholz 2005).

For the operation of road vehicles (d_1), the ratio vkm/tkm is calculated on the basis of the average load. Load figures for lorries of various vehicle types and sizes are available from (Knörr et al. 2000) and TREMOVE (2007). For the generic lorries modelled in ecoinvent, these figures are further aggregated employing the yearly kilometric performance of different vehicle types and size as a weighting factor. Demand factors for vehicle fleet components, i.e., vehicle manufacturing (d_2), vehicle maintenance (d_3) and vehicle disposal (d_4) with d_2=d_3=d_4, are calculated as the inverse of the vehicle's lifetime transport performance. Thus, assumptions on the lifetime kilometric performance and average load factor are required. In Table 5-114 and Table 5-115 these factors are summarised.

Table 5-114: Demand factors for freight transport vehicle fleet components

Vehicle Type	Location	Average load	Lifetime kilometric performance	Lifetime transport performance	Demand Factor
		t	vkm	tkm	$(tkm)^{-1}$
Van (<3.5t)	CH	0.27	220'000	58'609	1.71E-05
Van (<3.5t)	RER	0.19	220'000	41'498	2.41E-05
Lorry 3.5-20t	CH	2.90	540'000	1'566'000	6.39E-07
Lorry 20-28t	CH	5.80	540'000	3'132'000	3.19E-07
Lorry >28t	CH	9.80	540'000	5'292'000	1.89E-07
Lorry 3.5-7.5t	RER	5.00	540'000	2'700'000	3.70E-07
Lorry 7.5-16t	RER	7.50	540'000	4'050'000	2.47E-07
Lorry 16t-32t	RER	10.00	540'000	5'400'000	1.85E-07
Lorry >32t	RER	18.00	540'000	9'720'000	1.03E-07
Lorry 3.5-16t	RER	6.41	540'000	3'459'590	2.89E-07
Lorry >16t	RER	15.07	540'000	8'136'885	1.23E-07

Table 5-115: Demand factors for passenger transport vehicle fleet components

Vehicle Type	Location	Average load	Lifetime kilometric performance	Lifetime transport performance	Demand Factor
		p	vkm	pkm	$(pkm)^{-1}$
Passenger Car	CH	1.59	150'000	238'500	4.19E-06
Passenger Car	RER	1.60	150'000	240'000	4.17E-06
Regular Bus	CH	14.00	1'000'000	14'000'000	7.14E-08
Coach	CH	21.00	1'000'000	21'000'000	4.76E-08

The demand factor for road transport infrastructure is calculated taking into account the total length of the Swiss and European transport networks (see Table 5-120)

Table 5-116: Length of the total road network by category and country (IRF 2006)

Road Type	**Unit**	**EU15**	**CZ**	**HU**	**PL**	**SI**	**NO**	**CH**	**Total EU19 +2**
Motorways	thousand km	56.8	0.5	0.5	0.4	0.5	0.2	**1.7**	**60.6**
National Roads	thousand km	263.4	20.7	30.5	18.3	1.1	26.8	**0.4**	**361.2**
Secondary or Regional	thousand km	1094.3	34.1	53.7	28.4	4.8	27.2	**18.1**	**1260.6**
Other Roads	thousand km	2519.1	72.3	75.9	377.3	32.1	37.7	**51.4**	**3165.8**
Total	thousand km	3933.6	127.6	160.6	424.4	38.5	91.9	**71.6**	**4848.2**

In order to attribute the environmental burdens of road infrastructure supply to the various transport services allocation is required. For construction – including the renewal (d_5) and disposal (d_7) of infrastructure – the yearly Gross-tonne kilometre performance (Gtkm) is employed as the allocation rule to account for the fact that damage, and hence the resulting renewal expenditure of roads, is mainly due to vehicle weight. In contrast, for the determination of demand factors of infrastructure operation datasets (d_6), the temporal occupation of the infrastructure (employing kilometric vehicle performance in the year 2005 as a first approximation) by different user types irrespective of the vehicle weight is used as the allocation principle.

For example, in order to determine the Gtkm of a van, the following assumptions are made: Net vehicle weight is 2.5t, average load is 0.27t resulting in an average Gross-tonne vehicle weight of 2.77t. Based on these figures, we obtain a gross/net ratio of 10.4 Gtkm/tkm and, hence, a yearly Gross-tkm transport performance of 1.2E+10 Gtkm for vans. For the entire Swiss road network, we obtain a Gross-tkm performance of 1.34E+11 Gtkm. Thus, 9% of the road network is used for van transportation. Based on these assumptions and figures the specific road demand for a tkm van transport service is calculated as 5.56E-03 (m*a)/tkm.

The resulting demand factors and the underlying assumptions are presented in Table 5-117, Table 5-118 and Table 5-119. The total Gross-kilometric performance and kilometric performance of the Swiss road network is 1.34E+11 Gtkm and 6.28E+10 vkm, respectively. The calculated tkm-performance for lorry transport (heavy duty vehicles) of 1.49E+10 tkm matches the figure reported in the Swiss statistics (BFS 2006).

Table 5-117: Demand factors and underlying assumptions for Swiss road transport services. Performance data is derived from various sources, which are documented in the table footnotes.

		Van 1)	Lorry 3.5-20t 2)	Lorry 20-28t 2)	Lorry >32t 2)	Passenger Car 3)	Motorbike & Moped 4)	Regular Bus & Trolleybus 5)	Coach 6)
Vehicle kilometric performance	vkm	4.34E+09	6.48E+08	3.90E+08	1.10E+09	5.37E+10	2.28E+09	2.09E+08	9.40E+07
Net-transport performance	tkm or pkm	1.16E+09	1.88E+09	2.26E+09	1.08E+10	8.54E+10	2.51E+09	2.93E+09	1.97E+09
Net vehicle weight	t	2.5	7.5	13	18	1.24	0.175	11	11
Average load	t (p)	0.27	2.9	5.8	9.8	1.59	1.1	14	21
Average gross vehicle weight	t	2.8	10.4	18.8	27.8	1.33	0.24	14.0	21.0
Ratio vkm/tkm performance	vkm/tkm	3.75	0.34	0.17	0.10	0.63	0.91	0.07	0.05
Ratio Gtkm/tkm performance	Gtkm/tkm	10.4	3.6	3.2	2.8	0.8	0.2	1.0	1.0
Gross transport performance	Gtkm	1.20E+10	6.74E+09	7.33E+09	3.06E+10	7.16E+10	5.50E+08	2.93E+09	1.97E+09
Allocation Gtkm									
Demand of total road network	%	9.0%	5.0%	5.5%	22.9%	53.5%	0.4%	2.2%	1.5%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	5.56E-03	1.92E-03	1.74E-03	1.52E-03	4.49E-04	1.17E-04	5.36E-04	5.36E-04
Allocation vkm:									
Demand of total network	%	6.9%	1.0%	0.6%	1.8%	85.6%	3.6%	0.3%	0.1%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	4.28E-03	3.93E-04	1.97E-04	1.16E-04	7.18E-04	1.04E-03	8.15E-05	5.43E-05

1: vkm and tkm performance available from BFS (2006).

2: vkm performance for total lorry transport (heavy duty vehicles) in Switzerland is available from BFS (2006). Further differentiation is based on calculations performed with HBEFA. (Keller et al. 2004): 16t: 30.3%, 28t: 18.2%; 40t: 51.5%. Load factors are derived from (Knörr et al. 2000) and are slightly adjusted to match the calculated tkm performance with the tkm-performance reported in the BFS (2006).

3: load/ occupation factor is taken from ARE (2000)

4: vkm performance is available from Keller (2002). Occupation factors are taken from (TREMOVE 2006).

5: vkm performance is available from Keller (2002). Occupation factors are taken from (BFS 2000)

Table 5-118: Demand factors and underlying assumptions for European road transport services. Performance data is derived from TREMOVE (2006). Truck data is differentiated according to the classification in TREMOVE (2006), which is used for the emissions standard specific truck operation data.

		Van (Freight)	Lorry 3.5-7.5	Lorry 7.5-16t	Lorry 16-32t	Lorry >32t	Passenger Car	Motorbike & Moped	Regular Bus & Trolleybus	Coach
Vehicle kilometric performance	vkm	3.01E+11	5.88E+10	2.27E+10	1.09E+11	9.33E+10	2.93502E+12	5.84701E+11	8.28E+09	2.37E+10
Net-transport performance	tkm or pkm	5.67E+10	5.76E+10	7.42E+10	6.30E+11	1.09E+12	4.71E+12	1.89E+11	1.35E+11	3.46E+11
Net vehicle weight	t	2.5	5	7.5	10	18	1.24	0.14	11	11
Average load	t (p)	0.19	0.98	3.27	5.76	11.68	1.60	1.10	16.32	14.61
Average gross vehicle weight	t	2.7	6.0	10.8	15.8	29.7	1.3	0.2	12.0	11.9
Ratio gross-and net performance	Gtkm/tkm	14.3	6.1	3.3	2.7	2.5	0.8	0.2	0.7	0.8
Gross transport performance	Gtkm	8.08E+11	3.52E+11	2.44E+11	1.72E+12	2.77E+12	3.94E+12	3.50E+10	9.92E+10	2.81E+11
Allocation Gtkm										
Demand of total road network	%	7.9%	3.4%	2.4%	16.8%	27.0%	38.4%	0.3%	1.0%	2.7%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	6.74E-03	2.89E-03	1.56E-03	1.29E-03	1.20E-03	3.95E-04	8.77E-05	3.47E-04	3.84E-04
Allocation vkm:										
Demand of total network	%	7.3%	1.4%	0.5%	2.6%	2.3%	71.0%	14.1%	0.2%	0.6%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	6.21E-03	1.20E-03	3.58E-04	2.03E-04	1.00E-04	7.30E-04	3.63E-03	7.18E-05	8.02E-05

Table 5-119: Demand factors and underlying assumptions for European aggregated 16t (3.5-16t) and 32t (+16t) truck, used for the 2005 fleet average. Performance data is derived from TREMOVE (2006).

		Lorry 3.5-16t	Lorry >16t
Vehicle kilometric performance	vkm	8.15E+10	2.03E+11
Net-transport performance	tkm or pkm	1.32E+11	1.72E+12
Net vehicle weight	t	6.4	15.1
Average load	t (p)	2.27	9.51
Average gross vehicle weight	t	8.7	24.6
Ratio gross-and net performance	Gtkm/tkm	4.5	2.6
Gross transport performance	Gtkm	5.96E+11	4.49E+12
Allocation Gtkm			
Demand of total road network	%	5.8%	43.8%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	2.14E-03	1.24E-03
Allocation vkm:			
Demand of total network	%	2.0%	4.9%
Specific road demand per transport service and unit	(m*a)/tkm or (m*a)/pkm	7.25E-04	1.38E-04

5.14.1 Life Cycle Inventory Input Data

The applied demand factors are summarised in this section.

Table 5-120: Life cycle inventory input data of transport processes of Swiss passenger transport datasets

	401	InputGroup	OutputGroup	Name	Location	InfrastructureProcess	Unit	transport, passenger car, diesel, fleet average	transport, passenger car, diesel, fleet average 2010	transport, passenger car, petrol, fleet average	transport, passenger car, petrol, fleet average 2010	transport, passenger car	transport, regular bus	transport, coach	UncertaintyType	StandardDeviation 95%	GeneralComment
	662			Location				CH	CH	CH	CH	CH	CH	CH			
	493			InfrastructureProcess				0	0	0	0	0	0	0			
	403			Unit				pkm	pkm	pkm	pkm	pkm	pkm	pkm			
Products		-	0	transport, passenger car, diesel, fleet average	CH	0	pkm	1									
		-	0	transport, passenger car, diesel, fleet average 2010	CH	0	pkm		1.00E+0								
		-	0	transport, passenger car, petrol, fleet average	CH	0	pkm			1.00E+0							
		-	0	transport, passenger car, petrol, fleet average 2010	CH	0	pkm				1						
		-	0	transport, passenger car	CH	0	pkm					1					
		-	0	transport, regular bus	CH	0	pkm						1.00E+0				
		-	0	transport, coach	CH	0	pkm							1.00E+0			
technosphere		5	-	operation, passenger car, diesel, fleet average	CH	0	vkm	6.29E-1							1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, diesel, fleet average 2010	CH	0	vkm		6.29E-1						1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, petrol, fleet average	CH	0	vkm			6.29E-1					1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, petrol, fleet average 2010	CH	0	vkm				6.29E-1				1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car	CH	0	km					6.29E-1			1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, regular bus	CH	0	vkm						7.14E-2		1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, coach	CH	0	vkm							4.76E-2	1	2.01	(3,1,1,1,1,na); own calculations
		5	-	passenger car	RER	1	unit	4.19E-6	4.19E-6	4.19E-6	4.19E-6	4.19E-6			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	bus	RER	1	unit						7.14E-8	4.76E-8	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, passenger car	RER	1	unit	4.19E-6	4.19E-6	4.19E-6	4.19E-6	4.19E-6			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, bus	CH	1	unit						7.14E-8	4.76E-8	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, passenger car	RER	1	unit	4.19E-6	4.19E-6	4.19E-6	4.19E-6	4.19E-6			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, bus	CH	1	unit						7.14E-8	7.14E-8	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	road	CH	1	ma	4.53E-4	4.53E-4	4.53E-4	4.53E-4	4.53E-4	4.57E-4	3.16E-4	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	operation, maintenance, road	CH	1	ma	7.18E-4	7.18E-4	7.18E-4	7.18E-4	7.18E-4	8.15E-5	5.43E-5	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	disposal, road	RER	1	ma	4.53E-4	4.53E-4	4.53E-4	4.53E-4	4.53E-4	4.57E-4	3.16E-4	1	3.01	(3,1,1,1,1,na); own calculations

Table 5-121: Life cycle inventory input data of transport processes of Swiss freight transport datasets

	401	InputGroup	OutputGroup	Name	Location	InfrastructureProcess	Unit	transport, lorry 3.5-20t, fleet average	transport, lorry 20-28t, fleet average	transport, lorry >28t, fleet average	transport, van <3.5t	UncertaintyType	StandardDeviation95%	GeneralComment
	662			Location				CH	CH	CH	CH			
	493			InfrastructureProcess				0	0	0	0			
	403			Unit				tkm	tkm	tkm	tkm			
Products		-	0	transport, lorry 3.5-20t, fleet average	CH	0	tkm	1						
		-	0	transport, lorry 20-28t, fleet average	CH	0	tkm		1					
		-	0	transport, lorry >28t, fleet average	CH	0	tkm			1				
		-	0	transport, van <3.5t	CH	0	tkm				1			
technosphere		5	-	operation, lorry 3.5-20t, fleet average	CH	0	vkm	3.45E-1				1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, lorry 20-28t, fleet average	CH	0	vkm		1.72E-1			1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, lorry >28t, fleet average	CH	0	vkm			1.02E-1		1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, van < 3,5t	CH	0	km				3.70E+0	1	2.01	(3,1,1,1,1,na); own calculations
		5	-	lorry 16t	RER	1	unit	6.39E-07				1	3.01	(3,1,1,2,1,na); own calculations
		5	-	lorry 28t	RER	1	unit		3.19E-07			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	lorry 40t	RER	1	unit			1.89E-07		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	van <3.5t	RER	1	unit				1.6835E-05	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, lorry 16t	CH	1	unit	6.39E-7				1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, lorry 28t	CH	1	unit	0	3.19E-7			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, lorry 40t	CH	1	unit	0	0	1.89E-7		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, van < 3.5t	RER	1	unit				1.68E-5	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, lorry 16t	CH	1	unit	6.39E-7				1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, lorry 28t	CH	1	unit	0	3.19E-7			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, lorry 40t	CH	1	unit	0	0	1.89E-7		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, van < 3.5t	CH	1	unit				1.68E-5	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	road	CH	1	ma	1.94E-3	1.75E-3	1.53E-3	5.61E-3	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	operation, maintenance, road	CH	1	ma	3.93E-4	1.97E-4	1.16E-4	4.28E-3	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	disposal, road	RER	1	ma	1.94E-3	1.75E-3	1.53E-3	5.61E-3	1	3.01	(3,1,1,1,1,na); own calculations

Table 5-122: Life cycle inventory input data of transport processes of European passenger car transport datasets

	401	InputGroup	OutputGroup	Name	Location	InfrastructureProcess	Unit	transport, passenger car, diesel, fleet average	transport, passenger car, diesel, fleet average 2010	transport, passenger car, petrol, fleet average	transport, passenger car, petrol, fleet average 2010	transport, passenger car	UncertaintyType	StandardDeviation95%	GeneralComment
	662			Location				RER	RER	RER	RER	RER			
	493			InfrastructureProcess				0	0	0	0	0			
	403			Unit				pkm	pkm	pkm	pkm	pkm			
Products		-	0	transport, passenger car, diesel, fleet average	RER	0	pkm	1							
		-	0	transport, passenger car, diesel, fleet average 2010	RER	0	pkm		1						
		-	0	transport, passenger car, petrol, fleet average	RER	0	pkm			1					
		-	0	transport, passenger car, petrol, fleet average 2010	RER	0	pkm				1				
		-	0	transport, passenger car	RER	0	pkm					1			
technosphere		5	-	operation, passenger car, diesel, fleet average	RER	0	vkm	6.25E-1					1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, diesel, fleet average 2010	RER	0	vkm		6.25E-1				1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, petrol, fleet average	RER	0	vkm			6.25E-1			1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car, petrol, fleet average 2010	RER	0	vkm				6.25E-1		1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, passenger car	RER	0	km					6.25E-1	1	2.01	(3,1,1,1,1,na); own calculations
		5	-	passenger car	RER	1	unit	4.17E-6	4.17E-6	4.17E-6	4.17E-6	4.17E-6	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, passenger car	RER	1	unit	4.17E-6	4.17E-6	4.17E-6	4.17E-6	4.17E-6	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, passenger car	RER	1	unit	4.17E-6	4.17E-6	4.17E-6	4.17E-6	4.17E-6	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	road	CH	1	ma	3.95E-4	3.95E-4	3.95E-4	3.95E-4	3.95E-4	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	operation, maintenance, road	CH	1	ma	7.30E-4	7.30E-4	7.30E-4	7.30E-4	7.30E-4	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	disposal, road	RER	1	ma	3.95E-4	3.95E-4	3.95E-4	3.95E-4	3.95E-4	1	3.01	(3,1,1,1,1,na); own calculations

Table 5-123: Life cycle inventory input data of transport processes of European freight transport datasets, fleet average

	401	InputGroup	OutputGroup	Name	Location	InfrastructureProcess	Unit	transport, lorry 3.5-16t, fleet average	transport, lorry >16t, fleet average	transport, van <3.5t	UncertaintyType	StandardDeviation 95%	GeneralComment
	662			Location				RER	RER	RER			
	493			InfrastructureProcess				0	0	0			
	403			Unit				tkm	tkm	tkm			
Products		-	0	transport, lorry 3.5-16t, fleet average	RER	0	tkm	1					
		-	0	transport, lorry >16t, fleet average	RER	0	tkm		1				
		-	0	transport, van <3.5t	RER	0	tkm			1			
technosphere		5	-	operation, lorry 3.5-16t, fleet average	RER	0	vkm	4.40E-1			1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, lorry >16t, fleet average	RER	0	vkm		1.05E-1		1	2.01	(3,1,1,1,1,na); own calculations
		5	-	operation, van < 3,5t	RER	0	vkm			5.30E+0	1	2.01	(3,1,1,1,1,na); own calculations
		5	-	lorry 16t	RER	1	unit	8.16E-07			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	lorry 40t	RER	1	unit		1.95E-7		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	van <3.5t	RER	1	unit			2.41E-5	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, lorry 16t	CH	1	unit	8.16E-7			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, lorry 40t	CH	1	unit	0	1.95E-7		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	maintenance, van < 3.5t	RER	1	unit			2.41E-5	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, lorry 16t	CH	1	unit	8.16E-7			1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, lorry 40t	CH	1	unit		1.95E-7		1	3.01	(3,1,1,2,1,na); own calculations
		5	-	disposal, van < 3.5t	CH	1	unit			2.41E-5	1	3.01	(3,1,1,2,1,na); own calculations
		5	-	road	CH	1	ma	2.14E-3	1.24E-3	6.74E-3	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	operation, maintenance, road	CH	1	ma	7.25E-4	1.38E-4	6.21E-3	1	3.01	(3,1,1,1,1,na); own calculations
		5	-	disposal, road	RER	1	ma	2.14E-3	1.24E-3	6.74E-3	1	3.01	(3,1,1,1,1,na); own calculations

Table 5-124: Life cycle inventory input data of transport of European freight transport datasets, Euro class specific

	Name	Location	InfrastructureProcess	Unit	transport, lorry 3.5-7.5t, EURO3	transport, lorry 3.5-7.5t, EURO4	transport, lorry 3.5-7.5t, EURO5	transport, lorry 7.5-16t, EURO3	transport, lorry 7.5-16t, EURO4	transport, lorry 7.5-16t, EURO5	transport, lorry 16-32t, EURO3	transport, lorry 16-32t, EURO4	transport, lorry 16-32t, EURO5	transport, lorry >32t, EURO3	transport, lorry >32t, EURO4	transport, lorry >32t, EURO5	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER	RER	RER	RER	RER	RER	RER	RER	RER			
	InfrastructureProcess				0	0	0	0	0	0	0	0	0	0	0	0			
	Unit				tkm	tkm	tkm	tkm	tkm	tkm	tkm	tkm	tkm	tkm	tkm	tkm			
Products	transport, lorry 3.5-7.5t, EURO3	RER	0	tkm	1														
	transport, lorry 3.5-7.5t, EURO4	RER	0	tkm		1													
	transport, lorry 3.5-7.5t, EURO5	RER	0	tkm			1												
Products	transport, lorry 7.5-16t, EURO3	RER	0	tkm				1											
	transport, lorry 7.5-16t, EURO4	RER	0	tkm					1										
	transport, lorry 7.5-16t, EURO5	RER	0	tkm						1									
Products	transport, lorry 16-32t, EURO3	RER	0	tkm							1								
	transport, lorry 16-32t, EURO4	RER	0	tkm								1							
	transport, lorry 16-32t, EURO5	RER	0	tkm									1						
Products	transport, lorry >32t, EURO3	RER	0	tkm										1					
	transport, lorry >32t, EURO4	RER	0	tkm											1				
	transport, lorry >32t, EURO5	RER	0	tkm												1			
technosphere	operation, lorry 3.5-7.5t, EURO3	RER	0	vkm	1.02E+0												1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 3.5-7.5t, EURO4	RER	0	vkm		1.02E+0											1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 3.5-7.5t, EURO5	RER	0	vkm			1.02E+0										1	2.01	(3,1,1,1,1,na); own calculations
technosphere	operation, lorry 7.5-16t, EURO3	RER	0	vkm				3.06E-1									1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 7.5-16t, EURO4	RER	0	vkm					3.06E-1								1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 7.5-16t, EURO5	RER	0	vkm						3.06E-1							1	2.01	(3,1,1,1,1,na); own calculations
technosphere	operation, lorry 16-32t, EURO3	RER	0	vkm							1.73E-1						1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 16-32t, EURO4	RER	0	vkm								1.73E-1					1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry 16-32t, EURO5	RER	0	vkm									1.73E-1				1	2.01	(3,1,1,1,1,na); own calculations
technosphere	operation, lorry >32t, EURO3	RER	0	vkm										8.56E-2			1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry >32t, EURO4	RER	0	vkm											8.56E-2		1	2.01	(3,1,1,1,1,na); own calculations
	operation, lorry >32t, EURO5	RER	0	vkm												8.56E-2	1	2.01	(3,1,1,1,1,na); own calculations
	lorry 16t	RER	1	unit	1.89E-06	1.89E-06	1.89E-06	5.66E-07	5.66E-07	5.66E-07							1	3.01	(3,1,1,2,1,na); own calculations
	lorry 28t	RER	1	unit							3.21E-7	3.21E-7	3.21E-7		3.19E-07		1	3.01	(3,1,1,2,1,na); own calculations
	lorry 40t	RER	1	unit										1.59E-7	1.59E-7	1.59E-7	1	3.01	(3,1,1,2,1,na); own calculations
	maintenance, lorry 16t	CH	1	unit	1.89E-6	1.89E-6	1.89E-6	5.66E-7	5.66E-7	5.66E-7	0	0	0	0	0	0	1	3.01	(3,1,1,2,1,na); own calculations
	maintenance, lorry 28t	CH	1	unit	0	0	0	0	0	0	3.21E-7	3.21E-7	3.21E-7	0	3.19E-7	0	1	3.01	(3,1,1,2,1,na); own calculations
	maintenance, lorry 40t	CH	1	unit	0	0	0	0	0	0	0	0	0	1.59E-7	1.59E-7	1.59E-7	1	3.01	(3,1,1,2,1,na); own calculations
	disposal, lorry 16t	CH	1	unit	1.89E-6	1.89E-6	1.89E-6	5.66E-7	5.66E-7	5.66E-7	0	0	0	0	0	0	1	3.01	(3,1,1,2,1,na); own calculations
	disposal, lorry 28t	CH	1	unit	0	0	0	0	0	0	3.21E-7	3.21E-7	3.21E-7	0	3.19E-7	0	1	3.01	(3,1,1,2,1,na); own calculations
	disposal, lorry 40t	CH	1	unit	0	0	0	0	0	0	0	0	0	1.59E-7	1.59E-7	1.59E-7	1	3.01	(3,1,1,2,1,na); own calculations
	road	CH	1	ma	2.89E-3	2.89E-3	2.89E-3	1.56E-3	1.56E-3	1.56E-3	1.29E-3	1.29E-3	1.29E-3	1.20E-3	1.20E-3	1.20E-3	1	3.01	(3,1,1,1,1,na); own calculations
	operation, maintenance, road	CH	1	ma	1.20E-3	1.20E-3	1.20E-3	3.58E-4	3.58E-4	3.58E-4	2.03E-4	2.03E-4	2.03E-4	1.00E-4	1.00E-4	1.00E-4	1	3.01	(3,1,1,1,1,na); own calculations
	disposal, road	RER	1	ma	2.89E-3	2.89E-3	2.89E-3	1.56E-3	1.56E-3	1.56E-3	1.29E-3	1.29E-3	1.29E-3	1.20E-3	1.20E-3	1.20E-3	1	3.01	(3,1,1,1,1,na); own calculations

Table 5-125: Life cycle inventory input data of transport of Swiss average tram and trolley buses

Explanations	Name	Location	Infrastructure-Process	Unit	transport, trolleybus	transport, tram
	Location				CH	CH
	InfrastructureProcess				0	0
	Unit				pkm	pkm
Outputs	transport, trolleybus	CH	0	pkm	1.00E+0	
	transport, tram	CH	0	pkm		1.00E+0
Technosphere	operation, trolleybus	CH	0	vkm	3.85E-2	
	bus	RER	1	unit	5.03E-8	
	maintenance, bus	CH	1	unit	5.03E-8	
	disposal, bus	CH	1	unit	5.03E-8	
	road	CH	1	ma	5.30E-4	
	operation, maintenance, road	CH	1	ma	8.95E-5	
	disposal, road	RER	1	ma	5.30E-4	
	operation, tram	CH	0	vkm		1.89E-2
	tram	RER	1	unit		1.69E-8
	maintenance, tram	CH	1	unit		1.69E-8
	disposal, tram	CH	1	unit		1.69E-8
	tram track	CH	1	ma		1.20E-4
	operation, tram track	CH	1	ma		1.20E-4
	disposal, tram track	CH	1	ma		1.20E-4

Data Quality Considerations

For determining the uncertainty of the inventory input data, the simplified approach with a pedigree matrix has been used to calculate the standard deviation.

6 Life Cycle Inventories for Rail Transport

In this chapter we present and discuss the data employed for the rail transportation modules and outline the foundations and arguments for methodological choices made. In some cases we also give further information on alternative data available or choices possible.

6.1 Goal and Scope

The overall objective of the transport modeling is to supply sets of highly aggregated environmental interventions due to rail transport services to complete the assessment of energy and materials life cycles.

6.1.1 Functional Unit

In order to relate transport models to life cycles of other products and services, the environmental interventions are related to the reference unit of one tonne kilometer. A tonne kilometer by rail is defined as follows: “Unit of measure of goods transport which represents the transport of one tonne by a train over one kilometer” EUROSTAT (2000). Exchanges and environmental interventions of passenger transport are expressed in passenger kilometer [pkm].

6.1.2 System Boundaries

In this study goods transportation is modeled in two different versions to represent both, Swiss conditions and average European conditions. The resulting data represent an average Swiss goods transportation train and average European goods transportation train. Passenger rail transport is modeled, representing Swiss conditions. Two types of passenger rail transport are distinguished in this project: a) Swiss long distance rail traffic and b) Swiss regional rail traffic. Long distance rail traffic is performed by trains as follows: Intercity, Eurocity, CIS/ICE/TGV, Interregio, and Express trains. For regional traffic the following types of trains are in operation: S-Trains; RegioExpress and various regional trains. In addition, an ICE-Train operating in Germany is included in the ecoinvent database. If not stated explicitly, data and assumptions are directly taken from von Rozycki (2003). Thus, five passenger transport components are available from this project:

a) Regional train transport with SBB electricity mix

b) Long distance transport with SBB electricity mix

c) ICE-transport representing German conditions.

Environmental interventions of rail transportation can be classified in interventions due to direct processes and indirect processes. In this project we used this classification as a point of departure for the structuring the system under investigation and the data collection. Direct processes merely address environmental interventions due to rail operation. Indirect processes are further divided into two components a) rail equipment and b) rail infrastructure expenditures. Consequently, the system „rail transport“ is divided in three components:

- Rail Operation
- Rail Equipment
- Rail Infrastructure

Rail Operation: This component contains all processes that are directly connected with the operation of trains including shunting processes.

Goods Transport Equipment: Rail equipment is further divided in locomotives and wagons (often referred to as cars) and contains all processes that are connected with the vehicle life cycle (excluding the operation) such as manufacturing, maintenance as well as disposal.

Rail Infrastructure: This transport component comprises rail track construction, maintenance and disposal.

The second and third component summarise processes with numerous interfaces to other ecoinvent modules (materials and energy). Thus, the actual environmental interventions of these processes are calculated when these data are linked to the referring processes in the ecoinvent database, and are often referred to as indirect environmental interventions of transportation.

6.1.3 Reference Units and Key Figures

Values for energy consumption and environmental emissions are available for various reference units. In general a distinction can be made between load independent and load dependent reference units. In Figure 6-1 different types of reference units are illustrated.

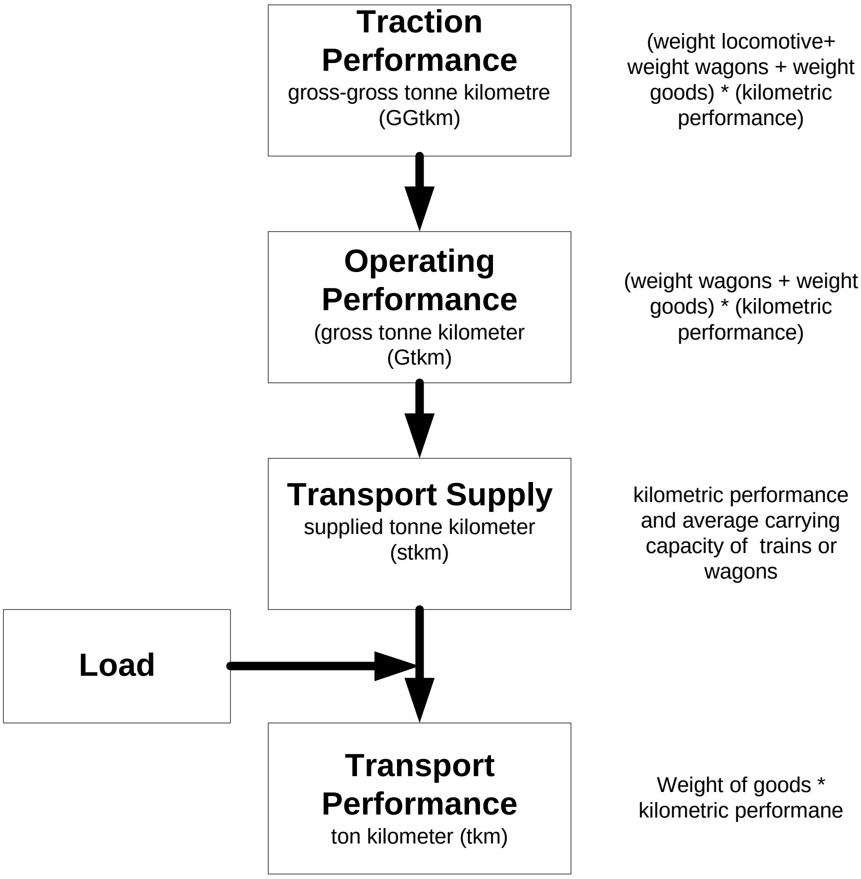


Figure 6-1: Steps in the transport performance formation and referring reference units

Furthermore, a distinction between fare-tkm and net-tkm must be made. The latter refers to the actual kilometric performance, whilst fare-tkm refer to the actually paid kilometric performance. Between these two reference values a difference up to 100% is possible[6]. In this project, we use the term tkm and refer to the net tkm.

Switzerland

In Table 6-1 and Table 6-2 key figures and relevant to calculate the specific environmental performance of the Swiss rail transport system are summarized.

[6] Oral communication with Helmut Kuppelwieser, SBB Environmental Management

Table 6-1: Key figures (2000) of Swiss goods transportation excluding private rail companies ((SBB, 2002) and (BfS, 2000))

Indicator	Unit	Value
Train kilometre (passenger and goods transportation)	Mio. vkm	130.995
Traction performance all trains (passenger and goods transportation)	Mio. Gtkm	59449.535
Traction performance goods transportation	Mio. Gtkm	24331.407
Goods train kilometric performance (train kilometer)	Mio. vkm	28
Transport performance good trains	Mio. tkm	10786
Gross tonne per fright train	Gt	824
Ratio gross tonne/carried goods	Gt/t	2.40

Table 6-2: Key figures (2001) of Swiss passenger transportation excluding private rail companies ((SBB, 2002) and oral communication with H. Kuppelwieser (SBB)).

Indicator	Unit	Value
Regional passenger train kilometric performance	Mio. vkm	53
Long distance passenger train kilometric performance	Mio. vkm	49
Traction performance regional trains	Mio. Gtkm/a	11498.682
Traction performance long distance trains	Mio. Gtkm/a	23833.449
Operating performance regional trains	Mio. Gtkm/a	7172.375
Operating performance long distance trains	Mio. Gtkm/a	17873.245
Supplied Seats regional train	Seats/train	315
Supplied Seats long distance train	Seats/train	627
Average load factor regional train	%	17
Average load factor long distance train	%	28
Transport performance regional train [1)]	Mio. pkm/a	2839.275
Transport performance long distance train [1)]	Mio. pkm/a	8522.560

1) own calculations

Europe

The availability of data required for the calculation of specific environmental interventions of the European Rail system is limited and the data available fairly uncertain. In Table 6-3 some key figures are summarised.

Table 6-3: Key figures for European goods transportation

Country	National	International	Total	National share on EU transport	Total
	Mio tkm/a	Mio tkm/a	Mio tkm/a	%	Mio Gtkm/a [1)]
Belgium	2166	4903	7069	3.2	14138
Denmark	476	n.a	476	0.2	952
Germany	35763	30084	65847	30.0	131694
Greece	121	191	312	0.1	624
Spain	9174	2148	11322	5.2	22644
France	32267	16241	48508	22.1	97016
Ireland	469	n.a.	469	0.2	938
Italy	11415	10992	22407	10.2	44814
Luxembourg	104	n.a.	104	0.0	208
Netherlands	763	3015	3778	1.7	7556
Austria	3093	7990	11083	5.1	22166
Portugal	1638	410	2048	0.9	4096
Finland	6313	3572	9885	4.5	19770
Sweden	18635	4803	23438	10.7	46876
UK	12440	n.a.	12440	5.7	24880
EU-15	134837	84349	219186	100.0	438372

1: Calculated with a gross-tons/net-tons ratio of 2.

n.a.: for the reference year 1998 no data was available

6.2 Operation of Goods Trains in Switzerland

The module operation of goods trains comprises both, the actual performance of goods trains as well as required shunting processes. For a technical and ecological consideration of rail transport services, a distinction between the type of traction, diesel and electricity is important. In Switzerland, however, diesel locomotives are almost exclusively used for shunting purposes.

6.2.1 Traction Energy

The data presented in the database represents average environmental interventions, calculated top down from the yearly energy consumption and yearly transport performance. For electricity consumption of freight trains, yearly average data is available from the SBB (SBB, 2002) . These data is linked to reference values as presented in Table 6-1 in order to calculate specific electricity consumption. In Table 6-4 these figures are summarised. More specific data, addressing different types of train compositions is available from other studies. (Borken et al. (1999); Maibach et al. (1999)).

Table 6-4: Specific electricity consumption at current collector for traction of goods trains

Indicator	Unit	Value
End-electricity consumption per train	kWh/(Mio vkm)	1.25E+07
Total electricity consumption	kWh	1.64E+09
Good transport total electricity consumption	kWh	6.70E+08
Specific electricity consumption goods transportation in 2000	kWh/tkm	0.0620
Specific electricity consumption goods transportation in 2006 [7]	kWh/tkm	0.0669

The actual consumption depends on numerous impact factors such as:

- Gradient of the tracks
- Train length and total weight
- Speed and acceleration

In an alpine country as Switzerland, this can result in a significantly higher specific electricity consumption compared to fairly flat countries such as the Netherlands or Germany. Borken (2003), for instance, calculate a final energy consumption for an average train (1000 Gt) and average load factor (0.5 net tons-per gross tons) of 0.034 kWh/tkm in a flat area and 0.051 kWh/tkm in a mountain region. The remaining difference between the latter value and the SBB value may be explained with the lower average load factor of the SBB in 2000 (0.42 t/Gt).

Transmission losses (transmission ex traction substation 4% and transmission and conversion ex high voltage network 6%) are accounted for with 10%, resulting in a final energy consumption of 0.0736 kWh/tkm for the SBB (reference year 2006).

6.2.2 Airborne Emissions

Due to the fact that on the Swiss rail network only very few diesel locomotives are in operation emissions to air are limited to particulate emissions due to abrasion and emission of sulphur hexafluoride (SF6) occurring during conversion at traction substations.

Source of abrasion are rail tracks, wheels, brakes, overhead contact line and exhaust emissions of shunting locomotives. In Table 6-5 PM10 emission factors as available from literature are summarised. Particulate emission due to abrasion are currently issue of intensive studies in Switzerland[8]. The figures presented here, therefore should only be considered as rough estimates. For the determination of PM 10 emission factors for brakes, wheels, rail and overhead contacting line, we employ the figures as presented in Table 6-5. For the determination of PM > 10 we assume a share of 25 % for wheel and rail abrasion. The abrasion of brakes and the resulting share of PM 10 depend on the wheel load and thus differ between fully loaded goods trains and empty goods train (see Table 6-6). The figure employed in this project represent an average based on the load factor of 0.42 for the Swiss average freight train.

[7] Email from Markus Halder, BahnUmwelt-Center SBB, 17th of april 2007

[8] Oral communication with Helmut Kuppelwieser, SBB Environmental Management

Table 6-5: PM10 emission of rail transportation

Source of Abrasion	Buwal (2002)		(SBB, 2001)		This project	
	Total abrasion	Assumed Share PM10	Total abra-sion	Assumed Share PM10	Total abra-sion	Assumed Share PM10 (goods transport)
	t/a	%	t/a	%	t/a	
Brakes	2066	100	250-475	12[1] –21[2]	363	17
Wheels	546	50	-		546	50
Rail	124	50	-		124	50
overhead con-tact line	36	100	-		36	100
Shunting loco-motive exhaust emissions	45	100	-			
Total	2816				1069	

1: figure for a fully loaded freight train (SBB, 2002)

2: figure for an empty freight train (SBB, 2002)

Table 6-6: Size distribution of braking line abrasion

Abrasion	Size distribution empty goods train and passen-ger train (wheel load: 2.5t) [1]	Size distribution fully loaded goods train (wheel load: 11.25t) [1]	This project (0.42 load factor)
	%	%	%
Non airborne emissions	56	28	44
PM10	21	12	17
PM>10	23	60	39
Total Abrasion	100	100	100

1: (SBB, 2002)

The essential allocation between goods and passenger transport is performed by employing the traction performance as allocation factor. In Table 6-7 the resulting figures are summarised.

Table 6-7: Specific emission factors of particulates due to abrasion

	unit	Total abrasion	PM 10 [1]	PM >10
Yearly load	t/a	1069		
Allocated yearly load goods transport	t/a	435	176.3	126.0
Specific emission factor	Kg/tkm	4.04E-05	1.63E-05	1.17E-05

1) the entire load of PM10 is classified as coarse particulates (a diameter > 2.5 um and < 10um)

For sulphur hexafluoride (SF6) emitted during conversion at traction substations we assume an emission index of 4.4E-08 kg/kWh Frischknecht (2003) resulting in a specific emission of 3.14E-09 kg/tkm.

6.2.3 Emissions to Soil

Abrasion (from braking lining, rail and wheel) is predominately composed of iron and mineral components BUWAL (2002). In this study we assume that all non-airborne emissions are emitted as iron to soil. In consequence, we assume a yearly load of 133.5 t/a iron emitted to soil. Emission of lubricates due to traction are not accounted for, since measures are in operation to avoid such emissions.

6.2.4 Diesel Consumption and Emissions of Shunting Processes

Diesel Consumption

A total diesel consumption of 8.695 Mio litres (in the year 2000) is reported for the SBB (SBB, 2002). In this study we assume that all diesel is consumed for shunting, neglecting the consumption of diesel for the lorry fleet and diesel aggregates. Furthermore we assume that 100% of the shunting processes for goods trains is performed with diesel locomotives. Consequently, we obtain a specific diesel consumption of 0.68 g/tkm. In Table 6-8 a summary of specific diesel consumption values for shunting as available in literature are presented.

Table 6-8: Summary of specific diesel consumption values for shunting processes

	Frischknecht et al. (1996) [1]	Knörr et al. (2000) [2]	This project
Specific Diesel Consumption for shunting [g/tkm]	0.93	0.68	0.68

1: in this study Gtkm is used as a reference value. The data presented in this table has been calculations based on the assumptions made in the referring study and SBB data from 1985. 100% of the diesel shunting is allocated to goods transportation.

2: in this study, tkm (supplied tonne kilometre) is used as a reference value. The given value (0.25 g/tkm) has been transformed based on the assumption of an average load factor of 37%. 90% of the diesel shunting is allocated to goods transportation.

Emissions to Air

In Knörr (2000), shunting specific emission indices are presented. These emission factors are representative for German conditions in 1995 and demonstrated in Table 6-9. Obviously these indices merely differ marginal from those of diesel traction in Germany J. Borken et al. (2003), apart from SO2 emissions, which strongly depend on the sulphur of the fuel. In addition, other emission indices as available from literature are presented in Table 6-9.

In this project CO_2 and SO_2 indices are estimated assuming that all carbon and sulphur in the fuel is transformed completely into CO_2 and SO_2, respectively. In line with assumptions made for road transport we assume a sulphur content of 300 ppm resulting in a emission index of 0.6 g/kg. For CO_2 we employ an emission index of 73.5 g/MJ or 3146 g/kg. The list of emission indices is enhanced with pollutants derived from heavy good vehicle emission factors for urban traffic conditions. These values reflect the Swiss average heavy good vehicle in urban traffic conditions and are derived from INFRAS (1999). The figures in the last column of Table 6-9 present the figures employed in this study.

Table 6-9: Emission indices for diesel locomotives

Emission	Unit	Knörr[1)]	Borken [2)]	Joergen-sen [6)]	Ecoinvent 96 [3)]	DB [4)]	SNFC [4)]	HGV [5)]	**This project**
CO2	g/kg	3175	3170	3180	3145	3.175	3150	3117.00	**3146.00**
CO	g/kg	15.8	n.a.	22	10	n.a.	n.a.	6.61	**15.80**
HC[7)]	g/kg	2.5	5.0	11	4	1.9	4.9	5.37	**-**
Nox	g/kg	55	55	53	44	55.4	39.6	35.10	**55.00**
PM	g/kg	1.4	1.5	3	3.8	2	1.5	1.82	**1.39**
SO2	g/kg	3	0.7	4	2.6	0.08	0.7	0.60	**0.6**
N2O	g/kg	n.a.	n.a.	n.a.	0.1	n.a.	n.a.	0.10	**0.10**
NMVOC[8)]	g/kg	n.a.	4.9	n.a.	3.8	1.8	4.7	5.25	**5.25**
CH4	g/kg	n.a.	0.1	n.a.	0.2	0.1	0.2	0.13	**0.13**
Benzene	g/kg	n.a.	n.a.	n.a.	0.001	n.a.	n.a.	0.10	**0.10**
NH3	g/kg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.02	**0.02**
Toluol	g/kg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.04	**0.04**
Xylol	g/kg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.04	**0.04**

1) figures represent shunting specific emission indices Knörr et al. (2000)

2) average emission indices for diesel traction J. Borken et al. (2003)

3) Frischknecht et al. (1996)

4) country specific emission factors taken from J. Borken et al. (2003). DB: Germany; DSB: Denmark; SNCF: France.

5) average emission factors for Swiss heavy good vehicles (HGV) for urban traffic conditions in 2000 derived from INFRAS (1999).

6) average emission factors for diesel railway locomotives including passenger and freight locomotivesJoergensen & Sorenson (1997)

7) the presented figures of HC emissions comprise CH_4 and NMVOC emissions

8) the presented figures of NMVOC emissions still contain emissions of Benzene, Toulol and Xylol

In Table 6-10 the assumptions and resulting figures for particulate emissions employed in this project are summarized.

Table 6-10: Particle size distributions of exhaust emissions and exhaust emission factors [g/kg] for diesel locomotives

Vehicle Category	Assumptions			Emission factors for different size classes [μm]		
	PM10 emission factor [g/kg][1]	Fraction of PM10 with a diameter < 2.5 μm	Fraction of TSP with diameter < 10 μm	Fine Particles (< 2.5)	Coarse Particles (2.5-10)	Large Particles (>10)
Diesel locomotive	1.39	92.3	96.2	1.28E+00	1.07E-01	5.49E-02

Table 6-11presents emission factors expressed in mg/kg fuel for cadmium, copper, chromium, nickel, selenium and zinc, as provided by the Expert Panel on Heavy Metals and POPs of the UNECE Task Force on Emission Inventories EEA (2000). However, these emission factors have to be considered as preliminary estimates only. More measurements are needed in order to confirm these values. Values for mercury and lead are taken from Jungbluth (2003).

Table 6-11: Heavy metal emission indices for Diesel locomotives

Cadmium [g/kg fuel]	Copper [g/kg fuel]	Chromium [g/kg fuel]	Nickel [g/g fuel]	Selenium [g/kg fuel]	Zinc [g/kg fuel]	Lead [g/kg fuel]	Mercury [g/kg fuel]
1,0E-05	1,7E-03	5,0E-05	7,0E-05	1,0E-05	1,0E-03	1,1E-07	2,0E-08

6.2.5 Life Cycle Inventory Input Data

In Table 6-12 the input data for the entire unit process operation is presented.

Table 6-12: Life cycle inventory table for operation of Swiss goods trains

	Name	Location	InfrastructureProcess	Unit	operation, freight train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				0			
	Unit				tkm			
product	operation, freight train	CH	0	tkm	1			
technosphere	electricity, high voltage, SBB, at grid	CH	0	kWh	7.36E-2	1	1.07	(2,1,1,1,1,1); Swiss rail company (SBB) statistics
technosphere	diesel, at regional storage	CH	0	kg	6.77E-4	1	1.08	(2,2,1,3,1,1); German railway (DB) study
emission air, unspecified	Benzene	-	-	kg	6.77E-8	1	1.56	(2,2,1,1,3,1); handbook emission factors for HGV
	Methane, fossil	-	-	kg	8.80E-8	1	1.56	(2,2,1,1,3,1); handbook emission factors for HGV
	Carbon monoxide, fossil	-	-	kg	1.07E-5	1	5.00	(2,2,1,3,1,1); German railway (DB) study
	Carbon dioxide, fossil	-	-	kg	2.13E-3	1	1.08	(2,2,1,3,1,1); German railway (DB) study
	Dinitrogen monoxide	-	-	kg	6.77E-8	1	1.56	(2,2,1,1,3,1); handbook emission factors for HGV
emission air, unspecified	Ammonia	-	-	kg	1.35E-8	1	1.30	(2,2,1,1,3,1); handbook emission factors for HGV
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.43E-6	1	1.56	(2,2,1,1,3,1); handbook emission factors for HGV
	Nitrogen oxides	-	-	kg	3.72E-5	1	1.56	(2,2,1,1,3,1); German railway (DB) study
	Particulates, > 10 um	-	-	kg	3.03E-5	1	1.52	(3,2,1,3,1,1); own calculation base on PM figures of DB study
	Particulates, > 2.5 um, and < 10um	-	-	kg	4.14E-5	1	2.01	(3,2,1,3,1,1); own calculation base on PM figures of DB study
	Particulates, < 2.5 um	-	-	kg	8.69E-7	1	3.01	(3,2,1,3,1,1); own calculation base on PM figures of DB study
	Sulfur dioxide	-	-	kg	4.06E-7	1	1.08	(2,2,1,3,1,1); European railway study
	Toluene	-	-	kg	2.71E-8	1	1.58	(3,2,1,1,3,1); handbook emission factors for HGV
	Xylene	-	-	kg	2.71E-8	1	1.58	(3,2,1,1,3,1); handbook emission factors for HGV
	Mercury	-	-	kg	1.35E-14	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Lead	-	-	kg	7.45E-14	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Cadmium	-	-	kg	6.77E-12	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Copper	-	-	kg	1.15E-9	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Chromium	-	-	kg	3.39E-11	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Nickel	-	-	kg	4.74E-11	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Selenium	-	-	kg	6.77E-12	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Zinc	-	-	kg	6.77E-10	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Sulfur hexafluoride	-	-	kg	3.14E-9	1	1.63	(3,5,1,2,3,1); literature
	Heat, waste	-	-	MJ	2.87E-1	1	1.07	(2,1,1,1,1,1); standard value
emission soil, unspecified	Iron	-	-	kg	6.02E-5	1	1.60	(4,4,3,2,1,3); own calculation based on literature

Data Quality and uncertainties

The quality of the electricity value is considered as good. Due to the fact that it has been obtained top down, uncertainties due to assumption about load factors are excluded. The diesel consumption of shunting processes is considered as less good, since further assumptions have been made that pose additional uncertainties due to choices on the diesel consumption figure. The quality of emission factors for shunting varies, and is addressed with basic uncertainties and data quality indicators such as reliability, technology correlation and representativeness.

6.3 Operation of Goods Trains in Europe

The module operation of goods trains comprises both; the actual performance of goods trains as well as required shunting processes. In contrast to operation in Switzerland, a distinction between the type of traction, diesel and electricity is important since in most European countries diesel and electro locomotives are in operation for both goods transportation and passenger transportation.

First, we determine the energy consumption for electric traction and diesel tractions separately. Second, we estimate specific energy consumption for a mixed electricity and diesel traction representing European goods transportation conditions in 2000.

6.3.1 Energy Consumptions of Electric trains

In a recent study, specific energy consumption figures for electric trains are calculated for different train weights and geographical conditions J. Borken et al. (2003). A typical average gross weight for international trains is assumed to be 1000 Gt. In addition, specific electricity consumption for a short train and a long train with an average weight of 500 Gt and 1500 Gt has been calculated. In Table 6-13 the resulting figures for each country are summarized.

Table 6-13: Specific final energy consumption for electric goods trains of different length

	Short (500 t)	Average (1000t)	Long (1500 t)
	Wh/tkm	Wh/tkm	Wh/tkm
Belgium	60.4	42.7	34.9
Denmark	48.3	34.2	27.9
Germany	60.4	42.7	34.9
Greece	60.4	42.7	34.9
Spain	60.4	42.7	34.9
France	60.4	42.7	34.9
Ireland	60.4	42.7	34.9
Italy	60.4	42.7	34.9
Luxembourg	60.4	42.7	34.9
Netherlands	48.3	34.2	27.9
Austria	72.4	51.2	41.8
Portugal	60.4	42.7	34.9
Finland	60.4	42.7	34.9
Sweden	48.3	34.2	27.9
UK	60.4	42.7	34.9
EU-15	58.9	41.6	34.0

In this study we use the EU-15 figure for an average train and further assume an energy loss due to transformation of 15% (see section 6.2.1). Thus, we achieve a final energy consumption including losses of 0.0478 KWh/tkm.

6.3.2 Energy Consumption of Diesel Trains

Borken (2003), stated that the available energy data for diesel traction ranges between 2.6 and 9.7 g/Gtkm. For a train of 1000 Gt in a hilly country they proposed a specific energy consumption of approximately 5 g/Gtkm or 10g/tkm. The later value is used in this study.

6.3.3 European Mix of Diesel and Electro Traction

Data for a European average goods train, comprising a share of both types of energy, diesel and electricity, was not readily available. Thus, some assumptions have been essential, which are described in this section.

Data for the energy consumption for rail traction is available from EUROSTAT (2001) and displayed in Table 6-14.

Table 6-14: Energy consumption of main fuels for European rail transport

	diesel	electricity	electricity	Changes diesel (85-98)	Changes electricity (85-98)
	tons/a	tons/a 1)	GWh/a 1)	%	%
Belgium	6.30E+04	1.17E+05	1.36E+03	-45	15
Denmark	7.90E+04	2.60E+04	3.02E+02	-32	119
Germany	6.24E+05	1.38E+06	1.61E+04	30	44
Greece	4.20E+04	1.50E+04	1.74E+02	-19	433
Spain	4.55E+05	3.22E+05	3.74E+03	150	33
France	4.54E+05	9.55E+05	1.11E+04	-8	46
Ireland	1.02E+05	2.00E+03	2.33E+01	135	100
Italy	1.92E+05	6.76E+05	7.86E+03	0	62
Luxembourg	5.00E+03	7.00E+03	8.14E+01	-44	85
Netherlands	0.00E+00	1.40E+05	1.63E+03	0	47
Austria	0.00E+00	1.88E+05	2.19E+03	0	-1
Portugal	4.70E+04	3.10E+04	3.60E+02	-18	37
Finland	5.40E+04	4.40E+04	5.12E+02	-25	43
Sweden	1.60E+04	2.41E+05	2.80E+03	-81	7
UK	5.89E+05	6.45E+05	7.50E+03	-21	54
EU-15	2.72E+06	4.79E+06	5.57E+04	-1	49

1: conversion factor used: 1GWh = 86 tons diesel

Whilst the data distinguishes between electricity consumption and diesel consumption, no distinction between goods and passenger transport for each energy type is available. Furthermore, the electricity data also includes urban transport systems. In consequence, these data cannot be easily used to determine the specific energy consumption for European fright rail transport. Data for the share of electricity and diesel traction in goods transportation, however, is available for the German rail company (DB), which is responsible for 30% of the total European goods transportation, as demonstrated in Table 6-3. In the recent environmental report DB (2000) figures for the primary energy consumption for electric and diesel traction are published and summarized in Table 6-15.

Table 6-15: Total primary energy consumption for electric and diesel traction in Germany

Type of traction	Unit	Type of Transport	1998	1999	2000	Ratio passenger/goods transport
Electric traction	GWh/a	passenger transport	23135	23165	23151	0.69
		goods transport	10189	10269	9911	0.31
		total	33324	33434	33062	1.00
Diesel traction	GWh/a	passenger transport	5576	4982	5170	0.75
		goods transport	1876	1924	1670	0.25
		total	7452	6906	6840	1.00

Primary energy consumption is treated as a key indicator of the DB and accounts for the generation of electricity and fuels besides the utilizable final energy, which is required for this project. Thus, the share of final energy on the primary energy for both diesel and electricity has to be determined. As stated in DB (2000), the primary energy is derived using the TREMOD computer model Knörr et al. (2000). In a recent publication, the final energy consumption share of the primary energy is published J. Borken et al. (2003) and demonstrated in Table 6-16. Based on these figures the specific final energy consumption can be determined. The resulting figures are also summarized in Table 6-16.

Table 6-16: Final energy consumption for diesel and electrify consumption and specific consumption factors

	Unit	Electric traction	Unit	Diesel traction
Ratio final energy/primary energy [1)]	%	0.27	%	0.89
Total final energy consumption (2000)	GWh/a	2775	kg/a	127821
Specific final energy consumption [2)]	KWh/tkm	0.0344	kg/tkm	0.0016
Spec. final energy (incl. Transform. Losses) [3)]	KWh/tkm	0.0396	kg/tkm	0.0016

1: derived from J. Borken et al. (2003)

2: based on a transport performance of 80634 Mio. tkm/a in the reference year 2000 DB (2000)

3: loss of 15 %

In the absence of further information for the remaining European countries we employ the German values for the representation of goods transportation conditions in Europe. However, it should be bear in mind that the share of diesel and electricity may vary significantly in the various European countries.

6.3.4 Airborne Emissions

Airborne emission indices due to diesel traction as available from literature are summarised in Table 6-9. The indices employed in this project are presented in the last column. For heavy metal emissions we employ the figures as presented in section 6.2.4.

6.3.5 Emissions to Soil

Iron emissions to soil are accounted for employing the figure for Swiss operation services. Emission of lubricates due to traction are not accounted for, since measures are in operation to avoid such emissions.

6.3.6 Diesel Consumption and Emissions of Shunting Processes

For energy consumption of shunting processes assumptions and data as presented in chapter 6.2.4 is applied.

6.3.7 Life Cycle Inventory Input Data

In Table 6-17 the inventory tables for the three modules, “operation freight train diesel”, “operation freight train electricity” and “operation freight train” are summarised. The latter module comprises both diesel and electro traction, and represents European average conditions.

Table 6-17: Life cycle inventory table for operation of goods trains in Europe

	Name	Loca-tion	Unit	*operation, freight train, diesel*	*operation, freight train, electricity*	*operation, freight train*	Uncertainty Type	Standard Deviation95%	GeneralComment
product	operation, freight train, diesel	RER	tkm	1.00E+0					
	operation, freight train, electricity	RER	tkm		1.00E+0				
	operation, freight train	RER	tkm			1.00E+0			
technosphere	diesel, at regional storage	RER	kg	1.07E-2	6.77E-4	2.26E-3	1	1.09	(2,3,1,3,1,1); International Rail study
	electricity, high voltage, production U	UCTE	kWh	-	4.78E-2	3.96E-2	1	1.09	(2,3,1,3,1,1); International Rail study
emissions to air	Benzene	-	kg	1.07E-6	6.77E-8	2.26E-7	1	2.06	(2,3,1,3,3,1); handbook emission factors for HGV
	Methane, fossil	-	kg	1.39E-6	8.80E-8	2.94E-7	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
	Carbon monoxide, fossil	-	kg	1.69E-4	1.07E-5	3.57E-5	1	5.01	(2,3,1,3,1,1); International Rail study
	Carbon dioxide, fossil	-	kg	3.36E-2	2.13E-3	7.12E-3	1	1.09	(2,3,1,3,1,1); International Rail study
	Dinitrogen monoxide	-	kg	1.07E-6	6.77E-8	2.26E-7	1	1.57	(2,3,1,3,3,1); International Rail study
	Ammonia	-	kg	2.14E-7	1.35E-8	4.52E-8	1	1.57	(2,3,1,3,3,1); International Rail study
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	5.41E-5	3.43E-6	1.15E-5	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
	Nitrogen oxides	-	kg	5.87E-4	3.72E-5	1.24E-4	1	1.51	(2,3,1,3,1,1); International Rail study
	Particulates, > 10 um	-	kg	3.09E-5	3.03E-5	3.04E-5	1	1.52	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
	Particulates, > 2.5 um, and < 10um	-	kg	4.24E-5	4.14E-5	4.15E-5	1	2.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
	Particulates, < 2.5 um	-	kg	1.37E-5	8.69E-7	2.90E-06	1	3.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
	Sulfur dioxide	-	kg	6.41E-6	4.06E-7	1.36E-6	1	1.09	(2,3,1,3,1,1); European railway study
	Toluene	-	kg	4.27E-7	2.71E-8	9.05E-8	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
	Xylene	-	kg	4.27E-7	2.71E-8	9.05E-8	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
	Mercury	-	kg	2.14E-13	1.35E-14	4.52E-14	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Lead	-	kg	1.17E-12	7.45E-14	2.49E-13	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Cadmium	-	kg	1.07E-10	6.77E-12	2.26E-11	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Copper	-	kg	1.82E-8	1.15E-9	3.85E-9	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Chromium	-	kg	5.34E-10	3.39E-11	1.13E-10	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Nickel	-	kg	7.47E-10	4.74E-11	1.58E-10	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Selenium	-	kg	1.07E-10	6.77E-12	2.26E-11	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Zinc	-	kg	1.07E-8	6.77E-10	2.26E-9	1	5.10	(4,5,1,2,1,1); expert estimate quoted from literature
	Sulfur hexafluoride	-	kg	-	2.10E-09	1.74E-09	1	1.63	(3,5,1,2,3,1); literature
	Heat, waste	-	MJ	4.85E-1	2.03E-1	2.45E-1	1	1.07	(2,1,1,1,1,1); standard value
emmissions to soil	Iron	-	kg	6.02E-5	6.02E-05	6.02E-05	1	3.00	(-,-,-,-,-,1); own calculation based on literature

Data Quality and Uncertainty

The data quality of the energy consumption for the modeled train types is considered as good. However, some uncertainties arise due to the selected load factor of 0.5. As demonstrated in the previous chapter, for Switzerland this figure is not realistic. Further uncertainties arise due to the application of an European electricity mix for electro traction. Some rail companies have their own electricity generation plants (e.g. about 20% of the German traction energy is produced by the DB itself). The emission factors are based on emission indices obtained from literature studies and complemented with average lorry emissions. The different quality for various emissions to air is addressed with the basic uncertainty for each pollutant and reliability and representativeness quality indicator scores.

6.4 Operation of Goods Trains in China

Three different types of freight transport are defined to reflect the use of electric, diesel, and steam locomotives in the coal industry and in China in general:

- “operation, coal freight train, diesel (CN)”, 70% of total coal transport by train;

- “operation, coal freight train, electricity (CN)”, 25% of total coal transport by train; and,

- “operation, coal freight train, steam (CN)”, 5% of total coal transport by train; mostly own mine trains, for transports within large coal mining areas and/or from mines to shunting/loading centres for long-range transports by national railways.

The 2004 China official statistics on the number of locomotives in operation in all railway Companies (national and local) give the shares 69.7%, 28.7% and 1.5%, respectively. These shares have been modified to reflect the likely specific use of steam locomotives for coal transport for some tens kilometres on the average.

Tables Table 6-18 through Table 6-20 show the three datasets corresponding to the different transport systems. The diesel technology is identical as described in the corresponding dataset for RER but assuming the consumption of diesel per tkm derived from Chinese statistics. However, the original diesel consumption per tkm has been corrected because it is most likely incompatible being only one quarter of the value taken from European statistics assumed in ecoinvent. The correction factor of 2.67 for fuel intensity is the product of two separate sub-factors: 2 to take into account of the fact that coal is transported only one way, and 1/3 to consider the weight of the freight car. In fact the Chinese statistics give on the same page the energy use per tkm, the “Utilization Rate of Loading Capacity of Freight Cars” at an astonishing 98% (definitively unrealistic because coal makes 40% of the total transported goods), and the total mass of loaded freight car “Static Load of Freight Cars (Standard Gauge)” of nearly 60 tonnes of which roughly 20 tonnes must be the car itself. With this correction, also applied to the electric and steam locomotive, the fuel utilization factor comes closer to the RER data. The uncertainly in the value due to the mentioned discrepancy has been signalled with an increased uncertainty factor compared to the corresponding item in the corresponding European dataset.

The electric train operation is also based upon the corresponding RER dataset in. However, also in this case the Chinese official statistics give a much lower energy use that the European ones, 3.6 time lower electricity consumption per tkm. Again, the original value has been increased by a factor of 2.67 and the uncertainty factor has been increased compared to the corresponding item in (Spielmann et al. 2004). In this dataset, the diesel consumption for diesel locomotives used in shunting has accordingly been decreased from the European value.

The steam locomotive dataset is modelled in first approximation by assuming a factor of 4 in fuel (equivalent) utilization compared with a diesel locomotive, based on consideration of likely actual efficiencies (mix of first generation steam locomotives with typical drawbar thermal efficiency of approximately 7% and some second generation with superheating with efficiency up to 15%. Further correction has been applied using the factor 2.67 explained above.

Emissions from the steam locomotive have been roughly estimated adjusting the emission rates (per MJ) from “hard coal, burned in coal mine power plant (CN)” by the average LHV (24 MJ/kg bituminous coal assumed to be used for locomotives vs. 12 MJ/kg poor quality coal for small power plants). Additionally, to somewhat take into account the less efficient combustion characteristics, emissions rates have been modified upwards using a factor 2 greater than the, corresponding ones (per MJ) from a small power plants, except CO2, CH4, NOx, and PM. For the latter, although coal for steam locomotives has a presumably lower ash content (say approximately 25% of coal weight) compared with coal for small coal mine plants (up to 50% of coal weight (Dones et al. 2003)), the retention efficiency is likely lower. Considering also that these locomotives are used mostly within Coal Bureaus, therefore in already highly polluted areas, and that pictures of some steam locomotive show dark and abundant plumes, the PM emission is likely high. Due to the assumptions on ash content, the disposal of ashes has been halved for the locomotive compared to small plants.

Due to the several approximations described above, the CN datasets for transport systems cannot be used for comparison of transport means in different countries, and should be used only when transport is not a major contributor to total environmental burdens of a Chinese process or product being investigated with LCA.

Table 6-18: Dataset "operation, coal freight train, diesel (CN)".

Name	Location	Unit	operation, coal freight train, diesel	Uncertainty Type	Standard Deviation 95%	General Comment
Location			CN			
InfrastructureProcess			1			
Unit			tkm			
diesel, at regional storage	RER	kg	2.50E-03	1	3	own assumption; original dataset for Europe 1.09 (2,3,1,3,1,1); International Rail study
Heat, waste		MJ	1.13E-01	1	1.07	(2,1,1,1,1,1); standard value
Ammonia		kg	5.00E-08	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Benzene		kg	2.50E-07	1	2.06	(2,3,1,3,3,1); handbook emission factors for HGV
Cadmium		kg	2.50E-11	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Carbon dioxide, fossil		kg	7.85E-03	1	1.09	(2,3,1,3,1,1); International Rail study
Carbon monoxide, fossil		kg	3.95E-05	1	5.01	(2,3,1,3,1,1); International Rail study
Chromium		kg	1.25E-10	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Copper		kg	4.25E-09	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Dinitrogen monoxide		kg	2.50E-07	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Lead		kg	2.73E-13	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Mercury		kg	5.00E-14	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Methane, fossil		kg	3.25E-07	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Nickel		kg	1.75E-10	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Nitrogen oxides		kg	1.37E-04	1	1.51	(2,3,1,3,1,1); International Rail study
NMVOC, non-methane volatile organic compounds, unspecified origin		kg	1.26E-05	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Particulates, < 2.5 um		kg	3.20E-06	1	3.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Particulates, > 10 um		kg	7.22E-06	1	1.52	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Particulates, > 2.5 um, and < 10um		kg	9.91E-06	1	2.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Selenium		kg	2.50E-11	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Sulfur dioxide		kg	1.50E-06	1	1.09	(2,3,1,3,1,1); International Rail study
Sulfur hexafluoride		kg	0.00E+00	1	1.63	(3,5,1,2,3,1); literature
Toluene		kg	9.98E-08	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
Xylene		kg	9.98E-08	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
Zinc		kg	2.50E-09	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Iron		kg	1.41E-05	1	3	(-,-,-,-,-,1); own calculation based on literature

Table 6-19: Dataset "operation, coal freight train, electricity (CN)".

Name	Location	Unit	operation, coal freight train, electricity	Uncertainty Type	Standard Deviation 95%	General Comment
Location			*CN*			
InfrastructureProcess			*1*			
Unit			*tkm*			
electricity, medium voltage, at grid	CN	kWh	1.11E-02	1	2	own assumption (original dataset for Europe 1.09)
diesel, at regional storage	RER	kg	6.77E-04	1	2	own assumption (original dataset for Europe 1.09)
Heat, waste		MJ	7.07E-02	1	1.07	(2,1,1,1,1,1); standard value
Ammonia		kg	1.35E-08	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Benzene		kg	6.77E-08	1	2.06	(2,3,1,3,3,1); handbook emission factors for HGV
Cadmium		kg	6.77E-12	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Carbon dioxide, fossil		kg	2.13E-03	1	1.09	(2,3,1,3,1,1); International Rail study
Carbon monoxide, fossil		kg	1.07E-05	1	5.01	(2,3,1,3,1,1); International Rail study
Chromium		kg	3.38E-11	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Copper		kg	1.15E-09	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Dinitrogen monoxide		kg	6.77E-08	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Lead		kg	7.40E-14	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Mercury		kg	1.35E-14	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Methane, fossil		kg	8.79E-08	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Nickel		kg	4.73E-11	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Nitrogen oxides		kg	3.71E-05	1	1.51	(2,3,1,3,1,1); International Rail study
NMVOC, non-methane volatile organic compounds, unspecified origin		kg	3.42E-06	1	1.57	(2,3,1,3,3,1); handbook emission factors for HGV
Particulates, < 2.5 um		kg	8.67E-07	1	3.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Particulates, > 10 um		kg	1.96E-06	1	1.52	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Particulates, > 2.5 um, and < 10um		kg	2.68E-06	1	2.02	(3,3,1,3,1,1); own calculation base on PM figures of int. Rail study
Selenium		kg	6.77E-12	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Sulfur dioxide		kg	4.06E-07	1	1.09	(2,3,1,3,1,1); International Rail study
Sulfur hexafluoride		kg	*2.10E-09*	1	1.63	(3,5,1,2,3,1); literature
Toluene		kg	2.70E-08	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
Xylene		kg	2.70E-08	1	2.06	(3,3,1,3,3,1); handbook emission factors for HGV
Zinc		kg	6.77E-10	1	5.1	(4,5,1,2,1,1); expert estimate quoted from literature
Iron		kg	3.81E-06	1	3	(-,-,-,-,-,1); own calculation based on literature

Table 6-20: Dataset "operation, coal freight train, steam (CN)".

Name	Location	Unit	operation, coal freight train, steam	Uncertainty Type	Standard Deviation 95%	General Comment
Location			CN			
InfrastructureProcess			1			
Unit			tkm			
hard coal, at mine	CN	kg	2.63E-02	1	2	own assumption (original dataset for Europe 1.09)
Heat, waste		MJ	4.65E-01	1	1.39	increased by a factor 1.3 from the corresponding uncertainty in "hard coal, burned in coal mine power plant"
Antimony		kg	2.49E-09	1	7.80	"
Arsenic		kg	1.52E-08	1	7.80	"
Barium		kg	1.53E-07	1	7.80	"
Benzene		kg	2.73E-07	1	3.25	"
Benzo(a)pyrene		kg	2.52E-13	1	3.25	"
Boron		kg	8.83E-07	1	7.80	"
Bromine		kg	7.19E-07	1	3.51	"
Butane		kg	2.39E-08	1	3.25	"
Cadmium		kg	1.46E-09	1	7.80	"
Carbon dioxide, fossil		kg	5.86E-02	1	1.45	"
Carbon monoxide, fossil		kg	2.52E-05	1	7.80	"
Chromium		kg	1.44E-08	1	7.80	"
Chromium VI		kg	1.78E-09	1	5.20	"
Cobalt		kg	5.95E-09	1	7.80	"
Copper		kg	1.92E-08	1	7.80	"
Dinitrogen monoxide		kg	3.15E-07	1	2.60	"
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin		kg	8.82E-15	1	5.20	"
Ethane		kg	5.17E-08	1	3.25	"
Formaldehyde		kg	7.31E-08	1	3.25	"
Hydrocarbons, aliphatic, alkanes, unspecified		kg	2.76E-07	1	3.25	"
Hydrocarbons, aliphatic, unsaturated		kg	2.72E-07	1	3.25	"
Hydrogen chloride		kg	3.85E-05	1	3.90	"
Hydrogen fluoride		kg	3.44E-06	1	3.90	"
Iodine		kg	3.68E-07	1	3.90	"
Lead		kg	7.97E-08	1	7.80	"
Lead-210		kBq	1.53E-04	1	7.80	"
Manganese		kg	7.60E-08	1	7.80	"
Mercury		kg	4.03E-09	1	7.80	"
Methane, fossil		kg	6.30E-07	1	3.25	"
Molybdenum		kg	2.71E-09	1	7.80	"
Nickel		kg	4.20E-08	1	7.80	"
Nitrogen oxides		kg	2.57E-04	1	2.60	"
PAH, polycyclic aromatic hydrocarbons		kg	1.26E-09	1	5.20	"
Particulates, < 2.5 um		kg	6.33E-03	1	5.20	"
Particulates, > 10 um		kg	1.58E-03	1	3.25	"
Particulates, > 2.5 um, and < 10um		kg	7.45E-04	1	4.55	"
Pentane		kg	1.85E-07	1	3.25	"
Polonium-210		kBq	2.80E-04	1	6.50	"
Potassium-40		kBq	3.76E-05	1	6.50	"
Propane		kg	4.41E-08	1	3.25	"
Propene		kg	2.02E-08	1	3.25	"
Radium-226		kBq	3.95E-05	1	6.50	"
Radium-228		kBq	1.17E-05	1	6.50	"
Radon-220		kBq	8.19E-04	1	6.50	"
Radon-222		kBq	4.61E-04	1	6.50	"
Selenium		kg	1.25E-08	1	7.80	"
Strontium		kg	1.39E-07	1	7.80	"
Sulfur dioxide		kg	1.58E-03	1	2.60	"
Thorium-228		kBq	6.30E-06	1	6.50	"
Thorium-232		kBq	9.90E-06	1	6.50	"
Toluene		kg	1.37E-07	1	3.25	"
Uranium-238		kBq	3.29E-05	1	6.50	"
Vanadium		kg	3.51E-08	1	7.80	"
Xylene		kg	1.16E-06	1	3.25	"
Zinc		kg	9.70E-08	1	7.80	"
disposal, hard coal ash, 0% water, to residual material landfill	PL	kg	8.39E-03	1.00	3.00	own assumption

6.5 Operation of Goods Trains in the USA

According to (Facanha & Horvath 2006) it can be assumed that US freight trains for coal transport are all operated using diesel engines. As a first approximation the corresponding European diesel freight transport dataset is used.

6.6 Operation of Swiss Passenger Trains

In Switzerland, passenger transport is performed almost exclusively by electric powered trains. In contrast to goods transportation no diesel locomotives are used for shunting processes in passenger transport.

6.6.1 Traction Energy

The data presented in the database represents average environmental interventions, calculated top down from the yearly energy consumption and yearly transport performance. For electricity consumption of regional and long distance trains, yearly average data is available from the SBB (SBB, 2002, see also Footnote 9). These data is linked to reference values as presented in Table 6-2 in order to calculate specific electricity consumption. In Table 6-21 and Table 6-22 these figures are summarised.

Table 6-21: Electricity consumption of regional traffic

Indicator	Unit	Value
Total consumption regional transport	Mio. kWh	486.3
Specific consumption operation performance	KWh/Gtkm	0.042
Specific consumption kilometric performance	kWh/vkm	9.174
Specific consumption transport performance in 2000	kWh/pkm	0.171
Specific consumption transport performance in 2006 [9]	kWh/pkm	0.161

Values refer to electricity consumption at traction substation

Table 6-22: Electricity consumption of long-distance traffic

Indicator	Unit	Value
Total consumption long-distance transport	Mio. kWh	743.4
Specific consumption operation performance	KWh/Gtkm	0.031
Specific consumption kilometric performance	kWh/vkm	15.318
Specific consumption transport performance in 2000	kWh/pkm	0.087
Specific consumption transport performance in 2006	kWh/pkm	0.077

Values refer to electricity consumption at traction substation

Transmission losses (transmission and conversion ex high voltage network) are accounted for with 10%, resulting in a final energy consumption of 0.0842 kWh/pkm and 0.1767 kWh/pkm for the operation of long distance trains and regional trains, respectively.

6.6.2 Airborne Emissions

Due to the fact that on the Swiss rail network only very few diesel locomotives are in operation emissions to air are limited to particulate emissions due to abrasion and emission of sulphur hexafluoride (SF6) occurring during conversion at traction substations.

Source of abrasion are rail tracks, wheels, brakes and overhead contact line. In Table 6-5 PM_{10} emission factors as available from literature are summarised. Particulate emission due to abrasion are currently issue of intensive studies in Switzerland[10]. The figures presented here, therefore should only be

[9] Email from Markus Halder, BahnUmwelt-Center SBB, 17th of april 2007

[10] Oral communication with Helmut Kuppelwieser, SBB Environmental Management

considered as rough estimates. For the determination of PM $_{10}$ emission factors for wheels, rail and overhead contacting line, we employ the same figures as used for goods transportation (see Table 6-5). For the determination of PM > 10 we assume a share of 25 % for wheel and rail abrasion. The abrasion of brakes and the resulting share of PM $_{10}$ depend on the wheel load and thus differ between fully loaded goods trains and passenger trains (see Table 6-23).

Table 6-23: Size distribution of braking line abrasion for passenger trains

Abrasion	Size distribution empty goods train and passenger train (wheel load: 2.5t) [1)]	Size distribution fully loaded goods train (wheel load: 11.25t) [1)]	This project for passenger trains
	%	%	%
Non airborne emissions	56	28	56
PM10	21	12	21
PM>10	23	60	23
Total Abrasion	100	100	100

1: (SBB, 2002)

The essential allocation is performed by employing the traction performance as allocation factor. In Table 6-24 the resulting figures are summarised.

Table 6-24: Specific emission factors of particulates due to abrasion

	unit	Total abrasion	PM 10 [1)]	PM >10
Yearly load	t/a	1069		
Allocated yearly load regional transport	t/a	206	86.2	49.4
Allocated yearly load long distance transport	t/a	427	178.7	100.3
Specific emission factor regional train	kg/pkm	7.25E-05	3.04E-05	1.70E-05
Specific emission factor long distance train	kg/pkm	5.01E-05	2.10E-05	1.18E-05

1) the entire load of PM10 is classified as coarse particulates (a diameter > 2.5 um and < 10um)

For sulphur hexafluoride (SF6) emitted during conversion at traction substations we assume an emission index of 4.4E-08 kg/kWh Frischknecht (2003) resulting in a specific emission of 4.03E-09 kg/pkm and 7.91E-09 kg/pkm for long-distance transport and regional transport, respectively.

6.6.3 Emissions to Soil

Abrasion (from braking lining, rail and wheel) is predominately composed of iron and mineral components BUWAL (2002). In this study we assume that all non-airborne abrasion emissions are emitted as iron to soil. In consequence, we assume a yearly iron load of 71.5 t/a and 148.1 t/a for regional and long distance transport, respectively.

Emission of lubricates due to traction are not accounted for, since measures are in operation to avoid such emissions.

6.6.4 Life Cycle Inventory Input Data

Table 6-25: Life cycle inventory table for operation of Swiss average long distance train

	Name	Location	InfrastructureProcess	Unit	operation, long-distance train, SBB mix	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				0			
	Unit				pkm			
product	operation, long-distance train, SBB mix	CH	0	pkm	1			
technosphere	electricity, high voltage, SBB, at grid	CH	0	kWh	8.42E-2	1	1.05	(1,1,1,1,1,1); SBB calculations, top down approach and anknown
emission air, unspecified	Particulates, > 2.5 um, and < 10um	-	-	kg	2.10E-5	1	2.05	(4,2,2,1,1,2); own estimates based on recent PM10 studies
	Particulates, > 10 um	-	-	kg	1.18E-5	1	1.56	(4,2,2,1,1,2); own estimates based
	Sulfur hexafluoride	-	-	kg	4.03E-9	1	1.63	(3,5,2,2,3,1); literature
	Heat, waste	-	-	MJ	3.30E-1	1	1.22	(2,1,1,1,1,5); standard value
emission soil, unspecified	Iron	-	-	kg	1.74E-5	1	1.56	(4,2,2,1,1,2); own estimates based on recent PM10 studies

Table 6-26: Life cycle inventory table for operation of Swiss average long distance train

	Name	Location	InfrastructureProcess	Unit	operation, regional train, SBB mix	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				0			
	Unit				pkm			
product	operation, regional train, SBB mix	CH	0	pkm	1			
technosphere	electricity, high voltage, SBB, at grid	CH	0	kWh	1.76E-1	1	1.05	(1,1,1,1,1,1); SBB calculations, top down approach and anknown
emission air, unspecified	Particulates, > 2.5 um, and < 10um	-	-	kg	3.04E-5	1	2.05	(4,2,2,1,1,2); own estimates based on recent PM10 studies
	Particulates, > 10 um	-	-	kg	1.70E-5	1	1.56	(4,2,2,1,1,2); own estimates based
	Sulfur hexafluoride	-	-	kg	7.91E-9	1	1.63	(3,5,2,2,3,1); literature
	Heat, waste	-	-	MJ	6.48E-1	1	1.22	(2,1,1,1,1,5); standard value
emission soil, unspecified	Iron	-	-	kg	2.52E-5	1	1.56	(4,2,2,1,1,2); own estimates based on recent PM10 studies

6.7 Operation of High Speed Trains (ICE)

As an example for high speed trains, data for the German ICE is presented in this project. If not stated explicitly, the data is taken from von Rozycki (2003).

6.7.1 Traction Energy

In Table 6-27 electricity consumption figures are summarised. In order to calculate the specific consumption per pkm we assume 309 passengers per train.

Table 6-27: Electricity consumption of an ICE (von Rozycki, 2003)

Traction energy (ICE I/II)	rail electricity	kWh/trainkm	22.5	kWh/pkm	0.0728
Train board energy (ICE I/II)	rail electricity	kWh/trainkm	1.35	kWh/pkm	0.0043
Overhead energy	rail electricity	kWh/trainkm	1.2	kWh/pkm	0.0038

6.7.2 Airborne Emissions

For airborne emissions we employ the figures we calculated for Swiss long distance transport (particulate emissions due to abrasion and emission of sulphur hexafluoride (SF6) occurring during conversion at traction substations). Emissions of copper due to abrasion of overhead contacting line (0.57288 g/trainkm (von Rozycki, 2003)), are completely accounted for as PM10 emissions resulting in a specific PM 10 emission of 2.11E-05 kg/pkm. For sulphur hexafluoride (SF6) emitted during conversion at traction substations we assume an emission index of 4.4E-08 kg/kWh Frischknecht (2003) resulting in a specific emission of 43.57E-9.

6.7.3 Emissions to Soil

Abrasion (from braking lining, rail and wheel) we employ the same figure as for the Swiss long distance train. Emission of lubricates due to traction are not accounted for, since measures are in operation to avoid such emissions.

6.7.4 Life Cycle Inventory Input Data

Table 6-28: Life cycle inventory table for operation of German average high speed train (ICE)

	Name	Location	Unit	*operation, ICE*	Uncertainty Type	StandardDeviation 95%	GeneralComment
	Location			***DE***			
	InfrastructureProcess			***0***			
	Unit			***pkm***			
product	operation, ICE	DE	pkm	1.00E+0			
technosphere	electricity, high voltage, at grid	DE	kWh	8.11E-2	1	1.20	literature studies; uncertainties are an estimate of the study team.
emissions to air	Particulates, > 10 um	-	kg	5.89E-6	1	2.50	own estimates based on recent PM 10 studies addressing Swiss conditions. Data represent average Swiss conditions resulting in an additional uncertainty compared to Swiss modules.
	Particulates, > 2.5 um, and < 10um	-	kg	1.15E-5	1	2.50	own estimates based on recent PM 10 studies addressing Swiss conditions. Data represent average Swiss conditions resulting in an additional uncertainty compared to Swiss modules.
	Sulfur hexafluoride	-	kg	3.57E-9	1	1.63	(3,5,1,2,3,1); literature
	Heat, waste	-	MJ	2.92E-1	1	1.20	(2,1,1,1,1,1); standard value
emmissions to soil	Iron	-	kg	8.69E-6	1	2.50	own estimates based on recent PM 10 studies addressing Swiss conditions. Data represent average Swiss conditions resulting in an additional uncertainty compared to Swiss modules.

6.8 Rail Transport Equipment

In this section, the environmental interventions of rail transport equipment due to manufacturing, maintenance and disposal are documented. In Table 6-29 the key figures for the Swiss freight transport equipment are presented.

Table 6-29: Key figures for the swiss rail transport equipment

	Unit	Total CH 1997 [1)]	SBB 1999 [2)]	SBB 2000 [2)]
Goods transport performance	tkm	8.63E+09	9.80E+09	1.08E+10
Wagons	unit	22229	20119	19791
Wagons per transport unit	unit/tkm	2.58E-06	2.05E-06	1.83E-06
Locomotives goods transportation [3)]	unit	431	307	307
Locomotives per transport unit	unit/tkm	1.22E-07	7.66E-08	6.95E-08

1: figures are taken from the Swiss national transport statistics Bundesamt für Statistik (BfS) (2000) and represent the total goods transport rail equipment in Switzerland, including all private rail companies.

2: figures are taken from an SBB report (SBB, 2002).

3: In the SBB report as well as the Swiss national statistic no further distinction between locomotives used for goods transportation and passenger transportation has been made. The figures presented here are based on the share of gross tonne kilometre of goods transportation of the SBB.

A comparison between the SBB figures of two years reveals a higher efficiency in the use of wagons in 2000. In this project we employ the SBB figures for the year 2000.

6.8.1 Manufacturing of Locomotives and Goods Transportation Rail Wagons

For manufacturing of locomotives and rail wagons, no new data has been colleted; i.e. the data is based on Elsener & Strub (1993).

Manufacturing of locomotives

The environmental interventions of the locomotive manufacturing are derived from an assessment of the “RE 460”. The “Re 460” is a locomotive which currently is used for both rail and passenger transportation in Switzerland. In the future this type will be replaced with a specific “goods transportation” locomotive the “Re 482”. In the year 2000, however, none of the latter was in operation. The life span of the locomotive “Re 460” is assumed to be 40 years resulting in a lifetime performance of 9.6 Mio. Kilometres Frischknecht et al. (1996). The materials with a weight above 200 kg are summarised in the in Table 6-37. Expenditures due to vehicle manufacturing are limited to energy consumption (electricity and light fuel oil, including administration).

Manufacturing of goods transportation rail wagons

In 1997, 22229 rail wagons are recorded in the Swiss statistic Bundesamt für Statistik (BfS) (2000). The vehicle park of rail wagons is extremely inhomogeneous (up to 70 different types). The SBB reports 19791 wagons in its wagon park for the year 2000, including 6770 private wagons. The share of 4 axial wagons is about 48%, with a dominating share of 4 axial wagons in the private wagon park (SBB, 2002).The available statistics, however, do not give information about the performance of different wagon types. Furthermore in the SBB statistics no tank wagons are listed since they are under control of a private company. In contrast, to a locomotive, the material composition of wagons is less comprehensive. The dominating materials are steel and aluminium. In Table 6-30 the material composition three types of goods wagons are summarised.

Table 6-30: Material composition of goods transport rail wagons

Material	Closed wagon		Tank wagon (not isolated)		Tank wagon isolated		Model average wagon
	2 axes [1)]	4 axes [2)]	2 axes [1)]	4 axes [1)]	2 axes [1)]	4 axes [1)]	
	Kg/unit	Kg/unit	Kg/unit	Kg/unit	Kg/unit	Kg/unit	Kg/unit
Steel	14830	30300	11895	24350	11577	23676	20952
Aluminum	1060	2160	-	-	135	305	1072
Wood	1050	2140	-	-	-	-	1037
Rubber	10	10	10	10	10	10	10
Paint	80	120	95	140	95	140	106
Mineral Fibre [3)]	-	-	-	-	183	369	32

1: data are based on oral communication with a Swiss wagon manufacturing company (Mr. Soder, Meier AG, mechanical engineering and wagon manufacturing, Rheinfelden 1993).

2: data has been extrapolated from the closed wagon 2 axes using the ratio (tank wagon 4 axes/tank wagon 2 axes) as factor.

3: mineral fibre is modelled as mineral wool.

The specific energy consumption per wagon is available from Frischknecht et al. (1996). The electricity consumption is 9224 kWh and the consumption of oil is 46000 MJ. We further assume that the oil is used for heating purposes.

As stated above the SBB operates various other types of wagons, for which no information has been available. Consequently, for further aggregation, we subsumed the not represented wagon types in the represented categories. In the absence of statistic information of the actual kilometric performance of the different types of rail wagons we model an average rail wagon as follows:

- Closed and open wagons are treated as closed wagons.
- 65 % of the tank wagons feature a thermal isolated cistern, which are mainly used for the transport of chemicals
- 65% of the transport is performed by closed wagons
- 35% of the transport performance is allocated to tank wagons
- 50% of the wagons in each category are 2 axis vehicles.

The resulting material consumption for an average wagon is given in Table 6-38.

Manufacturing of Regional Trains

In this study, a common SBB-regional transport train the “Kolibri” is modelled. The total weight of a Kolibri is 171 t. The material composition is summarised in Table 6-39. For a composition of such weight, 271 seats are offered. The average load is 17% (46 passengers). The yearly vehicle kilometre performance is 150’000 vkm. In this project we assume a life span of 40 years, resulting in a total lifetime kilometric performance of 6’000’000 vkm and a life time transport performance of 276’000’000 pkm. Estimates for energy consumption for manufacturing is taken from Frischknecht (1996) assuming an electricity consumption and light fuel oil consumption of 2.7 MJ/kg material and 3.8 MJ/kg material, respectively. The resulting values for the entire train are given in Table 6-39.

Manufacturing of Long-Distance Passenger Trains

In this study, a new SBB-intercity/interregio train composition, the IC 2000 (Dosto) is modelled. The IC 2000 usually is equipped with the Re 460 and a train composition comprises 7 cars offering about 1400 seats. The maximum speed is 200 km/h. In the year 2000 the SBB had 237 wagons in operation. In the near future the stock will be expanded.

The data presented here is taken from (Maibach, 1999). The total weight of a train composition is 317 t. The material composition is summarised in Table 6-40. In contrast to older train compositions using conventional passenger cars (e.g. EW 4) dominated by steel, the share of aluminium of the IC 2000 is significantly higher. The aim of the substitution of steel is to decrease the weight and hence the electricity consumption. The average load is assumed with 28 % (392 passengers). The yearly vehicle kilometre performance is 500'000 vkm (Maibach, 1999). In this project we assume a life span of 40 years, resulting in a total life time kilometric performance of 20'000'000 vkm and a life time transport performance of 7'840'000'000 pkm. Estimates for energy consumption for manufacturing is taken from Frischknecht (1996) assuming an electricity consumption and light fuel oil consumption of 2.7 MJ/kg material and 3.8 MJ/kg material, respectively. The resulting values for the entire train are given in Table 6-40.

Manufacturing of ICE trains

Train manufacturing data is available from von Rozycki (2003) mainly based on (Maibach, 1999). The resulting values for the entire train are given in Table 6-41.

6.8.2 Maintenance of Rail Equipment

Maintenance of Locomotives and Goods Transportation Rail Wagons

In Frischknecht et al. (1996) material expenditures for maintenance have been estimated separately for locomotives and goods transportation rail wagons pursuing a bottom up approach. The estimates are based on the assumption that break blocks are substituted after a performance of 40000 km and a comprehensive check every 4 - 6 years where amongst other things the breaking system is greased. The energy consumption for the wagon maintenance is assumed to be the same as for wagon manufacturing. For the maintenance of locomotives no energy values are available in Frischknecht et al. (1996). The material consumption merely reflects the scheduled maintenance of mechanical parts.

In this project new SBB data has been available for the stationary energy and material consumption of goods transportation equipment maintenance. We assume that these data comprises expenditures for both, locomotives and wagons. In Table 6-31 and Table 6-33 energy consumption and material expenditures, respectively, for maintenance are summarised.

Table 6-31: Yearly energy consumption for rail equipment maintenance

Energy carriers	Unit	**2001**	2000 1)	1999 1)	1998 1)	1997 1)	1996 1)
Electricity	kWh	**5.68E+06**	4.20E+06	3.78E+06	4.22E+06	5.51E+06	3.84E+06
Light fuel oil	kWh	**1.69E+07**	9.15E+06	8.90E+06	9.96E+06	9.09E+06	1.02E+07
Natural gas	kWh	**1.04E+07**	6.48E+06	7.03E+06	5.18E+06	6.12E+06	7.36E+06
Coal	kWh	**1.04E+06**	-	-	-	-	-
Total	kWh	**3.40E+07**	1.98E+07	1.97E+07	1.94E+07	2.07E+07	2.14E+07

1: The figures for the years 1996-2000 do not include the consumption of the service region Tessin, Basel, Zurich)

Due to the fact that the data for 2000 do not comprise all service garages, we employ the figures for 2001, representing expenditures of all SBB goods transportation service garages.

In order to allocate the maintenance expenditures between locomotives and wagons, we allocate 95% of the maintenance expenditures to wagon maintenance and 5% to locomotive maintenance. This allocation is based on the average vehicle weight (the weight of a locomotive is 3 times higher than an average wagon) and the number of vehicles in the rail equipment. Furthermore we assume that the frequency of maintenance is the same for either type. In Table 6-32 specific energy consumption and material expenditures for wagons and locomotives are presented.

Table 6-32: Specific energy consumption for maintenance of goods transport wagons and locomotives

Energy Carrier	**Unit [1)]**	**Locomotive**	**Wagon**	**Unit**	**Locomotive**	**Wagon**
Electricity	kWh/unit	3.41E+04	1.10E+04	kWh/tkm	5.92E-05	5.02E-04
Light fuel oil	MJ/unit	3.65E+05	1.17E+05	MJ/tkm	6.34E-04	5.38E-03
Natural gas	MJ/unit	2.25E+05	7.22E+04	MJ/tkm	3.90E-04	3.31E-03
Coal	MJ/unit	2.25E+04	7.22E+03	MJ/tkm	3.90E-05	3.31E-04

1: figures represent the total life span

In 2000 the SBB goods wagons are predominately equipped with gray-cast-iron brake shoes. The replacement of the latter with synthetic break shoes starts in 2004[11]. In 2001 186'578 units of break shoes have been replaced in goods wagon. The weight of one break shoe is about 10 kg. The specific material consumption for maintenance of goods transport wagons and locomotives is summarised in Table 6-33. In Table 6-34 the energy and figures used in this project are summarised and compared with data of Frischknecht et al. (1996).

Table 6-33: Specific material consumption for maintenance of goods transport wagons and locomotives

Material	**Unit**	**Locomotive**	**Wagon**	**Unit**	**Locomotive**	**Wagon**
Wheels	Unit/unit	n.a.	4.35E+00	Unit/unit	n.a.	2.00E-07
Cast iron [1)]	Unit/unit	n.a.	3.77E+02	Unit/unit	n.a	1.73E-05
Paint	kg/unit	1.21E+02	3.89E+01	kg/tkm	5.56E-06	1.79E-06
Cleaning agents	kg/unit	1.02E+03	3.27E+02	kg/tkm	4.66E-05	1.50E-05
Lubricates non biodegradable)	kg/unit	5.63E+02	1.81E+02	kg/tkm	2.58E-05	8.30E-06
Biodegradable lubricates	kg/unit	1.28E+02	4.11E+01	kg/tkm	5.86E-06	1.88E-06

1) Break shoes: Original material composition of gray-cast-iron brake shoes: 93% iron; 3.1% carbon; 1.7% silicon; 0.6% Mn; 0.9 % P.

11 Oral communication with Helmut Kuppelwieser, SBB Environmental Management

Table 6-34: Material and energy consuption for the maintenance of goods transportation rail equipment

	Unit [1)]	**This project**		Frischknecht et al. (1996) (bottom up)		Table 6-32, Table 6-33 (Top Down)	
		Loco-motive	**Wagon**	Loco-motive	Wagon	Loco-motive	Wagon
Steel low al-loyed/iron	Kg/vehicle	**29700**		29700	-	-	
Sintered metal	Kg/vehicle	**1330 [3)]**	**-**	1330	-	-.	-
Cast iron		**-**	**3510**	-	-	-	3510
Rubber	Kg/vehicle	**840**	**-**	840	-	-	-
Lubricate	Kg/vehicle	**690**	**222**	730	31.5 [2)]	691	222
PVC	Kg/vehicle	**40**	**-**	40	-	-	-
Paint	Kg/vehicle	**121**	**39**	-	-	121	39
Cleaning Agents	Kg/vehicle	**1020**	**327**	-	-	1020	327
Electricity	KWh/vehi cle	**34100**	**11000**	-	9224	34100	11000
Heating Oil	MJ/vehicle	**365000**	**117000**	-	46000	365000	117000
Natural Gas	MJ/vehicle	**225000**	**72200**	-	-	225000	72200
Coal	MJ/vehicle	**22500**	**7220**	-	-	22500	7220

1: values are given for the entire lifespan of a vehicle. For both locomotives and wagons a lifespan of 40 years is assumed.

2: In the quoted report, 21 kg/unit for two axis wagon and 42 kg/unit four axis vehicle are assumed. The value presented in the table assumes that 50% of the entire fleet are two axis and 50% are four axis vehicles.

3: for the sintered metal a composition as followed has been assumes in this project: 75% cast iron, 20% copper, 5% coke

Waste of maintenance processes

For SBB service garages waste disposal indicators are available. The figures used in this study represent the conditions for 2001, since the available data for 2000 does not include all SBB service garages. The specific waste due to maintenance activities has been calculated by pursuing the same approach as for the calculation of energy and material expenditures. In Table 6-35 the resulting figures are presented. The sludge is assumed to contain lubricates which result from cleaning activities. For dismantled metals, for instance used break shoes, we apply a cut off allocation, since they are recycled.

Table 6-35: Waste due to maintenance activities

Waste Type	unit	Total 2001	unit	wagon	locomotive
Wood	kg/a	959260	kg/unit	1849	5754
Sludge	kg/a	153440	kg/unit	296	920

Maintenance of Swiss Passenger Trains

For passenger transport equipment no SBB data has been available for the stationary energy and material consumption. Thus literature data is employed in this project. representing expenditures for one major revision (Maibach, 1999) as well as a regular substitution of break shoes (40 kg break shoes/car (Maibach, 1999). The resulting input data for maintenance of regional and long-distance passenger trains is presented Table 6-43 and Table 6-44, respectively.

Maintenance of ICE Trains

A comprehensive inventory of ICE maintenance is available from von Rozycki (2003). He further distinguishes two types of maintenance; a) regular maintenance and b) repair (Table 6-36).

In Table 6-45 the actual input data used in this project is summarized.

Table 6-36: Maintenance activities for a German ICE train

Regular maintenance	electricity (German mix)	KWh/train	1.48E+06
	heating (district heating)	MJ/train	2.38E+07
	drinking water	kg/train	4.00E+07
	natriumhydroxid, in water	kg/train	4.00E+04
	brake lining	kg/train	3.12E+04
	paper	kg/train	1.87E+04
	wastewater	m3/train	7.00E+00
Repair	electricity (German mix)	KWh/train	9.45E+04
	heating energy (district heating)	MJ/train	1.29E+06
	drinking water	kg/train	4.50E+05
	steel	kg/train	4.50E+04
	non-iron metals [1)]	kg/train	2.50E+02
	paint	kg/train	5.00E+03
	grease/solvents [2)]	kg/train	1.00E+03
	paper/wood etc. [3)]	kg/train	2.00E+03
	municipal solid waste	kg/train	3.00E+03
	wastewater	m3/train	4.50E+02

1: in the absence of further information we assume a split of 50% aluminum and 50% cooper

2: in the absence of further information we assume a split of 50% lubricating oil and 50% solvent

3: in the absence of further information wood is modeled as paper.

6.8.3 Disposal of Locomotives and Goods Transportation Rail Wagons

Disposal Locomotive

More than 80% of the materials of modelled locomotive are metals. For these metals we assume a complete recycling and thus make a cut of allocation. For the remaining materials, merely the disposal of plastics, glass and paint as well as used oil are taken into account. For the transportation, standard distances are applied for the disposal of glass and plastics. For the remaining materials, a distance of 50 km has been assumed.

Disposal Goods Wagon

The discarded wagons are scrapped and recycled. The bogies are reused and merely the body is renewed. Fractions of rubber and paint are very small and are neglected. Thus, the disposal of wagons is not modelled in the inventory.

Disposal regional and long distance trains

The majority of materials of the train compositions are metals. For these metals we assume a complete recycling and thus make a cut of allocation. For the remaining materials, merely the disposal of plastics, glass and paint are taken into account. For the transportation, standard distances are applied for the disposal of glass and plastics. For the remaining materials, a distance of 50 km has been assumed.

6.8.4 Life Cycle Inventory Input Data

Table 6-37: Life cycle inventory input data for manufacturing of a locomotive of the type "Re 462"

	Name	Location	Unit	locomotive	UncertaintyType	StandardDeviation95 %	GeneralComment
product	locomotive	RER	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	kg	3.42E+4	1	1.27	(4,3,2,1,1,3); oral communication
	steel, low-alloyed, at plant	RER	kg	1.64E+4	1	1.27	(4,3,2,1,1,3); oral communication
	chromium steel 18/8, at plant	RER	kg	2.81E+3	1	1.27	(4,3,2,1,1,3); oral communication
	aluminium, production mix, at plant	RER	kg	5.55E+3	1	1.27	(4,3,2,1,1,3); oral communication
	copper, at regional storage	RER	kg	6.81E+3	1	1.27	(4,3,2,1,1,3); oral communication
	polyethylene, HDPE, granulate, at plant	RER	kg	6.34E+3	1	1.27	(4,3,2,1,1,3); oral communication
	flat glass, uncoated, at plant	RER	kg	2.35E+2	1	1.27	(4,3,2,1,1,3); oral communication
	alkyd paint, white, 60% in solvent, at plant	RER	kg	3.85E+2	1	1.27	(4,3,2,1,1,3); oral communication
	polyvinylchloride, at regional storage	RER	kg	3.51E+2	1	1.27	(4,3,2,1,1,3); oral communication
	lubricating oil, at plant	RER	kg	3.56E+3	1	1.27	(4,3,2,1,1,3); oral communication
	lead, at regional storage	RER	kg	2.63E+2	1	1.27	(4,3,2,1,1,3); oral communication
	glued laminated timber, outdoor use, at plant	RER	m3	5.94E-1	1	1.27	(4,3,2,1,1,3); oral communication
	rock wool, packed, at plant	CH	kg	3.20E+1	1	1.27	(4,3,2,1,1,3); oral communication
	transport, lorry 32t	RER	tkm	3.53E+3	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	RER	tkm	1.44E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh	1.52E+5	1	1.27	(4,3,2,1,1,3); oral communication
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	MJ	1.44E+6	1	1.27	(4,3,2,1,1,3); oral communication
	Heat, waste	-	MJ	5.47E+5	1	1.27	(4,3,2,1,1,3); standard value

Table 6-38: Life cycle inventory input data for the module manufacturing of goods rail wagons

	Name	Location	Unit	goods wagon	UncertaintyType	StandardDeviation95 %	GeneralComment
product	goods wagon	RER	unit	1.00E+0			
technosphere	steel, low-alloyed, at plant	RER	kg	2.10E+4	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	aluminium, production mix, at plant	RER	kg	1.07E+3	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	synthetic rubber, at plant	RER	kg	1.00E+1	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	alkyd paint, white, 60% in solvent, at plant	RER	kg	1.06E+2	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	glued laminated timber, outdoor use, at plant	RER	m3	1.92E+0	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	transport, lorry 32t	RER	tkm	2.21E+3	1	2.28	(4,5,na,na,na,na); standard distance
	transport, freight, rail	RER	tkm	4.43E+3	1	2.28	(4,5,na,na,na,na); standard distance
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh	9.22E+3	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	MJ	4.60E+4	1	1.36	(4,3,3,3,1,4); own calculations based on oral communication
	Heat, waste	-	MJ	3.32E+4	1	1.36	(4,3,3,3,1,4); standard value

Table 6-39: Life cycle inventory input data for the module manufacturing of a regional train (Kolibri)

	Name	Location	Infra	Unit	regional train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1			
	Unit				unit			
product	regional train	CH	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	1.14E+5	1	1.27	(4,3,2,1,1,3); literature studies
	aluminium, production mix, at plant	RER	0	kg	1.00E+4	1	1.27	(4,3,2,1,1,3); literature studies
	copper, at regional storage	RER	0	kg	7.00E+3	1	1.27	(4,3,2,1,1,3); literature studies
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.30E+4	1	1.27	figure comprises various plastics used.
	flat glass, uncoated, at plant	RER	0	kg	7.23E+3	1	1.27	(4,3,2,1,1,3); literature studies
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	1.28E+3	1	1.27	(4,3,2,1,1,3); literature studies
	glued laminated timber, outdoor use, at plant	RER	0	m3	8.67E+0	1	1.27	(4,3,2,1,1,3); literature studies
	rock wool, packed, at plant	CH	0	kg	1.28E+3	1	1.27	(4,3,2,1,1,3); literature studies
	lead, at regional storage	RER	0	kg	1.45E+3	1	1.27	(4,3,2,1,1,3); literature studies
	transport, lorry 28t	CH	0	tkm	7.70E+3	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	CH	0	tkm	3.08E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, at grid	CH	0	kWh	1.28E+5	1	2.08	(4,3,2,1,1,3); literature studies; value represents a rough estimate (basic uncertainty =2)
	heat, light fuel oil, at industrial furnace 1MW	CH	0	MJ	1.81E+5	1	2.08	(4,3,2,1,1,3); literature studies; value represents a rough estimate (basic uncertainty =2)
	Heat, waste	-	-	MJ	4.62E+5	1	2.08	(4,3,2,1,1,3); standard value

Table 6-40: Life cycle inventory input data for the module manufacturing of a long distance train (IC 2000)

	Name	Location	Infra	Unit	long-distance train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1			
	Unit				unit			
product	long-distance train	CH	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	5.42E+4	1	1.27	(4,3,2,1,1,3); literature studies
	aluminium, production mix, at plant	RER	0	kg	1.60E+5	1	1.27	(4,3,2,1,1,3); literature studies
	copper, at regional storage	RER	0	kg	9.98E+3	1	1.27	(4,3,2,1,1,3); literature studies
	polyethylene, HDPE, granulate, at plant	RER	0	kg	7.70E+4	1	1.27	(4,3,2,1,1,3); literature studies
	flat glass, coated, at plant	RER	0	kg	9.51E+3	1	1.27	(4,3,2,1,1,3); literature studies
	tempering, flat glass	RER	0	kg	9.51E+3	1	1.27	(4,3,2,1,1,3); literature studies
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	6.34E+3	1	1.27	(4,3,2,1,1,3); literature studies
	transport, lorry 28t	CH	0	tkm	1.59E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	CH	0	tkm	6.34E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, at grid	CH	0	kWh	2.40E+5	1	1.27	(4,3,2,1,1,3); literature studies
	heat, light fuel oil, at industrial furnace 1MW	CH	0	MJ	1.20E+6	1	1.27	(4,3,2,1,1,3); literature studies
	Heat, waste	-	-	MJ	8.64E+5	1	1.27	(4,3,2,1,1,3); standard value

Table 6-41: Life cycle inventory input data for the module manufacturing of a German ICE

	Name	Location	Infra	Unit	ICE	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE			
	InfrastructureProcess				1			
	Unit				unit			
product	ICE	DE	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	2.34E+05	1	1.27	(4,3,2,1,1,3); literature studies
	steel, low-alloyed, at plant	RER	0	kg	8.88E+04	1	1.27	(4,3,2,1,1,3); literature studies
	aluminium, production mix, at plant	RER	0	kg	9.00E+04	1	1.27	(4,3,2,1,1,3); literature studies
	copper, at regional storage	RER	0	kg	3.44E+04	1	1.27	(4,3,2,1,1,3); literature studies
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.55E+05	1	1.27	(4,3,2,1,1,3); literature studies
	tempering, flat glass	RER	0	kg	2.50E+04	1	1.27	(4,3,2,1,1,3); literature studies
	flat glass, coated, at plant	RER	0	kg	2.50E+04	1	1.27	(4,3,2,1,1,3); literature studies
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	1.26E+04	1	1.27	(4,3,2,1,1,3); literature studies
	transport, lorry 32t	RER	0	tkm	2.76E+04	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	RER	0	tkm	1.10E+05	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, at grid	DE	0	kWh	6.11E+05	1	2.08	(4,3,2,1,1,3); literature studies; value represents a rough estimate (basic uncertainty =2)
	heat, light fuel oil, at industrial furnace 1MW	RER	0	MJ	1.94E+06	1	2.08	(4,3,2,1,1,3); literature studies; value represents a rough estimate (basic uncertainty =2)
	heat, natural gas, at industrial furnace >100kW	RER	0	MJ	1.94E+06	2	2.08	(4,3,2,1,1,3); literature studies; value represents a rough estimate (basic uncertainty =2)
	Heat, waste	-	-	MJ	2.20E+06	1	2.08	(4,3,2,1,1,3); standard value

Table 6-42: Life cycle inventory input data for goods transport rail equipment maintenance

	Name	Location	Unit	maintenance, locomotive	maintenance, goods wagon	UncertaintyType	StandardDeviation95 %	GeneralComment
product	maintenance, locomotive	RER	unit	1.00E+0				
	maintenance, goods wagon	RER	unit		1.00E+0			
technosphere	reinforcing steel, at plant	RER	kg	2.91E+4	-	1.00	1.36	(4,3,3,3,1,4); oral communication
	cast iron, at plant	RER	kg	9.98E+2	3.51E+3	1.00	1.36	(4,3,3,3,1,4); oral communication
	alkyd paint, white, 60% in solvent, at plant	RER	kg	1.21E+2	3.90E+1	1.00	1.26	(3,1,1,3,1,4); oral communication
	polyvinylchloride, at regional storage	RER	kg	4.00E+1	4.00E+1	1.00	1.26	(,,3,3,1,4); oral communication
	lubricating oil, at plant	RER	kg	6.90E+2	2.22E+2	1.00	1.26	(3,1,1,3,1,4); oral communication
	hard coal coke, at plant	RER	MJ	2.33E+3		1.00	1.26	(3,1,1,3,1,4); oral communication
	transport, lorry 32t	RER	tkm	3.20E+3	3.81E+2	1.00	2.05	(4,na,na,na,na,na); standard distance
	transport, freight, rail	RER	tkm	6.41E+3	7.62E+2	1.00	2.05	(4,na,na,na,na,na); standard distance
	natural gas, burned in industrial furnace >100kW	RER	MJ	2.25E+4	7.22E+4	1.00	1.26	(3,1,1,3,1,4); oral communication
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh	3.41E+4	1.10E+4	1.00	1.26	(3,1,1,3,1,4); oral communication
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	MJ	3.65E+5	3.65E+5	1.00	1.26	(3,1,1,3,1,4); oral communication
	hard coal, burned in industrial furnace 1-10MW	RER	MJ	2.25E+4	7.22E+3	1.00	1.26	(3,1,1,3,1,4); oral communication
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	kg	9.20E+2	1.85E+3	1.00	1.26	(3,1,1,3,1,4); oral communication
	disposal, wood untreated, 20% water, to municipal incineration	CH	kg	5.75E+3	2.96E+2	1.00	1.26	(3,1,1,3,1,4); oral communication
	Heat, waste	-	MJ	1.23E+5	3.96E+4	1.00	1.26	(3,1,1,3,1,4); standard value

Table 6-43: Input data for maintenance of regional passenger train equipment

	Name	Location	Infra	Unit	maintenance, regional train	UncertaintyType	StandardDeviation 95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1			
	Unit				unit			
product	maintenance, regional train	CH	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	5.00E+3	1	1.21	(2,2,2,3,3,3); literature studies
	aluminium, production mix, at plant	RER	0	kg	3.32E+2	1	1.21	(2,2,2,3,3,3); literature studies
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.97E+3	1	1.21	(2,2,2,3,3,3); literature studies
	synthetic rubber, at plant	RER	0	kg	1.02E+3	1	1.21	(2,2,2,3,3,3); literature studies
	flat glass, uncoated, at plant	RER	0	kg	6.60E+2	1	1.21	(2,2,2,3,3,3); literature studies
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	1.55E+2	1	1.21	(2,2,2,3,3,3); literature studies
	glued laminated timber, outdoor use, at plant	RER	0	m3	8.84E-1	1	1.21	(2,2,2,3,3,3); literature studies
	rock wool, packed, at plant	CH	0	kg	8.12E+1	1	1.21	(2,2,2,3,3,3); literature studies
	lead, at regional storage	RER	0	kg	2.03E+2	1	1.21	(2,2,2,3,3,3); literature studies
	solvents, organic, unspecified, at plant	GLO	0	kg	1.25E+2	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenance figures (assuming 25% of the ICE expenditures).
	lubricating oil, at plant	RER	0	kg	1.25E+2	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenance figures (assuming 25% of the ICE expenditures).
	paper, woodfree, uncoated, at regional storage	RER	0	kg	2.07E+4	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenance figures (assuming 25% of the ICE expenditures).
	tap water, at user	CH	0	kg	1.14E+5	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenance figures (assuming 25% of the ICE expenditures).
	bitumen, at refinery	CH	0	kg	3.75E+2	1	1.21	(2,2,2,3,3,3); literature studies
	transport, lorry 28t	CH	0	tkm	4.34E+2	1	2.28	(4,5,na,na,na,na); standard transport distance
	transport, freight, rail	CH	0	tkm	1.74E+3	1	2.28	(4,5,na,na,na,na); standard transport distance
	heat, natural gas, at industrial furnace >100kW	RER	0	MJ	9.74E+4	1	2.05	(2,2,2,3,3,3); literature studies; rough estimate (basic uncertainty =2)
	electricity, medium voltage, at grid	CH	0	kWh	1.39E+4	1	2.05	(2,2,2,3,3,3); literature studies; rough estimate (basic uncertainty =2)
	heat, light fuel oil, at industrial furnace 1MW	CH	0	MJ	9.74E+4	1	2.05	(2,2,2,3,3,3); literature studies; rough estimate (basic uncertainty =2)
	disposal, wood untreated, 20% water, to municipal incineration	CH	0	kg	6.32E+2	1	1.21	(2,2,2,3,3,3); own assumptions based on the new input
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	1.39E+1	1	1.21	(2,2,2,3,3,3); literature studies
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	6.60E+2	1	1.21	(2,2,2,3,3,3); own assumptions based on the new input
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.97E+3	1	1.21	(2,2,2,3,3,3); own assumptions based on the new input
	treatment, sewage, to wastewater treatment, class 1	CH	0	m3	114.25	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenance figures (assuming 25% of the ICE expenditures).
emissions to air	Heat, waste	-	-	MJ	4.99E+4	1	1.27	(4,3,2,1,1,3); standard value
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	7.83E+1	1	2.08	(4,3,2,1,1,3); Derived from the used paint and solvent, assuming all solvent is emitted to air.

Table 6-44: Input data for maintenance of long distance passenger train equipment

	Name	Location	Infra	Unit	maintenance, long-distance train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1			
	Unit				unit			
product	maintenance, long-distance train	CH	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	9.90E+4	1	1.27	(4,3,2,1,1,3); literature studies
	aluminium, production mix, at plant	RER	0	kg	1.31E+4	1	1.27	(4,3,2,1,1,3); literature studies
	copper, at regional storage	RER	0	kg	1.25E+2	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenace figures
	polyethylene, HDPE, granulate, at plant	RER	0	kg	7.82E+4	1	1.27	(4,3,2,1,1,3); literature studies
	synthetic rubber, at plant	RER	0	kg	1.32E+4	1	1.27	(4,3,2,1,1,3); literature studies
	flat glass, coated, at plant	RER	0	kg	2.61E+4	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenace figures
	tempering, flat glass	RER	0	kg	2.61E+4	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenace figures
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	6.18E+3	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenace figures
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	4.00E+4	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenace figures
	bitumen, at refinery	CH	0	kg	4.85E+3	1	1.21	(2,2,2,3,3,3); literature studies
	transport, lorry 28t	CH	0	tkm	1.08E+4	1	2.28	(4,5,na,na,na,na); standard transport distances
	transport, freight, rail	CH	0	tkm	4.33E+4	1	2.28	(4,5,na,na,na,na); standard transport distances
	solvents, organic, unspecified, at plant	GLO	0	kg	5.00E+2	1	1.21	(2,2,2,3,3,3); literature studies; estimate based on ICE maintenace figures
	lubricating oil, at plant	RER	0	kg	5.00E+2	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenace figures
	paper, woodfree, uncoated, at regional storage	RER	0	kg	2.07E+4	1	1.27	(4,3,2,1,1,3); literature studies; estimate based on ICE maintenace figures
	tap water, at user	CH	0	kg	4.57E+5	1	1.27	(4,3,2,1,1,3); literature studies, rough estimate
	heat, natural gas, at industrial furnace >100kW	RER	0	MJ	6.47E+4	1	2.08	(4,3,2,1,1,3); literature studies, rough estimate
	electricity, medium voltage, at grid	CH	0	kWh	5.42E+5	1	2.08	(4,3,2,1,1,3); literature studies, rough estimate
	heat, light fuel oil, at industrial furnace 1MW	CH	0	MJ	4.38E+6	1	2.08	(4,3,2,1,1,3); literature studies, rough estimate
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	6.45E+2	1	1.27	(4,3,2,1,1,3); literature studies
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.31E+4	1	1.27	(4,3,2,1,1,3); literature studies
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	2.61E+4	1	1.27	(4,3,2,1,1,3); literature studies
	treatment, sewage, to wastewater treatment, class 1	CH	0	m3	4.57E+2	1	1.27	(4,3,2,1,1,3); literature studies
emissions to air	Heat, waste	-	-	MJ	1.95E+6	1	1.27	(4,3,2,1,1,3); standard value
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.11E+3	1	1.21	(2,2,2,3,3,3); Derived from the used paint and solvent, assuming all solvent is emitted to air.

Table 6-45: Life cycle inventory input data for maintenance of a German ICE

	Name	Location	Infra	Unit	maintenance, ICE	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE			
	InfrastructureProcess				1			
	Unit				unit			
product	maintenance, ICE	DE	1	unit	1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	4.50E+4	1	1.17	(2,2,1,3,1,3); literature study (repair)
	aluminium, production mix, at plant	RER	0	kg	1.25E+2	1	1.17	(2,2,1,3,1,3); literature studies (repair)
	copper, at regional storage	RER	0	kg	1.25E+2	1	1.17	(2,2,1,3,1,3); literature studies (repair)
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	5.00E+3	1	1.17	(2,2,1,3,1,3); literature studies (repair)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	4.00E+4	1	1.17	(2,2,1,3,1,3); literature studies (regular maintenance)
	transport, lorry 32t	RER	0	tkm	5.60E+3	1	2.28	(4,5,na,na,na,na); calculation based on standard distances
	transport, freight, rail	RER	0	tkm	2.24E+4	1	2.28	(4,5,na,na,na,na); calculation based on standard distances
	heat, at cogen 1MWe lean burn, allocation exergy	RER	0	MJ	2.51E+7	1	1.17	(2,2,1,3,1,3); literature studies (repair & regular maintenance)
	electricity, medium voltage, at grid	DE	0	kWh	1.58E+6	1	1.17	(2,2,1,3,1,3); literature studies (repair & regular maintenance)
	tap water, at user	RER	0	kg	4.57E+5	1	1.17	(2,2,1,3,1,3); literature studies (repair & regular maintenance)
	paper, woodfree, uncoated, at regional storage	RER	0	kg	2.07E+4	1	1.17	(2,2,1,3,1,3); literature studies (repair & regular maintenance)
	solvents, organic, unspecified, at plant	GLO	0	kg	5.00E+2	1	1.17	(2,2,1,3,1,3); literature studies (repair)
	lubricating oil, at plant	RER	0	kg	5.00E+2	1	1.17	(2,2,1,3,1,3); literature studies (repair)
	treatment, sewage, to wastewater treatment, class 1	CH	0	m3	4.57E+2	1	1.17	(2,2,1,3,1,3); literature studies (repair & regular maintenance)
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	2.00E+3	1	2.03	(2,2,1,3,1,3); based on own calculations, assuming that 0.6 of the paint are emitted as NMVOCs.
emissions to air	Heat, waste	-	-	MJ	5.69E+6	1	1.17	(2,2,1,3,1,3); standard value
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.50E+3	1	2.03	(2,2,1,3,1,3); Derived from the used paint and solvent, assuming all solvent is emitted to air.

Table 6-46: Input data for disposal of goods train equipment

	Name	Location	Unit	disposal, locomotive	UncertaintyType	StandardDeviation95%	GeneralComment
product	disposal, locomotive	RER	unit	1.00E+0			
technosphere	transport, lorry 32t	RER	tkm	5.44E+2	1.00E+0	2.28E+0	(4,5,na,na,na,na); standard distance
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	kg	3.56E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); oral communication
	disposal, emulsion paint, 0% water, to municipal incineration	CH	kg	3.85E+2	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition locomotive
	disposal, glass, 0% water, to municipal incineration	CH	kg	2.35E+2	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition locomotive
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	kg	6.69E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition locomotive
	disposal, polyvinylchloride, 0.2% water, to municipal incineration	CH	kg	3.51E+2	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition locomotive

Table 6-47: Input data for disposal of regional passenger train equipment

	Name	Location	Infra	Unit	disposal, regional train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1.00E+0			
	Unit				unit			
product	disposal, regional train	CH	1	unit	1.00E+0			
technosphere	transport, lorry 28t	CH	0	tkm	1.32E+3	1.00E+0	2.28E+0	(4,5,na,na,na,na); standard distance
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	5.57E+0	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition train composition
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	7.23E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition train composition
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.30E+4	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition train composition
	disposal, wood untreated, 20% water, to municipal incineration	CH	0	kg	6.20E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); material composition train composition

Table 6-48: Input data for disposal of long-distance passenger train equipment

	Name	Location	Infra	Unit	disposal, long-distance train	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1.00E+0			
	Unit				unit			
product	disposal, long-distance train	CH	1	unit	1.00E+0			
technosphere	transport, lorry 28t	CH	0	tkm	6.58E+2	1.00E+0	2.28E+0	(4,5,na,na,na,na); standard distance
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	6.45E+2	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled IC (unit process IC manufacturing)
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	9.51E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled IC (unit process IC manufacturing)
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	3.00E+3	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled IC (unit process IC manufacturing)

Table 6-49: Life cycle inventory input data for disposal of a German ICE

	Name	Location	Infra	Unit	disposal, ICE	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE			
	InfrastructureProcess				1.00E+0			
	Unit				unit			
product	disposal, ICE	DE	1	unit	1.00E+0			
technosphere	transport, lorry 32t	RER	0	tkm	1.50E-1	1.00E+0	2.28E+0	(4,5,na,na,na,na); standard distance
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	1.00E+0	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled ICE (unit process ICE manufacturing)
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	1.00E+0	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled ICE (unit process ICE manufacturing)
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.00E+0	1.00E+0	1.26E+0	(3,1,1,3,1,4); derived from the material composition of the modelled ICE (unit process ICE manufacturing)

Data Quality and Uncertainties

The quality of the data documented for the “Re 462” is considered as good, however the locomotive is a fairly new locomotive and thus not representative for the current locomotive park of the SBB. The share of aluminium and plastic materials is assumed to be lower for older locomotives. Thus, the data is considered of medium quality. For wagons the quality of the data for a specific wagon is fairly good. Uncertainties result mainly from assumptions made to calculate an average wagon.

For the disposal the data quality is considered as sufficient. Since the actual amount of disposed material is directly linked to the material composition the reliability of the data is based on the quality of the manufacturing model.

6.9 Rail Infrastructure

In this project, generic data for the Swiss rail network has been determined. Environmental interventions and inputs from the technosphere are referred to 1-meter and year [ma] rail track. The Swiss rail network includes normal gauge and narrow gauge tracks. It comprises approximately 10200 km rail tracks (SBB, 2002). In addition, 1400 km siding are reported. As demonstrated in Table 6-29 more than 98% of the goods transport in Switzerland is performed by the SBB. Thus, in line with the inventories for operation and manufacturing, for the calculation of the interventions of rail infrastructure we merely take the SBB network into account. The SBB rail network predominately comprises one-way tracks and two-way tracks with a length of 1391 km and 1609 km (in the year 2000). One-way tracks are converted in two-way tracks, resulting in approximately 2300 km two way tracks. The material expenditures, if not stated differently, refer to a two-way track. In order to relate the long-term material investments for infrastructure to the reference unit, assumption about the life span are required and are documented in the following sections. All data presented in this section refers to the total network.

6.9.1 Infrastructure Demand and Allocation

Similar as road infrastructure, rail infrastructure is not solely used by goods trains. Thus, allocation between passenger and goods transportation is unavoidable. As outline in the chapter road transport, various allocation principles are available to allocate the environmental interventions of infrastructure processes.

Allocation of Construction and Disposal Expenditures

In line with the approach of road transport infrastructure we use the gross tonne kilometre as allocation factor for construction and disposal activities. For the Swiss rail network in the year 2000 we apply a total Gtkm-performance of 5.94E+10 Gtkm resulting in a specific rail demand per Gtkm of 3.88E-05 (m*a)/Gtkm. Assuming a ratio gross tonne/carried goods of 2.4 Gtkm/tkm we obtain a specific rail demand per functional unit of 9.30E-05 (m*a)/tkm. For the European rail network we apply the same demand factor as for Switzerland.

For the determination of passenger train infrastructure demand, for regional and long-distance transport we employ a gross tonne/transported passenger demand of 4.0 Gt/p and 2.8 Gt/p, respectively. Thus we obtain a specific rail demand per functional unit of 1.57E-04 and 1.09E-04 (m*a)/pkm for regional and long-distance transport, respectively.

For the German ICE, allocation is performed employing the kilometric train performance of freight and passenger trains. According to von Rozycki (2003), we assume a kilometric performance of the ICE of 10950 vkm/year (11% of total traffic). If we take into account an average load of 309 passenger per train we achieve an demand factor of 3.25E-8m*a/pkm.

Allocation of Operation and Maintenance Expenditures (Including Land Use)

For operation services, including land use, we use the yearly vehicle kilometre performance as allocation factor. For the Swiss road network in the year 2000 we account for a total vkm-performance of 1.31E+08 vkm resulting in a specific road demand per 1.76E-02 (m*a)/vkm. Assuming a ratio kilometric performance/transport performance of 2.60E-03 vkm/tkm we obtain a specific rail demand per functional unit of 4.57E-05 (m*a)/tkm. For the European rail network we apply the same demand factor as for Switzerland.

For the determination of passenger train infrastructure demand, for regional and long-distance transport we employ a ratio kilometric performance/transport performance of 4.0 vkm/pkm and 2.8 vkm/pkm, respectively. Thus we obtain a specific rail demand per functional unit of 3.29E-04 and 1.00E-04 (m*a)/pkm for regional and long-distance transport, respectively.

For the German ICE, allocation is performed employing the kilometric train performance of freight and passenger trains. According to von Rozycki (2003) we assume a kilometric performance of the

ICE of 10950 vkm/year (11% of total traffic). If we take into account an average load of 309 passenger per train we achieve an demand factor of 3.25E-8m*a/pkm.

6.9.2 Rail Track Construction and Renewal

The construction of rail track infrastructure includes the actual construction of the rail truck (substructure and track bedding) as well as expenditures for the construction of tunnels and bridges. In Figure 6-2 the different levels of a rail track are illustrated. Due to the fact that the life span of different components of the infrastructure varies significantly, material and energy expenditures are referred to one year. We assume a life span for the infrastructure of 100 years. Thus, all expenditures are aggregated for a life span of 100 years and referred to one year. It should be noted that the modelled energy consumption and material expenditures represent the conditions of the reference year 2000, even though some of these processes have been taken place in the past.

Further components of rail track infrastructure, such as signalling infrastructure, train overtaking stations, sound insulation walls and buildings (stations, service garages) are not included in this study. In a recent research von Rozycki et al. (2003), pointed out that these components do not contribute significantly to a life cycle resource consumption of a rail transport system. SF_6-emissions of electric transformer stations are accounted for in the train operation unit process.

Construction of Rail Track

For the construction of the rail driveway part material consumption due to track bedding (rails and railway sleepers (concrete reinforced with steel) and gravel) and substructure (bulldozed and compressed soil) are taken into account. In Figure 6-2 a simplified model of the layers of rail conventional rail track infrastructure is illustrated.

Figure 6-2: Layers of rail track infrastructure

Track Bedding	**Rails** **Railroad Sleepers**	
	Gravel	Coarse Fraction 22-63 mm diameter
		Fine Fraction <22 mm diameter
Substructure		Gravel-sand layers
Subsurface		Natural soil or rocks

In addition, material expenditures for construction of the catenary system (overhead contact line and steel masts) are accounted for. In Table 6-50 data available is summarised.

Table 6-50: Materials and energy used in the construction of for a rail track

Materials/Energy	Use	Unit	Elsener & Strub (1993)	von Rozycki et al. (2003)
Gravel, crushed	track bedding	kg/(m*a)	113.000	530.000
Concrete	railroad sleeper	kg/(m*a)	20.900	34.300
Steel	railroad sleeper		n.a	1.300
Wood	railroad sleeper	kg/(m*a)	4100.000	0
Steel	rail	kg/(m*a)	4.100	9.400
Steel low-alloyed	mast	kg/(m*a)	0.560	0.740
Zinc	protective coating mast	kg/(m*a)	0.006	0.005
Copper	overhead contact line	kg/(m*a)	0.055	0.420
Transport lorry 28t	track bedding	Tkm/(m*a)	423.862	

Timber railroad sleepers are not modelled in this study, since they are continuously replaced with concrete railroad sleepers. In Table 6-58 the figures as employed in this project are presented.

Construction of rail tunnels

Tunnels require a significant higher material input, primarily in form of concrete and steel for reinforcement. In addition, large quantities of soil and rocks, have to be excavated and removed. In the year 2000 the length of tunnels in Switzerland accounted for 218 km (SBB 2002). This results in a share of tunnels on the total rail track network of approximately 7% if we simply sum up one way and multi way tracks. Thus, per km rail, 70 m tunnel are accounted for in this project

For the construction of rail tunnels data is available from Maibach et al. (1999). These data is based on studies of the “Lötschberg-Basistunnel” and supplemented with information of the tunnel construction specialist of a Rothpelz-Lienhardt. The data represents a one-track tunnel with a diameter of 10m and a concrete layer of 0.5m. Von Rozycki (2003), further distinguishes two types of tunnel constructions approaches and supplies the referring basic material consumption, referring to a two-way track per pipe tunnel. In Table 6-51 this data is summarised.

Construction of Bridges

For material expenditures data is available from von Rozycki et al. (2003) and displayed in Table 6-52. In the year the length of bridges is accounted for 92 km. This results in a share of bridges on the total rail track network of approximately 3% if we simply sum up one way and multi way tracks. Thus, per km rail, 30 m bridge is accounted for in this project. In Table 6-58 the figures as employed in this project are presented.

Table 6-51: Material and Energy Consumption for construction of rail tunnels in Switzerland

Materials/Energy	Unit	Maibach (1999) including track	Maibach (1999) excl. Track 1)	Von Rozycki (2003)
gravel, crushed	kg/(m*a)	696	583	
concrete	kg/(m*a)	465	444.1	575
steel low-alloyed/iron	kg/(m*a)	1.58	1.02	
steel	kg/(m*a)	14.7	10.6	24.5
ceramics	kg/(m*a)	1.6	0	-
zinc	kg/(m*a)	0.006	0	-
aluminum	kg/(m*a)	0.05	0	-
copper	kg/(m*a)	0.055	0	-
PVC	kg/(m*a)	0.0653	0	-
electricity	kWh/(m*a)	-	569	-
diesel, building machine	MJ/(m*a)	-	135	-
transport lorry building materials	Tkm/(m*a)	-	103.872	-
excavation soil	kg/(m*a)	-	-	4850
transport lorry landfill	Tkm/(m*a)	-	-	48500

1: In Maibach (1999) the expenditures for tunnel construction also account for expenditures for track construction. In order to avoid double counting, these expenditures are subtracted.

Table 6-52: Material Expenditures for the construction of rail bridges

	absolute material consumption		life span	specific material consumption	
Material	concrete	steel		concrete	steel
Unit	t/km bridge	t/km bridge	years	kg/(m*a) bridge	kg/(m*a) bridge
Glen bridges	55000	3000	100	550	30
Road/railway bridges	89000	4900	50	1780	98
Average bridge this project 1)				673	36.8

1: The average bridge in this study comprises 90% glen bridge and 10% road rail bridges

6.9.3 Operation and Maintenance of Rail Infrastructure

Operation and Maintenance of SBB Rail Tracks

The renewal of materials is already addressed in the construction module Important components not addressed in the construction module are points or switches. Points are required to change tracks. For high-speed railway routes 2.1 points per average two-way rail track kilometre are reported von Rozycki et al. (2003). For the SBB-network about 18000 points are in operation. For main lines, on average a point is installed every 830 metres, on the remaining lines the average point density is 270 metres Oggier (2002). In von Rozycki et al. (2003) a heating energy consumption to avoid icing in winter of 400 kWh_{el}/(unit *a) has been stated. For main lines and remaining lines this result in energy consumption of 0.5 kWh/(m*a) and 1.5 kWh/(m*a), respectively. If we further assume that goods transportation predominately takes place on main lines, and use the allocation factor “gross tonne kilometer”, we obtain an average point electricity consumption of 0.2 kWh/(m*a) or 4.21E-05 kWh/tkm. The resulting figure, is significantly lower than the figure (32 kWh/m*a) stated in Frischknecht et al. (1996). The latter figure is obtained top down Manto (1994) and a lot of assumptions and allocation steps have been essential, resulting in a poor transparency and high uncertainty of the figure. In contrast, the figure for the point heating electricity consumption has been achieved with consistent assumption and thus is employed in this study. Figures for oil and natural gas combustion given in Frischknecht et al. (1996) and based on Manto (1994) are not included in this study for the same reason.

In addition, points need to be lubricated regularly. In the year 2000 the 69697 litre of lubricates have been consumed for point maintenance. The majority of the employed lubricates are biodegradable (SBB, 2002).

The use of herbicides in 2000 has been reported with 4.474 t SBB (2002). The concentration of the active agent is 360g Glyphosat/l. In spite of the fact that Glyphosat is considered as biodegradable Haas (2000) emissions to soil are accounted for in this project.

Operation and Maintenance of SBB Rail Tracks

Electricity consumption for points is directly taken from von Rozycki et al. (2003). The use of lubricates is estimated based on Swiss figures, assuming a use of 3.88 l/point*a and 2.1 point per km track. For the use and emissions of herbicides we use the figures derived from Swiss conditions.

Operation and Maintenance of Rail Tunnel

Data for operating expenditures are available from Maibach et al. (1999). The energy consumption of a rail tunnel has been estimated based on the electricity consumption of road tunnels. In contrast to road tunnels, lighting and ventilation are not installed in short rail tunnels, in Switzerland. In long, alp tunnels, however, the ventilation is required for thermal reason. In Maibach et al. (1999), the electricity consumption is estimated to be the half of a 12 h ventilation of a road tunnel and lighting has been neglected. In consequence the electricity consumption is calculated as 837 kWh/(m tunnel*a).

6.9.4 Land Use

In this project we distinguish between land transformation and land occupation. Whilst transformation directly changes the ecological quality of land, occupation postpones changes of the ecological quality. Furthermore, we distinguish between the area actually used for rail tracks and embankments.

In Table 6-53 detailed information on the nature of the network and resulting occupied area are summarised for both, the entire Swiss network and the SBB rail network.

Table 6-53: Length and occupied area of the Swiss rail network and the SBB network.

Total Swiss Network							
		Width [m] [1]	Length [km] [2]	Main area	Embank-ment [3]	Main area [4]	Embank-ment [4]
Unit		m	km	Km^2	Km^2	Km^2	Km^2
Normal gauge	One track	8.5	2418.0	20.6	18.7		
	Multi track	12	1268.3	15.2	13.8		
Siding		6	1400.0	8.4			
	Total		5086.3	44.2	32.5		
Narrow gauge	One Track	8	906.4	7.3	6.6		
	Multi track [6]	11.5	475.4	5.5	5.0		
	Total		1381.8	12.7	11.6		
Total CH			12936.1	56.9	44.1	50.2	46.87
SBB Network							
Normal gauge	One Track	8.5	1391.0	11.8	10.7		
	Multi track	12	1609.0	19.3	17.6		
Siding [5]		6	700	4.2	3.8		
	Total		3686.3	31.1	28.3	35.92	
Narrow gauge	One Track	8	74.0	0.6	0.5		
	Multi track	11.5		0.0	0.0		
	Total		74.0	0.6	0.5	0.45	
Total SBB			3060.3	35.9	32.7	36.4	

1: oral communication Müller Gleisbau

2: Bfs 2002

3: based on the ratio used in Hüsler: Embankment area = 0.9*Main area

4: as documented in Hüsler

5: the issue of Anschlussgleise is rather complicated. Currently very little is known how many kilometer of the Anschlussgleise are still in use. Thus, as an first assumption we merely account for 50% of the total length of Anschlussgleise.

6: Multi tracks are predominately two track routes. In 1993 the share of three track and four track routs on the total multi track network was about 4 %.

Land Occupation

Occupation refers to the time period for which the land is unavailable for other activities. The occupation intervention is expressed in terms of land use type, area and time. The unit is therefore square metres *year and the reference1-metre rail track. In Table 6-54 the resulting specific land occupation for the SBB network is summarised.

Table 6-54: Specific land occupation for rail transport

	unit	rail network	rail embankments
Total traffic area occupation (SBB)	m2/m*a	11.5	10.4
Total traffic area occupation (ICE track)	m2/m*a	13.5	10.4 [1]

1) in the absence of further information we employ the Swiss value for the German ICE track

Land Transformation

For transformation (the change of land use to be allocated to a certain user or user type) the situation is more difficult, mainly due to data variability. The yearly change in land use for a certain user may change considerably, as land use change is not a continuous process, but very much determined by political decisions and economic constraints and opportunities. Thus, to assess transformation, the yearly trend has been determined based on a fairly long period of 30 years, from 1971 to 2000. In **Fehler! Verweisquelle konnte nicht gefunden werden.** specific land transformation figures for the SBB network are presented. For the ICE track we assume a lifespan of 100 years.

Table 6-55: Specific land transformation for rail transport

	unit	Rail network	Rail embankments
Total traffic area transformation (SBB)	m2/m	2.66E-02	2.42E-02
Total traffic area transformation (ICE track)	m2/m	1.3E-01	1.04E-02 [1)]

1) in the absence of further information we employ the Swiss value for the German ICE track

6.9.5 Disposal of Rail Infrastructure

The disposal of rail infrastructure reflects the SBB situation in 2000. Environmentally relevant components are contaminated gravel of the track bedding and contaminated gravel-sand of the substructures. Also, the disposal of creosoted timber railroad sleepers requires a special treatment. In contrast, for rails and concrete railroad sleepers a cut off allocation has been made, since the arising amount is completely recycled SBB (2002).

Currently, the SBB rebuild approximately 140-160 km/year of its rail network track bedding. In addition, for approximately 30 km of these tracks a complete renewal is performed including both, track bedding and substructure. The resulting figures (Table 6-57), correspondents with the figure presented in the SBB environmental report SBB (2002). The excavation waste is reported with 412’800 t/a, including both gravel and gravel-sand. Also it is claimed that approximately 80% of the used gravel are transported to specific washing facilities. The cleaned gravel then usually is used for other purposes. Thus, a cut off allocation is applied here. However, 20% of the total amount (82500 t/a) is deposited at specific landfills.

For the ballastless ICE track no disposal is accounted for.

Table 6-56: Yearly excavation waste of the SBB Oggier (2002)

Source		gravel & gravel-sand [m^3/m]		Total gravel/ gravel sand [m^3/a]		average [t/a] [1)]
	rebuilt/year [km/a]	min	max	min	max	
Track bedding rebuilding	120	0.6	1	72000	120000	163200
Substructure rebuilding	30	4	6	120000	180000	255000
Total SBB	150			192000	300000	418200

1: it has been assumed that 1 m^3 gravel is equal to 1.7 kg gravel Oggier (2002).

Approximately 90% of wooden wastes are timber railroad sleepers. In 2000 and in particular 2001, the amount of wooden sleepers waste has increased significantly as demonstrated in Table 6-57. The underlying reason of this development is a change in legislation. Since autumn 2000, in Switzerland the sale of used wooden sleepers is prohibited. In 2001, the wooden sleepers are incinerated in thermal power plants. Thus, we merely include the transport of the wooden sleepers to thermal power plants. We assume an average distance of 200 km for the transport.

Table 6-57: Disposed railroad sleepers (modified from SBB (2002))

Waste type	unit	1996	1997	1998	1999	2000	2001
Timber sleeper	t	1090 [1)]	1180 [1)]	1040 [1)]	1.460 [1)]	2065 [2)]	7330 [2)]
Concrete sleeper	unit	n.a.	n.a.	n.a.	n.a.	23018	49296

1: the figures represent 90% of the total wood waste, as reported in SBB (2002)

2: since the significant increase of wood waste is due to an increase in waste from used wooden sleepers, not the 90% values has been taken but the 10% value of the reported wood waste quantity for 1999 has been subtracted from the values reported for 2000 and 2001 in SBB (2002)

6.9.6 Life Cycle Inventory Input Data

In this section the inventory input data for rail infrastructure processes are presented. For each component, a Swiss average track is assumed as well as a specific ICE rail track in Germany.

Table 6-58: Life cycle inventory input data for the construction of rail infrastructure in Switzerland

	Name	Location	Unit	railway track	UncertaintyType	Standard Deviation95%	GeneralComment	constr. railway track	constr. tunnel	constr. bridge
product	railway track	CH	ma	1.00E+0						
technosphere	concrete, exacting, at plant	CH	m3	4.31E-2	1	1.27	LCA case study; (3,3,1,3,3,4)	1.56E-02	2.61E-01	3.06E-01
	gravel, crushed, at mine	CH	kg	5.71E+2	1	1.27	LCA case study; (3,3,1,3,3,4)	5.30E+02	5.83E+02	
	steel, low-alloyed, at plant	RER	kg	5.60E-1	1	1.27	LCA case study; (3,3,1,3,3,4)	5.60E-01		
	reinforcing steel, at plant	RER	kg	1.35E+1	1	1.27	LCA case study; (3,3,1,3,3,4)	1.07E+01	2.45E+01	3.68E+01
	zinc for coating, at regional storage	RER	kg	6.00E-3	1	1.29	literature & oral comunication; (3,3,3,3,3,4)	6.00E-03		
	copper, at regional storage	RER	kg	5.50E-2	1	1.29	literature & oral comunication; (3,3,3,3,3,4)	5.50E-02		
	diesel, burned in building machine	GLO	MJ	9.50E+0	1	2.09	literature & oral comunication; (3,3,3,3,3,4)	5.00E-02	1.35E+02	
	electricity, medium voltage, at grid	CH	kWh	3.99E+0	1	1.29	literature & oral comunication; (3,3,3,3,3,4)	0.00E+00	5.69E+01	
	excavation, skid-steer loader	RER	m3	1.20E+0	1	2.09	literature & oral comunication; (3,3,3,3,3,4)	1.20E+00		
	transport, freight, rail	CH	tkm	8.48E+0	1	2.09	standard distance; (4,5,na,na,na,na)	6.79E+00	1.47E+01	2.21E+01
	transport, lorry 28t	CH	tkm	1.40E+1	1	2.09	standard distance; (4,5,na,na,na,na)	1.19E+01	2.44E+01	1.53E+01
emission to air	Heat, waste	-	MJ	1.44E+1	1	1.29	standard value; (3,3,3,3,3,4)			

Table 6-59: Life cycle inventory input data for operation and maintenance of rail infrastructure in Switzerland. Figures in this table represent ecoinvent data v1.1; the following elementary flows have been corrected for ecoinvent data v2.0: consumption of glyphosate (1.95E-3 kg/ma); emission of glyphosate (7.00E-4 kg/ma).

	Name	Location	Category	SubCategory	Unit	*operation, maintenance, railway track*	UncertaintyType	StandardDeviation95%	GeneralComment	*operation railway track*	*coperation tunnel*
product	operation, maintenance, railway track	CH			ma	1.00E+0					
technosphere	electricity, medium voltage, at grid	CH			kWh	5.91E+1	1	1.20	(3,3,3,1,1,4); LCA case studies	4.82E-01	8.37E+02
	glyphosate, at regional storehouse	CH			kg	1.95E+0	1	1.05	(1,1,1,1,1,1); environmental report		
	lubricating oil, at plant	RER			kg	2.54E-2	1	1.05	(1,1,1,1,1,1); environmental report		
emission to air	Heat, waste	-	air	unspecified	MJ	2.13E+2	1	1.29	(3,3,3,3,3,4); standard value		
emissions to soil	Glyphosate	-	soil	agricultural	kg	7.00E-1	1	1.20	(1,1,1,1,1,1); environmental report and own calculations		
	Oils, biogenic	-	soil	unspecified	kg	2.54E-2	1	1.20	(1,1,1,1,1,1); environmental report and own calculations		
land use	Occupation, traffic area, rail network	-	resource	land	m2a	1.15E+1	1	1.52	(3,2,1,1,na,na); literature &own calculations		
	Occupation, traffic area, rail embankment	-	resource	land	m2a	1.04E+1	1	1.52	(3,2,1,1,na,na); literature &own calculations		
	Transformation, from unknown	-	resource	land	m2	5.08E-2	1	2.01	(3,2,1,1,na,na); literature &own calculations		
	Transformation, to traffic area, rail network	-	resource	land	m2	2.66E-2	1	2.01	(3,2,1,1,na,na); literature &own calculations		
	Transformation, to traffic area, rail embankment	-	resource	land	m2	2.42E-2	1	2.01	(3,2,1,1,na,na); literature &own calculations		

Table 6-60: Life cycle inventory input data for disposal of rail infrastructure in Switzerland. Figures in this table represent ecoinvent data v1.1; the following elementary flows have been corrected for ecoinvent data v2.0: The input of waste treatment service "disposal, pollutants from rail ballast, 0% water, to residual material landfill, CH, [kg]" is too high by a factor of 256. Correct value is 0.140 kg/ma. Additional waste management service input is added, namely: 38.65 kg/ma "disposal, inert waste, 5% water, to inert material landfill, CH, [kg].

	3702	3703	3508	3706	3707
Explanations	Name	Location	Infrastructure-Process	Unit	disposal, railway track
	Location				CH
	InfrastructureProcess				1
	Unit				ma
Outputs	disposal, railway track	CH	1	ma	1.00E+0
Technosphere	transport, lorry 28t	CH	0	tkm	3.70E+1
	disposal, pollutants from rail ballast, 0% water, to residual material landfill	CH	0	kg	1.40E-1
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	3.87E+1

Table 6 50: Life cycle inventory input data for the construction of ICE rail infrastructure (ballastless) in Germany

	Name	Location	Infrastructure Process	Unit	railway track, ICE	UncertaintyType	Standard Deviation95%	GeneralComment	*constr. railway track*	*constr. tunnel*	*constr. bridge*
	Location				*DE*				*CH*	*CH*	*CH*
	InfrastructureProcess				*1*				*1*	*1*	*1*
	Unit				*ma*				*ma*	*ma*	*ma*
product	railway track, ICE	DE	1	ma	1.00E+0						
technosphere	concrete, exacting, at plant	CH	0	m3	4.19E-2	1	1.27	literature studies; (3,3,1,3,3,4)	3.47E-02	9.44E-02	2.01E-02
	steel, low-alloyed, at plant	RER	0	kg	1.88E+0	1	1.27	literature studies; (3,3,1,3,3,4)	1.77E+00	1.35E+00	3.62E-01
	reinforcing steel, at plant	RER	0	kg	1.06E+1	1	1.27	literature studies; (3,3,1,3,3,4)	1.00E+01	7.68E+00	2.05E+00
	copper, at regional storage	RER	0	kg	4.24E-1	1	1.29	literature studies; (3,3,3,3,3,4)	4.24E-01		
	diesel, burned in building machine	GLO	0	MJ	5.00E-2	1	2.09	literature studies; (3,3,3,3,3,4)	5.00E-02		
	excavation, skid-steer loader	RER	0	m3	1.89E+0	1	2.09	literature studies; (3,3,3,3,3,4)	1.81E+00	1.04E+00	
	aluminium, production mix, at plant	RER	0	kg	1.25E-1	1	2.09	literature studies; (3,3,3,3,3,4)	1.25E-01		
	ceramic tiles, at regional storage	CH	0	kg	1.20E-1	1	2.09	literature studies; (3,3,3,3,3,4)	1.20E-01		
	pig iron, at plant	GLO	0	kg	7.40E-1	1	2.09	literature studies; (3,3,3,3,3,4)	7.40E-01		
	tin, at regional storage	RER	0	kg	5.00E-3	1	2.09	literature studies; (3,3,3,3,3,4)	5.00E-03		
	transport, freight, rail	RER	0	tkm	2.63E+0	1	2.09	standard distance; (4,5,na,na,na,na)	2.36E+03	3.61E+03	4.82E+02
	transport, lorry 32t	RER	0	tkm	4.28E+1	1	2.09	standard distance; (4,5,na,na,na,na)	4.00E+04	4.00E+04	8.83E+02
disposal	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	2.86E+0	1	1.27	own calculation based on the excavation figures.; (3,3,3,1,1,5)	1.81E+00	1.04E+00	

Table 6-61: Life cycle inventory input data for operation and maintenance of ICE rail infrastructure in Germany. Figures in this table represent ecoinvent data v1.1; the following elementary flows have been corrected for ecoinvent data v2.0: consumption of glyphosate (1.95E-3 kg/ma); emission of glyphosate (7.00E-4 kg/ma).

Explanations	Name	Location	Infrastructure-Process	Unit	operation, maintenance, railway track, ICE
	Location				DE
	InfrastructureProcess				1
	Unit				ma
Outputs	operation, maintenance, railway track, ICE	DE	1	ma	1.00E+0
Technosphere	electricity, medium voltage, production DE, at grid	DE	0	kWh	6.46E+0
	glyphosate, at regional storehouse	CH	0	kg	7.00E-4
	lubricating oil, at plant	RER	0	kg	7.53E-3
	transport, freight, rail	RER	0	tkm	1.37E-3
resource, land	Occupation, traffic area, rail network			m2a	1.33E+1
	Occupation, traffic area, rail embankment			m2a	1.04E+1
	Transformation, from unknown			m2	2.37E-1
	Transformation, to traffic area, rail network			m2	1.33E-1
	Transformation, to traffic area, rail embankment			m2	1.04E-1
air, unspecified	Heat, waste			MJ	2.33E+1
soil, industrial	Glyphosate			kg	7.00E-4
soil, unspecified	Oils, biogenic			kg	7.53E-3

Data Quality and Uncertainties

The quality of the data for track expenditures is considered as good. The data for tunnel construction and bridges however is of lower quality, since it is based on set of assumptions, which are fairly uncertain. Furthermore the representativeness of the data for the total Swiss rail network is not known.

For land use data the representativeness and geographical correlation and hence the quality of the data is considered as good. The data is based on some simplification, such as that all multi lane tracks are accounted for as two way tracks, which leads to slight underestimation of the land use. Furthermore, the actual length of actually used siding is not available.

The representativeness for other countries or railway companies is unknown Further uncertainties are at stake, when applying these data to the current transport performance and calculate a the specific land use per tkm.

6.10 Rail Transport

6.10.1 Method

In this section the demand factors of various transport components (as described in the previous sections) required to fulfill the functional unit of one tkm fright transport are presented. For instance, the module "transport, freight train" accesses the sub module "locomotive" with a demand factor 7.11E-10; i.e. per functional unit 7.11E-10 locomotives are required. The determination of the share of vehicles per transport performance unit [tkm] data is documented in Table 6-62 and Table 6-63.

In Table 6-64 and Table 6-65 the actual demand of vehicle- and road infrastructure per transport performance [tkm] are presented for Switzerland and Europe respectively.

Table 6-62: Transport performance of locomotives

	Unit	SBB 2000	SBB 1999
Locomotives total	unit	750	750
Locomotive goods trans.		307	307
Goods transport performance	tkm	1.08E+10	9.80E+09
Yearly transport performance per vehicle	tkm/(unit*a)	3.52E+07	3.19E+07
Life time transport performance (40a)	tkm/unit	1.41E+09	1.28E+09
Share of vehicle per performed tkm	unit/tkm	**7.11E-10**	7.83E-10

Table 6-63: Transport performance of goods wagons

	Unit	SBB 2000	SBB 1999
Goods wagons total	unit	19791	20119
Goods transport performance	tkm	1.08E+10	9.80E+09
Yearly transport performance per wagon	tkm/(unit*a)	5.45E+05	4.87E+05
Life time transport performance (40a)	tkm/unit	2.18E+07	1.95E+07
Share of wagon per performed tkm	unit/tkm	**4.59E-08**	5.13E-08

In order to account for the fact that the same rail tracks are used for both passenger and goods transportation we apply the allocation factors as documented in section 6.9.1.

The dataset transport of coal by train in China is based on "transport, freight, rail (RER)" but instead of "operation, freight train (RER)" three different inputs are defined to reflect the use of electric, diesel, and steam locomotives in the coal industry and in China in general:

For the USA, according to (Facanha & Horvath 2006) it can be assumed that US freight trains for coal transport are all operated using diesel engines. The new dataset "transport, freight, rail, diesel/US/tkm" (Table 6-67) is based on the existing European freight transport by train ("transport, freight, rail/RER/tkm"). Instead of the average European share of electric and diesel freight train transport, only diesel as fuel is used.

6.10.2 Life Cycle Inventory Input Data

Table 6-64: Life cycle inventory input data for Swiss freight transport services

	Name	Location	Unit	*transport, freight, rail*	UncertaintyType	StandardDeviation 95%	GeneralComment
product	transport, freight, rail	CH	tkm	1.00E+0			
transport components	operation, freight train	CH	tkm	1.00E+0	1	1.00	own estimation
	locomotive	RER	unit	7.11E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999.
	goods wagon	RER	unit	4.59E-8	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999.
	maintenance, goods wagon	RER	unit	4.59E-8	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999.
	maintenance, locomotive	RER	unit	7.11E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999.
	disposal, locomotive	RER	unit	7.11E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999.
	railway track	CH	ma	9.30E-5	1	1.20	own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio.
	operation, maintenance, railway track	CH	ma	4.57E-5	1	1.20	own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio.
	disposal, railway track	CH	ma	9.30E-5	1	1.20	own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio.

Table 6-65: Life cycle inventory input data for European freight transport services

	3702	3703	3706	3707	3708	3709	3792
	Name	**Location**	**Unit**	***transport, freight, rail***	Uncertainty Type	Standard Deviation95%	**GeneralComment**
product	transport, freight, rail	RER	tkm	1.00E+0			
transport components	operation, freight train	RER	tkm	1.00E+0	1	1.00	
	locomotive	RER	unit	7.11E-10	1	1.30	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999 and further geographical uncertainties due to extrapolation
	goods wagon	RER	unit	4.59E-8	1	1.30	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999 and further geographical uncertainties due to extrapolation
	maintenance, goods wagon	RER	unit	4.59E-8	1	1.30	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999 and further geographical uncertainties due to extrapolation
	maintenance, locomotive	RER	unit	7.11E-10	1	1.30	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999 and further geographical uncertainties due to extrapolation
	disposal, locomotive	RER	unit	7.11E-10	1	1.30	own estimation based on comparison with the vehicle stock-transport performance ratio in 1999 and further geographical uncertainties due to extrapolation
	railway track	CH	ma	9.30E-5	1	1.30	(3,1,1,3,1,na); own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio and further geographical uncertainties due to extrapolation
	operation, maintenance, railway track	CH	ma	4.57E-5	1	1.30	(3,1,1,3,1,na); own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio and further geographical uncertainties due to extrapolation
	disposal, railway track	CH	ma	9.30E-5	1	1.30	(3,1,1,3,1,na); own estimation taken into account uncertainties in the infrastructure legth -transport performance ratio and further geographical uncertainties due to extrapolation

Table 6-66: Inventory data for the CN Dataset "transport, coal freight, rail (CN)"

Name	Location	Unit	transport, coal freight, rail	Uncertainty Type	Standard Deviation 95%	General Comment
Location			CN			
InfrastructureProcess			1			
Unit			tkm			
operation, coal freight train, electricity	CN	tkm	2.50E-01	1	1.5	own assumption
operation, coal freight train, diesel	CN	tkm	7.00E-01	1	1.5	own assumption
operation, coal freight train, steam	CN	tkm	5.00E-02	1	1.5	own assumption
disposal, railway track	CH	ma	9.30E-05	1	1.7	increased from 1.3 for corresponsing item in "transport, freight, rail RER"
goods wagon	RER	unit	4.59E-08	1	1.7	as for transport, freight, rail RER
locomotive	RER	unit	7.11E-10	1	1.7	as for transport, freight, rail RER
maintenance, goods wagon	RER	unit	4.59E-08	1	1.7	as for transport, freight, rail RER
maintenance, locomotive	RER	unit	7.11E-10	1	1.7	as for transport, freight, rail RER
operation, maintenance, railway track	CH	ma	4.57E-05	1	1.7	as for transport, freight, rail RER
railway track	CH	ma	9.30E-05	1	1.7	as for transport, freight, rail RER

Table 6-67: Inventory data for freight transport by diesel train in the US.

Name	Location	Category	Sub-Category	Unit	transport, freight, rail, diesel
Location					US
InfrastructureProcess					0
Unit					tkm
disposal, locomotive	RER			unit	7.11E-10
disposal, railway track	CH			ma	9.30E-05
goods wagon	RER			unit	4.59E-08
locomotive	RER			unit	7.11E-10
maintenance, goods wagon	RER			unit	4.59E-08
maintenance, locomotive	RER			unit	7.11E-10
operation, freight train, diesel	RER			tkm	1
operation, maintenance, railway track	CH			ma	4.57E-05
railway track	CH			ma	9.30E-05

Table 6-68: Life cycle inventory input data for Swiss regional rail transport services

	Name	Location	Infra	Unit	transport, regional train, SBB mix	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				0			
	Unit				pkm			
product	transport, regional train, SBB mix	CH	0	pkm	1.00E+0			
transport components	operation, regional train, SBB mix	CH	0	pkm	1.00E+0	1	1.00	own estimation
	regional train	CH	1	unit	3.62E-9	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	maintenance, regional train	CH	1	unit	3.62E-9	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	disposal, regional train	CH	1	unit	3.62E-9	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	railway track	CH	1	ma	1.57E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.
	operation, maintenance, railway track	CH	1	ma	3.29E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.
	disposal, railway track	CH	1	ma	1.57E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.

Table 6-69: Life cycle inventory input data for Swiss long distance rail transport services

	Name	Location	Infra	Unit	*transport, long-distance train, SBB mix*	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				***CH***			
	InfrastructureProcess				***0***			
	Unit				***pkm***			
product	transport, long-distance train, SBB mix	CH	0	pkm	1.00E+0			
transport components	operation, long-distance train, SBB mix	CH	0	pkm	1.00E+0	1	1.00	own estimation
	long-distance train	CH	1	unit	1.28E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	maintenance, long-distance train	CH	1	unit	1.28E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	disposal, long-distance train	CH	1	unit	1.28E-10	1	1.20	own estimation based on comparison with the vehicle stock-transport performance ratio in 2000.
	railway track	CH	1	ma	1.09E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.
	operation, maintenance, railway track	CH	1	ma	1.00E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.
	disposal, railway track	CH	1	ma	1.09E-4	1	1.20	own estimation taken into account uncertainties in the infrastructure length -transport performance ratio.

Table 6-70: Life cycle inventory input data for German high-speed rail transport services

	Name	Location	Unit	*transport, ICE*	UncertaintyType	StandardDeviation95%	GeneralComment
	Location			***DE***			
	InfrastructureProcess			***0***			
	Unit			***pkm***			
product	transport, ICE	DE	pkm	1.00E+0			
transport components	operation, ICE	DE	pkm	1.00E+0	1	1.00	own estimation
	ICE	DE	unit	3.24E-10	1	1.20	literature data. Uncertainties due to assumed kilometric performance, lifespan, and load factor
	maintenance, ICE	DE	unit	3.24E-10	1	1.20	literature data. Uncertainties due to assumed kilometric performance, lifespan, and load factor
	disposal, ICE	DE	unit	3.24E-10	1	1.20	literature data. Uncertainties due to assumed kilometric performance, lifespan, and load factor
	railway track, ICE	DE	ma	1.30E-4	1	1.20	literature data. Allocation principle (freight vs. Passeenger): yearly kilometric performance.
	operation, maintenance, railway track, ICE	DE	ma	1.30E-4	1	1.20	literature data. Allocation principle (freight vs. Passeenger): yearly kilometric performance.
	disposal, railway track, ICE	DE	ma	1.30E-4	1	1.20	literature data. Allocation principle (freight vs. Passeenger): yearly kilometric performance.

7 Life Cycle Inventories for Air Transport

7.1 Goal and Scope

In this chapter we present and discuss the data employed for the air transportation unit processes and outline the foundations and arguments for methodological choices made. In some cases we also give further information on alternative data available or choices possible.

The objective of the air transport-LCA modeling is to supply sets of highly aggregated environmental interventions due to air transport. Air freight transport (also referred to as air cargo transport) are addressed in separate inventories. The general approach is outlined for freight transport, for passenger transport, only differences are reported.

7.1.1 Functional Unit

In order to employ transport unit processes in material and energy inventories, the data is related to the functional unit of one tonne kilometer [tkm]. A tonne kilometer by aviation is defined as follows: "Unit of measure of goods transport which represents the transport of one tonne by an aircraft over one kilometer" EUROSTAT (2000). Exchanges and environmental interventions of passenger transport are expressed in passenger kilometer [pkm].

7.1.2 System Boundaries

The average energy consumption and hence emission strongly depend on the aircraft size and flight distance, since the energy consumption is highest in the start phase. Moreover, detours and turning loops account more for short haul flights. In this project we model three types of aircraft transportation:

a) short and medium haul flight (intra-Europe)

b) long haul flight (intercontinental).

c) average aircraft transportation (comprising a share of short/medium and long haul air transportation movements)

Environmental interventions of air transportations can be classified in interventions due to direct processes and due to indirect processes. In this project we use this classification as a point of departure for the data collection and documentation. Direct processes merely address environmental interventions due to aircraft operation. Indirect processes are further distinguished in unit processes that summaries environmental interventions of a) aircraft fleet (remaining aircraft life cycle processes) and b) airport infrastructure processes. Consequently, the system „air transport" is divided in three components:

- Aircraft Operation
- Aircraft Fleet
- Airport Infrastructure

Aircraft Operation: This first component contains all processes that are directly connected with the operation of the aircrafts. In this project, the fuel consumption and the airborne emissions are of special importance. For airborne emissions we further distinguish the location of emission; i.e. low population density area or stratosphere. All exchanges and interventions are referred to the transport performance of one tonne kilometre.

Aircraft Fleet: This second component contains processes describing the vehicle life cycle (excluding the operation) such as aircraft and part manufacture, aircraft maintenance and support as well as disposal of aircrafts and parts. All exchanges and interventions are referred to one vehicle [unit].

Airport Infrastructure: The third component comprises the airport infrastructure life cycle, including airport construction, airport operation and maintenance as well as airport disposal. In contrast to the previous subsystem the generated data predominately describes Swiss conditions. All exchanges and interventions are referred to the one airport.

The second and third component summarize processes with numerous interfaces to other ecoinvent unit processes (materials and energy). Thus, the actual environmental interventions of these processes are calculated when these data are linked to the referring processes in the ecoinvent database, and are often refereed to as indirect environmental interventions of transportation.

7.1.3 Technical Characteristics

Fright is transported in specific air freighters or in combination with passengers. The differences between air freighters and passenger jets are small, in most cases the same aircraft types can be used. Specific freight aircrafts are predominately used for the transportation of huge goods and are often utilized for military purposes. In this project these aircrafts are neglected. Most freight, however is carried in passenger aircraft (more than 75% of the world freight) and is generally transported over long distances Dings et al. (2002). KML's and Lufthansa'sDings et al. (2002) average flight distance is about 6000 km

Dings et al. (2002), determined four aircraft classes and specified technical characteristics, for each class. The resulting figures are summarized in Table 7-1. The presented figures present conditions for typical passenger aircrafts. The figures in the last column show that the share of freight is most important for long haul flights.

Table 7-1: Technical characteristics of aircrafts. Modified from Dings et al. (2002)

Air craft size	Distance [km]	Field of application	MTOW [1] [t]	Maximum payload [t]	Number passengers	Freight [t]	Freight [%]
1. 40 seats	200	Short distance domestic	17	4.5	20	0	0
2. 100 seats	500	Short haul intra Europe	52	12	65	1	8%
3. 200 seats	1500	Longer distance intra EU	110	24	140	2	8%
4. 400 seats	6000	Long haul intercontinental	395	72	320	25	35%

1. Maximum take-off weight

7.2 Operation of Aircrafts for Freight Transport

As stated above we distinguish 3 types of aircraft operation (long haul (intercontinental), short/medium haul (intra European), and average), for which fuel consumption and emissions are required.

7.2.1 Fuel Consumption of Aircrafts

The fuel used for air transportation is kerosene. In order to determine the specific fuel consumption per tonne kilometer, a top down approach is chosen, taking into account the total fuel consumption and transport performance of Swiss airports.

In Table 7-2 the kerosene consumption for intra-European aircraft movements and intercontinental air transportation are presented. Theses figures are calculated for Switzerland as place of departure.

During LTO (landing and take-off cycle phase; up to 905m) the specific fuel consumption is significantly higher than it is for cruising. As demonstrated in Table 7-7, the share of LTO of the total trip length is higher for a short/medium flight, than it is for a long haul flight. Thus, the specific energy consumption for intra-European flights is significantly higher than it is for intercontinental flights.

Table 7-2: Yearly fuel consumption for fright aircrafts movements inside Europe (intra-Europe) and intercontinental flights

	Fuel consumption	Fuel consumption	Transport Performance	Specific Fuel Consumption
Unit	Mio. l/a	Mio. Kg/a	Mio. tkm/a	Kg/tkm
Europe	**83.0**	**59.8**	**131.9**	**0.453**
Africa	87.1	62.7	217.8	0.288
Asia	468	337.2	1170.9	0.288
North America	372	267.7	929.6	0.288
Central America	1.2	0.9	3.1	0.288
South America	47.3	34.0	118.1	0.288
Total Intercontinental	**975.62**	**702.5976**	**2439.571**	**0.288**

1: BAZL/BFS (2002)

In order to determine the specific energy consumption of an average freight transport operation, the actual share of freight transported inside Europe and on intercontinental flights has been derived from the Swiss statistics BAZL/BFS (2002) for the most important international airports in Switzerland. The resulting figures are summarised in Table 7-3.

Table 7-3: Share of freight transported inside Europe and on intercontinental flights (own calculations based on BAZL/BFS (2002))

	Zurich	Genève	Basel Mulhouse	Average Share Swiss Airports
	%	%	%	%
Share Intra European	4.34	20.52	8.75	5.38
Share Intercontinental	95.66	79.48	91.25	94.62

As demonstrated in Table 7-3 intercontinental transport accounts for 94.6% of the total freight transport from Swiss airports. In consequence, the average aircraft operation accounts for 5.4% intra-

European transport and 94.6% intercontinental transport, resulting in an average kerosene consumption of 0.294 kg/tkm.

In Table 7-4 additional data for the specific energy consumption, as available from current literature, is summarized.

Table 7-4: Specific energy consumption for aviation [tkm]

Data Source	kg/tkm	Type
Lufthansa (2002)[1]	0.185	average
Lufthansa 1997[2]	0.245	average
Ifeu[3]	0.381	short and medium haul
Ifeu[3]	0.253	long distance
CE[4]	0.453	short and medium haul
CE[4]	0.256	long distance
INFRAS [5)]	0.280	no specification

1: Lufthansa (2001)
2: Lufthansa (1997)
3: Jens Borken et al. (1999)
4: Dijkstra & Dings (1997)
5: Maibach et al. (1999)

The figures found in literature do well correspond for long haul flights, however, the IFEU figure for short and medium haul flights is significantly lower than the figures from other sources. The reasons for that may be manifold and are not further investigated here. The extremely improvement of the average value for the Lufthansa aircraft fleet indicates the rapid development in the aircraft sector. In this project we use the values available from the Swiss statistics BAZL/BFS (2002), which take into account a today market's average aircraft fleet.

7.2.2 Airborne Gaseous Emissions

The combustion of kerosene in aircraft engines is directly coupled with the amount of carbon dioxide and water produced. Other exhaust products are sulfur dioxide, nitrogenous oxides, carbon monoxide, hydrocarbons and soot. The basis for the calculation of emission factors are so-called emission indices (EI). The EI is defined as the mass of a substance in grams per kilogram of fuel burned.

Fuel Content Dependent Emissions

Due to its nearly constant carbon to hydrogen ratio (a good approximation for the average sum formula is $C_{12}H_{23}$) the combustion of one kilogram kerosene results in about 3150 g carbon dioxide (CO_2) and about 1240 g water (H_2O). The emitted amount of sulfur dioxide (SO_2) is exclusively dependent on the fuel sulfur content. The international threshold for sulphur in kerosene is 0.3 M% (3 $g_S/kg_{kerosene}$) resulting in 6 g/kg SO_2. The figures in Table 7-5, however, reveal that the current sulphur content in kerosene is assumed to be significantly lower, between 0.025 M% and 0.05M%. In this study, we employ the latter figure, which is in line with the figure given in Jungbluth (2003) and Unique (2002). In contrast to Borken (1999) no distinction for long and short haul is made. Furthermore, in Borken (1999), an emission index for HCl emission of 2E-05 g/MJ (8.6E-04g/kg) is presented, based on the Cl content of diesel fuels.

Combustion Process Dependent Emissions

The production rates for other emissions such as nitrogenous oxides, carbon monoxide (CO), hydrocarbons (HC) and soot, are strongly dependent on the combustion process, i.e. on the type of aircraft engine, on the actual operating condition and on the ambient conditions.

In general, these emissions are measured in engine test facilities at sea level static conditions. Due to changes in ambient conditions and influences of increased speed, aircraft engine tests under sea level static (SLS) conditions are not appropriate to determine the emissions for in-flight situations. For the measurements in combustor test facilities the combustor parameters assigned to the in-flight conditions are commercially sensitive and often not available. The measurements at simulated in-flight conditions in an engine altitude test facility are very expensive. Real in-flight measurements (performed out of a window of an aircraft during flight or by a chase aircraft in behind) are complicated and expensive, too. Therefore special calculation procedures (so called correlation methods) have been developed. These correlations base on all kinds of measurements and are suitable for the determination of the amount of emissions depending on engine type and operating condition.

In Table 7-5 emission indices as can be found in the recent literature for the main pollutants and CO_2 are summarised.

Table 7-5: Emission indices for the main pollutants and CO2

Emission	Specific emission [g/kg fuel]							
	Lufthansa (2001) [1]	IFEU (1999)[2] Short haul	IFEU (1999)[2] Long haul	UNIQUE (2002)[3]	CE (2002)[4] State of the art aircraft	CE (2002)[4] Today's average aircraft	DLR (2001)[5]	This project
CO2	3145	3182	3182	3170	3150	3150	3150	**3150**
CO	2.5	5.59	3.6	1	-	-	3.7	**3.7**
SO2	0.5	0.6	1	1	0.6	0.6	-	**1**
NO_x	15.2	15.9	15.9	12.5	15	12	14	**14**
HC (VOC)	0.49	1.4	1.4	0.5	1	0.3	1.1	**-** [7)]
NMVOC		1.33	1.33					**1.05** [6)]
CH4		0.07	0.07					**0.05** [6)]
H2O	1240						1240	**1240**
N2O		0.03	0.03					**0.03**

1: Lufthansa (2001), figures represent a modern fleet

2: Jens Borken et al. (1999), values represent long haul flights

3: Unique (2002), figures from the Airport Zürich

4: Dings et al. (2002), figures represent the long haul flight and for NO_x the figure represent the cruise phase. The reverse development of NO_x and HC emissions can be explained with fuel consumption reductions, which are mainly achieved due to higher combustion temperatures, resulting in a more complete combustion of hydrocarbons to CO2 and H2O and an increased formation of NO_x.

5: Andreas Döpelheuer (2001), figures represent typical flight conditions.

6: Methane and NMVOC are calculated by employing a methane share of 5% of total HC emissions Jens Borken et al. (1999)

7: In line with Frischknecht (2003)

For the LTO cycle, a specific VOC profile is available from Shareef et al. (1988). It has been stated that the VOC profile varies with the trust setting of the aircraft, and therefore on the actual operation stage of the aircraft (cruising, take off, etc). In the absence of further information we apply this split to all stages.

Table 7-6: VOC species profile for aircraft engine emissions, based on an average LTO-cycle.

	Benzene	Formaldehyde	1,3 Butadiene	Ethylene	Total share on VOC
Unit	% VOC	% VOC	% VOC	% VOC	% VOC
LTO-average	1.9	15	1.8	17.4	36.1

Location of Emission

Airborne emissions of aircrafts open a new, third dimension since they are released in troposphere and stratosphere.

The cruise phase of most present-day passenger aircrafts takes place in an altitude range (8–13 km) that contains portions of the upper troposphere and lower stratosphere IPCC (1999). Because these two atmospheric regions are characterized by different dynamics and photochemistry, the placement of aircraft exhaust into these regions must be considered when evaluating the impact of exhaust species on atmospheric ozone. A clear distinction of the share of emission released into two atmospheric regions is complicated due to the highly variable and attitudinally dependent character of the tropopause. (i.e., the transition between the stratosphere and troposphere). Comparisons of aircraft cruise altitudes with mean tropopause heights has led to estimates for stratospheric release of 20–40% of total emissions .

In this project we assume that 30% of the emissions in cruising are released in the troposphere for both intra European and intercontinental flights.

Furthermore, we assume that airports are situated in at the periphery of cities and hence the emissions due to landing and take off are characterized as emissions in low population area. The assumptions made for the calculation and the resulting figures of the share of LTO are presented in Table 7-7.

Table 7-7: Share of fuel consumption of LTO

	Distance [km] 1)	LTO [kg/LTO] 1)	Cruise [kg/km] 1)	Cruise total [kg]	LTO [%]	Cruise [%]
Intra Europe	500	730	2	1050	**41.01**	**58.99**
Intercontinental Long Haul	6000	3100	11	66000	**4.49**	**95.51**
Average Freight Transport (5.4% EU, 94.6% INT)	5725	2982	10.55	60399	**4.70**	**95.30**
Average Passenger Transport (29.9% EU, 70.1% INT)	4157	2389	8.3	34507	**6.47**	**93.53**

1: figures are derived from Dings et al. (2002). For intra Europe aircraft movements we employed the distance of an average short haul flight in Europe.

The remaining emission in the upper troposphere are characterised as emissions to air, unspecified

7.2.3 Particulate Emissions

The soot production and oxidation mechanism is very complex. The non-homogeneous flow and temperature fields in the combustion chamber, the different effects of the injection systems and combustor technologies, the influence of the type of fuel burned and the rare measurement data available make it difficult to calculate the amount of soot emitted by aircraft engines Andreas Döpelheuer (2001).

Magnitude and Location of Particulate Emission

Emission Indices for different engines types are available in the literature. Old aircraft engines are reported to emit between 0.07 and 0.11 g soot per kg kerosene, whereas the modern engines (CF6-80 and CFM56) only produce between 0.01 and 0.02 g soot per kg kerosene burned.

In a global inventory for aircraft generated soot A. Döpelheuer (1997), differences in engines and operating conditions have been taken into account. The global mass of soot sums up to about 330 tons per month, resulting in an average emission index of soot of 0.038 g/kg for typical flight conditions.

Döpelheuer (1997)further concluded, that about 21 % of the soot is emitted below 1 km of altitude, 40 % between 1 and 10 km and 39 % above 10 km.

Particle Size Distribution

The soot emitted by an aircraft engine consists of a vast number of particles of different sizes. The main results for particle size distribution measurements are Andreas Döpelheuer (2001):

- The range of particle diameters is about 10 - 100 nm for climb, cruise and decent.
- Smaller diameters appear at Take-Off conditions.
- The particle diameter decrease with decreasing power setting and with increasing altitude.

In consequence, we assume that all emitted particles are classified as PM<2.5.

7.2.4 Heavy Metal Emissions

Sources of heavy metal emissions in the operation of vehicles are trace elements in kerosene fuels and tyre abrasion In contrast to road transport, for air transportation, we do not account for heavy metal emissions due to tyre abrasion.

Heavy Metal Emissions of Fuels

In fuels, a variety of heavy metals can be found. In Jungbluth (2003), however, merely an emission index for mercury is available. In order to complete the list we employ heavy metal emission indices for diesel fuels, assuming that the raw fuel and production processes of kerosene fuels are similar to those of diesel. Table 7-8 presents emission factors expressed in mg/kg kerosene for, as used in this study.

Table 7-8: Heavy metal emission indices of kerosene EEA (2000) and Jungbluth (2003).

Cadmium [g/kg Fuel]	Copper [g/kg Fuel]	Chromium [g/kg Fuel]	Nickel [g/kg Fuel]	Selenium [g/kg Fuel]	Zinc [g/kg Fuel]	Lead [g/kg Fuel]	Mercury [g/kg Fuel]
1.0E-05	1.7E-03	5.0E-05	7.0E-05	1.0E-05	1.0E-03	2.0E-05	7.0E-08

7.2.5 Life Cycle Inventory Input Data

In Table 7-9 the specific emission factors and fuel consumption as used in this project are summarized.

Table 7-9: Input data for the operation of passenger aircrafts (Part 1: Regulated emissions, CO2 and Kerosene cons.). Figures in the table correspond to ecoinvent data v1.1; the following elementary flow has been corrected for ecoinvent data v2.0: "kerosene, at regional storage", 0.297 kg/tkm.

Explanations	Name	Location	Category	Sub-Category	Infrastructure-Process	Unit	operation, aircraft, freight, Europe	operation, aircraft, freight, intercontinental	uncertaintyType	StandardDeviation 95%	GeneralComment
	Location						RER	RER			
	InfrastructureProcess						0	0			
	Unit						tkm	tkm			
Outputs	operation, aircraft, freight, Europe	RER			0	tkm	1				
	operation, aircraft, freight, intercontinental	RER			0	tkm		1			
Technosphere	kerosene, at regional storage	RER			0	kg	4.53E-1	2.88E-1	1	1.17	(2,3,2,3,1,nA)
air, lower stratosphere + upper troposphere	Carbon dioxide, fossil		air	lower stratosphere + upper troposphere		kg	2.53E-1	2.60E-1	1	1.15	(2,3,2,2,1,nA)
	Heat, waste		air	lower stratosphere + upper troposphere		MJ	3.66E+0	3.76E+0	1	1.146	(2,3,2,2,1,nA)
	Mercury		air	lower stratosphere + upper troposphere		kg	5.61E-12	5.78E-12	1	5.34	(4,5,3,1,3,nA)
	Lead		air	lower stratosphere + upper troposphere		kg	1.60E-9	1.65E-9	1	5.34	(4,5,3,1,3,nA)
	Zinc		air	lower stratosphere + upper troposphere		kg	8.02E-8	8.25E-8	1	5.34	(4,5,3,1,3,nA)
	Selenium		air	lower stratosphere + upper troposphere		kg	8.02E-10	8.25E-10	1	5.34	(4,5,3,1,3,nA)
	Nickel		air	lower stratosphere + upper troposphere		kg	5.61E-9	5.78E-9	1	5.34	(4,5,3,1,3,nA)
	Chromium		air	lower stratosphere + upper troposphere		kg	4.01E-9	4.13E-9	1	5.34	(4,5,3,1,3,nA)
	Copper		air	lower stratosphere + upper troposphere		kg	1.36E-7	1.40E-7	1	5.34	(4,5,3,1,3,nA)
	Cadmium		air	lower stratosphere + upper troposphere		kg	8.02E-10	8.25E-10	1	5.34	(4,5,3,1,3,nA)
	Hydrogen chloride		air	lower stratosphere + upper troposphere		kg	6.89E-8	7.10E-8	1	2.28	(3,5,5,5,3,nA)
	water		air	lower stratosphere + upper troposphere		kg	9.94E-2	1.02E-1	1	1.15	(2,3,2,2,1,nA)
	Ethylene oxide		air	lower stratosphere + upper troposphere		kg	1.46E-5	1.51E-5	1	2.28	(3,5,5,5,3,nA)
	Butadiene		air	lower stratosphere + upper troposphere		kg	1.52E-6	1.56E-6	1	2.28	(3,5,5,5,3,nA)
	Benzene		air	lower stratosphere + upper troposphere		kg	1.60E-6	1.65E-6	1	2.28	(3,5,5,5,3,nA)
	Formaldehyde		air	lower stratosphere + upper troposphere		kg	1.26E-5	1.30E-5	1	2.28	(3,5,5,5,3,nA)
	Dinitrogen monoxide		air	lower stratosphere + upper troposphere		kg	2.41E-6	2.48E-6	1	1.54	(2,3,3,2,1,nA)
	NMVOC, non-methane volatile organic compounds, unspecified origin		air	lower stratosphere + upper troposphere		kg	5.38E-5	5.54E-5	1	1.53	(2,3,2,2,1,nA)
	Particulates, < 2.5 um		air	lower stratosphere + upper troposphere		kg	3.05E-6	3.14E-6	1	2.02	(2,3,2,2,1,nA)
	Methane, fossil		air	lower stratosphere + upper troposphere		kg	4.01E-6	4.13E-6	1	1.53	(2,3,2,2,1,nA)
	Nitrogen oxides		air	lower stratosphere + upper troposphere		kg	1.12E-3	1.16E-3	1	1.53	(2,3,2,2,1,nA)
	Sulfur dioxide		air	lower stratosphere + upper troposphere		kg	8.02E-5	8.25E-5	1	1.15	(2,3,2,2,1,nA)
	Carbon monoxide, fossil		air	lower stratosphere + upper troposphere		kg	2.97E-4	3.05E-4	1	5.03	(2,3,2,2,1,nA)
air, low population density	Carbon dioxide, fossil		air	low population density		kg	5.85E-1	4.07E-2	1	1.15	(2,3,2,2,1,nA)
air, unspecified	Carbon dioxide, fossil		air	unspecified		kg	5.89E-1	6.07E-1	1	1.15	(2,3,2,2,1,nA)
air, low population density	Carbon monoxide, fossil		air	low population density		kg	6.87E-4	4.78E-5	1	5.03	(2,3,2,2,1,nA)
air, unspecified	Carbon monoxide, fossil		air	unspecified		kg	6.92E-4	7.12E-4	1	5.03	(2,3,2,2,1,nA)
air, low population density	Sulfur dioxide		air	low population density		kg	1.86E-4	1.29E-5	1	1.15	(2,3,2,2,1,nA)
air, unspecified	Sulfur dioxide		air	unspecified		kg	1.87E-4	1.93E-4	1	1.15	(2,3,2,2,1,nA)
air, low population density	Nitrogen oxides		air	low population density		kg	2.60E-3	1.81E-4	1	1.53	(2,3,2,2,1,nA)
air, unspecified	Nitrogen oxides		air	unspecified		kg	2.62E-3	2.70E-3	1	1.53	(2,3,2,2,1,nA)
air, low population density	Methane, fossil		air	low population density		kg	9.29E-6	6.47E-7	1	1.53	(2,3,2,2,1,nA)
air, unspecified	Methane, fossil		air	unspecified		kg	9.35E-6	9.63E-6	1	1.53	(2,3,2,2,1,nA)
air, low population density	Particulates, < 2.5 um		air	low population density		kg	7.06E-6	4.91E-7	1	2.02	(2,3,2,2,1,nA)
air, unspecified	Particulates, < 2.5 um		air	unspecified		kg	7.11E-6	7.32E-6	1	2.02	(2,3,2,2,1,nA)
air, low population density	NMVOC, non-methane volatile organic compounds, unspecified origin		air	low population density		kg	1.25E-4	8.68E-6	1	1.53	(2,3,2,2,1,nA)
air, unspecified	NMVOC, non-methane volatile organic compounds, unspecified origin		air	unspecified		kg	1.26E-4	1.29E-4	1	1.53	(2,3,2,2,1,nA)
air, low population density	Dinitrogen monoxide		air	low population density		kg	5.57E-6	3.88E-7	1	1.54	(2,3,3,2,1,nA)
air, unspecified	Dinitrogen monoxide		air	unspecified		kg	5.61E-6	5.78E-6	1	1.53	(2,3,1,2,1,nA)
air, low population density	Formaldehyde		air	low population density		kg	2.93E-5	2.04E-6	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Formaldehyde		air	unspecified		kg	2.95E-5	3.03E-5	1	2.28	(3,5,5,5,3,nA)
air, low population density	Benzene		air	low population density		kg	3.71E-6	2.58E-7	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Benzene		air	unspecified		kg	3.73E-6	3.84E-6	1	2.28	(3,5,5,5,3,nA)
air, low population density	Butadiene		air	low population density		kg	3.51E-6	2.44E-7	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Butadiene		air	unspecified		kg	3.54E-6	3.64E-6	1	2.28	(3,5,5,5,3,nA)
air, low population density	Ethylene oxide		air	low population density		kg	3.39E-5	2.36E-6	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Ethylene oxide		air	unspecified		kg	3.42E-5	3.52E-5	1	2.28	(3,5,5,5,3,nA)
air, low population density	water		air	low population density		kg	2.30E-1	1.60E-2	1	1.15	(2,3,2,2,1,nA)
air, unspecified	water		air	unspecified		kg	2.32E-1	2.39E-1	1	1.15	(2,3,2,2,1,nA)
air, low population density	Hydrogen chloride		air	low population density		kg	1.60E-7	1.11E-8	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Hydrogen chloride		air	unspecified		kg	1.61E-7	1.66E-7	1	2.28	(3,5,5,5,3,nA)
air, low population density	Cadmium		air	low population density		kg	1.86E-9	1.29E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Cadmium		air	unspecified		kg	1.87E-9	1.93E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Copper		air	low population density		kg	3.16E-7	2.20E-8	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Copper		air	unspecified		kg	3.18E-7	3.27E-7	1	5.34	(4,5,3,1,3,nA)
air, low population density	Chromium		air	low population density		kg	9.29E-9	6.47E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Chromium		air	unspecified		kg	9.35E-9	9.63E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Nickel		air	low population density		kg	1.30E-8	9.05E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Nickel		air	unspecified		kg	1.31E-8	1.35E-8	1	5.34	(4,5,3,1,3,nA)
air, low population density	Selenium		air	low population density		kg	1.86E-9	1.29E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Selenium		air	unspecified		kg	1.87E-9	1.93E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Zinc		air	low population density		kg	1.86E-7	1.29E-8	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Zinc		air	unspecified		kg	1.87E-7	1.93E-7	1	5.34	(4,5,3,1,3,nA)
air, low population density	Lead		air	low population density		kg	3.72E-9	2.59E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Lead		air	unspecified		kg	3.74E-9	3.85E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Mercury		air	low population density		kg	1.30E-11	9.05E-13	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Mercury		air	unspecified		kg	1.31E-11	1.35E-11	1	5.34	(4,5,3,1,3,nA)
air, low population density	Heat, waste		air	low population density		MJ	8.47E+0	5.90E-1	1	1.146	(2,3,2,2,1,nA)
air, unspecified	Heat, waste		air	unspecified		MJ	8.53E+0	8.78E+0	1	1.146	(2,3,2,2,1,nA)

Data Quality and Uncertainties

If not stated explicitly, for the representation of uncertainties a lognormal distribution was applied. The standard deviation comprises a basic uncertainty and further uncertainties generated with the pedigree matrix Frischknecht et al. (2003). The scores of the different data quality indicators are given in the above table.

Fuel consumption

Long haul transport consumption figures match fairly good with figures available in literature. For short/medium haul transport, however, the range of reported figures is significantly wider, resulting in a higher uncertainty of the employed figure. The same applies for the average fuel consumption. The literature comparison reveals the extreme dependency of the fuel consumption on the composition of the aircraft fleet. For instance, by modernising its aircraft fleet in the last 5 years, Lufthansa achieved a 25% reduction of its average fuel consumption (see Table 7-4).

In this study we assume that the aircrafts operating at Swiss airports have a lower fuel consumption than those in other European countries, in particular East European countries. In consequence, we assume that the figures presented in this study slightly underestimate European. A log normal distribution is thus an appropriate distribution function.

Airborne Emissions

The qualities of the emission indices differ significantly for the considered pollutants. As already mentioned CO_2 and H_2O are simply obtained by calculations and the quality is considered as good. Medium variation has been found for NO_x and SO_2. Since the SO2 content exclusively depends on the sulphur content in the fuel, uncertainties arise from assumption about the sulphur content of fuels. The literature study, however, has revealed a great variability of the CO figure. The same applies for the VOC value.

It should be beared in mind that for most figures no information is available whether the data is derived directly from engine tests or further modelling has been performed. In the absence of this information and the ignorance about the aircraft engine types included, we apply the pedigree matrix for the determination of basic uncertainties. Moreover, the fuel consumption is another critical figure. Uncertainty arises from several assumptions made, and the non-consideration of the average load factor. Due to the fact that the emission factors are obtained by means of multiplication of the fuel consumption and emission indices the obtained data shall be regarded as point of reference.

Particles

The quality of the size distribution for this project is considered as very good. The employed figure is calculated for typical flight conditions, however, as described above, the process of particulate formation is complex. Thus, we use the fairly high basic uncertainty for particles as proposed for this project to quantify uncertainties. In addition further uncertainties arises when combining the particle indices with the fuel consumption to calculate transport specific emission factors.

Heavy metals

The figures for Cadmium, Copper, Chromium, Nickel, Selenium and Zinc are provided by an Expert Panel on Heavy Metals of the UNECE Task Force on Emission Inventories EEA (2000). These emissions indices are merely preliminary estimates.

7.3 Operation of Aircrafts for Passenger Transport

In aviation it is common to attribute a certain weight to passengers. The actually attributed weight of one passenger, however, varies significantly in literature. The Swiss statistics accounts for a passenger with a mass of 100 kg BAZL/BFS (2002), taking into account a an average weight of 70 kg of one passenger and 30 kg language. Other studies claimed that a correct allocation requires allocating the mass of all facilities required for a passenger transport to the passenger. In Maibach et al. (1999) a weight of 190 kg/passenger is applied. Recently Dings (2002) proposes a representative mass of 240 kg for one passenger. The latter is used in this study to transform tonne kilometre [tkm**]** into passenger kilometre, the reference unit employed for passenger transport in this study.

7.3.1 Fuel Consumption of Aircrafts

In order to calculate the specific fuel consumption the values presented in Table 7-2 are employed and multiplied with a factor of 0.24, resulting in 0.109 kg/pkm and 0.069 kg/pkm for a intra-European and intercontinental flight, respectively.

The average passenger air transport is calculated by employing the actual share of intra European and intercontinental passenger transport performance [tkm**]**, with Switzerland as point of departure. The essential data is derived from the Swiss statistics BAZL/BFS (2002). In Table 7-10 the latter data and the resulting share are summarised.

Table 7-10: Share of freight transported inside Europe and on intercontinental flights (own calculations based on BAZL/BFS (2002))

	Zürich	Genève	Basel Mulhouse	Total Swiss	Average Share Swiss Airports
	%	%	%	%	%
Share Intra Europe	25.4	72.8	68.8	32.7	32.7
Share Intercontinental	74.6	27.2	31.2	67.3	67.3

As demonstrated in Table 7-10 intercontinental transport accounts for 67.3% of the total freight transport from Swiss Airports. In consequence, the average aircraft operation accounts for 32.7% intra Europe transport and 67.3% intercontinental transport, resulting in a kerosene consumption of 0.082 kg/pkm

7.3.2 Airborne Gaseous Emissions and Particulate Emissions

For the determination of airborne gaseous emissions as well as or particulate emissions, data as presented in section 7.2.2 and 7.2.3 respectively is employed.

7.3.3 Heavy Metal Emissions

For the determination of heavy metal emissions, data as presented in section 7.2.4 is employed.

7.3.4 Life Cycle Inventory Input Data

In Table 7-11 the specific emission factors and fuel consumption as used in this project are summarized.

Table 7-11: Input data for the operation of passenger aircrafts (Part 1: Regulated emissions, CO2 and Kerosene cons.)

Explanations	Name	Location	Category	Sub-Category	Infrastructure-Process	Unit	operation, aircraft, freight, Europe	operation, aircraft, freight, intercontinental	uncertaintyType	StandardDeviation 95%	GeneralComment
	Location						RER	RER			
	InfrastructureProcess						0	0			
	Unit						tkm	tkm			
Outputs	operation, aircraft, freight, Europe	RER			0	tkm	1				
	operation, aircraft, freight, intercontine	RER			0	tkm		1			
Technosphere	kerosene, at regional storage	RER			0	kg	4.53E-1	2.88E-1	1	1.17	(2,3,2,3,1,nA)
air, lower stratosphere + upper troposphere	Carbon dioxide, fossil		air	lower stratosphere + upper troposphere		kg	2.53E-1	2.60E-1	1	1.15	(2,3,2,2,1,nA)
	Heat, waste		air	lower stratosphere + upper troposphere		MJ	3.66E+0	3.76E+0	1	1.146	(2,3,2,2,1,nA)
	Mercury		air	lower stratosphere + upper troposphere		kg	5.61E-12	5.78E-12	1	5.34	(4,5,3,1,3,nA)
	Lead		air	lower stratosphere + upper troposphere		kg	1.60E-9	1.65E-9	1	5.34	(4,5,3,1,3,nA)
	Zinc		air	lower stratosphere + upper troposphere		kg	8.02E-8	8.25E-8	1	5.34	(4,5,3,1,3,nA)
	Selenium		air	lower stratosphere + upper troposphere		kg	8.02E-10	8.25E-10	1	5.34	(4,5,3,1,3,nA)
	Nickel		air	lower stratosphere + upper troposphere		kg	5.61E-9	5.78E-9	1	5.34	(4,5,3,1,3,nA)
	Chromium		air	lower stratosphere + upper troposphere		kg	4.01E-9	4.13E-9	1	5.34	(4,5,3,1,3,nA)
	Copper		air	lower stratosphere + upper troposphere		kg	1.36E-7	1.40E-7	1	5.34	(4,5,3,1,3,nA)
	Cadmium		air	lower stratosphere + upper troposphere		kg	8.02E-10	8.25E-10	1	5.34	(4,5,3,1,3,nA)
	Hydrogen chloride		air	lower stratosphere + upper troposphere		kg	6.89E-8	7.10E-8	1	2.28	(3,5,5,5,3,nA)
	water		air	lower stratosphere + upper troposphere		kg	9.94E-2	1.02E-1	1	1.15	(2,3,2,2,1,nA)
	Ethylene oxide		air	lower stratosphere + upper troposphere		kg	1.46E-5	1.51E-5	1	2.28	(3,5,5,5,3,nA)
	Butadiene		air	lower stratosphere + upper troposphere		kg	1.52E-6	1.56E-6	1	2.28	(3,5,5,5,3,nA)
	Benzene		air	lower stratosphere + upper troposphere		kg	1.60E-6	1.65E-6	1	2.28	(3,5,5,5,3,nA)
	Formaldehyde		air	lower stratosphere + upper troposphere		kg	1.26E-5	1.30E-5	1	2.28	(3,5,5,5,3,nA)
	Dinitrogen monoxide		air	lower stratosphere + upper troposphere		kg	2.41E-6	2.48E-6	1	1.54	(2,3,3,2,1,nA)
	NMVOC, non-methane volatile organic compounds, unspecified origin		air	lower stratosphere + upper troposphere		kg	5.38E-5	5.54E-5	1	1.53	(2,3,2,2,1,nA)
	Particulates, < 2.5 um		air	lower stratosphere + upper troposphere		kg	3.05E-6	3.14E-6	1	2.02	(2,3,2,2,1,nA)
	Methane, fossil		air	lower stratosphere + upper troposphere		kg	4.01E-6	4.13E-6	1	1.53	(2,3,2,2,1,nA)
	Nitrogen oxides		air	lower stratosphere + upper troposphere		kg	1.12E-3	1.16E-3	1	1.53	(2,3,2,2,1,nA)
	Sulfur dioxide		air	lower stratosphere + upper troposphere		kg	8.02E-5	8.25E-5	1	1.15	(2,3,2,2,1,nA)
	Carbon monoxide, fossil		air	lower stratosphere + upper troposphere		kg	2.97E-4	3.05E-4	1	5.03	(2,3,2,2,1,nA)
air, low population density	Carbon dioxide, fossil		air	low population density		kg	5.85E-1	4.07E-2	1	1.15	(2,3,2,2,1,nA)
air, unspecified	Carbon dioxide, fossil		air	unspecified		kg	5.89E-1	6.07E-1	1	1.15	(2,3,2,2,1,nA)
air, low population density	Carbon monoxide, fossil		air	low population density		kg	6.87E-4	4.78E-5	1	5.03	(2,3,2,2,1,nA)
air, unspecified	Carbon monoxide, fossil		air	unspecified		kg	6.92E-4	7.12E-4	1	5.03	(2,3,2,2,1,nA)
air, low population density	Sulfur dioxide		air	low population density		kg	1.86E-4	1.29E-5	1	1.15	(2,3,2,2,1,nA)
air, unspecified	Sulfur dioxide		air	unspecified		kg	1.87E-4	1.93E-4	1	1.15	(2,3,2,2,1,nA)
air, low population density	Nitrogen oxides		air	low population density		kg	2.60E-3	1.81E-4	1	1.53	(2,3,2,2,1,nA)
air, unspecified	Nitrogen oxides		air	unspecified		kg	2.62E-3	2.70E-3	1	1.53	(2,3,2,2,1,nA)
air, low population density	Methane, fossil		air	low population density		kg	9.29E-6	6.47E-7	1	1.53	(2,3,2,2,1,nA)
air, unspecified	Methane, fossil		air	unspecified		kg	9.35E-6	9.63E-6	1	1.53	(2,3,2,2,1,nA)
air, low population density	Particulates, < 2.5 um		air	low population density		kg	7.06E-6	4.91E-7	1	2.02	(2,3,2,2,1,nA)
air, unspecified	Particulates, < 2.5 um		air	unspecified		kg	7.11E-6	7.32E-6	1	2.02	(2,3,2,2,1,nA)
air, low population density	NMVOC, non-methane volatile organic compounds, unspecified origin		air	low population density		kg	1.25E-4	8.68E-6	1	1.53	(2,3,2,2,1,nA)
air, unspecified	NMVOC, non-methane volatile organic compounds, unspecified origin		air	unspecified		kg	1.26E-4	1.29E-4	1	1.53	(2,3,2,2,1,nA)
air, low population density	Dinitrogen monoxide		air	low population density		kg	5.57E-6	3.88E-7	1	1.54	(2,3,3,2,1,nA)
air, unspecified	Dinitrogen monoxide		air	unspecified		kg	5.61E-6	5.78E-6	1	1.53	(2,3,1,2,1,nA)
air, low population density	Formaldehyde		air	low population density		kg	2.93E-5	2.04E-6	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Formaldehyde		air	unspecified		kg	2.95E-5	3.03E-5	1	2.28	(3,5,5,5,3,nA)
air, low population density	Benzene		air	low population density		kg	3.71E-6	2.58E-7	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Benzene		air	unspecified		kg	3.73E-6	3.84E-6	1	2.28	(3,5,5,5,3,nA)
air, low population density	Butadiene		air	low population density		kg	3.51E-6	2.44E-7	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Butadiene		air	unspecified		kg	3.54E-6	3.64E-6	1	2.28	(3,5,5,5,3,nA)
air, low population density	Ethylene oxide		air	low population density		kg	3.39E-5	2.36E-6	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Ethylene oxide		air	unspecified		kg	3.42E-5	3.52E-5	1	2.28	(3,5,5,5,3,nA)
air, low population density	water		air	low population density		kg	2.30E-1	1.60E-2	1	1.15	(2,3,2,2,1,nA)
air, unspecified	water		air	unspecified		kg	2.32E-1	2.39E-1	1	1.15	(2,3,2,2,1,nA)
air, low population density	Hydrogen chloride		air	low population density		kg	1.60E-7	1.11E-8	1	2.28	(3,5,5,5,3,nA)
air, unspecified	Hydrogen chloride		air	unspecified		kg	1.61E-7	1.66E-7	1	2.28	(3,5,5,5,3,nA)
air, low population density	Cadmium		air	low population density		kg	1.86E-9	1.29E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Cadmium		air	unspecified		kg	1.87E-9	1.93E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Copper		air	low population density		kg	3.16E-7	2.20E-8	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Copper		air	unspecified		kg	3.18E-7	3.27E-7	1	5.34	(4,5,3,1,3,nA)
air, low population density	Chromium		air	low population density		kg	9.29E-9	6.47E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Chromium		air	unspecified		kg	9.35E-9	9.63E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Nickel		air	low population density		kg	1.30E-8	9.05E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Nickel		air	unspecified		kg	1.31E-8	1.35E-8	1	5.34	(4,5,3,1,3,nA)
air, low population density	Selenium		air	low population density		kg	1.86E-9	1.29E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Selenium		air	unspecified		kg	1.87E-9	1.93E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Zinc		air	low population density		kg	1.86E-7	1.29E-8	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Zinc		air	unspecified		kg	1.87E-7	1.93E-7	1	5.34	(4,5,3,1,3,nA)
air, low population density	Lead		air	low population density		kg	3.72E-9	2.59E-10	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Lead		air	unspecified		kg	3.74E-9	3.85E-9	1	5.34	(4,5,3,1,3,nA)
air, low population density	Mercury		air	low population density		kg	1.30E-11	9.05E-13	1	5.34	(4,5,3,1,3,nA)
air, unspecified	Mercury		air	unspecified		kg	1.31E-11	1.35E-11	1	5.34	(4,5,3,1,3,nA)
air, low population density	Heat, waste		air	low population density		MJ	8.47E+0	5.90E-1	1	1.15	(2,3,2,2,1,nA)
air, unspecified	Heat, waste		air	unspecified		MJ	8.53E+0	8.78E+0	1	1.15	(2,3,2,2,1,nA)

Data Quality and Uncertainties

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Long haul transport consumption figures match fairly good with figures available in literature. For short/medium haul transport, however, the range of reported figures is significantly wider, resulting in a higher uncertainty of the employed figure. The same applies for the average fuel consumption. The literature comparison reveals the extreme dependency of the fuel consumption on the composition of the aircraft fleet. For instance, by modernising its aircraft fleet in the last 5 years, Lufthansa achieved a 25% reduction of its average fuel consumption (see Table 7-4).

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It should be beared in mind that for most figures no information is available whether the data is derived directly from engine tests or further modelling has been performed. In the absence of this information and the ignorance about the aircraft engine types included, we apply the pedigree matrix for the determination of basic uncertainties. Moreover, the fuel consumption is another critical figure. Uncertainty arises from several assumptions made, and the non-consideration of the average load factor. Due to the fact that the emission factors are obtained by means of multiplication of the fuel consumption and emission indices the obtained data shall be regarded as point of reference.

Particles

The quality of the size distribution for this project is considered as very good. The employed figure is calculated for typical flight conditions, however, as described above, the process of particulate formation is complex. Thus, we use the fairly high basic uncertainty for particles as proposed for this project to quantify uncertainties. In addition further uncertainties arises when combining the particle indices with the fuel consumption to calculate transport specific emission factors.

Heavy metals

The figures for Cadmium, Copper, Chromium, Nickel, Selenium and Zinc are provided by an Expert Panel on Heavy Metals of the UNECE Task Force on Emission Inventories EEA (2000). These emissions indices are merely preliminary estimates.

7.4 Aircraft Fleet

The data in this module merely addresses the production of aircrafts. The maintenance and operation data is included in the module airport infrastructure. Also, due to its low impact on the total environmental interventions, and a lack of knowledge about the disposal of aircrafts, the disposal of an aircraft has not been taken into account.

Furthermore the data is presented for two aircraft types (long haul and medium haul) and an average aircraft. For long haul transport we assume an “Airbus A340-600”, with 240t max. zero fuel weight and a typical seating of 380 seats. For short and medium haul transport we assume an “Airbus A 320 with a max. zero fuel weight of 61t and a typical seating of 150 seats.

7.4.1 Aircraft production

Material Composition

The data presented here follows the approach proposed in Maibach (1999). Thus, we merely take into account two materials; synthetic (10%) and aluminium (90%). The basic weight, however, have been adjusted to represent long haul operation as well as medium and short rail operation. The resulting data is presented in Table 7-12.

Table 7-12: Material composition of an aircraft

	Unit	Short/medium haul	Long haul	Average Freight Transport	Average Passenger Transport
Max. zero- fuel weight	t	61	240	233.7	181.7
Aluminium	t/unit	54.9	216	210.3	163.5
Polyethylene, HDPE, granulate,	t/unit	6.1	24	23.7	18.2

Manufacturing of Aircrafts

For manufacturing expenditures and environmental interventions, data is available from 16 Airbus manufacturing facilities Airbus (2002). Airbus currently captures 50% of the commercial airliner orders.

Alongside environmental interventions and energy expenditures that arise from any industrial activity, there are four environmental relevant aircraft manufacturing specific activities:

- Metal and composite working (inputs: metals, cutting oils, water, energy; outputs: metallic scarp, VOC, waste, effluents)
- Surface finishing and treatment (inputs: solvents, greases, chemicals, water, energy; outputs: VOC, waste, effluents)
- Component assembly (inputs: sealants, greases, solvents, paints, water, energy; outputs: VOC, waste, effluents)
- Final Assembly (inputs: sealants, solvents, paints, water, energy; outputs VOC, waste effluents)

In table Table 7-13 the quantities for the main expenditures and interventions are summarised.

Table 7-13: Environmental exchanges of aircraft manufacturing (reference year 2000; for all 16 airbus manufacturing sites in Germany, UK, France and Spain)

	unit		unit	
Energy consumption (Total)	GWh/a	1286	MWh/seat	23.1
Electricity	%	40	MWh/seat	9.24
Natural gas	%	57	MWh/seat	13.167
Heating oil	%	3	MWh/seat	0.693
VOC	t/a	2350	kg/seat	42
total water consumption	m3	1.70E+06	m3/seat	30
total water discharge	m3	5.90E+05	m3/seat	10.7

Table 7-14: Environmental exchanges allocated to different aircraft types

	Seats	Electricity	Natural gas	Heating oil	VOC emis-sions	total water consumption/ discharge
	number	GWh/unit	TJ/unit	TJ/unit	kg/unit	m^3/unit
Short/medium haul	150	1.39	7.11	0.37	6300	1610
Long haul	380	3.51	18.0	0.95	16000	4070
Average Fright transport	367.58	3.40	17.4	0.92	15400	3930
Average Passenger Transport	304.79	2.82	14.4	0.76	12800	3260

7.4.2 Life Cycle Inventory Input Data for Aircraft Manufacturing

In Table 7-15 the input data for the manufacturing of aircrafts as used in this project are summarized.

Table 7-15: Input data for the manufacturing of aircrafts

	Name	Location	Unit	aircraft, medium haul	aircraft, long haul	aircraft, freight	aircraft, passenger	UncertaintyType	StandardDeviation95%	GeneralComment
product	aircraft, medium haul	RER	unit	1.00E+0						
	aircraft, long haul	RER	unit		1.00E+0					
	aircraft, freight	RER	unit			1.00E+0				
	aircraft, passenger	RER	unit				1.00E+0			
technosphere	aluminium, production mix, at plant	RER	kg	5.49E+4	2.16E+5	2.10E+5	1.64E+5	1	1.50	(5,na,na,na,na,na); estimate from literature
	polyethylene, HDPE, granulate, at plant	RER	kg	6.10E+3	2.40E+4	2.37E+4	1.82E+4	1	1.50	(5,na,na,na,na,na); estimate from literature
	natural gas, burned in industrial furnace >100kW	RER	MJ	7.11E+6	1.80E+7	1.74E+7	1.44E+7	1	1.07	(1,2,1,1,1,1); environmental report
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh	1.39E+6	3.51E+6	3.40E+6	2.82E+6	1	1.07	(1,2,1,1,1,1); environmental report
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	MJ	3.74E+5	3.51E+6	9.17E+5	7.60E+5	1	1.09	(1,2,2,1,1,1); environmental report
	tap water, at user	RER	kg	4.50E+6	1.14E+7	1.10E+7	9.14E+6	1	1.22	(4,2,1,1,1,1); environmental report and own assumptions
	transport, freight, rail	RER	tkm	1.22E+4	4.80E+4	4.68E+4	3.63E+4	1	2.28	(4,5,na,na,na,na); standard transport distances
	transport, lorry 32t	RER	tkm	3.05E+3	1.20E+4	1.17E+4	9.09E+3	1	2.28	(4,5,na,na,na,na); standard transport distances
	treatment, sewage, unpolluted, to wastewater treatment, class 3	CH	m3	1.61E+6	4.07E+6	3.93E+6	3.26E+6	1	1.22	(4,2,1,1,1,1); environmental report and own assumptions
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin		kg	6.30E+3	1.60E+4	1.54E+4	1.28E+4	1	2.00	(1,2,1,1,1,1); environmental report
	Heat, waste		MJ	4.99E+6	1.26E+7	1.22E+7	1.01E+7	1	1.07	(1,2,1,1,1,1); standard values

7.5 Airport Infrastructure

In this section, we summarise the data employed for the airport infrastructure modules and describe the assumptions made to generate and link the data. The data in this section is related to an entire airport. If not explicitly stated, the data represents conditions at the major Swiss Airport in Zurich.

7.5.1 Infrastructure Demand and Allocation

The total transported tonnage (cargo and passengers) is used as allocation principle to determine the demand factor for airport infrastructure. The following assumption have been made and applied:

- A passenger is accounted for with a weight of 100 kg.
- For intra-European flights and intercontinental flights we assume a distance of 500 km and 6000 km respectively.
- For each flight two airports are accounted for.
- The yearly transported tonnage [t] and number of passengers (local + transfer) for 2000 as available from the Swiss statistics BAZL/BFS (2002)is employed.

Based on the above assumptions the total airport infrastructure demand per transported tonne is calculated to be 7.43E-07 unit/t. In Table 7-16 the above assumptions and resulting figures are summarised.

Table 7-16: Refernece figures for the airport infrastructure

Reference figure	Unit	Freight transport			Passenger transport		
		Intra- Europe	Intercontinental	Average	Intra- Europe	Intercontinental	Average
transported goods (passenger)	t	55729	162672		787215	340633	
distance	km	500	6000		500	6000	
parts airport per tkm/pkm	unit/tkm (unit/pkm)	2.97E-09	2.48E-10	3.23E-10	2.97E-10	2.48E-11	6.87E-11

It should be noted that the total transport performance (calculated from the specific tonnage and the assumed flight distances) is lower than the values presented in section 7.1.3 (derived from BAZL/BFS (2002)). The reason for this is, that the actual distances for intra-European and intercontinental flights are higher than the average distances applied here.

7.5.2 Airport Construction

Construction expenditures for sealed area at airports (excluding built up area) data is available from Maibach et al. (1999). The data represents the airport in Zurich (now unique Airport) and is based on assumptions as follows:

- Foundation layer: 40 cm gravel and a life span of 100 years.

- Concrete floor: of 22 cm with a concrete reinforcement of 1.8 kg steel/m^2. The lifespan of the concrete layer is assumed to be 30 years [12].
- Transport: The transport to the construction site is 25 km.

The data presented in Maibach et al. (1999) represents the condition in the early 1990'ties and assuming a sealed area of 190 ha. In 2000 the sealed area is reported with 330 ha. 40 ha, however, are built up land, so that the sealed non built up area of 290 ha is taken into account in this project. In consequence, the data presented is adjusted by a factor of 1.5 to represent current conditions. The so calculated figures are presented in the below table.

Table 7-17: Materials and energy used in the construction of the sealed area of the Zurich airport

Material/Energy/Service	**Unit**	Maibach et al. (1999))	This project
Concrete, exacting, with de-icing salt contact	Kg/unit	3.22E+07	4.83E+07
Gravel, crushed	Kg/unit	1.59E+07	2.39E+07
Reinforcing steel	Kg/unit	1.20E+05	1.80E+05
Transport, lorry 28t	tkm/unit	1.21E+06	1.82E+06
Excavation, skid-steer loader	m^3/unit	4.98E+04	7.47E+04
Electricity, medium voltage	KWh/unit	2.38E+06	3.57E+06
Diesel, burned in building machine	MJ/unit	1.67E+07	2.51E+07
Heat waste	MJ/unit	8.56E+06	1.28E+07

For material and energy consumption due to the construction and disposal of buildings we employed generic modules as available from Kellenberger et al. (2003). For the type, height and specific area consumptions of single buildings no information was readily available. In order to facilitate a first estimate we made the following assumptions:

- 70% of the built up area is occupied with building halls
- 30% are multi storey buildings with an average of 5 floors. The assumed height between the floors is 2 7m Kellenberger et al. (2003).

In addition to expenditures due to construction, expenditures due to refurbishment and demolition are accounted for.

7.5.3 Airport Operation and Land Use

The data used for this module describe the situation at the Zurich airport as reported in the environmental report of the Zurich Airport Unique (2002). Additional information was available from experts at the airport.

The data merely represent clearing services and infrastructure expenditures within the area of the airport. Air traffic related activities (e.g. traffic to and from the airport) and infrastructure (e.g. operation of multi storage car parks for passengers and airport staff) are not accounted for.

Aircraft Clearing

Clearing of the aircraft comprises various transport services (e.g. passenger transport for which a variety of vehicles are used). Whilst some of them are conventional road vehicles, also airport specific ve-

[12] Within the life span of 30 years ongoing maintenance work at the concrete paving slabs is required, which are not accounted for in this project.

hicles are in operation, for which no life cycle data is available. Thus, the emission data merely represent operation emissions. In addition, the yearly diesel consumption is accounted for, so we obtain emissions of the fuel chain. In data the emission data for transport services due to aircraft clearing are summarised.

Table 7-18: Expenditures and emissions due to clearing of aircrafts

Environmental Exchanges	unit	environmental report	this project
Gasoline	kg/a	6.16E+5	6.16E+5
Diesel	kg/a	3.23E+6	3.23E+6
Nox [1)]	kg/a	1.75E+5	5.21E+4
VOC [2)]	kg/a	2.37E+5	2.37E+5
CO [1)]	kg/a	2.40E+4	7.14E+3
CO2 [1)]	kg/a	4.07E+7	1.21E+7

1: Data of aircraft clearing in the environmental report includes kerosene consumption caused by turbine starting and operation of auxiliary turbines. The consumption of kerosene is already accounted for in the operation of an aircraft. Thus, environmental exchanges due to kerosene use are excluded. This is achieved by calculating the CO2 emissions of the used diesel and gasoline and determine the share of CO2 emissions due to the burning of these fuels. About 1/3 of the CO2 emissions result from burning of diesel and gasoline fuels for on-site transport processes.

2: the major source of VOC accounted for as NMVOC are processes in the service garage.

Aircraft clearing further includes de-icing activities of both, sealed area and aircraft. Glycol brines are usually used for de icing. Propylene glycol and diethylen glycolare are used for de-icing of aircrafts. For de-icing of sealed area, a composition of isopropanol and ethylene glycol is used. The actually use of these materials differs significantly from year to year. Thus, the geometrical mean for 3 years (see Table 7-19) has been determined and employed in this study.

Table 7-19: Expenditures due to de-icing

Activity and Chemicals used	1999	2000	2001	Geometric mean
De-icing aircraft and anti-icing(liquid): Propylenglykol)[m3/a]	2350	1490	924	1479
De-icing area (liquid): Ethylenglykol [m3/a]	635	480	204	396

For the actual treatment of de-icing materials, no quantitative information is available. In line with Maibach et al. (1999) for 20% of the used chemicals we estimate the magnitude of the following emissions: BOD5, Biological Oxygen Demand; DOC, Dissolved Organic Carbon; TOC, Total Organic Carbon and COD, Chemical Oxygen Demand.

Operation of Airport Infrastructure

Operation of airport infrastructure comprises the heat and electricity consumption for buildings and aircraft maintenance. Most of the heat consumed at the airport is generated on site using natural gas and oil. Also, water consumption, waste water and waste disposal are included. In Table 7-20 the resulting figures are summarised.

Table 7-20: Operation of airport infrastructure

Exchanges	Unit	Environmental report	Unit	**This project**
heating oil	MWh/a	2.90E+4	MJ/a	1.04E+8
natural gas	MMh/a	1.60E+5	MJ/a	5.76E+8
electricity	Mwh/a	1.72E+5	Kwh/a	1.72E+8
water consumption	m3/a	7.79E+5	kg/a	7.79E+8
water to treatment	m3/a	1.32E+6	m3/a	1.32E+6

7.5.4 Land Use

In this project we further distinguish between land transformation and land occupation Frischknecht et al. (2003).Whilst transformation directly changes the ecological quality of land, occupation postpones changes of the ecological quality.

Land Occupation

Occupation refers to the time period for which the land is unavailable for other activities. The occupation intervention is expressed in terms of land use type, area and time. The unit is therefore square metres*year [m^2/a]. In general, the airport may be classified as industrial area. In addition we further distinguish three subcategories. The category “industrial area, vegetation” includes the entire non-sealed area of the airport. Sealed area is further divided into built up land and traffic area comprising runways and parking area. In Table 7-21 land use figures for the Zurich Airport are summarised.

Table 7-21: Specific land occupation of the Zurich Airport

Land Use Type	Unit	Total
Occupation, industrial area	m2a/unit	8.80E+06
Occupation, industrial area, built up	m2a/unit	4.00E+05
Occupation, industrial area, vegetation	m2a/unit	5.50E+06
Occupation, traffic area, road network	m2a/unit	2.90E+06

The figures are based on oral communication with Mr. Strahm (Masterplanung; uniqueairport, Zürich)

Land Transformation

For transformation (the change of land use to be allocated to a certain user or user type) we assumed a life span of 100 years for the Zurich airport. We further assume that the expansions of existing airports are less important. Information on the initial use of the considered airport area has not been considered, since it is not considered as representative. Also, no information on the use of the airport area after a possible cut back has been available. In table Table 7-22 the resulting data, based on figures presented in Table 7-21, are illustrated.

Table 7-22: Specific land transformation of the Zurich Airport

Land Type	Unit	Total
Transformation, from unknown	m2/unit	8.80E+04
Transformation, to industrial area	m2/unit	8.80E+04
Transformation, to industrial area, built up	m2/unit	4.00E+03
Transformation, to industrial area, vegetation	m2/unit	5.50E+04
Transformation, to traffic area, road network	m2/unit	2.90E+04

7.5.5 Airport Disposal

The data presented in this module is derived from Maibach (1999) and adjusted with a corrections factor of 1.5. It has been assumed that after 100 years the entire construction material will be disposed. For the disposal a distance of 20 km has been applied. The data is summarised in Table 7-23. The disposal of buildings is included in the construction module of buildings.

Table 7-23: Disposal airport

module	unit	
excavation, skid-steer loader	m^3/unit	2.10E+04
transport, lorry 28t	tkm/unit	1.15E+06
disposal, concrete, 5% water, to inert material landfill	Kg/unit	4.83E+07

7.5.6 Life Cycle Inventory Input Data

In this section, the input tables for the three unit processes describing the airport infrastructure are presented.

Table 7-24: Life cycle inventory input for airport construction

	Name	Location	Unit	*airport*	Uncertainty Type	Standard Deviation 95%	GeneralComment
product	airport	RER	unit	1.00E+0			
technosphere	concrete, exacting, at plant	CH	m3	2.20E+4	1	1.24E+0	(4,3,3,3,1,1); literature and own adjustments
	gravel, crushed, at mine	CH	kg	2.39E+7	1	1.24E+0	(4,3,3,3,1,1); literature and own adjustments
	reinforcing steel, at plant	RER	kg	1.80E+5	1	1.24E+0	(4,3,3,3,1,1); literature and own adjustments
	diesel, burned in building machine	GLO	MJ	2.51E+7	1	2.06E+0	(4,3,3,3,1,1); literature and own adjustments
	electricity, medium voltage, at grid	CH	kWh	3.57E+6	1	1.24E+0	(4,3,3,3,1,1); literature and own adjustments
	excavation, skid-steer loader	RER	m3	7.47E+4	1	2.06E+0	(4,3,3,3,1,1); literature and own adjustments
	building, hall	CH	m2	2.80E+5	1	3.09E+0	(4,3,1,3,3,1); standard modules applied with own assumptions
	building, multi-storey	RER	m3	1.62E+6	1	3.09E+0	(4,3,1,3,3,1); standard modules applied with own assumptions
	transport, lorry 28t	CH	tkm	1.82E+6	1	2.09E+0	(4,5,na,na,na,na); standard distance
emissions to air	Heat, waste	-	MJ	1.28E+7	1	1.24E+0	(4,3,3,3,1,1); standard value

Table 7-25: Life cycle inventory input for airport operation (including land use)

	Name	Location	Unit	*operation, maintenance, airport*	Uncertainty Type	StandardDeviation 95%	GeneralComment
product	operation, maintenance, airport	RER	unit	1.00E+0			
technosphere	electricity, medium voltage, at grid	CH	kWh	1.72E+8	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
	natural gas, burned in industrial furnace >100kW	RER	MJ	5.76E+8	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	MJ	1.04E+8	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
	diesel, at regional storage	CH	kg	3.23E+6	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
	petrol, unleaded, at regional storage	CH	kg	6.16E+5	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
	ethylene glycol, at plant	RER	kg	4.10E+5	1	2.00	environmental report. Value represent the geometrical mean of 3 years.
	propylene glycol, liquid, at plant	RER	kg	1.64E+6	1	1.70	environmental report. Value represent the geometrical mean of 3 years.
	tap water, at user	RER	kg	7.79E+8	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
disposal	treatment, sewage, unpolluted, to wastewater treatment, class 3	CH	m3	1.32E+6	1	1.24	(1,4,1,1,3,1); environmental report and own calculations
emissions to air	Carbon dioxide, fossil	-	kg	1.21E+7	1	1.24	(1,4,1,1,3,1); environmental report and oral comunication
	Carbon monoxide, fossil	-	kg	7.14E+3	1	5.07	(1,4,1,1,3,1); environmental report and oral comunication
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	2.37E+5	1	1.58	(1,4,1,1,3,1); environmental report and oral comunication
	Nitrogen oxides	-	kg	5.21E+4	1	1.58	(1,4,1,1,3,1); environmental report and oral comunication
	Heat, waste	-	MJ	7.85E+8	1	1.05	standard value
emissions to water	BOD5, Biological Oxygen Demand	-	kg	6.81E+5	1	6.00	20% of the amont of ethylene glycol and propylene glycol are accounted for. Uncertainties due to uncertainties in input and uncertainties about the assumption of percentage.
	DOC, Dissolved Organic Carbon	-	kg	2.02E+5	1	6.00	20% of the amont of ethylene glycol and propylene glycol are accounted for. Uncertainties due to uncertainties in input and uncertainties about the assumption of percentage.
	TOC, Total Organic Carbon	-	kg	2.02E+5	1	6.00	20% of the amont of ethylene glycol and propylene glycol are accounted for. Uncertainties due to uncertainties in input and uncertainties about the assumption of percentage.
	COD, Chemical Oxygen Demand	-	kg	6.81E+5	1	6.00	20% of the amont of ethylene glycol and propylene glycol are accounted for. Uncertainties due to uncertainties in input and uncertainties about the assumption of percentage.
land use	Occupation, industrial area, built up	-	m2a	4.00E+5	1	1.58	(1,4,1,1,3,1); environmental report and oral comunication
	Occupation, industrial area, vegetation	-	m2a	5.50E+6	1	1.58	(1,4,1,1,3,1); environmental report and oral comunication
	Occupation, traffic area, road network	-	m2a	2.90E+6	1	1.58	(1,4,1,1,3,1); environmental report and oral comunication
	Transformation, from unknown	-	m2	8.80E+4	1	2.06	(1,4,1,1,3,1); environmental report and oral comunication
	Transformation, to industrial area, built up	-	m2	4.00E+3	1	2.06	(1,4,1,1,3,1); environmental report and oral comunication
	Transformation, to industrial area, vegetation	-	m2	5.50E+4	1	2.06	(1,4,1,1,3,1); environmental report and oral comunication
	Transformation, to traffic area, road network	-	m2	2.90E+4	1	2.06	(1,4,1,1,3,1); environmental report and oral comunication

Table 7-26: Life cycle inventory input for airport disposal

	Name	Location	Unit	*disposal, airport*	Uncertainty Type	Standard Deviation 95%	GeneralComment
product	disposal, airport	RER	unit	1.00E+0			
technosphere	excavation, skid-steer loader	RER	m3	2.10E+4	1	2.10	(4,3,1,3,1,5); literatre and own adjustments
	transport, lorry 28t	CH	tkm	1.15E+6	1	2.09	(4,5,na,na,na,na); standard distance
disposal	disposal, inert waste, 5% water, to inert material landfill	CH	kg	4.83E+7	1	2.00	literatre and own adjustments

Data Quality and Uncertainties

Construction

The quality of the figures presented in this module is considered of medium quality. Standard data quality scores are employed to quantify uncertainties.

Operation

The quality of the figures presented in this module is considered of medium quality. Standard data quality scores are employed to quantify uncertainties. Emissions to water are highly uncertain, since they are merely based on assumptions. The attributed uncertainty scores account for both a) variability in the use of de-icing chemicals and b) the share of chemicals actually emitted to the natural environment.

Land Use

The data for land occupation and transformation represent the current conditions of the major airport in Switzerland. Thus, for Swiss conditions the quality may be considered as good, however, the representativeness for other international airports is unknown. The life span assumed to calculate land transformation is also uncertain. In recent years airports, and in particular the Zurich airport have been frequently extended and so has the area. Currently it is fairly uncertain whether this process will continue in the future.

Disposal

The quality of the figures presented in this module is considered as poor and may be regarded as a first estimate. It should be beared in mind that the impact of the environmental interventions of this module on the total environmental performance of air transportation is low.

7.6 Air Transport

7.6.1 Method

In this section the demand factors of various transport components (as described in the previous sections) required to fulfill the functional unit of one tkm fright transport ([pkm] passenger transport) are presented. For instance, the module “transport, aircraft, fright, Europe” accesses the unit process “aircraft, medium haul” with a demand factor 1.08E-09; i.e. per functional unit 1.08E-09 aircrafts are needed.

Table 7-27: Reference figures various aircraft types

Reference figure	unit	Intra Europe (freight)	Interconti-nental (freight)	Intra Europe (passen-ger)	Interconti-nental (passen-ger)	Average freight transport	Average passenger transport
Kilometric performance per vehicle 1)	km/vehicle	5.59E+07	5.59E+07	5.59E+07	5.59E+07	5.59E+07	5.59E+07
Average load 2)	t/vehicle (p/vehicle)	1	25	65	320	23.8	256.25
Transport performance per vehicle	tkm/vehicle (pkm/vehicle)	5.59E+07	1.40E+09	3.63E+09	1.79E+10	1.33E+09	1.43E+10
Vehicle demand per transport unit	Vehicle/tkm (vehicle/pkm)	1.8E-08	7.1E-10	2.8E-10	5.6E-11	7.5E-10	7.0E-11
Allocation passenger/freight		0.060	0.246	0.940	0.754	0.279	0.721
Allocated vehicle demand per transport unit	Vehicle/tkm (vehicle/pkm)	1.08E-09	1.75E-10	2.63E-10	4.22E-11	2.09E-10	5.05E-11

1: taken from Maibach et al. (1999)

2: taken from Table 7-1

For the average aircraft, a ratio of intercontinental/intra Europe of 95/5 for freight and 75/25 for passenger transportation has been applied to determine the average load.

The determination of the demand factor for airport infrastructure is documented in section 7.5.1.

In Table 7-28 and Table 7-29 the actual demand of kilometric performance, vehicle- and airport infrastructure per transport performance [tkm] or [pkm] are presented, respectively.

7.6.2 Life Cycle Inventory Input Data

Table 7-28: Input data for freight transport

	Name	Unit	*transport, aircraft, freight, Europe*	*transport, aircraft, freight, intercontinental*	UncertaintyType	Standard Deviation95%	GeneralComment
product	transport, aircraft, freight, Europe	tkm	1.00E+0				
	transport, aircraft, freight, intercontinental	tkm		1.00E+0			
transport components	operation, aircraft, freight, Europe	tkm	1.00E+0	-	1	1.00	
	operation, aircraft, freight, intercontinental	tkm	-	1.00E+0	1	1.00	
	aircraft, medium haul	unit	1.08E-9	-	1	1.50	own estimation based on uncertainties in the assumed life time performance of aircrafts.
	aircraft, long haul	unit		1.76E-10	1	1.50	own estimation based on uncertainties in the assumed life time performance of aircrafts and the share of freight.
	airport	unit	2.97E-11	2.48E-12	1	2.00	life span of airports is uncertain
	operation, maintenance, airport	unit	2.97E-9	2.48E-10	1	1.50	uncertainties in flight distance
	disposal, airport	unit	2.97E-11	2.48E-12	1	2.00	life span of airports is uncertain

Table 7-29: Input data for passenger transport

Explanations	401	Input-Group	Output-Group	Name	Location	Category	Sub-Category	Infrastructure-Process	Unit	transport, aircraft, passenger, Europe	transport, aircraft, passenger, intercontinental	uncertaintyType	StandardDeviation 95%	GeneralComment
	662			Location						RER	RER			
	493			InfrastructureProcess						0	0			
	403			Unit						pkm	pkm			
Outputs			0	transport, aircraft, passenger, Europe	RER			0	pkm	1.00E+0				
			0	transport, aircraft, passenger, intercontinental	RER			0	pkm		1.00E+0			
Technosphere		5		operation, aircraft, passenger, Europe	RER			0	pkm	1.00E+0		1	1.00	
		5		aircraft, medium haul	RER			1	unit	2.59E-10		1	1.50	own estimation based on uncertainties in the assumed life time performance of aircrafts.
		5		airport	RER			1	unit	2.97E-12	2.48E-13	1	2.00	life span of airports is uncertain
		5		operation, maintenance, airport	RER			0	unit	2.97E-10	2.48E-11	1	1.50	uncertainties in flight distance
		5		disposal, airport	RER			1	unit	2.97E-12	2.48E-13	1	2.00	life span of airports is uncertain
		5		operation, aircraft, passenger, intercontinental	RER			0	pkm		1.00E+0	1	1.00	
		5		aircraft, long haul	RER			1	unit		4.22E-11	1	1.50	own estimation based on uncertainties in the assumed life time performance of aircrafts.

8 Life Cycle Inventories For Water Transport

8.1 Goal and Scope

In this chapter we present and discuss the data employed for the water transportation unit processes and outline the foundations and arguments for methodological choices made. In some cases we also give further information on alternative data available or choices possible.

The objective of the water transport-LCA modeling is to supply sets of highly aggregated environmental interventions due to water transport.

8.1.1 Functional Unit

In order to employ transport unit processes in material and energy inventories, the data is related to the functional unit of one tonne kilometer [tkm]. A tonne kilometer by shipping is defined as follows: "Unit of measure of goods transport which represents the transport of one tonne by a vessel over one kilometer" EUROSTAT (2000).

8.1.2 System Boundaries

In this project we model four different types of water transportation:

- transoceanic tanker (~ 150'000 dwt; average of slow speed engine and steam turbine propulsion)
- transoceanic freight ship (~ 50'000 dwt dry bulk carrier; average of slow speed engine and steam turbine propulsion)
- barge tanker (average barge tanker operating on inland waterways)
- barge (average barge operating on inland waterways)

Environmental interventions of water transportations can be classified in interventions due to direct processes and due to indirect processes. In this project we use this classification as a point of departure for the data collection and documentation. Direct processes merely address environmental interventions due to vessel operation. Indirect processes are further distinguished in unit processes that summaries environmental interventions of a) vessel fleet (remaining vessel life cycle processes) and b) port infrastructure processes. Consequently, the system „water transport“ is divided in three components:

- Vessel Operation
- Vessel Fleet
- Port Infrastructure

Vessel Operation: This first component contains all processes that are directly connected with the operation of the aircrafts. All exchanges and interventions are referred to the transport performance of one tonne kilometre.

Vessel Fleet: This second component contains processes describing the vehicle life cycle (excluding the operation). All exchanges and interventions are referred to one vehicle [unit].

Port Infrastructure: The third component comprises the port infrastructure life cycle, including port construction, port operation and maintenance as well as port disposal. All exchanges and interventions are referred to the one port [unit]. In addition, for inland shipping, artificial waterways (construction and operation of canals) are modeled.

The second and third component summarize processes with numerous interfaces to other ecoinvent unit processes (materials and energy). Thus, the actual environmental interventions of these processes are calculated when these data are linked to the referring processes in the ecoinvent database, and are often refereed to as indirect environmental interventions of transportation.

8.1.3 Technical Characteristics of Transoceanic Transportation

The dominant segment of oceanic maritime traffic concerns freight, as passengers are now a marginal leisure function solely serviced by cruise shipping. The last century has seen a growth of the number of ships as well as their average size. Rodrigue (2004) pointed out several reasons for the systematic growth of maritime freight traffic:

- Increase in energy and mineral cargoes derived from a growing demand from developed economies of North America, Europe and Japan. For instance, coal is mainly used for energy generation and steel-making. Many developing countries, such as China, are also increasingly involved in importing raw materials.
- Globalization that went on par with an international division of the production and trade liberalization.
- Technical improvements in ship and maritime terminals have facilitated the flows of freight.
- Economies of scale permitted maritime transportation to remain a low cost mode, a trend which has been strengthened by containerization.

Classification and Carrying Capacity

Maritime traffic is commonly measured in deadweight tons (dwt), which refers to the amount of cargo that can be loaded on an "empty" ship, without exceeding its operational design limit. Maritime freight may be further distinguished in three categories:

- Dry Bulk Cargo
- Liquid Bulk Cargo
- Break-bulk Cargo

Maritime shipping is dominated by bulk cargo, which roughly accounted for 72.6% of all the ton-miles shipped in 2000 Rodrigue (2004).

Dry Bulk Cargo

Dry Bulk Cargo refers to dry freight that is not packaged such as minerals (coal, iron ore) and grains. It often requires the use of specialized ships equipped with specialized transshipment and storage facilities. Conventionally, this cargo has a single origin, destination and client. It is also prone to economies of scale. The largest dry bulk carriers are around 350’000 dwt. In Frischknecht et al. (1996) however, a dry bulk cargo with a carrying capacity of about 50’000 dwt is modeled. **Liquid Bulk Cargo**

Liquid Bulk Cargo refers to liquid freight. It requires the use of specialized ships such as oil tankers. Conventionally, this cargo has a single origin, destination and client. It is also prone to economies of scale. Tankers are further classified in various weight categories. In Table 8-1 these categories and total carrying capacity are summarized. The largest tankers (ULCC) are not accounted for. The only remaining constraints in ship size are now the capacity of ports, harbors and canals.

Table 8-1: Tanker carrying capacity categories and total carrying capacity FHH (2003)

Class name	Carrying capacity category	Total carrying capacity of class		Midpoint of class	Contribution to average tanker size
	kdwt	mio dwt	share		
VLCC	200-320	117.8	0.40	260'000	104'818
Suezmax	120-200	42.8	0.15	160'000	23'436
Aframax	80-120	55.9	0.19	100'000	19'130
Panamax	60-80	14.6	0.05	70'000	3'497
Handysize	30-60	41.9	0.14	45'000	6'452
Small Tankers	10-30	19.2	0.07	20'000	1'314
	total	292.2	1		**158'649**

Break-bulk Cargo

Break-bulk Cargo refers to general cargo that has been packaged in some way with the use of bags, boxes or drums. This cargo tends to have numerous origins, destinations and clients. Before containerization, economies of scale were difficult to achieve with break-bulk cargo.

Fuels and Propulsion

To cope with speed requirements, the propulsion and engine technology has improved from sailing to steam, to diesel, to gas turbines and to nuclear (only for military ships; civilian attempts were abandoned in the early 1980s).

Marine diesel engines are the predominant form of power unit within the marine industry for propulsion. In 1991 motor ships accounted for around 98% by number of the world merchant fleet, the remaining 2% of vessels were powered by steam plant CORINAIR (2002).

Kolle (1991) reported a share 95% for transoceanic (solid) fright carriers. For transoceanic tankers propulsion however, he reported 62% steam turbine and 38% diesel engines.

Marine diesel engines are generally further categorized into two distinct groups Lloyds (1993) :

Slow speed engines (average speed of ships is about 15 knots (1 knot = 1 marine mile = 1,853 meters), which is 28 km per hour. Under such circumstances, a ship would travel about 575 km per day.), operating on the two stroke cycle at speeds between 80-140 rpm, are normally crosshead engines of 4-12 cylinders. Within the marine industry such engines are exclusively used for main propulsion purposes and comprise the greater proportion of installed power and hence fuel consumption within the industry.

Medium speed engines (speeds between 25 to 30 knots (45 to 55 km per hour).), generally operating on the four stroke cycle at speeds ranging from 400-1000 rpm, are normally trunk piston engines of up to 12 cylinders in line or 20 cylinders in vee formation. Engines of this type may be used for both main propulsion and auxiliary purposes in the marine industry. For propulsion purposes such engines may be used in multi-engine installations and will normally be coupled to the propeller via a gearbox.

8.1.4 Technical Characteristics of Inland Waterways Transportation

Inland waterways are defined as a stretch of water, not part of the sea, over which vessels of a carrying capacity of not less than 50 tonnes can navigate when normally loaded. This term covers both navigable rivers and lakes and navigable canals EUROSTAT (2000).

8.2 Operation of Transoceanic Vessels

As stated above we distinguish 2 types of transoceanic vessel operation for which fuel consumption and emission data are presented in this project.

8.2.1 Fuel Consumption

Fuels supplied to ships engaged in international operations irrespective of the flag of the carrier, is referred to as International Marine Bunkers. International Marine Bunkers consists primarily of residual and distillate fuels. Marine bunkers are a common term adopted for marine fuels combusted in ships' engines. Such fuel oils are normally used for the main engines propelling the vessel. Lighter fuels, diesel oils and gas oils, are usually used for the auxiliary engines that provide for lighting, pumping, cargo handling, etc. IMO (2000). In this project, merely fuel consumption for propelling is accounted for and the fuel is modelled as heavy fuel oil, at regional storage.

In Table 8-2 data for the specific energy consumption, as available from current literature, is summarized.

Table 8-2: Specific fuel consumption of transoceanic vessels

	Specific Fuel consumption [g/tkm]						
	Frisch-knecht et al. (1996) 1)	Jens Bor-ken et al. (1999) 2)	Kolle et al. (1991) 3)	Bialonski (1990) 4)	GEMIS (1993)	Habersat-ter (1991) 5)	**this project**
transoceanic tanker	1.8	1.3	1.6	0.9-1.8	1.3	2.7	1.3
transoceanic freight ship (dry bulk carrier)	2.2	2.5	2.2	0.9-1.8	-	4.9	2.5

1: for diesel engine concept and steam turbine

2: for both diesel engine concept and steam turbine

3: for both diesel engine concept and steam turbine (motor: 140 kdwt/ turbines 280 kdwt)

4: 300-150 kdwt

5: steam turbine

The figures found in literature differ significantly. The values employed in this project represent a rather low fuel consumption. However, using a lognormal uncertainty function, higher values are also accounted for.

8.2.2 Airborne Gaseous Emissions

Exhaust emissions from marine diesel engines comprise carbon dioxide, carbon monoxide, oxides of sulphur and nitrogen, partially reacted and non-combusted hydrocarbons and particles. Metals and organic micro-pollutants are emitted in very small quantities.

The amount of gases emitted from marine engines into the atmosphere is directly related to total fuel consumption. The basis for the calculation of emission factors are so-called emission indices (EI). The EI is defined as the mass of a substance in grams per kilogram of fuel burned.

Fuel Content Dependent Emissions

The emitted amount of sulfur dioxide (SO_2) is exclusively dependent on the fuel sulfur content. In Jungbluth (2003) a S-content of 3.5 M% for marine bunkers is reported, resulting in an emission index of 70 g/kg SO_2. The CO_2 emission index is determined as 3080 g/kg, assuming a C-content of 84 M%

Jungbluth (2003). In addition emissions of HCl and HF are accounted for, employing the figures for combustion of heavy fuel oil stated in Jungbluth (2003).

Combustion Process Dependent Emissions

In Table 8-3 and Table 8-4 emission indices of combustion process dependent caused by diesel engines and steam turbines, respectively as can be found in literature are summarised.

Table 8-3: Emission indices for diesel engines

Emission	Specific emission [g/kg fuel]									
	Lloyds (1990) 1)	Lloyds (1991) 2)	MHEP (1980) 3)	MHEP (1980) 4)	CORINAIR (2002)1	Jens Borken et al. (1999)	Kolle et al. (1991)	Techne (1998) 5)	Techne (1998)6)	This project
NO_x	57.5	80.4	35.0	43.0	57.0-87.0	84.0	70.0	87.0	57.0	**80.4**
CO	7.9	8.7	7.0	3.4	7.4	8.93	-	7.4	7.4	**7.4**
HC	6.6	7.0	4.5	3.0	2.7	2.5	-	2.4	2.4	**2.7**
N2O	-	-	-	-	0.08	0.33	-	-	-	**0.08**

1: medium speed fuel consumption at full power
2: slow speed fuel consumption at full power
3: maximum power
4: 70% power
5: slow speed
6: medium speed
7: slow speed (15 knoten)

The emission factors of NO_x for medium and slow speed engines differ significantly. The selected factor in this research represents a slow speed engine.

Table 8-4: Emission indices for steam turbines

Emission	Specific emission [g/kg fuel]							
	MHEP (1980)1)	MHEP (1980)2)	CORINAIR (2002) 3)	CORINAIR (2002) 4)	Kolle et al. (1991)	Jens Borken et al. (1999)	Techne (1998)	This project 5)
NO_x	3.5	1.7	3.3	7.0	8.0	1.95	6.98	**5.98**
CO	0.5	0.3	0.6	0.4	-	0.3	0.43	**0.46**
HC	0.25	0.12	0.50	0.10	-	0.15	0.09	**0.21**
N2O	-	-	0.08	0.08	-	0.08	-	**0.08**

1: maximum power
2: 70% power
3: distilled fuel
4: residual fuel
5: figures derived from CORINAIR (2002) using a distilled/residual ratio of 28:72 IMO (2000)

For Methane emissions in CORINAIR (2002)a emission index of 0.05 g/kg fuel for engine vessels is reported. In the absence of further information we apply the same fraction (CH_4/HC) for the determination of CH4 emissions of steam vessels resulting in an emission index of 0.004 g/kg fuel. In Table 8-5 theses figures and emission indices for additional hydrocarbons (Benzene, Toulene and Xylene) are presented. For the latter we applied the fractions as employed for diesel concepts of heavy duty vehicles.

Table 8-5: HC species profile for transoceanic vessels

	Methane	Benzene	Toluene	Xylene
Unit	% HC	% HC	% HC	% HC
Fraction HC	0.20	1.9	0.8	0.8
Unit	g/kg	g/kg	g/kg	g/kg
Emission index motor vessel	0.050	0.047	0.020	0.020
Emission index turbine vessel	0.004	0.004	0.002	0.002
Average emission index tanker	0.022	0.020	0.008	0.008
Average emission index bulk carrier	0.048	0.044	0.019	0.019

8.2.3 Particulate Emissions

In the literature on emission factors little information on inland shipping particulate emission is available. Lloyds (1991) reported particulate emissions ranges from 1.1-7.7 g/kg fuel for motor vessels. In Techne (1998) a range of PM_{10} emission indices for steam turbine propulsion from 2.1 – 2.5 g/kg fuel is stated. However, no further information on the particle size distribution as required for this project is available. Thus, in the absence of these information, we employ the figures for the combustion of heavy fuel oil as available from Jungbluth (2003) and presented in Table 8-6.

Table 8-6: Particulate emissions of transoceanic vessels

Combustion heavy fuel oil (RER)	PM2.5	PM10	TSP	PM2.5	PM10	TSP
Unit	kg/TJ_{In}	kg/TJ_{In}	kg/TJ_{In}	g/kg	g/kg	g/kg
Particle size distribution	0.28	0.32	0.4			
Emission index	35	40	50	1.44	1.64	2.06

The resulting figures are within the range of the figures given in Lloyds (1991).

8.2.4 Heavy Metal Emissions

Heavy Metal emissions depend on the metal content of the fuel. This, in turn, depend upon the metal content of the original crude and vary significantly between oil fields. Heavy metal emission factors differentiated in distilled and residual fuels are available from CORINAIR (2002) and are summarised in Table 8-7. These figures represent average fuel concentrations but are based on a small sample number and thus are highly uncertain. In general, the metal content is higher in residual fuel oil. The figures employed in this project represent a mix using a distilled/residual ratio of 28:72 IMO (2000).

Table 8-7: Heavy Metal Emission Indices of Marine Bunkers

Heavy Metal Emissions	Distilled fuel	Residual fuel	Average used in this project [1)]
	g/kg	g/kg	g/kg
As	5.00E-05	5.00E-04	3.76E-04
Cd	1.00E-05	3.00E-05	2.45E-05
Cr	4.00E-05	2.00E-04	1.56E-04
Cu	5.00E-05	5.00E-04	3.76E-04
Ni	7.00E-05	3.00E-02	2.18E-02
Pb	1.00E-04	2.00E-04	1.72E-04
Se	2.00E-04	4.00E-04	3.45E-04
Zn	5.00E-04	9.00E-04	7.90E-04
Hg	5.00E-05	2.00E-05	2.83E-05

1: figures derived from CORINAIR (2002) using a distilled/residual ratio of 28:72 IMO (2000)

8.2.5 Persistent Organic Compounds

In CORINAIR (2002)emission indices for Persistent Organic Compounds (POPs) are listed. For Dioxin a range of 0.1-8 TEQ ng/kg fuel is reported. For total PAHs 2mg/kg fuel is reported. In this project we assume an average value of 1ng/kg Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2mg/kg PAH accounted for as Benzo(a)pyrene. The emission indices for POPs are based on very limited data sets and are highly uncertain.

8.2.6 Emissions to Water

Tributyltin compounds are used as antifoulants on ships. The amount of paint used is about 120 g tributyltin compound/m^2 Champ & Bleil (1988). The leaching is reported as 5 – 50 mg tributyltin compound/m^2d. For the transport performance of 1 tkm, Frischknecht (1996) calculated a specific emission of 0.3 ng/m^2. Assuming a painted surface of 34’000 m^2 Heusser (1992) the above assumptions result in a emission of 10 µg tributylin compound/tkm.

8.2.7 Disposal

The disposal of bilge oil is modeled in this project. Frischknecht (1996) stated that 0.4-1M% of the fuel accumulate as bilge oil. In this project we assume a bilge oil emission index of 0.6 g/kg fuel.

8.2.8 Life Cycle Inventory Input data

The below tables summarise the input data for the transoceanic tanker and transoceanic freight ship (bulk carrier). In addition the uncertainty scores are presented in these tables and briefly explained below the last table.

Table 8-8: Life cycle inventory table for the operation for a transoceanic tanker.

	Name	Location	Infra	Unit	*operation, transoceanic tanker*	UncertaintyType	StandardDeviation95%	GeneralComment
product	operation, transoceanic tanker	OCE	0	tkm	1.00E+0			
technosphere	heavy fuel oil, at regional storage	RER	0	kg	1.30E-3	1	2.0	literature studies. Uncertainty range accounts for a emission factor between 0.65 and 2.6 g/ tkm
emissions to air	Benzene	-	-	kg	2.86E-8	1	2.0	NMVOC values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Methane, fossil	-	-	kg	3.61E-8	1	2.0	NMVOC values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Carbon monoxide, fossil	-	-	kg	4.02E-6	1	2.0	literature studies; average steam and diesel engine concept
	Carbon dioxide, fossil	-	-	kg	4.00E-3	1	1.1	calculated from carbon content in heavy fuel oil
	Dinitrogen monoxide	-	-	kg	1.04E-7	1	2.0	literature studies; average steam and diesel engine concept
	Ammonia	-	-	kg	5.20E-7	1	2.0	estimate based on the emission of heavy fuel oil burned in industrial furnance
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.50E-6	1	1.5	literature studies; average steam and diesel engine concept
	Nitrogen oxides	-	-	kg	3.30E-5	1	1.5	literature studies; average steam and diesel engine concept
	Sulfur dioxide	-	-	kg	9.10E-5	1	1.5	calculated from sulphur content in heavy fuel oil
	Toluene	-	-	kg	1.20E-8	1	2.0	NMVOC values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Xylene	-	-	kg	1.20E-8	1	2.0	NMVOC values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Particulates, > 10 um	-	-	kg	2.68E-6	1	1.5	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Particulates, > 2.5 um, and < 10um	-	-	kg	2.14E-6	1	2.0	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Particulates, < 2.5 um	-	-	kg	1.87E-6	1	3.0	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Lead	-	-	kg	2.24E-10	1	5.0	literature studies; average for distilled and residue fuels
	Cadmium	-	-	kg	3.18E-11	1	5.0	literature studies; average for distilled and residue fuels
	Copper	-	-	kg	4.89E-10	1	5.0	literature studies; average for distilled and residue fuels
	Chromium	-	-	kg	2.03E-10	1	5.0	literature studies; average for distilled and residue fuels
	Nickel	-	-	kg	2.83E-8	1	5.0	literature studies; average for distilled and residue fuels
	Selenium	-	-	kg	4.48E-10	1	5.0	literature studies; average for distilled and residue fuels
	Zinc	-	-	kg	1.03E-9	1	5.0	literature studies; average for distilled and residue fuels
	Mercury	-	-	kg	3.67E-11	1	5.0	literature studies; average for distilled and residue fuels
	Arsenic	-	-	kg	4.89E-10	1	5.0	literature studies; average for distilled and residue fuels
	Hydrogen chloride	-	-	kg	7.71E-8	1	1.5	calculated from Cl content in heavy fuel oil
	Hydrogen fluoride	-	-	kg	7.71E-9	1	1.5	calculated from F content in heavy fuel oil
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.30E-15	1	8.0	literature studies. Uncertainty range accounts for a factor between 1.25E-10 g/ kg and 8E-09 g/ kg
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	2.60E-9	1	3.0	literature studies
emissions to water	Tributyltin compounds	-	-	kg	1.00E-8	1	2.0	literature studies
	BOD5, Biological Oxygen Demand	-	-	kg	2.86E-4	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	COD, Chemical Oxygen Demand	-	-	kg	2.86E-4	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	DOC, Dissolved Organic Carbon	-	-	kg	7.87E-5	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	TOC, Total Organic Carbon	-	-	kg	7.87E-5	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	Oils, unspecified	-	-	kg	9.09E-5	1	2.0	literature studies and own calculations. Oil spilled is assuemed to be 0.8 kg/ t and an average transport of 8800 km is assumed.
heat waste	Heat, waste	-	-	MJ	5.20E-2	1	2.0	standard values, depneds on the fuel burned.
technosphere	disposal, bilge oil, 90% water, to hazardous waste incineration	CH	0	kg	6.50E-6	1	1.5	literature studies. Uncertainty range accounts for a factor between 0.65 and 2.6 g/ tkm

Table 8-9: Life cycle inventory table for the operation for a transoceanic fright ship (bulk carrier)

	Name	Unit	*operation, transoceanic freight ship*	UncertaintyType	StandardDeviation95%	GeneralComment
product	operation, transoceanic freight ship	tkm	1.00E+0			
technosphere	heavy fuel oil, at regional storage	kg	2.50E-3	1	2.00	literature studies. Uncertainty range accounts for a factor between 1.25 and 5.0 g/ tkm
emissions to air	Benzene	kg	1.22E-7	1	2.00	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Methane, fossil	kg	1.55E-7	1	2.00	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Carbon monoxide, fossil	kg	1.76E-5	1	2.00	literature studies; average steam and diesel engine concept
	Carbon dioxide, fossil	kg	7.79E-3	1	1.05	calculated from carbon content in heavy fuel oil
	Dinitrogen monoxide	kg	2.00E-7	1	2.00	literature studies; average steam and diesel engine concept
	Ammonia	kg	1.00E-6	1	2.00	estimate based on the emission of heavy fuel oil burned in industrial furnance
	NMVOC, non-methane volatile organic compounds, unspecified origin	kg	6.44E-6	1	1.50	literature studies; average steam and diesel engine concept
	Nitrogen oxides	kg	1.36E-4	1	1.50	literature studies; average steam and diesel engine concept
	Sulfur dioxide	kg	1.20E-4	1	1.50	calculated from sulphur content in heavy fuel oil
	Toluene	kg	5.15E-8	1	2.00	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Xylene	kg	5.15E-8	1	2.00	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Particulates, > 10 um	kg	5.00E-6	1	1.50	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Particulates, > 2.5 um, and < 10um	kg	4.00E-6	1	2.00	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Particulates, < 2.5 um	kg	3.50E-6	1	3.00	estimate based on the emission of heavy fuel oil burned in industrial furnance
	Lead	kg	4.31E-10	1	5.00	literature studies; average for distilled and residue fuels
	Cadmium	kg	6.12E-11	1	5.00	literature studies; average for distilled and residue fuels
	Copper	kg	9.40E-10	1	5.00	literature studies; average for distilled and residue fuels
	Chromium	kg	3.90E-10	1	5.00	literature studies; average for distilled and residue fuels
	Nickel	kg	5.44E-8	1	5.00	literature studies; average for distilled and residue fuels
	Selenium	kg	8.62E-10	1	5.00	literature studies; average for distilled and residue fuels
	Zinc	kg	1.97E-9	1	5.00	literature studies; average for distilled and residue fuels
	Mercury	kg	7.07E-11	1	5.00	literature studies; average for distilled and residue fuels
	Arsenic	kg	9.40E-10	1	5.00	literature studies; average for distilled and residue fuels
	Hydrogen chloride	kg	1.44E-7	1	1.50	calculated from Cl content in heavy fuel oil
	Hydrogen fluoride	kg	1.44E-8	1	1.50	calculated from F content in heavy fuel oil
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	kg	2.50E-15	1	8.00	literature studies. Uncertainty range accounts for a factor between 1.25E-10 g/ kg and 8E-09 g/ kg
	PAH, polycyclic aromatic hydrocarbons	kg	5.00E-9	1	3.00	literature studies
emissions to water	Tributyltin compounds	kg	1.00E-8	1	2.00	literature studies
heat waste	Heat, waste	MJ	1.00E-1	1	2.00	standard values, depneds on the fuel burned.
technosphere	disposal, bilge oil, 90% water, to hazardous waste incineration	kg	1.25E-5	1	1.50	literature studies. Uncertainty range accounts for a factor between 0.4 and 0.9 % of the specific fuel consumption

8.3 Operation of Inland Waterways Transport

As stated above we distinguish 2 types of inland waterways transport vessel (barge and barge tankers) operation for which fuel consumption and emission data are presented in this project.

8.3.1 Fuel Consumption

In this project, we assume the exclusively use of diesel for propelling.

The average fuel consumption is calculated by employing carrying capacity specific fuel consumption available from Dorland (2000) as quoted in Bickel (2001). The class specific fuel consumption is aggregated using the total carrying capacity of each class ZKR (2003)as allocation factor. In Table 8-10 and Table 8-11 the employed figures for dry bulk barges and barge tankers, respectively are documented.

Table 8-10: Specific fuel consumption for dry bulk barges

Vessel class (carrying capacity)	Total carrying capacity [1)]	Share	Class specific fuel consumption [2)]	Contribution to average fuel consumption
	t		g/tkm	g/tkm
< 249 t	58'602	0.01	23	0.14
250-399	669'641	0.07	23	1.64
400-650	948'175	0.10	10.4	1.05
650-999	1'388'681	0.15	7	1.04
1000-1499	2'027'326	0.22	8.2	1.77
1500-2999	3'602'864	0.38	8.2	3.15
> 3000	679'794	0.07	8.2	0.59
TOTAL	**9'375'083**	1.00		**9.39**

1: ZKR (2003)

2: Dorland & Olsthoorn (2000) as quoted in Bickel (2001); average load factor 71%

Table 8-11: Specific fuel consumption for barge tankers

Vessel class (carrying capacity)	Total carrying capacity [1)]	Share	Class specific fuel consumption [2)]	Contribution to average fuel consumption
	t		g/tkm	g/tkm
< 249 t	30'589	0.02	23	0.38
250-399	33'773	0.02	23	0.42
400-650	74'928	0.04	10.4	0.42
650-999	99'869	0.05	7	0.38
1000-1499	495'728	0.27	8.2	2.18
1500-2999	928'457	0.50	8.2	4.09
> 3000	198'320	0.11	8.2	0.87
TOTAL	**1'861'664**	**1.00**		**8.74**

1: ZKR (2003)

2: Dorland & Olsthoorn (2000) as quoted in Bickel (2001); average load factor 71%

In Table 8-12 data for the specific energy consumption, as available from current literature, is summarized.

Table 8-12: Specific fuel consumption of inland shipping transportation

	Specific fuel consumption [g/tkm]						
	Frisch-knecht et al. (1996)	Borken et al. (1999) 1)	Borken et al. (1999) 2)	Borken et al. (1999) 3)	Bialonski (1990) 4)	Bialonski (1990) 5)	**this project**
Barge tanker	12	10	3.7	9.3	1.7-3.3	5.8-12	**8.74**
Barge (dry bulk carrier)	11	10	3.7	9.3	1.7-3.3	5.8-12	**9.39**

1: average value for 1996 comprising all vessel classes.

2: steady state operation downstream; vehicle class: 1750t; load factor 100%

3: steady state operation upstream; vehicle class: 1750t; load factor 100%

4: downstream on the River Rhine; vehicle class: 650-8'800t; load factor 60%

5: upstream on the River Rhine; vehicle class: 650-8'800t; load factor 60%

As can be seen in the above tables, fuel consumption can differ significantly depending on several parameters such as upstream/downstream operation, vehicle size class among others. A detailed comparison of the data found in literature with the data employed for this project is beyond the scope of this project.

8.3.2 Airborne Gaseous Emissions

Exhaust emissions from inland waterway vessels - predominately powered by diesel engines – are characterized by a similar emission profiles as diesel engines of heavy-duty vehicles. The amount of gases emitted into the atmosphere is directly related to total fuel consumption. The basis for the calculation of emission factors are so-called emission indices (EI). The EI is defined as the mass of a substance in grams per kilogram of fuel burned.

Fuel Content Dependent Emissions

The emitted amount of sulfur dioxide (SO_2) is exclusively dependent on the fuel sulfur content. In Jungbluth (2003) a S-content of 0.05 M% for diesel is reported, resulting in an emission index of 1 g/kg SO_2. The CO_2 emission index is determined as 3172 g/kg, assuming a C-content of 86.5 M% Jungbluth (2003).

Combustion Process Dependent Emissions

In Table 8-13 emission indices for diesel engines of barges as can be found in literature are summarized. A comprehensive state of the art review on inland shipping emission factors is available from Dorland (2000). In this project we employ the figures from Dorland (2000) as quoted in Bickel (2001).

Table 8-13: Emission indices for diesel engines of barges

Emission	Specific emission [g/kg fuel]				
	Frischknecht et al. (1996)	Jens Borken et al. (1999)	BUWAL (1996)	Dorland & Olsthoorn (2000) as quoted in Bickel (2001)	This project
NO_x	25.0	60.1	-	50	**50**
CO	14.1	11.1	-	2.7	**2.7**
HC	3.3	4.9	-	1.0	**1.0**
N_2O	-	0.33	0.08		**0.08**

For the further specification of HC – species, we applied the fractions as employed for diesel concepts of heavy-duty vehicles. In Table 8-14 theses figures and resulting emission indices are presented.

Table 8-14: HC species profile for diesel engines of barges

	Methane	Benzene	Toluene	Xylene
Unit	% HC	% HC	% HC	% HC
Fraction HC	2.4	1.9	0.8	0.8
Unit	g/kg	g/kg	g/kg	g/kg
Emission index	0.024	0.019	0.008	0.008

8.3.3 Particulate Emissions

In the literature on emission factors little information on inland shipping particulate emission is available. Dorland (2000) as quoted in Bickel (2001) reported a PM_{10} emission index of 1 g/kg fuel which is employed in this project. However, no further information on the particle size distribution as required for this project is available. In the absence of this information, we employ the same size distribution as for heavy-duty vehicle diesel engines. In Table 8-15 the assumed size distribution and the resulting emission indices are presented.

Table 8-15: Particulate emissions of diesel engines of barges

Assumptions			This project		
PM10 emission index [g/kg]	Fraction pm<2.5/pm<10 [%]	Fraction pm<10/TSP [%]	PM2.5 (Fine) [g/kg]	PM10-PM2.5 (Coarse) [g/kg]	TPM-PM10 (large) [g/kg]
1.00	92.3	96.2	0.923	0.077	0.039

8.3.4 Heavy Metal Emissions

Heavy Metal emissions depend on the metal content of the fuel. This, in turn, depend upon the metal content of the original crude and vary significantly between oil fields. In this project we use the same figures as we employed for heavy-duty vehicle diesel engines. In Table 8-16 the emission indices are summarised.

Table 8-16:Heavy metal emission indices of diesel fuels EEA (2000) and Jungbluth (2003).

Cadmium [g/kg Fuel]	Copper [g/kg Fuel]	Chromium [g/kg Fuel]	Nickel [g/kg Fuel]	Selenium [g/kg Fuel]	Zinc [g/kg Fuel]	Lead [g/kg Fuel]	Mercury [g/kg Fuel]
1.0E-05	1.7E-03	5.0E-05	7.0E-05	1.0E-05	1.0E-03	1.1E-07	2.0E-08

8.3.5 Persistent Organic Compounds

In Jens Borken et al. (1999)emission indices for Persistent Organic Compounds (POPs) are reported and applied in this project. For Dioxin an emission index of 5.99E-11 TEQ ng/kg fuel and for Benzo(a)pyrene 7.70E-06 g/kg fuel (180 ng/MJ) is taken into account.

8.3.6 Life Cycle Inventory Input data

The below tables summarize the input data for the barge tanker and barge (dry bulk). In addition the uncertainty scores are presented in these tables and briefly explained below the last table.

Table 8-17: Life cycle inventory table for the operation for a barge tanker

	Name	Unit	*operation, barge tanker*	UncertaintyType	StandardDeviation95%	GeneralComment
product	operation, barge tanker	tkm	1.00E+0			
technosphere	diesel, at regional storage	kg	8.74E-3	1	1.4	own calculations
emissions to air	Benzene	kg	1.66E-7	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Methane, fossil	kg	2.10E-7	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Carbon monoxide, fossil	kg	2.36E-5	1	2.0	literature studies
	Carbon dioxide, fossil	kg	2.77E-2	1	1.1	calculated from carbon content in diesel
	Dinitrogen monoxide	kg	6.99E-7	1	2.0	literature studies
	Ammonia	kg	4.53E-7	1	2.0	literature studies
	NMVOC, non-methane volatile organic compounds, unspecified origin	kg	8.74E-6	1	1.5	literature studies
	Nitrogen oxides	kg	4.37E-4	1	1.5	literature studies
	Sulfur dioxide	kg	8.74E-6	1	1.5	calculated from sulphur content in diesel fuel
	Toluene	kg	6.99E-8	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Xylene	kg	6.99E-8	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Particulates, > 10 um	kg	3.45E-7	1	1.5	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Particulates, > 2.5 um, and < 10um	kg	6.73E-7	1	2.0	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Particulates, < 2.5 um	kg	8.06E-6	1	3.0	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Lead	kg	1.75E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Cadmium	kg	8.74E-11	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Copper	kg	1.49E-8	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Chromium	kg	4.37E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Nickel	kg	6.12E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Selenium	kg	8.74E-11	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Zinc	kg	8.74E-9	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Mercury	kg	6.12E-13	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Hydrogen chloride	kg	9.25E-9	1	1.5	calculated from Cl content in heavy fuel oil
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	kg	5.23E-19	1	8.0	literature studies.
	Benzo(a)pyrene	kg	6.73E-14	1	3.0	literature studies
	Heat, waste	MJ	3.74E-1	1	2.0	standard values, depends on the fuel burned.
technosphere	disposal, bilge oil, 90% water, to hazardous waste incineration	kg	4.37E-5	1	1.5	literature studies. Uncertainty range accounts for a factor between 0.4 and 0.9 % of the specific fuel consumption

Table 8-18: Life cycle inventory table for the operation for a transoceanic fright ship (bulk carrier)

	Name	Unit	*operation, barge*	UncertaintyType	StandardDeviation95%	GeneralComment
product	operation, barge	tkm	1.00E+0			
technosphere	diesel, at regional storage	kg	9.39E-3	1	1.3	own calculations
emissions to air	Benzene	kg	1.78E-7	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Methane, fossil	kg	2.25E-7	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Carbon monoxide, fossil	kg	2.54E-5	1	2.0	literature studies
	Carbon dioxide, fossil	kg	2.98E-2	1	1.1	calculated from carbon content in diesel
	Dinitrogen monoxide	kg	7.52E-7	1	2.0	literature studies
	Ammonia	kg	4.87E-7	1	2.0	literature studies
	NMVOC, non-methane volatile organic compounds, unspecified origin	kg	9.39E-6	1	1.5	literature studies
	Nitrogen oxides	kg	4.70E-4	1	1.5	literature studies
	Sulfur dioxide	kg	9.39E-6	1	1.5	calculated from sulphur content in diesel fuel
	Toluene	kg	7.52E-8	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Xylene	kg	7.52E-8	1	2.0	nmvoc values is based on literature studies and specific value is calculated from VOC split of diesel engines
	Particulates, > 10 um	kg	3.71E-7	1	1.5	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Particulates, > 2.5 um, and < 10um	kg	7.23E-7	1	2.0	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Particulates, < 2.5 um	kg	8.67E-6	1	3.0	literature studies; split results from PM split of diesel road vehicle exhaust emissions.
	Lead	kg	1.88E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Cadmium	kg	9.39E-11	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Copper	kg	1.60E-8	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Chromium	kg	4.70E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Nickel	kg	6.58E-10	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Selenium	kg	9.39E-11	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Zinc	kg	9.39E-9	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Mercury	kg	6.58E-13	1	5.0	literature studies; standard basic uncertainty for heavy metals
	Hydrogen chloride	kg	9.95E-9	1	1.5	calculated from Cl content in heavy fuel oil
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	kg	5.63E-16	1	8.0	literature studies.
	Benzo(a)pyrene	kg	7.24E-11	1	3.0	literature studies
	Heat, waste	MJ	4.02E-1	1	2.0	standard values, depends on the fuel burned.
technosphere	disposal, bilge oil, 90% water, to hazardous waste incineration	kg	4.70E-5	1	1.5	literature studies. Uncertainty range accounts for a factor between 0.4 and 0.9 % of the specific fuel consumption

8.4 Vessel Fleet

In this section, exchanges due to vessel manufacturing and disposal as well as maintenance and are addressed. All interventions and exchanges are related to one vehicle [unit].

In order to relate these interventions to the functional unit of 1 tkm, kilometric performance and transport performance per average vehicle must be determined. The figures used in this project are presented in Table 8-19.

Table 8-19: Reference figures for average vessels as modelled in this project

Reference figure	unit	Transoceanic tanker	Transoceanic freight carrier (dry bulk)	Barge tanker	Barge
Yearly Kilometric performance	vkm/a	145'000 [1)]	100'000 [1)]	26'677 [2)]	26'677 [2)]
Average life span	a	27 [3)]	20	32.5 [5)]	46.5 [5)]
Total kilometric performance per vehicle	vkm (life span)	3'920'000	2'000'000	867'000	1'240'000
Average carrying capacity	t	143'000 [3)]	50'000 [4)]	1'200 [5)]	1'000 [5)]
Average load factor	%	50 [1)]	65 [4)]	71 [6)]	71 [6)]
Average load	t/vehicle	71'400	32'500	852	710
Transport performance per vehicle	**tkm/vehicle**	**279'501'456'622**	**65'000'000'000**	**738'644'684**	**881'119'408**

1: Heusser (1992)
2: Maibach et al. (1999)
3: calculated from information available in FHH (2003)
4: Kolle et al. (1991)
5: calculated from information available in ZKR (2003)
6: Dorland & Olsthoorn (2000) as quoted in Bickel (2001)

8.4.1 Vessel Manufacturing and Disposal

The exchanges of the tanker manufacturing are derived from an assessment of a vessel, with a load capacity of 150'000t. For a transoceanic fright transporter (bulk carrier) we assume a load capacity of 51'500t.

The exchanges of the barge and barge tanker manufacturing represent the current average total capacity for a barge (1000 t/vessel) and a barge tanker (1200 t/vessel) as calculated from information available in ZKR (2003).

Material Consumption

For maritime vessels the data employed in this study represents the material composition of an average vessel used for solid goods transportation. The bulk material of a vessel is steel. The steel consumption of a tanker is estimated to be between 12 and 17 % of its carrying capacity Heusser (1992). In this project we assume 15% for the calculation of consumed steel. The copper share is assumed to be 0.1% of the total steel consumption Frischknecht et al. (1996). In addition, 11'000 kg paint for a freight ship Maibach et al. (1999) and 19'000 kg for a tanker are accounted for. For the transportation of materials standard distance are applied. NMVOC emissions are estimated based on a 60% solvent content in the used paint and assuming that the entire amount of solvents is released as NMVOC.

The exchanges of the barge and barge tanker manufacturing are derived from an assessment of one barge, with a load capacity of 2800t Bialonski (1990; Engelkamp (1993) as quoted in Maibach et al. (1999). This data was adjusted to model a barge and a barge tanker, representing the current average total capacity for a barge (1000 t/vessel) and a barge tanker (1200 t/vessel).

Vessel Manufacturing

For manufacturing, electricity and heavy oil burned in industrial furnace are included. Energy consumption in manufacturing was estimated as 50% of the cumulative energy of the used materials. The split of energies is 10% electricity and 90% heavy fuel oil Frischknecht et al. (1996).

Vessel Disposal

In this project waste treatment processes for non metal components of vessels are accounted for. The resulting input data for transoceanic vessels and barges is presented in Table 8-19 and Table 8-20, respectively.

8.4.2 Vessel Maintenance

This inventory includes the use of paint and emissions of the solvent of the paint as NMVOC. In this project we assume that a maritime vessels are painted 6 times in their entire life span. For inland waterways vessels we assume that they are painted 10 times in their entire life span.

The consumption of lubricates is included in the fuel consumption for vessel operation. The input data is presented in Table 8-22.

8.4.3 Life Cycle Inventory Input data

Table 8-20 summarizes the manufacturing and disposal input data for the transoceanic tanker and transoceanic freight ship (bulk carrier). In Table 8-21 the manufacturing and disposal input data for the barge tanker and barge (bulk carrier) are presented. Table 8-22 summarizes the maintenance input data.

In addition the uncertainty scores are presented in these tables and briefly explained below the last table.

Table 8-20: Life cycle inventory table for the manufacturing and disposal of transoceanic vessels

	Name	Location	Infra	Unit	transoceanic fr	transoceanic tar	UncertaintyType	StandardDeviation95%	GeneralComment
	transoceanic freight ship	OCE	1	unit	1.00E+0				
	transoceanic tanker	OCE	1	unit		1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	7.50E+6	2.25E+7	1	1.50	literature studies. Uncertainty value addresses uncertainties in the amount of actual used material for a certain ship as well as uncertainties due to variations in size of ships.
	copper, at regional storage	RER	0	kg	7.50E+3	2.25E+4	1	1.50	literature studies. Uncertainty value addresses uncertainties in the amount of actual used material for a certain ship as well as uncertainties due to variations in size of ships.
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	1.10E+4	1.91E+4	1	1.50	literature studies. Uncertainty value addresses uncertainties in the amount of actual used material for a certain ship as well as uncertainties due to variations in size of ships.
	transport, lorry 32t	RER	0	tkm	7.52E+5	1.30E+6	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	RER	0	tkm	1.50E+6	2.61E+6	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	3.06E+3	9.17E+3	1	1.94	(4,5,4,3,5,4); literatures studies
	heavy fuel oil, burned in industrial furnace 1MW, non-modulatir	RER	0	MJ	9.90E+4	1.98E+5	1	1.94	(4,5,4,3,5,4); literatures studies
	polyethylene, LDPE, granulate, at plant	RER	0	kg	1.57E+3	4.70E+3	1	1.70	literature studies. Uncertainty value addresses uncertainties in the amount of actual used material for a certain ship as well as uncertainties due to variations in size of ships.
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	4.40E+3	3.05E+3	1	1.70	(3,4,3,3,5,5); own estimate, based on material composition
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.57E+3	4.70E+3	1	1.70	(3,4,3,3,5,5); own estimate, based on material composition
emissions to air	Heat, waste	-	-	MJ	1.10E+4	2.20E+4	1	1.27	(4,3,2,1,1,3); standard value
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	6.60E+3	1.14E+4	1	1.70	(3,4,3,3,3,4); estimated from the used paint (60%B solvent as NMVOC)

Table 8-21: Life cycle inventory table for the manufacturing and disposal of inland waterways vessels

	Name	Location	Infra	Unit	barge	barge tanker	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				1	1			
	Unit				unit	unit			
product	barge	RER	1	unit	1.00E+0				
	barge tanker	RER	1	unit		1.00E+0			
technosphere	reinforcing steel, at plant	RER	0	kg	2.65E+5	3.18E+5	1	1.38	(3,4,3,3,3,4); literatures studies
	chromium steel 18/8, at plant	RER	0	kg	3.45E+3	4.14E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	cast iron, at plant	RER	0	kg	1.73E+4	2.07E+4	1	1.38	(3,4,3,3,3,4); literatures studies
	aluminium, production mix, at plant	RER	0	kg	1.57E+2	1.88E+2	1	1.38	(3,4,3,3,3,4); literatures studies
	copper, at regional storage	RER	0	kg	2.20E+3	2.64E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	polyethylene, HDPE, granulate, at plant	RER	0	kg	7.84E+2	9.41E+2	1	1.38	(3,4,3,3,3,4); literatures studies
	synthetic rubber, at plant	RER	0	kg	4.71E+2	5.65E+2	1	1.38	(3,4,3,3,3,4); literatures studies
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	1.57E+3	1.88E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	glued laminated timber, outdoor use, at plant	RER	0	m3	1.17E+0	1.40E+0	1	1.38	(3,4,3,3,3,4); literatures studies
	rock wool, packed, at plant	CH	0	kg	2.83E+3	3.39E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	transport, lorry 32t	RER	0	tkm	3.00E+4	3.60E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	transport, freight, rail	RER	0	tkm	6.01E+4	7.21E+4	1	2.28	(4,5,na,na,na,na); calculation based on standadard distances
	electricity, medium voltage, production UCTE, at grid	UCTE	0	kWh	1.05E+5	1.26E+5	1	1.94	(4,5,4,3,5,4); literatures studies
	heavy fuel oil, burned in industrial furnace 1MW, non-modulatir	RER	0	MJ	3.40E+6	4.08E+6	1	1.94	(4,5,4,3,5,4); literatures studies
	ceramic tiles, at regional storage	CH	0	kg	1.10E+3	1.32E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	cement, unspecified, at plant	CH	0	kg	3.61E+3	4.34E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	polyethylene, LDPE, granulate, at plant	RER	0	kg	1.57E+3	1.88E+3	1	1.38	(3,4,3,3,3,4); literatures studies
	disposal, wood untreated, 20% water, to municipal incineration	CH	0	kg	6.29E+2	7.55E+2	1	2.28	(5,5,3,3,5,5); own estimate, based on material composition
	disposal, emulsion paint, 0% water, to municipal incineration	CH	0	kg	6.28E+2	7.53E+2	1	1.87	(3,4,3,3,5,5); own estimate, based on material composition
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	2.35E+3	2.82E+3	1	1.87	(3,4,3,3,5,5); own estimate, based on material composition
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	9.42E+2	1.13E+3	1	1.68	(3,4,3,3,3,4); estimated from the used paint (60%B solvent as NMVOC)
	Heat, waste	-	-	MJ	3.78E+5	4.53E+5	1	1.27	(4,3,2,1,1,3); standard value

Table 8-22: Life cycle inventory table for the maintenance of transoceanic and inland waterways vessels

	Name	Location	Infra	Unit	*maintenance, barge*	*maintenance, transoceanic freight ship*	UncertaintyType	StandardDeviation95 %	GeneralComment
product	maintenance, barge	RER	1	unit	1.00E+0				
	maintenance, transoceanic freight ship	RER	1	unit		1.00E+0			
technosphere	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	4.36E+4	6.60E+4	1	2.0	Literature studies. The value is a worst case assumption, assuming that all used paint has a solvent content of 60%
	transport, lorry 32t	RER	0	tkm	4.36E+3	6.60E+3	1	2.3	100 km lorry transport. Standard uncertainty is applied.
	transport, freight, rail	RER	0	tkm	2.62E+4	3.96E+4	1	2.3	600 km rail transport. Standard uncertainty is applied.
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.57E+4	2.38E+4	1	2.0	Derived from the used paint, assuming all solvent is emitted to air.

8.5 Port Infrastructure

In this section, we summarise the data employed for the port infrastructure modules and describe the assumptions made to generate and link the data. The data in this section is related to an entire port. If not explicitly stated, the data represents conditions at the Port of Rotterdam in the Netherlands.

8.5.1 Infrastructure Demand and Allocation

The total transported tonnage is used to determine the demand factor for port infrastructure. In Table 8-23 the yearly throughput by commodity at the port of Rotterdam is presented. The last column contains the average value (1997-2002) as applied in this study

Table 8-23: Throughput at the Port of Rotterdam, timetable and average (1997-2002) RMPM (2003)

		1997	1998	1999	2000	2001	2002	Average
Dry bulk goods	Agribulk	1.19E+07	1.14E+07	1.26E+07	1.07E+07	1.13E+07	9.44E+06	1.12E+07
	Ores and scrap	4.68E+07	4.35E+07	3.72E+07	4.51E+07	3.80E+07	4.05E+07	4.18E+07
	Coal	2.20E+07	2.25E+07	1.83E+07	2.33E+07	2.48E+07	2.38E+07	2.24E+07
	Others	1.09E+07	1.20E+07	1.17E+07	1.15E+07	1.05E+07	9.73E+06	1.10E+07
	Total dry bulk goods	9.15E+07	8.93E+07	7.96E+07	9.07E+07	8.45E+07	8.34E+07	8.65E+07
Liquid bulk goods	Crude Oil	9.92E+07	1.01E+08	9.50E+07	9.77E+07	9.79E+07	9.63E+07	9.78E+07
	Mineral oil products and petcoke	1.91E+07	1.94E+07	2.16E+07	2.49E+07	2.79E+07	3.51E+07	2.47E+07
	Others	2.25E+07	2.34E+07	2.29E+07	2.52E+07	2.51E+07	2.46E+07	2.39E+07
	Total liquid bulk goods	1.41E+08	1.43E+08	1.40E+08	1.48E+08	1.51E+08	1.56E+08	1.46E+08
General Cargo	Roll on/ Roll off	1.00E+07	9.97E+06	9.94E+06	1.00E+07	9.00E+06	9.67E+06	9.77E+06
	Containers/ flats	5.86E+07	6.14E+07	6.63E+07	6.52E+07	6.22E+07	6.58E+07	6.32E+07
	Others	1.00E+07	9.55E+06	8.26E+06	8.75E+06	8.10E+06	7.24E+06	8.65E+06
	Total Cargo	7.86E+07	8.10E+07	8.45E+07	8.39E+07	7.93E+07	8.28E+07	8.17E+07
Total Dry		1.70E+08	1.70E+08	1.64E+08	1.75E+08	1.64E+08	1.66E+08	**1.68E+08**
Total Liquid		1.41E+08	1.43E+08	1.40E+08	1.48E+08	1.51E+08	1.56E+08	**1.46E+08**
Total Throughput		3.11E+08	3.14E+08	3.04E+08	3.22E+08	3.15E+08	3.22E+08	**3.15E+08**

Based on the above figures, the total port infrastructure demand per transported tonne is calculated to be 3.18E-09 unit/t.

In order to calculate the port demand per transport performance, assumption for the average transport distance have been made and applied. In Table 8-24 these assumptions and resulting figures are summarised.

Table 8-24: Refernece figures for the airport infrastructure

Reference figure	Unit	Maritime Transport		Inland Shipping	
		Tanker	Dry freight	Tanker	Dry freight
Average transport distance	km	8800 1)	5000 2)	500 3)	250 2)
Demand port per tkm	unit/tkm	7.23E-13	1.27E-12	6.36E-12	1.27E-11

1: ocean-going oil tankers OPEC countries WEC (1988)

2: own estimate

3: Frischknecht et al. (1996)

8.5.2 Port Construction and Disposal

Construction expenditures for sealed area of ports data is available from Maibach et al. (1999). The data represents the Port of Rotterdam. Material composition and demand of the sealed industrial area is derived from the construction and disposal expenditures of a Swiss highway. The built-up are is modelled as a steel building. The life span of the port is assumed to be 100 years.

The figures for disposal are derived from Maibach et al. (1999) and are rough estimates, accounting for excavation and transport of the deconstructed material as well as for disposal of the materials as inert waste, 5% water on inert material landfill. In Table 8-27 the resulting input data is presented.

8.5.3 Port Operation and Maintenance

Oil spills occurring in the water area are accounted for as emissions to water. Energy consumption at the port is based on assumptions for the specific electricity consumption at the port in Hamburg. Land occupation and transformation are taken into account.

In Table 8-25 yearly oil spills between 1994 and 1998 and the calculated geometric mean are summarised.

Table 8-25: Oil spilled at the Port of Rotterdam [13]

	Unit	1994	1995	1996	1997	1998	Geometric Mean (used in this project)	2*stdev
total spilled oil	m^3	186	300	123	119	299		
Removed oil	m^3	24	73	44	61	172		
Oil to water	m^3	162	227	79	58	127		
Oil to water	kg	139’320	195’220	67’940	49’880	109’220	**100’133**	9.52

In the basic information for the calculation of land occupation and land transformation are summarized. These figures represent the area of the Port of Rotterdam in the year 2002.

Table 8-26: Land use figures for the Port of Rotterdam (2002)

	Unit	
Total Port Area 1)	ha	10’500
Area of water 1)	ha	3’500
Land area	ha	7’000
Share of area used from industry 2)		0.65
Area used from industry on site	ha	4’550
Area used for logistics and transport infrastructure	ha	2’450
Share industrial area (logistics)		0.5
Total Industrial area	ha	1’225
Total road area	ha	1’225

1: RMPM (2002)

2: Oral communication with Mr. Vink, Port management Rotterdam, August 2003

[13] Oral communication with Mr. Vink, Port management Rotterdam, August 2003

8.5.4 Life Cycle Inventory Input Data

In Table 8-27 the input data for the unit process port construction and disposal are summarized. It should be noted that the figures for the exchanges “excavation, skid-steer loader” and “transport, lorry 32t” include both, construction and disposal expenditures.

Table 8-27 presents the input data for the port operation, including land use.

Table 8-27: Life cycle inventory input for port construction and disposal

	Name	Location	Unit	*port facilities*	UncertaintyType	StandardDeviation95%	GeneralComment
product	port facilities	RER	unit	1.00E+0			
technosphere	bitumen, at refinery	RER	kg	2.55E+7	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	concrete, exacting, at plant	CH	m3	2.79E+4	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
technosphere	gravel, crushed, at mine	CH	kg	7.77E+8	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh	4.53E+7	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	diesel, burned in building machine	GLO	MJ	3.80E+6	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	excavation, skid-steer loader	RER	m3	3.70E+6	1	3.00E+0	Literature studies. The value includes construction and disposal activities and is a rough estimate.
	transport, lorry 32t	RER	tkm	3.31E+7	1	3.00E+0	Literature studies. The value includes construction and disposal activities and is a rough estimate.
	building, hall, steel construction	CH	m2	4.15E+4	1	3.00E+0	Literature studies. The value is a rough estimate.
	steel, low-alloyed, at plant	RER	kg	1.65E+6	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	reinforcing steel, at plant	RER	kg	1.67E+4	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
emissions to air	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	2.55E+4	1	3.00E+0	Literature studies. The value represents construction activities and is a rough estimate.
	Heat, waste		MJ	1.63E+8	1	3.00E+0	standard value
emissions to water	Oils, unspecified	-	kg	-		-	
disposal	disposal, inert waste, 5% water, to inert material landfill	CH	kg	1.11E+9	1	3.00E+0	Literature studies. The data addresses disposal activities and is a rough estimate.

Table 8-28: Life cycle inventory input for port operation (including land use)

	Name	Location	Category	SubCategory	Infra	Unit	operation, maintenance, port	UncertaintyType	StandardDeviation95%	GeneralComment
	Location						RER			
	InfrastructureProcess						1			
	Unit						unit			
product	operation, maintenance, port	RER			1	unit	1.00E+0			
technosphere	electricity, medium voltage, production UCTE, at grid	UCTE			0	kWh	2.27E+9	1	2.0	data based on literature studies for the port in Hamburg.
emissions to air	Heat, waste		air	low population density		MJ	8.18E+9	1	3.0	standard value
emissions to water	Oils, unspecified	-	water	unspecified	-	kg	1.00E+5	1	9.5	oral communication. The data represents the geomean of a data from 1994-1998.
	BOD5, Biological Oxygen Demand	-	water	ocean	-	kg	3.15E+5	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	COD, Chemical Oxygen Demand	-	water	ocean	-	kg	3.15E+5	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	DOC, Dissolved Organic Carbon	-	water	ocean	-	kg	8.66E+4	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
	TOC, Total Organic Carbon	-	water	ocean	-	kg	8.66E+4	1	2.0	own calculation, according to quality guidelines, derived from emissions of oil.
land use	Occupation, industrial area, built up		resource	land		m2a	4.15E+4	1	1.5	Port statistics and oral communication. Data represent occupied area in 2002
	Occupation, industrial area		resource	land		m2a	1.22E+7	1	1.5	Port statistics and oral communication. Data represent occupied area in 2002
	Occupation, traffic area, road network		resource	land		m2a	1.23E+7	1	1.5	Port statistics and oral communication. Data represent occupied area in 2002
	Occupation, water bodies, artificial		resource	land		m2a	3.50E+7	1	1.5	Port statistics and oral communication. Data represent occupied area in 2002
	Transformation, from unknown		resource	land		m2	5.95E+5	1	1.5	Estimation based on land occupation and an assumed life span of the port of 100 years.
	Transformation, to industrial area, built up		resource	land		m2	4.15E+2	1	1.5	Estimation based on land occupation and an assumed life span of the port of 100 years.
	Transformation, to industrial area		resource	land		m2	1.22E+5	1	1.5	Estimation based on land occupation and an assumed life span of the port of 100 years.
	Transformation, to traffic area, road network		resource	land		m2	1.23E+5	1	1.5	Estimation based on land occupation and an assumed life span of the port of 100 years.
	Transformation, to water bodies, artificial		resource	land		m2	3.50E+5	1	1.5	Estimation based on land occupation and an assumed life span of the port of 100 years.

8.6 Canal Infrastructure

In addition to operation on rivers and lakes barges operate on canals (artificial waterways). In this section, we summarise the data employed for canal infrastructure modules and describe the assumptions made to generate and link the data.

8.6.1 Infrastructure Demand and Allocation

According to Stiller (1993), the yearly transport performance on one kilometre canal is about 4’300’000 tkm/(km*a) taking into account the transport performance on rivers. Consequently, the specific canal demand is 2.33E-04 (m*a)/tkm.

8.6.2 Canal Construction

Assumptions for the construction of the canal are derived from the Main-Donau-Canal in Germany. The canal is characterised by a width of 42 m and an average depth of 4m. The life span of the canal is assumed to be 118 years. The data employed in this study is derived from Maibach et al. (1999) and presented in Table 8-29.

8.6.3 Canal Operation

Data for electricity consumption, predominately due the operation of sluices is derived from Enquête (1994) as quoted in Maibach et al. (1999). The canal bed area is estimated with 42m^2/m canal. In addition, 10 meters at each edge is modelled as road traffic area. The data employed in this study is presented in Table 8-29.

8.6.4 Life Cycle Inventory Input Data

Table 8-29: Life cycle inventory input for canal construction and operation (incl. Land use)

	Name	Location	Unit	canal	UncertaintyType	StandardDeviation95%	GeneralComment	maintenance, operation, canal	UncertaintyType	StandardDeviation95%	GeneralComment
product	canal	RER	ma	1.00E+0							
	maintenance, operation, canal	RER	ma					1.00E+0			
technosphere	bitumen, at refinery	RER	kg	8.70E-3	1	1.5	Literature studies. The value represents construction activities and is of fair quality.	-	1		
	concrete, exacting, at plant	CH	m3	1.30E-1	1	1.5	Literature studies. The value represents construction activities and is of fair quality.	-	1		
	electricity, medium voltage, production UCTE, at grid	UCTE	kWh					3.42E+0	1	3.0	Literature studies. The value represents operation of watergates and is a rough estimate.
	transport, lorry 32t	RER	tkm	1.21E+0	1	3.0	Literature studies. The value represents construction activities and is a rough estimate.	-	1		
	reinforcing steel, at plant	RER	kg	8.68E+0	1	1.5	Literature studies. The value represents construction activities and is of fair quality.	-	1		
	excavation, skid-steer loader	RER	m3	4.03E+0	1	3.0	Literature studies. The value represents construction activities and is a rough estimate.	-	1		
emissions to air	Heat, waste		MJ		1	-		1.23E+1	1	3.0	standard value
	Occupation, traffic area, road network		m2a		1			2.00E+1	1	1.5	Literature data, representing occupied area in the 90'ties.
	Occupation, water courses, artificial		m2a		1			4.20E+1	1	1.5	Literature data, representing occupied area in the 90'ties.
	Transformation, from unknown		m2		1			5.25E-1	1	1.5	Estimation based on land occupation and an assumed life span of the canal of 118 years.
	Transformation, to traffic area, road network		m2		1			1.69E-1	1	1.5	Estimation based on land occupation and an assumed life span of the canal of 118 years.
	Transformation, to water courses, artificial		m2		1			3.56E-1	1	1.5	Estimation based on land occupation and an assumed life span of the canal of 118 years.

8.7 Water Transport

8.7.1 Method

In this section the demand factors of various transport components (as described in the previous sections) required to fulfill the functional unit of one tkm fright transport are presented. For vehicles the demand is calculated as reciprocal value of the transport performance per vehicle as presented in Table 8-19. Demand figures for port and canal infrastructure are already presented in section 8.5.1and section 8.6.1, respectively.

In Table 8-30 the actual demand of vehicle- and port/canal infrastructure per transport performance [tkm] are presented, respectively.

8.7.2 Life Cycle Inventory Input Data

Table 8-30: Life Cycle inventory input data for water transport

	Name	Location	Unit	*transport, transoceanic tanker*	*transport, transoceanic freight ship*	*transport, barge tanker*	*transport, barge*	UncertaintyType	StandardDeviation95%	GeneralComment
	Location			***OCE***	***OCE***	***RER***	***RER***			
	InfrastructureProcess			***0***	***0***	***0***	***0***			
	Unit			***tkm***	***tkm***	***tkm***	***tkm***			
product	transport, transoceanic tanker	OCE	tkm	1.00E+0						
	transport, transoceanic freight ship	OCE	tkm		1.00E+0					
	transport, barge tanker	RER	tkm			1.00E+0				
	transport, barge	RER	tkm				1.00E+0			
transport components	operation, transoceanic tanker	OCE	tkm	1.00E+0	-	-				
	operation, transoceanic freight ship	OCE	tkm	-	1.00E+0	-				
	operation, barge tanker	RER	tkm	-	-	1.00E+0				
	operation, barge	RER	tkm	-	-	-	1.00E+0	1		
	transoceanic tanker	OCE	unit	3.58E-12	-		-			uncertainties due to assumed kilometric performance, average age, average load
	transoceanic freight ship	OCE	unit		1.54E-11	-				uncertainties due to assumed kilometric performance, average age, average load
	barge tanker	RER	unit		-	1.35E-9				uncertainties due to assumed kilometric performance, average age, average load
	barge	RER	unit			-	1.13E-9	1	1.2	uncertainties due to assumed kilometric performance, average age, average load
	maintenance, transoceanic freight ship	RER	unit	3.58E-12	1.54E-11		-			uncertainties due to assumed kilometric performance, average age, average load
	maintenance, barge	RER	unit		-	1.35E-9	1.13E-9	1	1.2	uncertainties due to assumed kilometric performance, average age, average load
	port facilities	RER	unit	7.23E-15	1.27E-14	6.36E-14	1.27E-13	1	1.5	uncertainties in the assumed life span of the port and the applied average transport distance.
	operation, maintenance, port	RER	unit	7.23E-13	1.27E-12	1.45E-12	2.54E-12	1	1.2	uncertainties due to the applied average transport distance.
	canal	RER	ma			2.33E-4	2.33E-4	1	2.0	uncertainties due to canal performance data
	maintenance, operation, canal	RER	ma			2.33E-4	2.33E-4	1	2.0	uncertainties in the performance on the canal and alloction between tank and solid vessels.

Glossary

Articulated lorry	Road tractor couple with a semi trailer
EI	Emission Indices
Electric Locomotive	Locomotive with one or more electric motors, deriving current primarily from overhaead wires or conductor rails.
EU 15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom,
EU 19	EU 15 plus Czech Republic, Hungary, Poland, Slovak Republic
EU 19+2	EU19 plus Switzerland and Norway
Euro3,4,5	European emission limits for road transport vehicles
Freight train	Train for the carriage of goods (freight) made up of one or more wagons.
Gross tonne-kilometre hauled	Unit of measure representing the movement over a distance of one kilometre of one tonne of vehicle and contents excluding the weight of tractive vehicle. (Weight of rail cars is included.)
Gross Vehicle Weight	Legally permissible maximum weight: Total weight of the vehicle (or combinations of vehicles) including its load when stationary and ready for the road declared permissible by the competent authority of the country of registration of the vehicle
Gross-gross tonne kilometre hauled	Unit of measure representing the movement over a distance of one kilometre of one tonne of rail vehicle including the weight of tractive vehicle. (Weight of vehicle, of its load and tractive unit are all included.)
Load Capacity	Maximum weight of goods declared permissible by the competent authority of the country of registration of the vehicle
Locomotive	Railway vehicle equipped with a prime mover and motor only used for hauling railway vehicles
Lorry	Rigid motor vehicle designed exclusively or primarily to carry goods. This category excludes vans.
NEDC	New European Driving Cycle
NMHC	Non Methane Hydrocarbons (often presented as NMVOC)
NST/R classification	Standard Goods Nomenclature for Transport Statistics / Revised, which consists of 24 goods groups. For detailed information on the NST/R classification, please refer to ‘Ramon’, Eurostat’s Classification Server (www.europa.eu.int/ comm/ eurostat/ramon).
ppt	Parts per million
Rail Transport Equipment	Mobile equipment running exclusively on rails, moving either under its own power (locomotives and rail cars) or hauled by another vehicle (coaches, railcar trailers, vans and wagons)

SBB	Schweizer Bundesbahnen (Swiss Federal Railways)
Track	A pair of rails over which railway vehicles can run.
Tractive Vehicles	A vehicle equipped with prime mover and motor only used for hauling other vehicles (a locomotive) or for both hauling other vehicles and the carriage of passengers and/or goods. (a railcar)
Train	One or more railway vehicles hauled by one or more locomotives or railcars.
Vehicle Category	Vehicle categories as used in ecoinvent. Differentiation is based on the gross vehicle weight. Each Heavy-Duty Vehicle Category includes various vehicle types.
Vehicle Types	Heavy Good Vehicles are further distinguished in single unit lorry, lorry and trailer, articulated lorries.
vkm	Vehicle kilometre
Vol.%	Percentage volume
w.%	Percentage weight
Wagon	Railway vehicle normally intended for the transport of goods
Wagon-Kilometre	Unit of measure representing any movement of a wagon loaded or empty over a distance of one kilometre.

References

This report comprises two reference lists. The first list contains all references used for the update and extension of road transport data. The second list contains all reference use for the previous report on ecoinvent data v1.1.

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Appendices: EcoSpold Meta Information

A1: Meta information for operation of Swiss average diesel and petrol passenger cars.

Type	ID	Field name, IndexNumber	34001	34002	34003	34004	2891
ReferenceFunction	401	Name	operation, passenger car, diesel, fleet average	operation, passenger car, diesel, fleet average 2010	operation, passenger car, petrol, fleet average	operation, passenger car, petrol, fleet average 2010	operation, passenger car
Geography	662	Location	CH	CH	CH	CH	CH
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0
ReferenceFunctio	403	Unit	vkm	vkm	vkm	vkm	km
DataSetInformatio	201	Type	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are included.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are included.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are included.
	404	Amount	1	1	1	1	1
	490	LocalName	Betrieb, Pkw, Diesel, Flottendurchschnitt	Betrieb, Pkw, Diesel, Flottendurchschnitt 2010	Betrieb, Pkw, Benzin, Flottendurchschnitt	Betrieb, Pkw, Benzin, Flottendurchschnitt 2010	Betrieb, Pkw
	491	Synonyms					
	492	GeneralComment	Average data for the operation of an average diesel passenger car (fleet average) Switzerland in the year 2005, comprising various emission technologies.	Average data for the operation of an average diesel passenger car (fleet average) Switzerland in the year 2005, comprising various emission technologies.	Average data for the operation of an average petrol passenger car (fleet average) Switzerland in the year 2005, comprising various emission technologies.	Average data for the operation of an average petrol passenger car (fleet average) Switzerland in the year 2005, comprising various emission technologies.	Average data for the operation of an average passenger car (fleet average) Switzerland in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula					
	501	StatisticalClassification					
	502	CASNumber					
TimePeriod	601	StartDate	2005	2010	2005	2010	2005
	602	EndDate	2005	2010	2005	2010	2005
	603	DataValidForEntirePeriod	1	1	1	1	1
	611	OtherPeriodText					
Geography	663	Text	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions
Technology	692	Text	diesel engine including various emission standards	diesel engine including various emission standards	petrol engine including various emission standards	petrol engine including various emission standards	diesel and petrol cars
Representativene	722	Percent	100	100	100	100	100
	724	ProductionVolume	8915 Mio.vkm/a	44774 Mio.vkm/a	15258 Mio.vkm/a	41279 Mio.vkm/a	53689 Mio.vkm/a
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59	59
	756	DataPublishedIn					
	757	ReferenceToPublishedSource	14	14	14	14	14
	758	Copyright	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0
	760	CompanyCode					
	761	CountryCode					
	762	PageNumbers					

A2: Meta information for operation of diesel powered regular bus and coach. .

ReferenceFunction	401	Name	operation, regular bus	operation, coach
Geography	662	Location	CH	CH
ReferenceFunctio	493	InfrastructureProcess	0	0
ReferenceFunctio	403	Unit	vkm	vkm
DataSetInformatio	201	Type	1	1
	202	Version	2.0	2.0
	203	energyValues	0	0
	205	LanguageCode	en	en
	206	LocalLanguageCode	de	de
DataEntryBy	302	Person	59	59
	304	QualityNetwork	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.
	404	Amount	1	1
	490	LocalName	Betrieb, Linienbus	Betrieb, Reisebus
	491	Synonyms		
	492	GeneralComment	Average data for the operation of an average Swiss regular bus (fleet average) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss coach (fleet average) in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1	1
	495	Category	transport systems	transport systems
	496	SubCategory	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse
	499	Formula		
	501	StatisticalClassification		
	502	CASNumber		
TimePeriod	601	StartDate	2005	2005
	602	EndDate	2005	2005
	603	DataValidForEntirePeriod	1	1
	611	OtherPeriodText		
Geography	663	Text	Data refer to Swiss Conditions	Data refer to Swiss Conditions
Technology	692	Text	diesel engine	diesel engine
Representativene	722	Percent	100	100
	724	ProductionVolume	209 Mio.vkm/a	94 Mio.vkm/a
	725	SamplingProcedure	Literature data.	Literature data.
	726	Extrapolations	none	none
	727	UncertaintyAdjustments	none	none
DataGeneratorAnd	751	Person	59	59
	756	DataPublishedIn		
	757	ReferenceToPublishedSource	14	14
	758	Copyright	1	1
	759	AccessRestrictedTo	0	0
	760	CompanyCode		
	761	CountryCode		
	762	PageNumbers		

A3: Meta information for operation of Swiss lorries

ReferenceFunction	401	Name	operation, lorry 3.5-20t, fleet average	operation, lorry 20-28t, fleet average	operation, lorry >28t, fleet average	operation, lorry 3.5-20t, empty, fleet average	operation, lorry 20-28t, empty, fleet average	operation, lorry >28t, empty, fleet average	operation, lorry 3.5-20t, full, fleet average	operation, lorry 20-28t, full, fleet average	operation, lorry >28t, full, fleet average
Geography	662	Location	CH	CH	CH	CH	CH	CH	CH	CH	CH
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0	0	0	0	0
ReferenceFunctio	403	Unit	vkm	vkm	vkm	vkm	vkm	vkm	vkm	vkm	vkm
DataSetInformatio	201	Type	1	1	1	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1	1	1	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrision are included as well.
	404	Amount	1	1	1	1	1	1	1	1	1
	490	LocalName	Betrieb, Lkw 3.5-20t, Flottendurchschnitt	Betrieb, Lkw 20-28t, Flottendurchschnitt	Betrieb, Lkw >28t, Flottendurchschnitt	Betrieb, Lkw 3.5-20t, leer, Flottendurchschnitt	Betrieb, Lkw 20-28t, leer, Flottendurchschnitt	Betrieb, Lkw >28t, leer, Flottendurchschnitt	Betrieb, Lkw 3.5-20t, voll, Flottendurchschnitt	Betrieb, Lkw 20-28t, voll, Flottendurchschnitt	Betrieb, Lkw >28t, voll, Flottendurchschnitt
	491	Synonyms									
	492	GeneralComment	Average data for the operation of an average Swiss lorry (fleet average) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) without load (empty trip) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) without load (empty trip) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) without load (empty trip) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) fully loaded (100%) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) fully loaded (100%) in the year 2005, comprising various emission technologies.	Average data for the operation of an average Swiss lorry (fleet average) fully loaded (100%) in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1	1	1	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula									
	501	StatisticalClassification									
	502	CASNumber									
TimePeriod	601	StartDate	2005	2005	2005	2005	2005	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005	2005	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1	1	1	1
	611	OtherPeriodText									
Geography	663	Text	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions	Data refer to Swiss Conditions
Technology	692	Text	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine
Representativene	722	Percent	100	100	100	100	100	100	100	100	100
	724	ProductionVolume	nachliefern	nachliefern	nachliefern	nachliefern	nachliefern	nachliefern	nachliefern	nachliefern	nachliefern
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none	none	none	none
DataGeneratorAnd	751	Person	59	59	59	59	59	59	59	59	59
	756	DataPublishedIn									
	757	ReferenceToPublishedSource	14	14	14	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0	0	0	0
	760	CompanyCode									
	761	CountryCode									
	762	PageNumbers									

A4: Meta information for operation of Swiss vans

ReferenceFunction	401	Name	operation, van < 3,5t
Geography	662	Location	CH
ReferenceFunctio	493	InfrastructureProcess	0
ReferenceFunctio	403	Unit	km
DataSetInformatio	201	Type	1
	202	Version	2.0
	203	energyValues	0
	205	LanguageCode	en
	206	LocalLanguageCode	de
DataEntryBy	302	Person	59
	304	QualityNetwork	1
ReferenceFunctio	400	DataSetRelatesToProduct	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.
	404	Amount	1
	490	LocalName	Betrieb, Lieferwagen < 3,5t
	491	Synonyms	
	492	GeneralComment	Average data for the operation of an average Swiss van (fleet average) in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1
	495	Category	transport systems
	496	SubCategory	road
	497	LocalCategory	Transportsysteme
	498	LocalSubCategory	Strasse
	499	Formula	
	501	StatisticalClassification	
	502	CASNumber	
TimePeriod	601	StartDate	2005
	602	EndDate	2005
	603	DataValidForEntirePeriod	1
	611	OtherPeriodText	
Geography	663	Text	Data refer to Swiss Conditions
Technology	692	Text	diesel and petrol vehicles.
Representativene	722	Percent	100
	724	ProductionVolume	4343 Mio.vkm/a
	725	SamplingProcedure	Literature data.
	726	Extrapolations	none
	727	UncertaintyAdjustments	none
DataGeneratorAnd	751	Person	59
	756	DataPublishedIn	
	757	ReferenceToPublishedSource	14
	758	Copyright	1
	759	AccessRestrictedTo	0
	760	CompanyCode	
	761	CountryCode	
	762	PageNumbers	

A5: Meta information for operation of European passenger cars

ReferenceFunction	401	Name	operation, passenger car, diesel, fleet average	operation, passenger car, diesel, fleet average 2010	operation, passenger car, petrol, fleet average	operation, passenger car, petrol, fleet average 2010	operation, passenger car
Geography	662	Location	RER	RER	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0
ReferenceFunctio	403	Unit	vkm	vkm	vkm	vkm	km
DataSetInformatio	201	Type	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.
	404	Amount	1	1	1	1	1
	490	LocalName	Betrieb, Pkw, Diesel, Flottendurchschnitt	Betrieb, Pkw, Diesel, Flottendurchschnitt 2010	Betrieb, Pkw, Benzin, Flottendurchschnitt	Betrieb, Pkw, Benzin, Flottendurchschnitt 2010	Betrieb, Pkw
	491	Synonyms					
	492	GeneralComment	Average data for the operation of an average diesel passenger car (fleet average) in Europe in the year 2005, comprising various emission technologies.	Average data for the operation of an average diesel passenger car (fleet average) in Europe in the year 2005, comprising various emission technologies.	Average data for the operation of an average petrol passenger car (fleet average) in Europe in the year 2005, comprising various emission technologies.	Average data for the operation of an average petrol passenger car (fleet average) in Europe in the year 2010, comprising various emission technologies.	Average data for the operation of an average passenger car (fleet average) in Europe in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula					
	501	StatisticalClassification					
	502	CASNumber					
TimePeriod	601	StartDate	2005	2010	2005	2010	2005
	602	EndDate	2005	2010	2005	2010	2005
	603	DataValidForEntirePeriod	1	1	1	1	1
	611	OtherPeriodText					
Geography	663	Text	Data refers to European Conditions	Data refers to European Conditions	Data refers to European Conditions	Data refers to European Conditions	Data refers to European Conditions
Technology	692	Text	diesel engine including various emission standards	diesel engine including various emission standards	petrol engine including various emission standards	petrol engine including various emission standards	diesel and petrol cars
Representativene	722	Percent	100	100	100	100	100
	724	ProductionVolume	920000 Mio.vkm/a	1200000 Mio.vkm/a	910000 Mio.vkm/a	840000 Mio.vkm/a	1800000 Mio.vkm/a
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none
DataGeneratorAnd	751	Person	59	59	59	59	59
	756	DataPublishedIn					
	757	ReferenceToPublishedSource	14	14	14	14	14
	758	Copyright	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0
	760	CompanyCode					
	761	CountryCode					
	762	PageNumbers					

A6: Meta information for operation of European truck transport (3.5-7.5t and 7.5-16t) (Euro-Class-Specific)

ReferenceFunction	401	Name	operation, lorry 3.5-7.5t, EURO3	operation, lorry 3.5-7.5t, EURO4	operation, lorry 3.5-7.5t, EURO5	operation, lorry 7.5-16t, EURO3	operation, lorry 7.5-16t, EURO4	operation, lorry 7.5-16t, EURO5
Geography	662	Location	RER	RER	RER	RER	RER	RER
ReferenceFunction	493	InfrastructureProcess	0	0	0	0	0	0
ReferenceFunction	403	Unit	vkm	vkm	vkm	vkm	vkm	vkm
DataSetInformation	201	Type	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1
ReferenceFunction	400	DataSetRelatesToProduct	1	1	1	1	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.
	404	Amount	1	1	1	1	1	1
	490	LocalName	Betrieb, Lkw 3.5-7.5t, EURO3	Betrieb, Lkw 3.5-7.5t, EURO4	Betrieb, Lkw 3.5-7.5t, EURO5	Betrieb, Lkw 7.5-16t, EURO3	Betrieb, Lkw 7.5-16t, EURO4	Betrieb, Lkw 7.5-16t, EURO5
	491	Synonyms						
	492	GeneralComment	Average data for the operation of an average European Euro3 lorry operating in the year 2005.	Average data for the operation of an average European Euro4 lorry operating in the year 2005.	Average data for the operation of an average European Euro5 lorry operating in the year 2005.	Average data for the operation of an average European Euro3 lorry operating in the year 2005.	Average data for the operation of an average European Euro4 lorry operating in the year 2005.	Average data for the operation of an average European Euro5 lorry operating in the year 2005.
	494	InfrastructureIncluded	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula						
	501	StatisticalClassification						
	502	CASNumber						
TimePeriod	601	StartDate	2005	2005	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1
	611	OtherPeriodText						
Geography	663	Text	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions
Technology	692	Text	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine
Representativeness	722	Percent	100	100	100	100	100	100
	724	ProductionVolume	22597 Mio vkm	7.6 Mio vkm	3.0 Mio vkm	8752 Mio vkm	6.6 Mio vkm	2.6 Mio vkm
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none
DataGeneratorAndPub	751	Person	59	59	59	59	59	59
	756	DataPublishedIn						
	757	ReferenceToPublishedSource	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0
	760	CompanyCode						
	761	CountryCode						
	762	PageNumbers						

A7: Meta information for operation of European truck transport (16-32t and >32t) (Euro-Class-Specific)

ReferenceFunction	401	Name	operation, lorry 16-32t, EURO3	operation, lorry 16-32t, EURO4	operation, lorry 16-32t, EURO5	operation, lorry >32t, EURO3	operation, lorry >32t, EURO4	operation, lorry >32t, EURO5
Geography	662	Location	RER	RER	RER	RER	RER	RER
ReferenceFunction	493	InfrastructureProcess	0	0	0	0	0	0
ReferenceFunction	403	Unit	vkm	vkm	vkm	vkm	vkm	vkm
DataSetInformation	201	Type	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1
ReferenceFunction	400	DataSetRelatesToProduct	1	1	1	1	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.
	404	Amount	1	1	1	1	1	1
	490	LocalName	Betrieb, Lkw 16-32t, EURO3	Betrieb, Lkw 16-32t, EURO4	Betrieb, Lkw 16-32t, EURO5	Betrieb, Lkw >32t, EURO3	Betrieb, Lkw >32t, EURO4	Betrieb, Lkw >32t, EURO5
	491	Synonyms						
	492	GeneralComment	Average data for the operation of an average European Euro3 lorry operating in the year 2005.	Average data for the operation of an average European Euro4 lorry operating in the year 2005.	Average data for the operation of an average European Euro5 lorry operating in the year 2005.	Average data for the operation of an average European Euro3 lorry operating in the year 2005.	Average data for the operation of an average European Euro4 lorry operating in the year 2005.	Average data for the operation of an average European Euro5 lorry operating in the year 2005.
	494	InfrastructureIncluded	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula						
	501	StatisticalClassification						
	502	CASNumber						
TimePeriod	601	StartDate	2005	2005	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1
	611	OtherPeriodText						
Geography	663	Text	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions	Data refer to European Conditions
Technology	692	Text	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine	diesel engine
Representativeness	722	Percent	100	100	100	100	100	100
	724	ProductionVolume	41084 Mio vkm	20.9 Mio vkm	8.3 Mio vkm	34889 Mio vkm	61.1 Mio vkm	24.4 Mio vkm
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none
DataGeneratorAndPub	751	Person	59	59	59	59	59	59
	756	DataPublishedIn						
	757	ReferenceToPublishedSource	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0
	760	CompanyCode						
	761	CountryCode						
	762	PageNumbers						

A8: Meta information for operation of European truck transport (average fleet)

ReferenceFunction	401	Name	operation, lorry 3.5-16t, fleet average	operation, lorry >16t, fleet average
Geography	662	Location	RER	RER
ReferenceFunction	493	InfrastructureProcess	0	0
ReferenceFunction	403	Unit	vkm	vkm
DataSetInformation	201	Type	1	1
	202	Version	2.0	2.0
	203	energyValues	0	0
	205	LanguageCode	en	en
	206	LocalLanguageCode	de	de
DataEntryBy	302	Person	59	59
	304	QualityNetwork	1	1
ReferenceFunction	400	DataSetRelatesToProduct	1	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion.
	404	Amount	1	1
	490	LocalName	Betrieb, Lkw 3.5-16t, Flottendurchschnitt	Betrieb, Lkw >16t, Flottendurchschnitt
	491	Synonyms		
	492	GeneralComment	Average data for the operation of an average European lorry (fleet average) in the year 2005, comprising various emission technologies.	Average data for the operation of an average European lorry (fleet average) in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1	1
	495	Category	transport systems	transport systems
	496	SubCategory	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse
	499	Formula		
	501	StatisticalClassification		
	502	CASNumber		
TimePeriod	601	StartDate	2005	2005
	602	EndDate	2005	2005
	603	DataValidForEntirePeriod	1	1
	611	OtherPeriodText		
Geography	663	Text	Data refer to European Conditions	Data refer to European Conditions
Technology	692	Text	diesel engine	diesel engine
Representativeness	722	Percent	100	100
	724	ProductionVolume	81488 Mio vkm	202503 Mio vkm
	725	SamplingProcedure	Literature data.	Literature data.
	726	Extrapolations	none	none
	727	UncertaintyAdjustments	none	none
DataGeneratorAndPub	751	Person	59	59
	756	DataPublishedIn		
	757	ReferenceToPublishedSource	14	14
	758	Copyright	1	1
	759	AccessRestrictedTo	0	0
	760	CompanyCode		
	761	CountryCode		
	762	PageNumbers		

A9: Meta information for operation of European van transport

ReferenceFuncti on	401	Name	operation, van < 3,5t
Geography	662	Location	RER
ReferenceFunctio	493	InfrastructureProcess	0
ReferenceFunctio	403	Unit	vkm
DataSetInformatio	201	Type	1
	202	Version	2.0
	203	energyValues	0
	205	LanguageCode	en
	206	LocalLanguageCode	de
DataEntryBy	302	Person	59
	304	QualityNetwork	1
ReferenceFunctio	400	DataSetRelatesToProduct	1
	402	IncludedProcesses	Fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Hydrocarbon emissions include evaporation. Heavy metal emissions to soil and water caused by tyre abrasion are accounted for.
	404	Amount	1
	490	LocalName	Betrieb, Lieferwagen < 3,5t
	491	Synonyms	
	492	GeneralComment	Average data for the operation of an average van (fleet average) in Europe in the year 2005, comprising various emission technologies.
	494	InfrastructureIncluded	1
	495	Category	transport systems
	496	SubCategory	road
	497	LocalCategory	Transportsysteme
	498	LocalSubCategory	Strasse
	499	Formula	
	501	StatisticalClassification	
	502	CASNumber	
TimePeriod	601	StartDate	2005
	602	EndDate	2005
	603	DataValidForEntirePeriod	1
	611	OtherPeriodText	
Geography	663	Text	Data refers to European Conditions
Technology	692	Text	diesel and petrol cars
Representativene	722	Percent	100
	724	ProductionVolume	300700 Mio.vkm/a
	725	SamplingProcedure	Literature data.
	726	Extrapolations	none
	727	UncertaintyAdjustments	none
DataGeneratorAnd	751	Person	59
	756	DataPublishedIn	
	757	ReferenceToPublishedSourc e	14
	758	Copyright	1
	759	AccessRestrictedTo	0
	760	CompanyCode	
	761	CountryCode	
	762	PageNumbers	

A10: Meta information for datasets transport passenger car and buses in Switzerland

ReferenceFunction	401	Name	transport, passenger car, diesel, fleet	transport, passenger car, diesel, fleet	transport, passenger car, petrol, fleet	transport, passenger car, petrol, fleet	transport, passenger car	transport, regular bus	transport, coach
Geography	662	Location	CH	CH	CH	CH	CH	CH	CH
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0	0	0
ReferenceFunctio	403	Unit	pkm	pkm	pkm	pkm	pkm	pkm	pkm
DataSetInformatio	201	Type	1	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;	operation of vehicle; production, maintenance and disposal of vehicles;
	404	Amount	1	1	1	1	1	1	1
	490	LocalName	Transport, Pkw, Diesel, Flottendurchschnitt	Transport, Pkw, Diesel, Flottendurchschnitt 2010	Transport, Pkw, Benzin, Flottendurchschnitt	Transport, Pkw, Benzin, Flottendurchschnitt 2010	Transport, Pkw	Transport, Linienbus	Transport, Reisebus
	491	Synonyms							
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula							
	501	StatisticalClassification							
	502	CASNumber							
TimePeriod	601	StartDate	2005	2010	2005	2010	2005	2005	2005
	602	EndDate	2005	2010	2005	2010	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1	1
	611	OtherPeriodText							
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel, various emission treatment	Diesel, various emission treatment	Petrol, various emission treatment	Petrol, various emission treatment	Petrol, various emission treatment	Diesel, various emission treatment	Diesel, various emission treatment
Representativene	722	Percent	100	100	100	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59	59	59	59
	756	DataPublishedIn							
	757	ReferenceToPublishedSource	14	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0	0
	760	CompanyCode							
	761	CountryCode							
	762	PageNumbers							

A11: Meta information for transport datasets freight transport in Switzerland

ReferenceFunction	401	Name	transport, lorry 3.5-20t, fleet average	transport, lorry 20-28t, fleet average	transport, lorry >28t, fleet average	transport, van <3.5t
Geography	662	Location	CH	CH	CH	CH
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0
ReferenceFunctio	403	Unit	tkm	tkm	tkm	tkm
DataSetInformatio	201	Type	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0
	205	LanguageCode	en	en	en	en
	206	LocalLanguageCode	de	de	de	de
DataEntryBy	302	Person	59	59	59	59
	304	QualityNetwork	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.
	404	Amount	1	1	1	1
	490	LocalName	Transport, Lkw 3.5-20t, Flottendurchschnitt	Transport, Lkw 20-28t, Flottendurchschnitt	Transport, Lkw >28t, Flottendurchschnitt	Transport, Lieferwagen <3.5t
	491	Synonyms				
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse
	499	Formula				
	501	StatisticalClassification				
	502	CASNumber				
TimePeriod	601	StartDate	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1
	611	OtherPeriodText				
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel, various emission treatment standards	Diesel, various emission treatment standards	Petrol, various emission treatment standards	Petrol, various emission treatment standards
Representativene	722	Percent	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59
	756	DataPublishedIn				
	757	ReferenceToPublishedSource	14	14	14	14
	758	Copyright	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0
	760	CompanyCode				
	761	CountryCode				
	762	PageNumbers				

A12: Meta information for transport datasets passenger car transport in Europe

ReferenceFunction	401	Name	transport, passenger car, diesel, fleet average	transport, passenger car, diesel, fleet average 2010	transport, passenger car, petrol, fleet average	transport, passenger car, petrol, fleet average 2010	transport, passenger car
Geography	662	Location	RER	RER	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0
ReferenceFunctio	403	Unit	pkm	pkm	pkm	pkm	pkm
DataSetInformatio	201	Type	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance
	404	Amount	1	1	1	1	1
	490	LocalName	Transport, Pkw, Diesel, Flottendurchschnitt	Transport, Pkw, Diesel, Flottendurchschnitt 2010	Transport, Pkw, Benzin, Flottendurchschnitt	Transport, Pkw, Benzin, Flottendurchschnitt 2010	Transport, Pkw
	491	Synonyms					
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula					
	501	StatisticalClassification					
	502	CASNumber					
TimePeriod	601	StartDate	2005	2010	2005	2010	2005
	602	EndDate	2005	2010	2005	2010	2005
	603	DataValidForEntirePeriod	1	1	1	1	1
	611	OtherPeriodText					
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel, various emission treatment standards	Diesel, various emission treatment standards	Petrol, various emission treatment standards	Petrol, various emission treatment standards	Petrol, various emission treatment standards
Representativene	722	Percent	100	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59	59
	756	DataPublishedIn					
	757	ReferenceToPublishedSource	14	14	14	14	14
	758	Copyright	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0
	760	CompanyCode					
	761	CountryCode					
	762	PageNumbers					

A13: Meta information for transport datasets passenger car transport in Europe

ReferenceFunction	401	Name	transport, passenger car, diesel, fleet average	transport, passenger car, diesel, fleet average 2010	transport, passenger car, petrol, fleet average	transport, passenger car, petrol, fleet average 2010	transport, passenger car
Geography	662	Location	RER	RER	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0
ReferenceFunctio	403	Unit	pkm	pkm	pkm	pkm	pkm
DataSetInformatio	201	Type	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance
	404	Amount	1	1	1	1	1
	490	LocalName	Transport, Pkw, Diesel, Flottendurchschnitt	Transport, Pkw, Diesel, Flottendurchschnitt 2010	Transport, Pkw, Benzin, Flottendurchschnitt	Transport, Pkw, Benzin, Flottendurchschnitt 2010	Transport, Pkw
	491	Synonyms					
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 2.39E05 pkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula					
	501	StatisticalClassification					
	502	CASNumber					
TimePeriod	601	StartDate	2005	2010	2005	2010	2005
	602	EndDate	2005	2010	2005	2010	2005
	603	DataValidForEntirePeriod	1	1	1	1	1
	611	OtherPeriodText					
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel, various emission treatment standards	Diesel, various emission treatment standards	Petrol, various emission treatment standards	Petrol, various emission treatment standards	Petrol, various emission treatment standards
Representativene	722	Percent	100	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59	59
	756	DataPublishedIn					
	757	ReferenceToPublishedSource	14	14	14	14	14
	758	Copyright	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0
	760	CompanyCode					
	761	CountryCode					
	762	PageNumbers					

A14: Meta information for European freight transport datasets, fleet average

Type	ID	Field name, IndexNumber	2986	2987	1851
ReferenceFunction	401	Name	transport, lorry 3.5-16t, fleet average	transport, lorry >16t, fleet average	transport, van <3.5t
Geography	662	Location	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0
ReferenceFunctio	403	Unit	tkm	tkm	tkm
DataSetInformatio	201	Type	1	1	1
	202	Version	2.0	2.0	2.0
	203	energyValues	0	0	0
	205	LanguageCode	en	en	en
	206	LocalLanguageCode	de	de	de
DataEntryBy	302	Person	59	59	59
	304	QualityNetwork	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.
	404	Amount	1	1	1
	490	LocalName	Transport, Lkw 3.5-16t, Flottendurchschnitt	Transport, Lkw >16t, Flottendurchschnitt	Transport, Lieferwagen <3.5t
	491	Synonyms			
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 tkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 tkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 220000 tkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1
	495	Category	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse
	499	Formula			
	501	StatisticalClassification			
	502	CASNumber			
TimePeriod	601	StartDate	2005	2005	2005
	602	EndDate	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1
	611	OtherPeriodText			
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel, various emission treatment standards	Diesel, various emission treatment standards	Petrol and diesel various emission treatment standards
Representativene	722	Percent	100	100	100
	724	ProductionVolume	1.32E11 Mio tkm	1.72E12 Mio tkm	5.7E10 Mio tkm
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none
	727	UncertaintyAdjustments	none	none	none
DataGeneratorAnd	751	Person	59	59	59
	756	DataPublishedIn			
	757	ReferenceToPublishedSource	14	14	14
	758	Copyright	1	1	1
	759	AccessRestrictedTo	0	0	0
	760	CompanyCode			
	761	CountryCode			
	762	PageNumbers			

A15: Meta information for transport datasets European freight transport datasets, differentiated with respect to Euro-emission standards. (3.5-7.5t and 7.5-16t)

ReferenceFunction	401	Name	transport, lorry 3.5-7.5t, EURO3	transport, lorry 3.5-7.5t, EURO4	transport, lorry 3.5-7.5t, EURO5	transport, lorry 7.5-16t, EURO3	transport, lorry 7.5-16t, EURO4	transport, lorry 7.5-16t, EURO5
Geography	662	Location	RER	RER	RER	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0	0
ReferenceFunctio	403	Unit	tkm	tkm	tkm	tkm	tkm	tkm
DataSetInformatio	201	Type	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.
	404	Amount	1	1	1	1	1	1
	490	LocalName	Transport, Lkw 3.5-7.5t, EURO3	Transport, Lkw 3.5-7.5t, EURO4	Transport, Lkw 3.5-7.5t, EURO5	Transport, Lkw 7.5-16t, EURO3	Transport, Lkw 7.5-16t, EURO4	Transport, Lkw 7.5-16t, EURO5
	491	Synonyms						
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula						
	501	StatisticalClassification						
	502	CASNumber						
TimePeriod	601	StartDate	2005	2005	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1
	611	OtherPeriodText						
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Representativene	722	Percent	100	100	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none
DataGeneratorAnd	751	Person	59	59	59	59	59	59
	756	DataPublishedIn						
	757	ReferenceToPublishedSource	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0
	760	CompanyCode						
	761	CountryCode						
	762	PageNumbers						

A14: Meta information for transport datasets European freight transport datasets, differentiated with respect to Euro-emission standards. (16-32t and >32t)

ReferenceFunction	401	Name	transport, lorry 16-32t, EURO3	transport, lorry 16-32t, EURO4	transport, lorry 16-32t, EURO5	transport, lorry >32t, EURO3	transport, lorry >32t, EURO4	transport, lorry >32t, EURO5
Geography	662	Location	RER	RER	RER	RER	RER	RER
ReferenceFunctio	493	InfrastructureProcess	0	0	0	0	0	0
ReferenceFunctio	403	Unit	tkm	tkm	tkm	tkm	tkm	tkm
DataSetInformatio	201	Type	1	1	1	1	1	1
	202	Version	2.0	2.0	2.0	2.0	2.0	2.0
	203	energyValues	0	0	0	0	0	0
	205	LanguageCode	en	en	en	en	en	en
	206	LocalLanguageCode	de	de	de	de	de	de
DataEntryBy	302	Person	59	59	59	59	59	59
	304	QualityNetwork	1	1	1	1	1	1
ReferenceFunctio	400	DataSetRelatesToProduct	1	1	1	1	1	1
	402	IncludedProcesses	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.	operation of vehicle; production, maintenance and disposal of vehicles; construction and maintenance and disposal of road.
	404	Amount	1	1	1	1	1	1
	490	LocalName	Transport, Lkw 16-32t, EURO3	Transport, Lkw 16-32t, EURO4	Transport, Lkw 16-32t, EURO5	Transport, Lkw >32t, EURO3	Transport, Lkw >32t, EURO4	Transport, Lkw >32t, EURO5
	491	Synonyms						
	492	GeneralComment	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.	Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction, renewal and disposal of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 540000 vkm/vehicle has been assumed.
	494	InfrastructureIncluded	1	1	1	1	1	1
	495	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	496	SubCategory	road	road	road	road	road	road
	497	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	498	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	499	Formula						
	501	StatisticalClassification						
	502	CASNumber						
TimePeriod	601	StartDate	2005	2005	2005	2005	2005	2005
	602	EndDate	2005	2005	2005	2005	2005	2005
	603	DataValidForEntirePeriod	1	1	1	1	1	1
	611	OtherPeriodText						
Geography	663	Text	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.	The data for vehicle operation and road infrastructure reflect Swiss conditions. Data for vehicle manufacturing and maintenance represents generic European data. Data for the vehicle disposal reflect the Swiss situation.
Technology	692	Text	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Representativene	722	Percent	100	100	100	100	100	100
	724	ProductionVolume	not known	not known	not known	not known	not known	not known
	725	SamplingProcedure	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.	Literature data.
	726	Extrapolations	none	none	none	none	none	none
	727	UncertaintyAdjustments	none	none	none	none	none	none
DataGeneratorAn	751	Person	59	59	59	59	59	59
	756	DataPublishedIn						
	757	ReferenceToPublishedSource	14	14	14	14	14	14
	758	Copyright	1	1	1	1	1	1
	759	AccessRestrictedTo	0	0	0	0	0	0
	760	CompanyCode						
	761	CountryCode						
	762	PageNumbers						