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EcoTransIT: Ecological Transport Information Tool

Environmental Methodology and Data

Final Report

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commissioned by

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Contents

1 Background and task

Goods traffic causes energy consumption, carbon dioxide emissions and exhaust emissions. Progressive transport planners wish to know the eco-impact of diverse transports according to transport mode in order to reduce this impact. For this purpose

- DB CARGO (Germany),
- Green Cargo AB (Sweden),
- Schweizerische Bundesbahnen (SBB Switzerland),
- Société Nationale des Chemins de Fer Francais (SNCF France) and
- Trenitalia S.p.A (Italy)

have decided to create an environmental database, a methodology and an internet tool for calculation. The result is named EcoTransIT (Ecological Transport Information Tool).

EcoTransIT is a tool to compare the emissions and energy consumption of different transport modes for freight traffic. The transport modes to be assessed are

- road transport,
- rail transport,
- inland waterway transport,
- sea transport and
- air transport.

The user is provided with information on any individual route and variable transport volume. Thus the relevant environment related parameters of each transport process, like route characteristics and length, load factor, vehicle size and engine type, are individually taken into account. The evaluation includes energy consumption, carbon dioxide emissions and exhaust emissions.

The basic methodology for environment calculations was developed by IFEU in cooperation with the participating railway companies. Data and methodology have been discussed and harmonised with the Swedish organisation NTM (Nätverket för Transporter och Miljön) and the NTM software NTM^{CALC} /NTM 2003a/. The methodology and data basis for ferry transport have been directly taken from NTM.

The internet version of EcoTransIT as well as the integrated route planner have been realised by HACON/RmCom Hannover.

The following report summarizes the methodology and data used for the EcoTransIT online computer program. The main task is to deliver specific energy and emission data for European cargo transports.

2 System boundaries and basic definitions

2.1 Environmental impacts

Transportation has various impacts on the environment. These have been mainly analysed by means of life cycle analysis (LCA). An extensive investigation of all kinds of environmental impacts has been outlined in /Borken 1999/. The following categories were determined:

1. Resource consumption
2. Land use
3. Greenhouse effect
4. Depletion of the ozone layer
5. Acidification
6. Eutrophication
7. Eco-toxicity (toxic effects on ecosystems)
8. Human toxicity (toxic effects on humans)
9. Summer smog
10. Noise

The transportation of cargo has impacts within all these categories. However, only for some of these categories is it possible to make a comparison of individual transports on a quantitative basis. In this version of EcoTransIT therefore the selection of environmental performance values had to be limited to a few but important parameters. The selection was done according to the following criteria:

- Particular relevance of the impact
- Proportional significance of cargo transports compared to overall impacts
- Data availability
- methodological suitability for a quantitative comparison of individual transports.

The following parameters for environmental impacts of transports were selected:

Table 1 Environmental impacts included in EcoTransIT

Abbr.	Description	Reasons for inclusion
PEC	Primary energy consumption	Main indicator for resource consumption
CO_2	Carbon dioxide emissions	Main indicator for greenhouse effect
NOx	Nitrogen oxide emissions	Eutrophication, eco-toxicity, human toxicity, summer smog
SO_2	Sulphur dioxide emissions	Acidification, eco-toxicity, human toxicity
NMHC	Non-methane hydro carbons	Human toxicity, summer smog
PM_{dir}	Particulate matter from vehicles (mainly diesel combustion)	Human toxicity, greenhouse effect
PM_{ind}	Particulate matter from energy production and provision (mainly power plants, refineries, sea transport of primary energy carriers)	Human toxicity, greenhouse effect
Dust	Sum of PM_{dir} and PM_{ind}	

Thus the categories **land use**, **noise**, **safety** and **nuclear risk** were not taken into consideration. A comparison between electricity powered carriage by rail and fossil fuel powered vehicles is limited, because the current version of EcoTransIT does not display whether the **primary energy consumption** is from **renewable or non-renewable sources**. Therefore the use of regenerative energy sources, like hydro power, has not been adequately considered in favour of rail transport on the one hand. On the other hand, risks of nuclear power generation are also not considered against electricity driven rail transport.

Furthermore **methane emissions** are also not included in the current version. This is due to the fact that CO_2 is the dominant greenhouse gas in the transport sector and methane emissions are therefore only of minor importance. Methane’s highest contribution to the green house effect is in hard coal electricity generation. In this process methane emissions contribute more than 10 % to the total green house effect (Global Warming Potential, GWP). It can therefore not be justified to include methane emissions as a separate result without relation to CO_2 emissions. It is rather discussed to display the GWP as an independent result in an updated version.

Location of emission sources

Depending on the impact category, the location of the emission source can be highly significant. With regard to those emissions which contribute to the greenhouse effect, the location is not relevant. Regarding eco-toxicity and human toxicity on the other hand, the location of the emission source is highly relevant:

Particulate emissions from power plants and from engine combustion might have different impacts (due to different particle sizes and possibly also their composition) but it cannot be ruled out that they might also have the same impact. The knowledge about health effects is quite uncertain and the data base given does not allow a further differentiation. Yet at least it can be ascertained that particulates resulting from combustion of diesel fuel have adverse health impacts.

Therefore in EcoTransIT the results are presented as “particulates resulting from diesel combustion by vehicle engines” (**particles**) and the sum of “particulates resulting from extraction, conversion, transport and combustion” (**dust**).

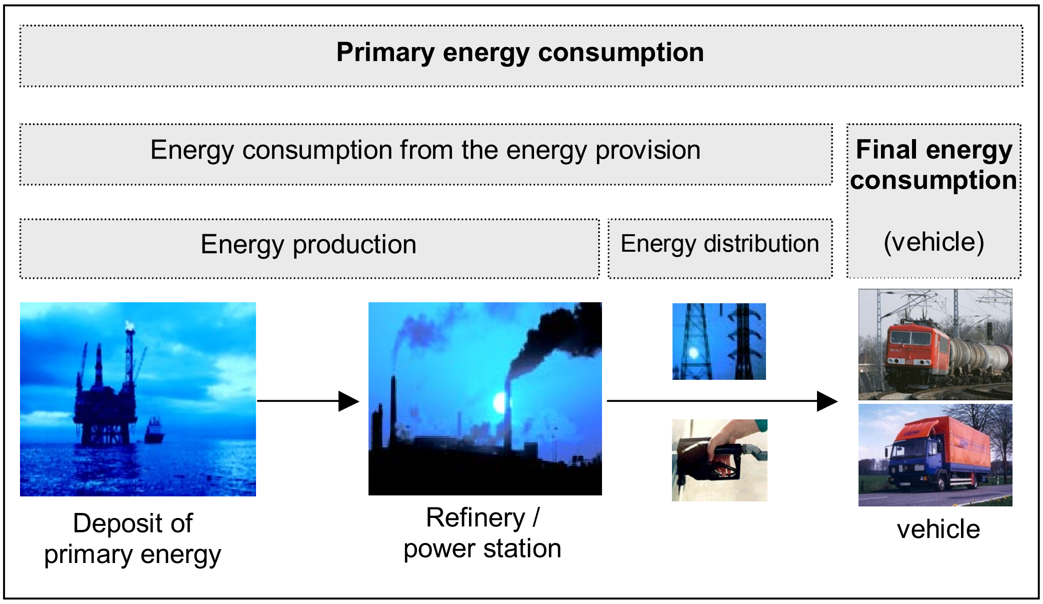
System boundaries

In EcoTransIT, only those environmental impacts are considered which are linked to the operation of vehicles and to fuel production. Not included are therefore:

- the production and maintenance of vehicles
- the construction and maintenance of traffic routes
- additional resource expenditures on the production and maintenance of energy conversion plants, administration buildings and the like.

All emissions directly caused by the use of vehicles and the final energy consumption are taken into account. Additionally all emissions and the energy consumption of the generation of final energy (fuels, electricity) are included. The following figure shows an overview of the system boundaries.

Figure 1 System boundaries



2.2 Spatial differentiation

In this version of EcoTransIT, transports within and between the following **countries** will be considered :

Table 2 Included countries

Austria	Belgium	Czech Republic	Denmark
Finland	France	Germany	Hungary
Italy	Luxembourg	Netherlands	Norway
Poland	Slovakia	Slovenia	Sweden
Switzerland			

The environmental impacts of cargo transports partly differ between the countries. Significant influencing factors are the topology, the types of vehicles used, and the type of energy carriers and conversion used. Wide differences result particularly from the method of electricity production.

Less pronounced are the differences in end energy consumption of similar vehicles in different countries. Thus in all countries usually relatively modern trucks of different international manufacturers are used for long-distance traffic on road. For ship and air transport, the existing vehicles are likewise used internationally.

Differences could exist for railway transport, where the various railway companies employ different locomotives and train configurations. However, the observed differences in the average energy consumption are not significant enough to be established statistically with certainty. Furthermore, within the scope of this project it was not possible to determine specific values for railway transport for all countries. Therefore a country specific differentiation of the specific energy consumption of cargo trains was not carried out.

Thus the data are differentiated according to the following spatial criteria:

Country specific values: electricity production and the route characteristic (gradient). For some countries, rail specific emission data are available, e.g. emission factors for diesel traction and the sulphur content of diesel fuel.

Common data: emission factors for exploration of primary energy carriers for the electricity production, exploration and conversion of diesel fuel, emission factors for lorry, ship and air transport, specific energy consumption for all modes.

2.3 Transport modes and propulsion systems

Transportation of cargo in Europe is performed by different transport modes. Within EcoTransIT the most important modes using common vehicle types and propulsion systems are considered. They are listed in the following table.

Table 3 Transport modes, vehicles and propulsion systems

Transport mode	Vehicles	Propulsion energy
Road	Road transport with single trucks and truck trailers/articulated trucks	Diesel fuel
Rail	Rail transport with short, average and long trains	Electricity and diesel fuel
Sea	Ocean-going sea ships and ferries	Heavy fuel oil / marine diesel oil
Inland waterways	Inland ships	Diesel fuel
Aircraft	Air planes	Kerosene

2.4 Transport processes

A transport process can be divided into different sub-processes:

Main Line

Transport between two main points with one or several main transport modes. This is the focus of the program because it causes most of the environmental impacts of the transport.

Feeder

Feeding and delivery are the transports from the place of departure (e.g. the manufacturer) to the transfer terminal, and from the transfer terminal to the destination (e.g. the client), respectively. These are usually carried out by feeder trains and trucks, respectively.

In this EcoTransIT version, a particular distance and transport mode can be selected as feeder. Thereby also transports from and to places which are not available within the route-planner can be included in the calculations.

Intermodal transfer and shunting

At the transfer terminals, additional environmentally relevant activities are usually required, e.g. intermodal transfer and shunting. Only the additional environmental impacts of processes not occurring in all alternatives are relevant for a comparison of different transport modes. The process of loading or unloading, for example, can be neglected in this comparative analysis if it occurs in all transport modes.

In order to assess the relevance of these transport steps, their energy consumption was determined and sensitivity analyses were carried out.

A shunting process therefore consumes about the same energy per t of goods as 10 train-km. An intermodal transfer consumes the equivalent of energy in the range between 4 and 40 train-km, depending on the type of transfer. 40 train-km, however, will only be consumed by the transfer of bulk goods or large parts with a crane.

These effects, however, are less relevant in long distance transports, and will therefore not be considered. The values for the energy consumption of these processes as well as the assumptions for the sensitivity estimate are shown in the Appendix.

2.5 Cargo specifications

Every transport vessel has a maximum load capacity which is defined by the maximum load weight allowed and the maximum volume available. Typical goods where the load weight is the restricting factor are coal, ore, oil and some chemical products. Typical products with volume as the limiting factor are vehicle parts, clothes and furniture. It is evident that volume restricted goods need more transport vessels and in consequence e.g. more wagons for rail transport or more lorries for road transport. Therefore more vehicle weight per ton of cargo has to be transported and more energy will be consumed.

In the basic version of EcotransIT three **weight types** are defined:

- bulk goods (coal, ore, oil, fertilizer etc.)
- the “average good”: this stands for the statistically determined average value for all transports of a given carrier in a reference year
- volume goods (industrial parts, shopping goods such as furniture, clothes, etc.)

The cargo specification will be defined due to the typical load factor including all empty trips. For rail transport the parameter for the load factor is the relation net ton / gross ton hauled. For lorry and ship the load factor is defined as the relation net ton / max. ton capacity. The following table shows some typical load factors for different weight types.

Table 4 Load factors for different weight types

Weight typeo	Rail [net-tons/gross-tons]	Road [net tons / tons-capacity]
hard coal, ore, oil	0,7	100%
waste	0,6-0,65	100%
passenger cars	0,35	30%
vehicle parts	0,3-0,55	25-80%
bananas	0,63	100%
seat furnitures	0,46	50%
clothes	0,24	20%

Remarks: Special transport examples, without empty trips
Source: Mobilitäts-Bilanz /IFEU 1999a/
IFEU Heidelberg 2003

The task now is to determine typical load factors for the three categories (bulk, average, volume), including empty trips. This is easy for the average good, since in this case values are available from various statistics. It is more difficult for bulk and volume goods:

Bulk: For bulk goods, at least with regard to the actual transport, a full load (in terms of weight) can be assumed. What is more difficult is assessing the lengths of the additionally required empty trips. The transport of many types of goods, e.g. coal and ore, necessitate the return transport of empty wagons. The transport of other types of goods however allows the loading of other cargo on the return trip. The possibility of taking on new cargo also depends on the type of carrier. Thus for example an inland navigation vessel is better suited than a train to take on other goods on the return trip after a shipment of coal. In general however it can be assumed that the transport of bulk goods necessitates more empty trips than that of volume goods.

Volume: For volume goods, the capacity utilisation with regard to the actual transport trip varies a lot. Due to the diversity of goods, a typical value cannot be determined. Therefore some value must be defined to represent the transport of volume goods. The same goes for the share of additional empty trips. Here it can be assumed that volume goods necessitate fewer empty trips than bulk goods.

The share of additional empty trips depends not only on the cargo specification but also to a large extent on the logistical organisation, the specific characteristics of the carriers and their flexibility. An evaluation and quantification of the technical and logistic characteristics of the transport carriers is not possible. We use the statistical averages for the “average cargo” and estimate an average load factor and the share of empty vehicle km for bulk and volume goods in rail, road and waterway traffic.

The load factor for the “average cargo” of different railway companies are in a similar range of about 0.5 net-tons per gross-ton /Railway companies 2002a/. The average load factor in long distance road transport with heavy trucks was 50 % in 2001 /KBA 2002a/. These values include also empty vehicle-km. The share of additional empty vehicle-km in road traffic was about 17 %. The share of empty vehicle-km in France was similar to Germany in 1996 (/Kessel und Partner 1998/).

No data for the empty vehicle-km in rail transport is available. According to /Kessel und Partner 1998/ the German Railways (DB AG) share of additional empty vehicle-km was 44 % in 1996. This can be explained by a high share of bulk commodities in railway transport and a relatively high share of specialised rail cars. IFEU calculations have been carried out for a specific train configuration, based on the assumption of an average load factor of 0.5 net-tons per gross ton. It can be concluded that the share of empty vehicle-km in long distance transport is still significantly higher for rail compared to road transport.

The additional empty vehicle-km for railways can be partly attributed to characteristics of the transported goods. Therefore we presume smaller differences for bulk goods and volume goods and make the following assumptions:

- The full load is achieved for the loaded vehicle-km with bulk goods. Additional empty vehicle-km are estimated in the range of 60 % for road and 80 % for rail transport.
- The weight related load factor for the loaded vehicle-km with volume goods is estimated in the range of 30 % for all transport carriers. 20 % and 10 % empty vehicle-km are estimated for rail and road transport respectively.

These assumptions take into account the higher flexibility of road transport as well as the general suitability of the carrier for other goods on the return transport. The assumptions are summarised in Table 6.

Table 5 Load factors for different weight types

Rail	**Load factor train without empty trips [net-tons/gross-tons]**	**Additional empty trips**	**Load factor rail including empty trips [net-tons/gross-tons]**
Bulk cargo*	0.72	+80%	0.6
Average cargo	n.a.	n.a.	0.5
Volume cargo*	0.44	+20%	0.4
Road	**Load factor lorry without empty trips [net-tons/capacity]**	**Additional empty trips**	**Load factor lorry including empty trips [net-tons/capacity]**
Bulk cargo*	100%	+60%	63%
Average cargo	58%	+17%	50%
Volume cargo*	30%	+10%	27%

* Estimated values; n.a.: not available
Source: KBA, different railway companies, IFEU estimation IFEU Heidelberg 2003

Due to a lack of data, the load factor for road transport is assumed for waterways as well.

3 Energy and emission data

3.1 Energy supply

The main energy carriers used in freight transport processes are diesel fuel and electricity. To compare the environmental impacts of transport processes with different energy carriers, the total energy chain has to be considered:

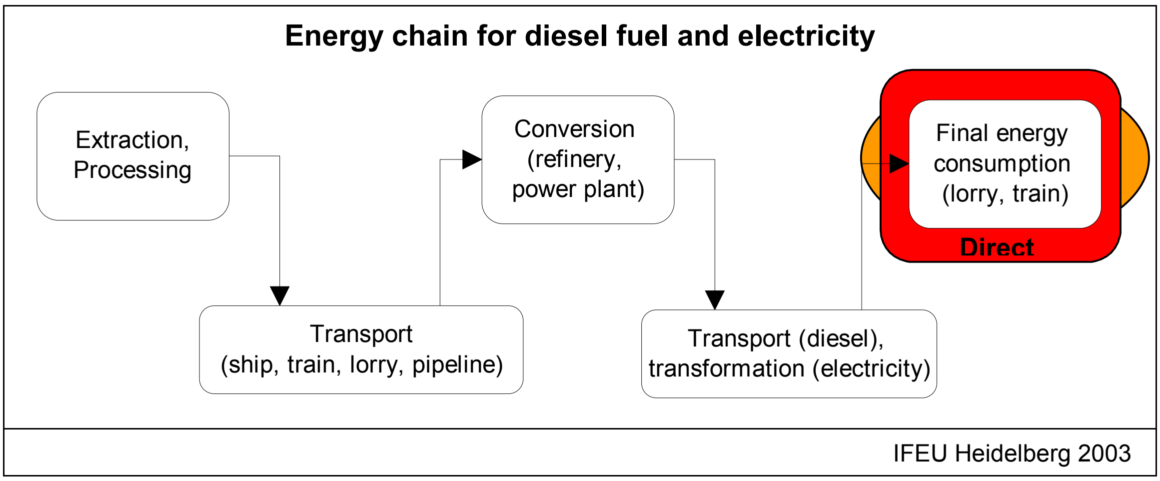
Energy chain of electricity production:

- Exploration and extraction of the primary energy carrier (coal, oil, gas, nuclear etc.) and transport to the entrance of the power plant
- Conversion within the power plant
- Energy distribution (transforming and cable losses)

Energy chain of diesel production:

- Exploration and extraction of primary energy (crude oil) and transport to the entrance of the refinery
- Conversion within the refinery
- Energy distribution (transport to petrol station, filling losses)

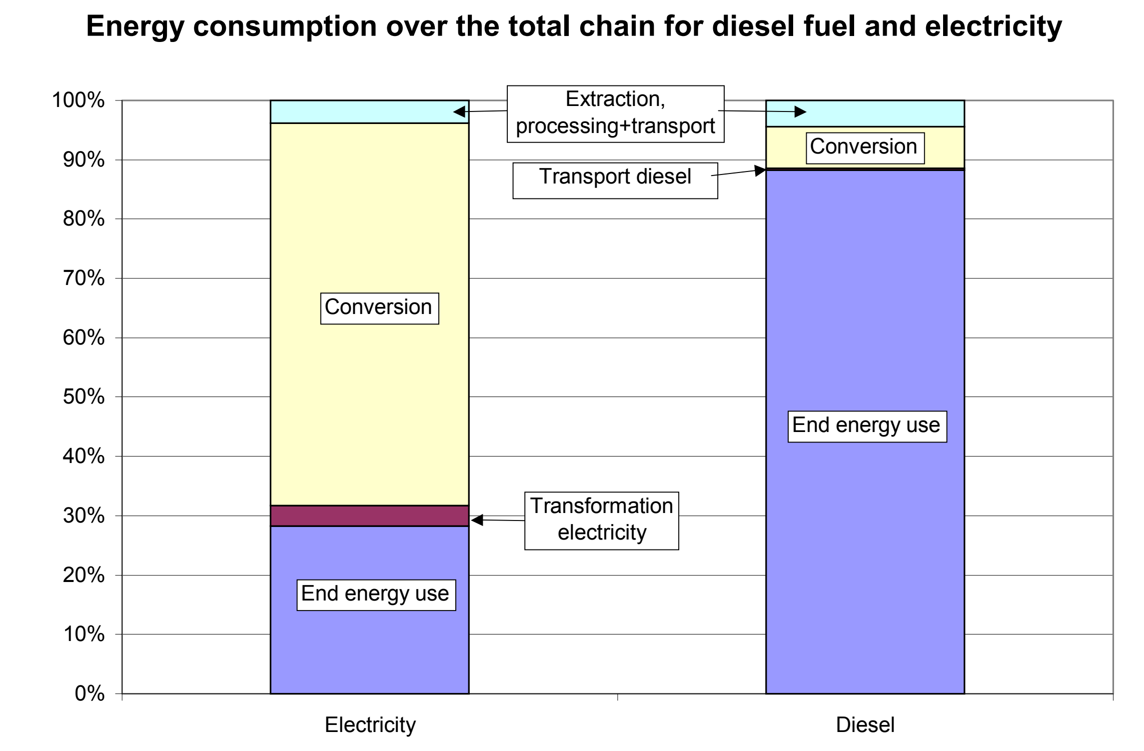
Figure 2 Energy chain for diesel fuel and electricity



For every process step, energy is required. Most of the energy demand is covered with fossil primary energy carriers. But also renewable energy carriers and nuclear power are applied. The latter is associated with low emissions but other environmental impacts on human health and ecosystems.

The energy consumption over the total energy chain depends on the efficiency of the individual steps of the chain. The following figure shows schematically the contribution of each step of energy production and consumption. If electricity is used, about 2/3 (depending on the input mix) of the energy consumption are required for conversion and the upstream process steps, whereas for diesel fuel, the final energy use contributes about 90 % of the total primary energy demand.

Figure 3 Energy chain for diesel fuel and electricity



Note: Schematic presentation IFEU Heidelberg 2003

In EcoTransIT, energy consumption is differentiated into renewable and non-renewable energy. This distinction is only relevant to railway transport with electric trains, because all other modes are powered by non-renewable fossil fuels. Here the yet small shares of fuels from renewable resources are not considered.

3.1.1 Exploration, extraction, transport and production of diesel fuel

The emission factors and energy demand for the exploration and preparation of different input fuels and the transport to the refineries are taken from /IFEU 2002b/. The values have been worked out for the situation in Germany. As the contribution of these process steps to the total impacts is low (less than 5 % of the full fuel chain including vehicle operation), the error resulting from differing import and supply structures is not significant.

The conversion of mineral oil into diesel fuel takes place in refineries. Besides diesel, other mineral oil products are produced, so the energy consumption and the emissions of the conversion process in refineries have to be allocated to the different products. The allocation method uses the energy content of the products and the assumption that the production of diesel requires fewer expenditures than for example gasoline.

Because the processes in refineries in Europe are more or less equal and the contribution of diesel production to the energy consumption of the transport is less than 10%, we assume that the values analysed for German refineries are representative for Europe. This assumption aligns with results of the MEET-project /AEA Technology 1997, where emission factors for fuel production in different European countries were investigated. The following table shows the specific figures for the emissions and the energy consumption for the prechain.

Table 6 Emission factors and energy consumption of diesel fuel for the conversion in refineries and transport to the filling station

	PE	CO_2	NO_X	SO_2	NMHC	PM_{ind}
	MJ/kg	g/kg	g/kg	g/kg	g/kg	g/kg
Diesel	48.5	413	1.2	1.8	0.68	0.13
Heavy fuel oil	45.6	348	1.1	1.6	0.58	0.12
Kerosene	48.5	413	1.2	1.8	0.68	0.13

Emission factors related to final energy (kg fuel)
PE: Primary energy including energy content of fuel
Source. TREMOD (IFEU 2002b) IFEU Heidelberg 2003

3.1.2 Exploration, extraction, processing and transport of primary energy carriers for electricity production

The emission factors and energy demand for the exploration, extraction and processing of different input fuels and the transport to power plants have been calculated according to the situation in Germany. Although the origin and the processes of fuel extraction and processing can be totally different in other countries (e.g. North Sea oil vs. oil from Saudi Arabia or hard coal from Germany vs. hard coal from South Africa), we assume in this study that the emission factors of these process steps are similar in all countries. The possible error of this assumption is very small because the exploration and transport of primary energy take up about 4-10 % of the total energy used in transport processes. This values are similar to the values used in the MEET-project /AEA Technology 1997/.

Table 7 Emission factors and energy consumption for different input energies (exploration and transport to the power plant)

	PE	CO_2	NO_X	SO_2	NMHC	PM_{ind}
	TJ/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Hard coal	1.08	4'734	34	32	1.5	2.6
Lignite	1.05	5'400	3	7	0.1	0.2
Natural gas	1.10	5'880	23	16	26.5	0.8
Oil	1.11	8'495	27	38	14.1	3.0
Nuclear power	1.04	2'852	7	11	0.6	1.3

Emission factors related to energy input
PE: Primary energy related to energy content of the input energy
Source: VDEW, German Federal Environmental Agency, IFEU assumptions IFEU Heidelberg 2003

3.1.3 Production and supply of electricity

The energy split including the shares of fuel inputs for thermal power generation, the conversion efficiency and the emission factors have been determined for each country. The emission factors of electricity production depend mainly on the mix of energy carriers and the efficiency of the production. The main problem of quantifying ecological impacts of electricity is that electrons cannot, in real life, be traced to a particular power plant. Special properties of electricity have to be considered:

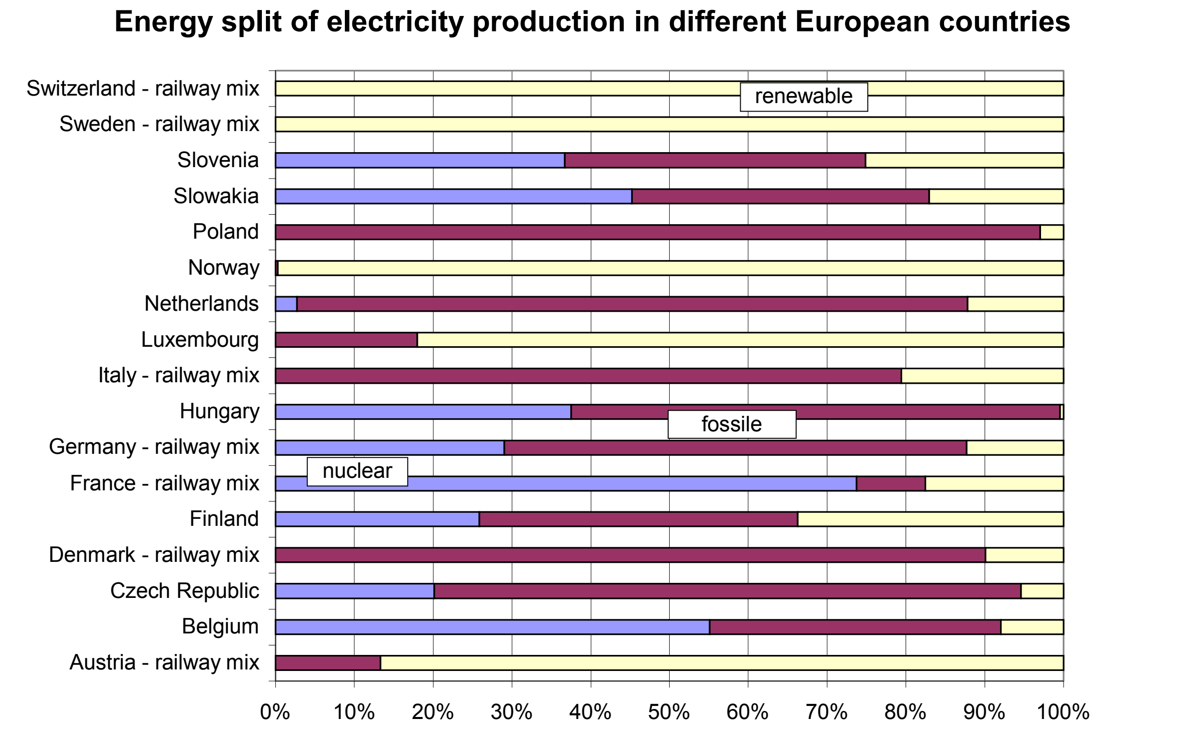
- Each country in Europe has its own electricity production mix; in some countries the railways have, at least partially, their own power plants or buy a special kind of electricity.
- The split of production differs between night and day and also between winter and summer. For example gas-fired power plants can more easily accommodate changes in the power demand than coal fired power plants. This means that during the night the percentage of electricity that is generated by coal is higher than during the day. The emissions of a coal-fired plant are usually higher than those of a gas fired plant.
- The liberalisation of the energy market leads to an international trade of electricity making the determination of a specific electricity mix even more difficult.

The most accepted method to estimate emission factors for electricity production is to take the average electricity split per year and country or, where available, the railway-specific average. For cargo, transport occurs night and day and over the whole year. Therefore, it makes sense to use this assumption for this study.

Energy split

In this study, we use the energy content of different energy carriers as a basis for the description of the energy split for the electricity production. The values are taken from /DG TREN 2002a/ and reflect for most of the countries the situation of the years 1999. For the Czech Republic, Poland, Hungary, Slovenia and Slovakia, 1998 data have been used, as only incomplete estimates for 1999 were available. If available, a special mix for railway electricity is used. The following figure shows the share of the input energies for electricity production in different European countries.

Figure 4 Energy split of electricity production in different European countries



Note: Data of public electricity except railway mix (electricity mix for railway)
Source: European Commission DG TREN, Railway companies, IFEU estimations IFEU Heidelberg 2003

Efficiency factors

The efficiency of electricity production in thermal power plants ranges from about 30 % to 40 % (relation of net electricity to fuel input)) /DG TREN 2002a/. Efficient hard coal power plants achieve over 40 % efficiency, oil plants slightly more and gas plants even over 50 % efficiency. For other types of electricity production (nuclear, hydro) no efficiency can be calculated, because the input energies have no chemical energy content. For these energy carriers, conventions have to be made to quantify the “primary energy input”. As is common practice in international energy statistics (see for instance /IEA 2001b/), we assume an efficiency of nuclear power plants of 33 %.[1] Hydroelectric power plants are set to 100 % efficiency.

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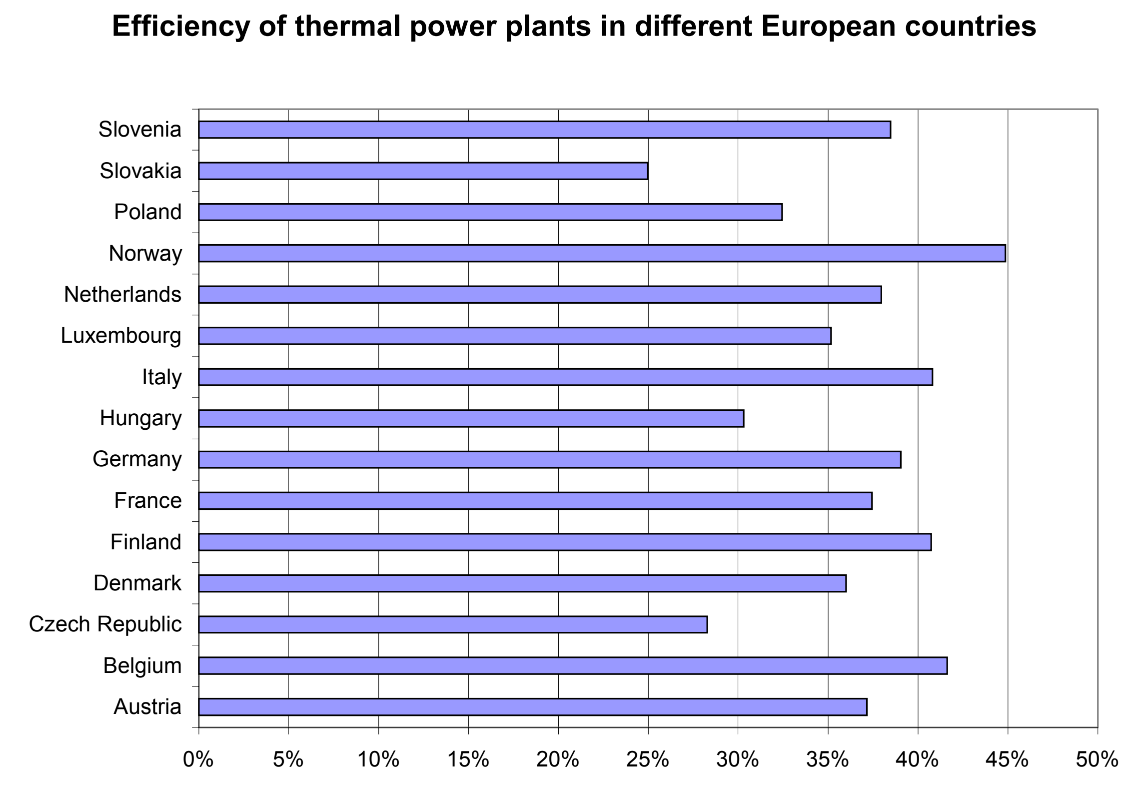
1 It has to be noted that alternative ways of analysing the primary energy demand for electricity production from nuclear power exist. One is to determine the average heat of fission of uranium ore and relating this to the electricity produced. Depending on the assumptions of using by-products, such as depleted uranium, and others, the efficiencies of such a nuclear power plant range between 29 % and 15 %. The latter case would significantly alter the results for primary energy demand presented in this project.

The following Figure shows the average efficiency of all thermal power plants (electricity production by hard coal, lignite, oil and natural gas) in different European countries.

Figure 5 Efficiency of thermal power plants in different European countries



Source: European Commission DG TREN IFEU Heidelberg 2003

In some countries, combined heat and power production (CHP) increases the total efficiency of energy conversion. A high CHP share of the total electricity generation is achieved in Denmark (62 %), the Netherlands (52 %), Finland (36 %), Austria (25 %) and Italy (18 %) /DG TREN 2002b/.

The rating of CHP in life-cycle analysis is still under dispute. Though the overall efficiency of the whole process is around 80 %, the efficiency of electricity generation is lower due to the combined production. How much of the heat production can attributed to the electricity production depends on the degree to which the heat is used as an equivalent to electricity. It has therefore to be taken into account if, for example, houses, open air pools or greenhouses are heated.

Such an evaluation is beyond the scope of this project. We use the assumptions of the OMIT-Project /OMIT 2001/ with a value of 80 % for the overall efficiency of CHP.

In addition, parasitic power consumption, transforming and transport of electricity to the end-user (for example locomotives) lead to further losses. The database for this step is very poor. We estimate these losses to be about 10 % related to net electricity production /IFEU 1999a, 2002b/.

Emission factors

The emission factors for carbon dioxide depend on the carbon content of the different input energies and their mass-related energy content. Natural gas shows the lowest emission factors, followed by oil. Solid fuels exhibit the highest CO_2 emissions. The CO_2 emissions from lignite combustion vary depending on the quality. The other emissions depend strongly on the standard of the air cleaning technology. Table 8 shows actual emission factors for Germany.

Table 8 Emission factors of fossil input energies for electricity production in Germany (in kg/TJ_{Input})

	CO_2	NO_X	SO_2	NMHC	PM_{ind}
Hard coal	92’000	64	60	1.5	3.2
Lignite	110’000	57	145	1.5	3.2
Natural gas	56’000	60	0.5	0.3	0.1
Fuel oil	78’000	50	114	3.5	5.5
Source: German Federal Environmental Agency, IFEU estimations					IFEU Heidelberg 2003

Emission factors for electricity production in various European countries were generated and published e.g. in the data bases /Ecoinvent 1996/ and /GEMIS 2002/. The Ecoinvent data are several years old by now. A new version is expected to be available by mid-2003.

The GEMIS data base is more up-to-date. Therefore we primarily use this data base as the main source of emission factors for electricity generation.

GEMIS provides, among others, the following data:

- The **emission factors** for electricity parks, *including* prechains (in kg/1000TJ)
- The **energy split** for these electricity parks (in %)
- The ***direct* emissions** (i.e. without prechains) of the power stations involved, (in kg/TJ)
- The **conversion efficiency** (in %) of these power stations.

Therefore in order to obtain the direct emissions of the power stations per input energy, the direct emissions were multiplied with the conversion efficiency factor. The average emission factors for each country were then calculated using the most recent EU-data for the respective energy splits /DG TREN 2002a/, i.e. the GEMIS data for the energy splits (which differ slightly from the EU-values) were not used, as the EU values were considered more authoritative. It was not possible to verify whether the GEMIS data correctly reflect the current standards of waste gas purification in each country.

For the Czech Republic, Hungary, Slovakia and Slovenia, GEMIS provides no data. For these countries, the data from Poland were used with regard to hard coal. For natural gas, oil and other fossil energy carriers, the German data were used.

For the countries Austria, Denmark, Germany, Italy, Sweden and Switzerland, we had data from the railway companies for the split of electricity for railways. which were used. For a better comparison the emission factors are calculated with the country specific basic factors of the GEMIS model.

Total energy chain

Consolidating the energy split for electricity production, the respective emission factors, and the conversion efficiencies for each country gives the end energy related emission factors. They are listed in the table below.

Table 9 Primary energy consumption and emission factors of the electricity supply for railway transport in European countries

	PE	CO_2	NOx	SO_2	NMHC	PM_{ind}
	MJ/kWh	kg/kWh	g/kWh	g/kWh	g/kWh	g/kWh
Austria*	4.69	0.08	0.24	0.07	0.02	0.05
Belgium	11.03	0.28	0.90	0.29	0.08	0.23
Czech Republic	14.14	1.03	4.32	7.56	0.05	1.81
Denmark*	6.59	0.54	0.60	0.41	0.06	0.06
Finland	7.84	0.27	0.43	0.42	0.04	0.04
France*	11.02	0.11	0.33	0.30	0.02	0.03
Germany*	11.17	0.63	0.58	0.67	0.03	0.03
Hungary	13.72	0.69	2.00	3.23	0.12	0.70
Italy*	8.15	0.53	1.61	3.24	0.13	0.30
Luxembourg	5.03	0.10	0.38	0.03	0.05	0.00
Netherlands	7.05	0.43	1.03	0.23	0.13	0.56
Norway	4.02	0.00	0.01	0.00	0.00	0.00
Poland	12.88	1.26	3.91	11.22	0.04	3.05
Slowakia	12.97	0.54	1.86	3.05	0.07	0.71
Slovenia	9.94	0.40	1.64	2.87	0.02	0.68
Sweden*	4.56	0.00	0.00	0.00	0.00	0.00
Switzerland*	4.14	0.00	0.00	0.00	0.00	0.00

Remarks: *railway mix
Source: European Commission DG TREN, Railway companies, IFEU estimations, GEMIS
IFEU Heidelberg 2003

3.2 Transport modes

3.2.1 Road transport

The energy consumption of road transport depends on various factors. The following aspects are of significant importance:

- vehicle size and weight, vehicle configuration (trailer), motor concept, transmission
- weight of load (load factor)
- driving pattern: influence of the driver and of the road characteristics (road category, number and width of lines, curves, gradient).

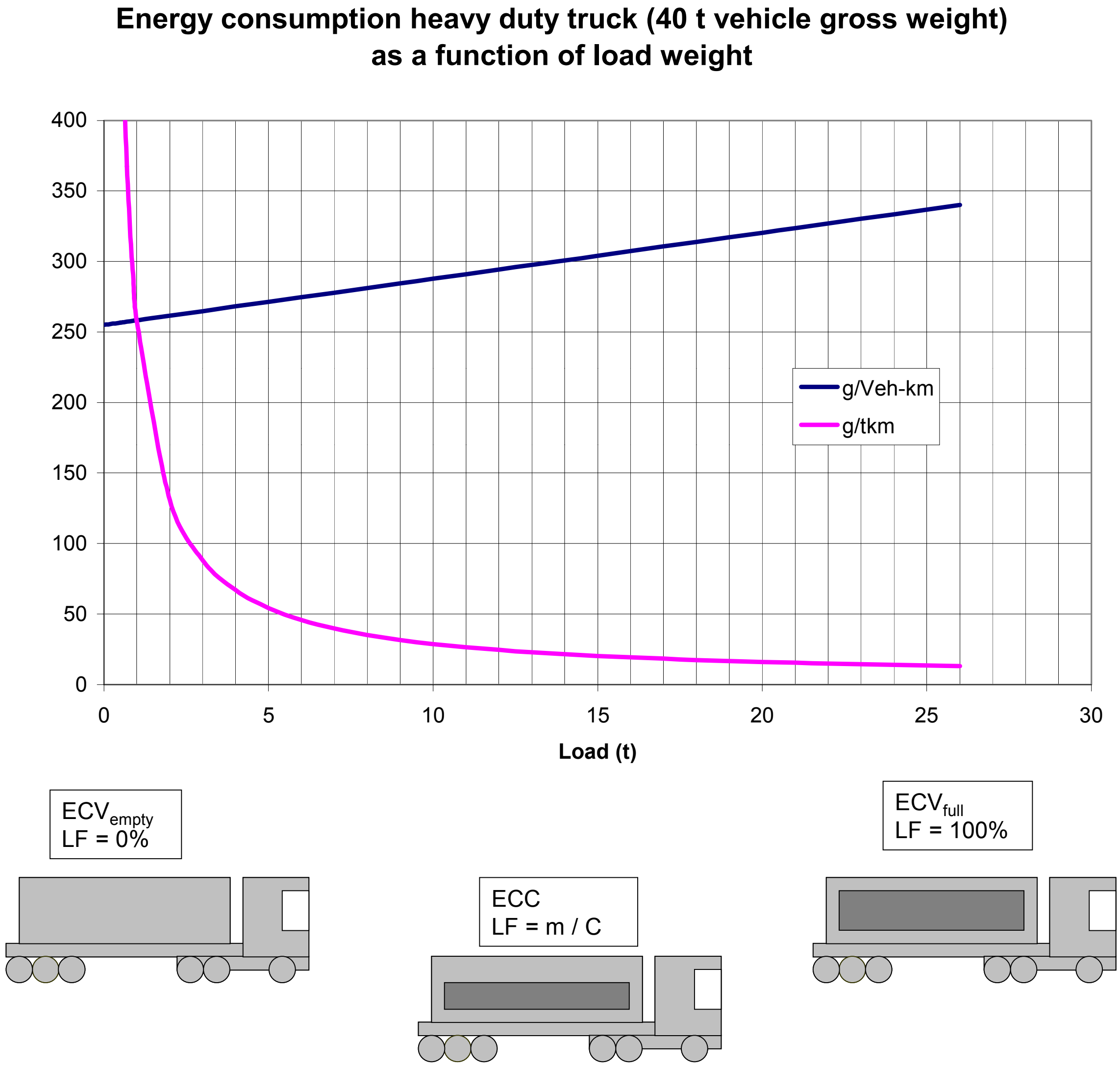
In EcoTransIT, international long distance transports are focussed on. These are typically accomplished using truck trains and articulated trucks with a gross weight of 40 tons. For feeding or special transports also other lorry types are used. In EcoTransIT three gross weight classes are defined which cover all vehicle sizes used for cargo transport:

- Lorry < 7,5 gross tons (load capacity: 3,5 tons)
- Lorry or train 7,5 - 28 gross tons (load capacity: 15 tons)
- Truck train or articulated truck 28 - 40 gross tons (load capacity: 26 tons)
- Sweden and Finland truck train 40 - 60 gross tons (load capacity: 40 tons)

Besides the vehicle size, the emission standard of the vehicle is an important criterion for the emissions of the vehicle. In European transport, different standards are in use in 2003: EURO 1, EURO 2, EURO 3. These standards can be selected. The Pre-EURO 1-standard is not relevant anymore for most long distance transports, and was therefore not included.

The influence of the **load factor** is modelled according to the differentiated values in the Handbook of Emission Factors /INFRAS 1999a/. Accordingly, the fuel consumption of an empty vehicle can be 1/3 below the fuel consumption of the fully loaded vehicle. This influence can be even stronger depending on the driving characteristics and the gradient. The following figure shows an example for the energy consumption per vehicle-km and per ton-km as a function of load factor.

Figure 6 Example: energy consumption heavy duty truck (40 t vehicle gross weight) as a function of load weight



$$ECC = ECV_{empty} + (ECV_{full} - ECV_{empty}) * LF$$

ECV	Energy consumption vehicle (g/km)
EC_{empty}	Energy consumption vehicle without load (g/km)
EC_{full}	Energy consumption vehicle with full load (g/km)
ECC	Energy consumption of specific cargo (g/km)
m	mass of specific cargo (t)
C	load capacity (t)
LF	Load factor (weight load / load capacity)

Source: Handbook emission factors (INFRAS 1999a) , TREMOD (IFEU 2002b) IFEU Heidelberg 2003

Energy consumption and emissions also depend on the driving pattern. Two typical driving patterns, one for highway traffic and one for traffic on other extra-urban roads, are considered by EcoTransIT. Traffic on urban roads is almost irrelevant in long distance transport and therefore not taken into account.

Another parameter is the **gradient**. Similar to rail transport, the gradient takes into account country-specific factors which represent the average topology of the country (“flat”, “hilly”, “mountains”). IFEU and INFRAS analyses for Germany /IFEU 2002b/ and Switzerland /INFRAS 1995/ show 5-10 % higher energy consumption and emissions for heavy duty vehicles if the country specific gradients are taken into account. No significant differences could determined between the countries of Germany and Switzerland. For this analyses, however, the entire traffic on all roads has been considered.

The share of gradients for the different countries in international road transport can only be estimated. No adjustments will be made for the ‘flat countries of Denmark, Netherlands and Sweden, while energy consumption and emissions will be assumed 5 % higher for the ‘hilly countries’ (all others with exception of Austria and Switzerland) and 10 % higher for Switzerland and Austria.

The energy and emission factors of road transport for EcoTransIT are derived from the Handbook of Emission Factors /INFRAS 1999a/. The database of the Handbook will be updated midyear 2003. Since the update will comprise new data for EURO 1,2 and 3 lorries from new measurements on an European level, it is recommendable to integrate these values as soon as possible. The following Table shows some of the emission factors used in EcoTransIT.

Table 10 Emissions factors for lorry transport (articulated truck <40 t, no gradient)

Emission standard	weight type	EC (GJ/tkm)	CO_2 (g/tkm)	NO_X (mg/tkm)	SO_2 (mg/tkm)	NMHC (mg/tkm)	PN_{dir} (mg/tkm)
Euro 1	bulk	913	68	583	47	55	23
	average	1’110	82	703	57	68	28
	volume	1’920	142	1.198	99	123	49
Euro 2	bulk	913	68	503	47	43	11
	average	1’110	82	606	57	53	14
	volume	1’920	142	1.033	99	96	25
Euro 3	bulk	913	68	343	47	37	8
	average	1’110	82	413	57	46	10
	volume	1’920	142	705	99	82	18
Source: Handbook of Emission Factors (INFRAS 1999a), IFEU estimations IFEU Heidelberg 2003							

Truck train with 60 tons gross weight in Finland and Sweden

The total gross weight allowance for truck trains in Sweden in Finland is 60 t and therefore about 20 t higher than in most other European countries. No values for energy consumption and emission factors for these trucks trains are included in the Handbook /INFRAS 1999a/. Therefore data from NTM /NTM 2002a/ will be used.

According to the NTM values, a 60 t truck train is about 10 % more efficient (per tkm) in comparison with the 40 t truck train. The NTM values, however, can not be compared to the values of the Handbook /INFRAS 1999a/ which are used in this study. It is therefore suggested that the specific values for a 60 t truck train will be estimated by reducing the corresponding values for the 40 t truck train by 10 %. As with the energy consumption, all specific emissions will be reduced by 10 %.

3.2.2 Rail transport

The main influencing factors for rail transport regarding energy consumption are:

- traction type (diesel, electric)
- train length and total weight
- proportion of load weight to empty weight of wagons and transport vessel
- route characteristics (gradient)
- driving behaviour (speed, acceleration) and air resistance.

The main indicator for calculating energy and emissions of rail transport is the energy consumption of the total train depending on the gross weight of the train.

Gross ton weight of train

Different railway companies have been interviewed for an appraisal of a typical train length for international transport /Railway companies 2002/. The railway companies state 1’000 t as a typical average gross weight for international trains. The maximum gross weight for international traffic is up to 2’000 t. Thus we estimate the gross weight of a long and therefore more energy efficient train to be around 1’500 t. The gross weight of short trains has been estimated to be around 500 t.

Energy consumption

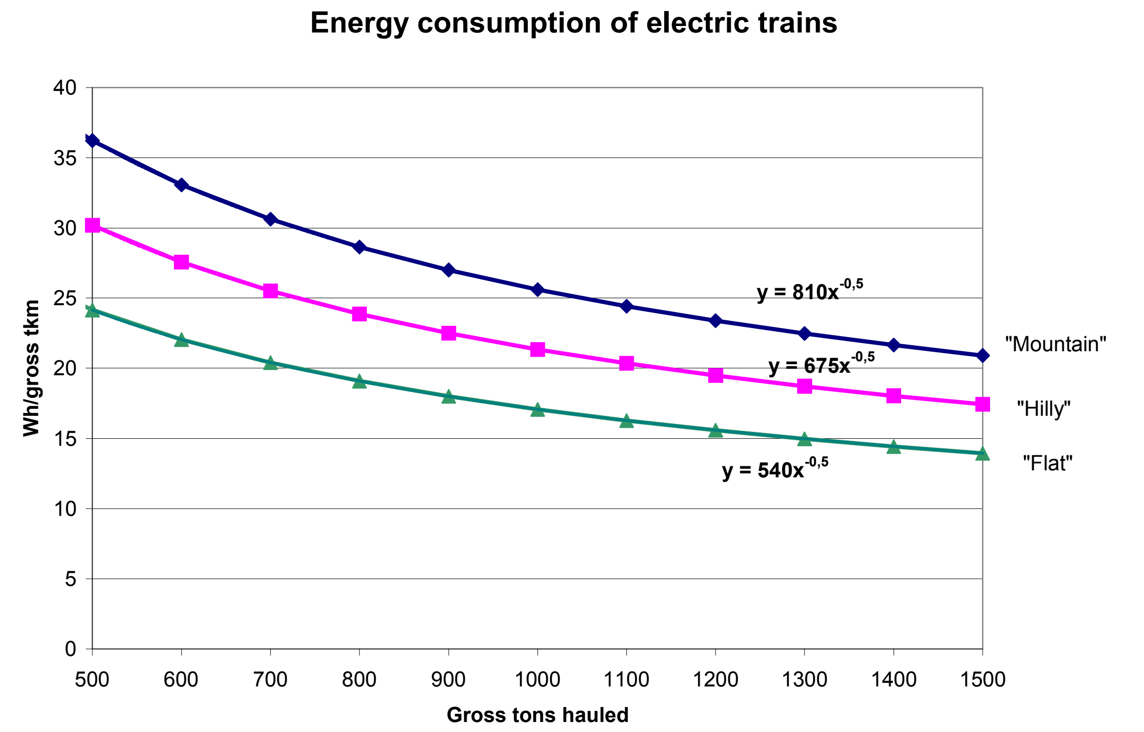
Different average energy consumption data are available which already include the influence of these parameters, such as

- average annual consumption of typical freight transport by different companies.
- energy functions for specific energy consumption of rail transport /IFEU 1999a/, /TEMA 2000/, /OMIT 2001/.

In EcoTransIT, energy functions are used which are verified by average values from different European railways. To take into account the different topologies of the European countries, three types of functions are used, which shall represent a “flat” (Denmark, Netherlands, Sweden), “mountain” (Austria, Switzerland) or “hilly” topology (all other countries).

Due to the lack of more recent data EcoTransIT uses the same functions which have already been derived for the OMIT project /OMIT 2001/. No significant discrepancies have been found in an analysis of the average energy consumption of different railway companies /Railway companies 2002/. The functions are shown in the following figure.

Figure 7 Functions for the energy consumption of electric trains



Source: DB, IFEU, OMIT 2001 IFEU Heidelberg 2003

Table 11 Specific final energy consumption for electric trains

Wh/tkm		Flat	Hilly	Mountain
Short Train (500 t)	Bulk	40.2	50.3	60.4
	Average	48.3	60.4	72.4
	Volume	60.4	75.5	90.6
Average Train (1.000 t)	Bulk	28.5	35.6	42.7
	Average	34.2	42.7	51.2
	Volume	42.7	53.4	64.0
Long Train (1.500 t)	Bulk	23.2	29.0	34.9
	Average	27.9	34.9	41.8
	Volume	34.9	43.6	52.3

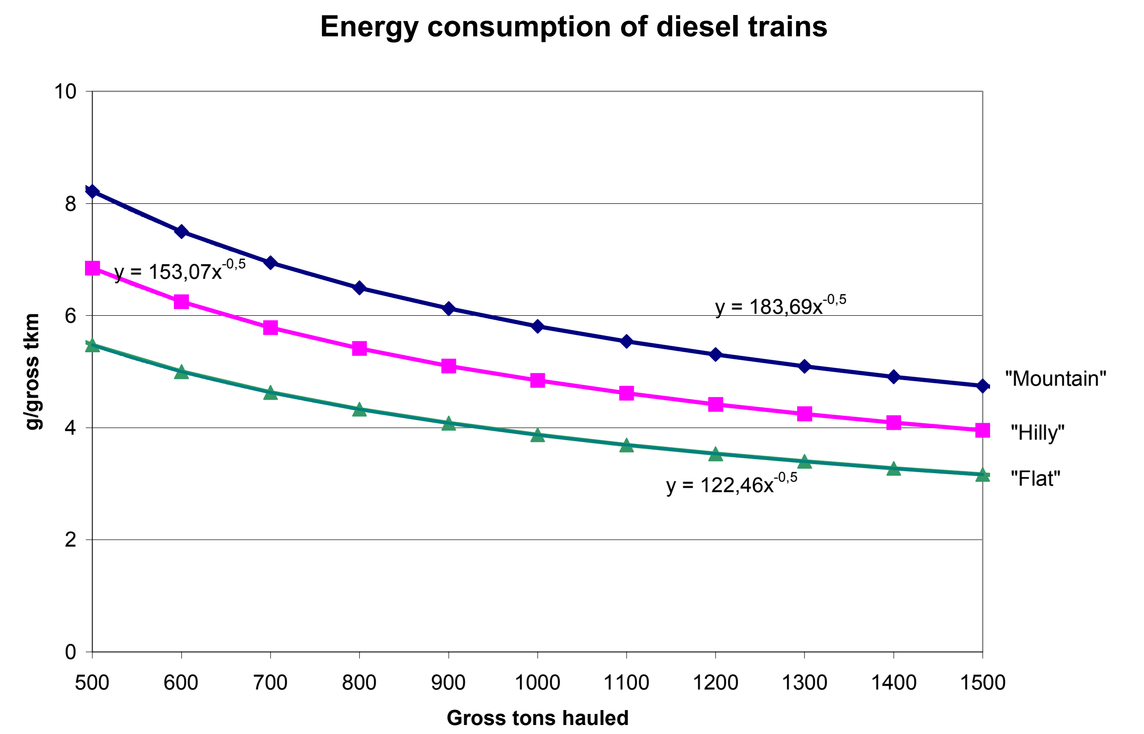
Source: OMIT, IFEU estimations IFEU Heidelberg 2003

Energy consumption of diesel trains

The available energy data for diesel traction ranges between 2.6 and 9.7 g/gross-ton-km /Railways companies 2002/. The statistical uncertainties can be due the unreliable allocation of the fuel consumption to different users (passenger and goods transport, shunting, etc.). This study therefore uses the method of /OMIT 2001/: The primary energy consumption of diesel traction is estimated on the basis of the primary energy consumption of electro traction. This procedure can be used, because the total efficiency of diesel traction (including the production of fuel) is similar to the total efficiency of electro traction (including electricity generation).

So the same functional dependence as for electric traction is taken and has to be divided by the efficiency of the diesel-electric conversion of about 37 %.

Figure 8 Energy consumption of diesel trains



Source: OMIT 2001 IFEU Heidelberg 2003

Emission factors for diesel trains

Different from electro traction, emissions for diesel traction are also produced during the operation of the vehicle. These emission factors are stated as fuel consumption specific values (in g/kg diesel fuel). This study uses the values which have been made available by several railway companies /Railway companies 2002/. Default values have been defined for all other railway companies and are used for further calculations. Table 12 summarises the emission factors for diesel trains of different railway companies.

Table 12 Emission factors for diesel trains

in g/kg	CO_2	NOx	SO_2	NMHC	PM_{dir}
Green Cargo	3’170	70	0.01	2.8 (HC)	1.8
DB	3’175	55.4	0.08	6.0	2.0
DSB	3’170	56.7	0.07	1.8	0.1
TI	3’100	60	0.7	4.9	5,0
SNCF	3’150	39.6	0.7	4.7	1.5
Default	3’170	55	0,7	4.9	1.5
Source: different Railway companies, IFEU-estimation					IFEU Heidelberg 2003

Allocation methodology for rail transport

The allocation of energy consumption for the transport of a special cargo is easy if the total train transports only one type of cargo. To determine the energy consumption and the emissions of the rail transport of one loading unit in a single wagon train, the energy consumption of the total train is allocated to the individual loading units such that

- different energy consumptions for loading units with differing sizes and differing total weight are considered,
- the sum of all energy consumptions of individual loading units equals the total energy consumption/emissions of the entire train.

In the following, two different methodologies are presented.

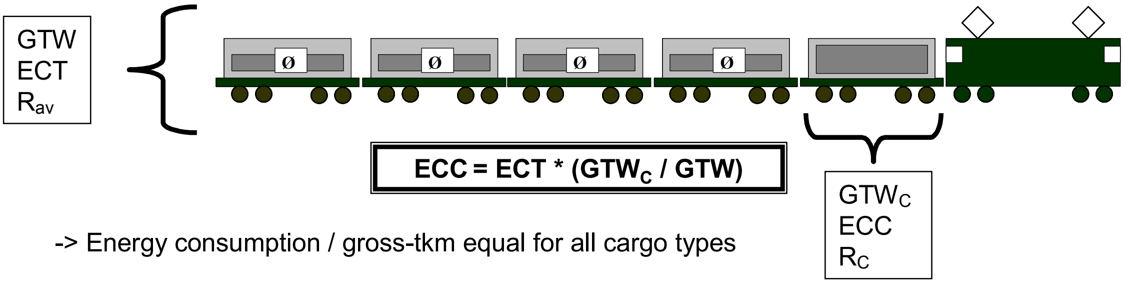
Allocation according to “Mobilitäts Bilanz“ (also used in EcoTransIT)

In the DB study “Mobilitäts Bilanz” /IFEU 1999a/ the average train was defined as a train with a constant gross weight that is equal for the transport of various types of cargo. In consequence, the energy consumption per gross ton km was used for all types of cargo in the train. The data required to calculate energy consumption per net ton-km of the specific cargo are:

- the gross ton weight of the total train
- the gross ton weight of the wagons with specific cargo
- the net weight of the specific cargo

Figure 9 Allocation of energy consumption in "Mobilitäts-Bilanz" and "EcoTranIT"

Allocation of energy consumption ("Mobilitäts-Bilanz", "EcoTransIT")



Definitons:

GTW:	Gross ton weight train (in t)
EW:	Empty weight of waggons (t)
R_C:	Relation netto-t/gross-t of specific Cargo
R_{av}:	Relation netto-t/gross-t of average Cargo in train
ECT:	Energy consumption train (in Wh/train-km)
ECC:	Energy consumption of specific cargo (Wh/cargo-km)

IFEU Heidelberg 2003

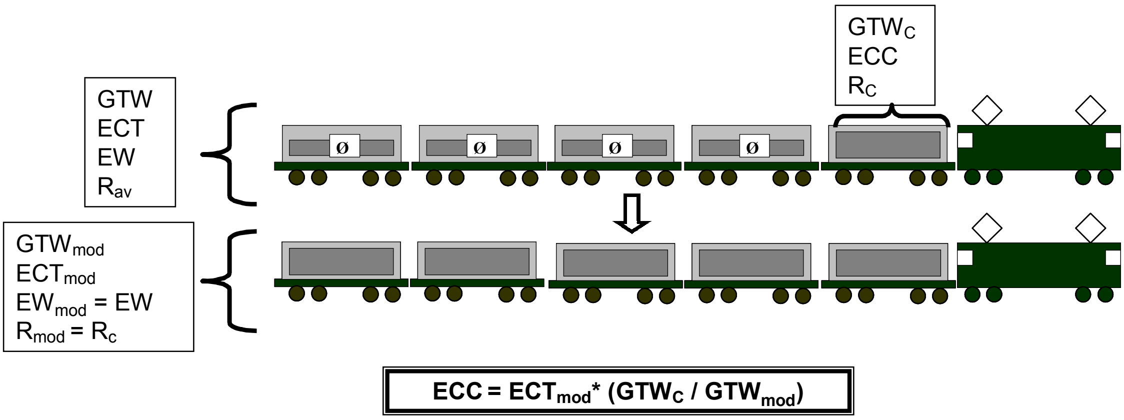
With this methodology, the information about the empty weight of the train is not required. The result is the same for a long train with volume good or with a high share of empty wagons and a short train with bulk good, if both trains have the same gross ton weight.

Allocation according to „Block Train"

The second methodology defines the average train as a train with a constant empty weight of wagons, and so with the same number of wagons, a typical "block train configuration". If the weight of cargo varies, the gross ton weight of the train changes and, in consequence, the energy consumption per gross ton-km changes.

Figure 10 Allocation of energy consumption ("Block Train")

Allocation of energy consumption ("Block Train")



Definitons:

GTW:	Gross ton weight train (in t)
EW:	Empty weight of waggons (t)
R_C:	Relation netto-t/gross-t of specific Cargo
R_{av}:	Relation netto-t/gross-t of average Cargo in train
ECT:	Energy consumption train (in Wh/train-km)
ECC:	Energy consumption of specific cargo (Wh/cargo-km)

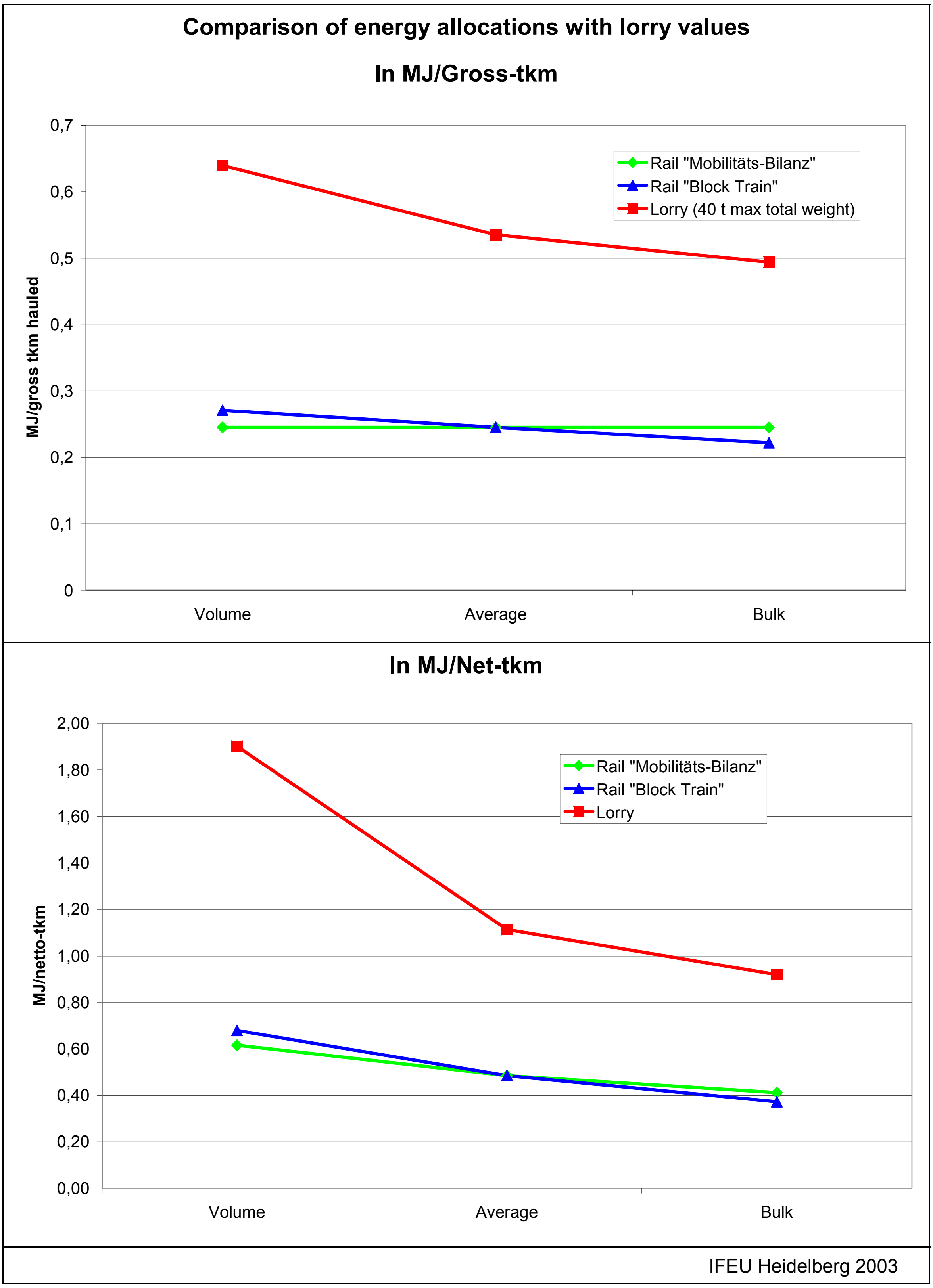
IFEU Heidelberg 2003

This methodology was used for example in the IRU-study for trains of combined transport /IFEU 2002a/.

The following figure shows possible results of the two methodologies: specific energy consumption per net-tkm dependent on load weight (in percent of the maximum load weight).

The consequence of the first methodology (gross weight of train constant) is a lower energy difference between bulk goods (high cargo weight) and volume good (low cargo weight). The second methodology has higher differences in energy consumption between bulk and volume good. It is more similar to the lorry transport, which has the highest differences in energy consumption depending on load weight.

Figure 11 Comparison of energy allocations with lorry values dependent kind of good



Which methodology is more realistic?

For an average approach which is chosen in EcoTransIT it is difficult to decide which methodology is the more realistic approach: For a block train the decision is easy. For a normal train the methodology of Mobilitäts-Bilanz is more realistic, if the composition of a train with light goods contains more wagons than a train with bulk goods, which was the implicit assumption in "Mobilitäts-Bilanz".

We propose to use the methodology of "Mobilitäts Bilanz" for EcoTransIT, because it characterises the more common situation, whereas "Block train" is a special kind of train.

3.2.3 Sea transport

There are three categories of sea ships, which take into account size and capacity utilisation, and thus also the specific energy consumption and resultant emissions /Borken 1999/:

- **General cargo vessels, Ro-Ro-vessel and containerships:** these vessels have a load carrying capacity of 9,000 t to 23,000 t and operate more or less at full capacity on all trips. Ro-Ro-vessel are employed for short ferry boat trips.
- **Bulk cargo vessels:** these have an average load carrying capacity of around 40,000 t; they often operate at full capacity one way and return empty.
- **Tankers:** tankers are usually used for the transport of petroleum and have a load carrying capacity of 50,000 t to 200,000 t. They usually operate either at zero or full capacity.

Energy consumption and emission factors

In order to determine energy consumption and emissions of sea transport, in /Borken 1999/ several international sources were analysed. Regarding the energy consumption of different types of ships, the following ranges were obtained:

Table 13 Energy consumption (crude oil) of sea ships

Ship type	g/tkm
General cargo vessels	3.8 - 9.6
Bulk cargo vessels	2.2 - 4.9
Tankers	0.7 - 2.6
Source : Borken 1999 (different international studies)	

From these values we estimate the following figures for the three weight types in EcoTransIT:

Table 14 Energy consumption (crude oil) of sea ships for three weight types

Ship type / cargo specification	g/tkm
Bulk cargo	2
Average cargo	4
Volume cargo	7
Source : IFEU-Estimation based on Borken 1999 (different international studies)	

The emission factors are also taken from /Borken 1999/. They are summarised in the following table.

Table 15 Emission factors for sea ships

	CO_2	NOx	SO_2	NMHC	PM_{dir}
Sea ship	3'185	84	80	2.4	6.1
Source : Borken 1999 (different international studies)					

Allocation method for ferries

The modelling of ferries is tricky because all vessels are quite different from each other and because the allocation between passenger and goods transport is a controversial issue. So different allocation methodologies are proposed, e.g. by /Kristensen 2000/ or /Kusche 2000/.

For EcoTransIT we use the allocation method which has been suggested for the calculation model of NTM by /Bäckström 2003/. This method allocates according to the number of decks on the ferry. The number of passenger and vehicles decks are considered in the first step of the allocation. It should also be taken into account if these decks are only partially used for certain vehicle categories or if they do not extend over the full length of the ship. The second step of the allocation divides the length of lanes (lanemeters) occupied by the considered vehicles by the total length of the occupied lanes.

The following average values have been calculated according to this method for the concrete example of the Scanlines ferry:

Lorry (30 gross tons) 27 g/gross-ton-km

Railcar (46 gross tons) 22 g/gross-ton-km

These values are taken and differentiated according to vehicle types and kind of good. The resulting specific energy values are summarised in the following table.

Table 16 Specific Energy Consumption for ferries

g/tkm	Rail	Lorry <7,5t	Lorry <28t	Lorry <40t
bulk	37	75	63	49
average	45	87	72	55
volume	56	139	112	79
Source : Bäckström 2003, IFEU-assumptions				IFEU Heidelberg 2003

These values represent a ferry example and are derived by a concrete allocation method. They indicate the order of magnitude, but may vary much for other ferries and ferry companies.

Emission factors for ferries

Ferries operate almost exclusively with medium speed engines usually running on gas oil/marine diesel oil. In EcoTransIT we use the NTM values. According to /Bäckström 2003/, the sulphur content in Sweden is around 0,5-1%. This fuel, however, commonly has a sulphur content of up to 3 %. We therefore use an average value of 1,5 % in this study.

Table 17 Emission factors for ferries

	CO_2	NOx	SO_2	NMHC	PM_{dir}
Ferries	3’100	70	30	0.98	2
Source : NTM, Estimation for SO_2					IFEU Heidelberg 2003

3.2.4 Inland waterway transport

As for other means of transport, energy consumption and emissions of inland navigation vessels depend on parameters such as size (load capacity), motor power, engine technology and engine utilisation. These in turn correlate with the age of the ship, the load factor and the water flow conditions. For a detailed analysis, at least the main factors should be considered, which are ship size, load factor and water flow conditions. This, however, is possible only to a limited extent /Borken 1999/.

Energy consumption

Energy values for inland ship transport are available for

- different ship classes
- different operation conditions upstream/downstream, free-flow/with sluices

The following table is derived from an IFEU investigation based on different national and international sources /Borken 1999/.

Table 18 Energy consumption of inland ships dependent on ship size and type of waterway

operation condition		Free flow		With sluices	
Ship type (payload)		**down-stream**	**upstream**	**down-stream**	**upstream**
Empty ship					
800 t	g/km	2'740	7’072	3’442	4’683
1'250 t	g/km	3'770	9’718	4’754	6’463
1.750 t	g/km	4'871	12’551	6’112	8’336
2.500 t	g/km	5'643	14’495	7’072	9’624
Load factor 50 %					
800 t	g/tkm	7.7	20.1	9.4	12.9
1'250 t	g/tkm	6.8	17.8	8.2	11.2
1.750 t	g/tkm	6.3	16.4	7.5	10.3
2.500 t	g/tkm	5.2	13.1	6.1	8.4
Load factor 100 %					
800 t	g/tkm	4.4	11.7	4.9	7.0
1'250 t	g/tkm	4.0	10.3	4.4	6.1
1.750 t	g/tkm	3.7	9.4	4.0	5.6
2.500 t	g/tkm	3.0	7.7	3.3	4.7
Source: Borken 1999 based in different international sources					

For EcoTransIT, specific energy values are required for an average ship in three operating conditions: no stream, upstream and downstream, as well as for three weight types. Three assumptions are made in this regard:

- For a typical ship, a vessel of the Europe type with a load carrying capacity of up to 1,250 t is used.
- For the operating conditions “upstream” and “downstream”, the respective mean values for free flow and barrage regulated / with sluices conditions are used.
- For non-flowing watercourses, the mean value of barrage regulated, upstream and downstream conditions is used.

When differentiating between the three weight types with regard to the energy consumption, it must be taken into consideration that empty trips are usually made against the course of the actual transport: an empty return trip following a transport upstream will therefore be downstream. In the calculations of the energy consumptions, this was taken into account by assigning the assumed empty trip part of the calculation an energy consumption value according to the counter-direction. The consumption values thus determined are listed in the following table.

Table 19 Energy consumption values for inland navigation

g/tkm	Upstream	Downstream	No stream
Bulk	9.6	7.0	7.2
Average	13.6	8.2	9.6
Volume	22.9	12.6	15.8
Source: Borken 1999, IFEU-assumptions			

The emission factors for inland ships were taken from /Borken 1999/. They are listed in the following table.

Table 20 Emission factors for inland ships

	CO_2	NOx	SO_2	NMHC	PM_{dir}
Inland ships	3’175	60	0.9	4.7	1.7
Source : TREMOD (IFEU 2002b)					

3.2.5 Aircraft transport

Air freight service includes inland courier flights by small propeller powered planes as well as intercontinental jet flights for the transport of complete technical assets. Predominantly perishable and expensive goods are transported, and almost exclusively piece goods. The goods are either transported in cargo planes or together with passengers in airliners /Borken 1999/.

Specific energy consumption and emissions of air cargo transport depend heavily on the length of the flight. This is because their values vary between different flight phases: thus for example the take-off has the highest specific energy demand. Its share of the total flight obviously declines as the length of the flight increases.

If cargo is transported along with passengers, the energy consumption must be split between them. This is done by taking into account the weight of the passengers.

In recent years, air transport saw continuous energy savings. Therefore for EcoTransIT we use as up-to-date a value as possible for the energy consumption of air cargo traffic:

- In the TREMOD model currently a mean value of 220 g/tkm is used for all flight lengths.
- The Deutsche Lufthansa currently gives a value of 189 g/tkm for 2001 /Lufthansa 2002a/.

These values agree reasonably well with each other. We therefore consider it justified to follow the information of the Deutsche Lufthansa for EcoTransIT, and to assume the specific energy consumption to be 190 g/tkm for air cargo traffic. Mainly high value volume goods are shipped by air freight and the permissible maximum weight is limited. Therefore no other types of goods (bulk, average) will differentiated.

The emission factors are taken from TREMOD. The values are based on a detailed investigation of the environmental effects of air traffic, on behalf of the German Federal Environmental Agency /TÜV Rheinland 1999a/.

Table 21 Emission factors for aircraft cargo transport (long distance flights)

	CO_2	NOx	SO_2	NMHC	PM_{dir}
Cargo air plane	3’120	12.7	0.5	0.77	0.02
Source : TREMOD (IFEU 2002b)					

4 Appendix: Special values for processes not included in EcoTransIT

Container transport

EcoTransIT does not differentiate conventional transport and container transport. Container transport results in the transportation of more deadweight. To take into account container transport a share of the container weight has to assigned to the net weight of the cargo. The following approximate values can be used if only the net weight of the cargo is known:

Bulk cargo:	7 tons additional container weight per 100 tons of cargo
Average cargo:	11 tons additional container weight per 100 tons of cargo
Volume cargo:	23 tons additional container weight per 100 tons of cargo

These values are based on the following assumptions: The weight of a 40' container is about 3.5 t. No vehicle superstructures are needed and therefore the additional considered empty weight will be only around 1.5 t. 22 t maximum load are assumed (corresponds with the possible load of bulk cargo).

Transport without empty trips

EcoTransIT uses an estimated share of empty trips for all cargo types. The results can be reduced if it is known that vessels and vehicles do not return empty. The reduction can only be estimated, because the relation between the energy consumption of a loaded trip and an empty trip depends on the type of goods and for inland navigation vessels also on the direction of the flow.

Additional empty trips are relevant mainly for bulk cargo. If there are no empty trips in the transport chain, all values calculated with a share of empty trips can - conservatively estimated – be reduced by 20-30 %. For average cargo the reduction will be around 10-20 % and for volume cargo around 5-10 %.

Intermodal transfer

Intermodal transfer can be relevant in a comparison of two transport variants, i.e. if one transport variant requires more transfer processes than the other. The following energy values (/IFEU 1999a, /IFEU 2002a/) can be used as a first estimation:

- 2.2-4.4 kWh per transfer process (container)
- 1.3 kWh/t (bulk or general cargo)
- 0.4 kWh/t (oil transfer)

To make an estimation about the relevance, we assume a rail transport (average electric train, average cargo, no gradient) which requires 0.034 kWh/tkm; then one transfer process requires the same energy as

- 6-11 km (Container assumption: container with 12 tonnes cargo weight)

- 38 km transport of bulk and general cargo
- 12 km (Oil)

Shunting

Several values for shunting have been made available by railway companies /Railway companies 2002/. An average value for a shunting process is in the range of 35 g diesel fuel per gross-ton. With the consumption of an average diesel train (with average cargo and no gradient) being about 4 g/gross-tkm, the shunting process consumes about the same as 10 train-km.

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