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Ecological Transport Information Tool for Worldwide Transports

Methodology and Data Update 2018

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Commissioned by
EcoTransIT World Initiative (EWI)

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Content

Foreword

The EcoTransIT Initiative (EWI) is an independent industry driven platform for carriers, logistics service providers and shippers dedicated to maintain and develop a globally recognized tool and methodology for carbon footprints and environmental impact assessments of the freight transport sector.

In line with its vision to increase transparency on the environmental impact of the freight transport and to demonstrate the continuous improvement of EcoTransIT methodology and EcoTransIT World (ETW) calculator, EWI members have commissioned their scientific and IT partners to provide an updated methodology report. The methodology was already embedded in the calculator; it follows the guidelines of the standard EN 16258 "Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services" and integrates latest research available for the air pollutants.

Current EWI members are:

Asia Shipping, Brazil	Dachser, Germany
DB, Germany	Henkel, Germany
Hapag-Lloyd, Germany	Hupac, Switzerland
Gebrüder Weiss, Austria	Lineas, Belgium
Gefco, France	Kühne+Nagel, Germany
Geodis, France	Austrian Railways (ÖBB), Austria
Greencarrier, Sweden	Panalpina, Switzerland
Group7, Germany	Posti, Finland
Hamburg Süd, Germany	Rhenus, Germany
Savino Del Bene, Italia	SBB, Switzerland
Scandinavian Logistics (Scanlog), Sweden	SNCF, France
System Alliance Europe (SAE), Germany	International Union of Railways (UIC), France

These members also thank their scientific and IT partners - INFRAS Berne, ifeu Heidelberg and IVE Hannover - for their continuous support to the vision of EWI.

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1 Introduction

1.1 Background and task

As freight transport mainly relies on conventional energy carriers like diesel, kerosene and heavy fuel oil, it significantly contributes to major challenges of the 21st century: pollution and climate change. According to the Fifth Assessment Report from the Intergovernmental Panel on Climate Change, transport accounts for about a quarter of global energy-related carbon emissions. This contribution is rising faster than on any other energy end-use sector.

EcoTransIT World means Ecological Transport Information Tool – worldwide (ETW). It is a free of charge internet application, which shows the environmental impact of freight transport – for any route in the world and any transport mode. More than showing the impact of a single shipment, it analyses and compares different transport chains with each other, thus making evident which solution has the lowest impact.

For professional users, ETW offers dedicated services that allow companies to calculate large numbers of shipments at once without manual handling efforts. It provides a customized interface based on individual customer's operational data and answering its needs and requirements. Thus, with ETW Business Solutions the corporate data warehouse can be filled with all information required to realize specific environmental reports, regional inventories, establish carbon reporting or provide carbon accounting benchmarks efficiently.

With this purpose in mind, EcoTransIT World aims to address:

- Forwarding companies willing to reduce the environmental impact of their shipments;
- Carriers and logistic providers being confronted with growing requests from customers as well as legislation to show their carbon footprint and improve their logistical chains from an environmental perspective;
- Political decision makers, consumers and non-governmental organisations which are interested in a thorough environmental comparison of logistic concepts including all transport modes (lorry, railway, ship, airplane and combined transport).

The environmental parameters covered are energy consumption, carbon dioxide (CO_2), sum of all greenhouse gases (measured as CO_2 equivalents) and air pollutants, such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane hydro carbons (NMHC) and particulate matter (PM).

The online application offers two levels: In a "standard" input mode it allows a rough estimate. This can be refined in an "extended" input mode according to the degree of information available for the shipment. Thus, all relevant parameters like route characteristics and distance, load factor and empty trips, vehicle size and engine type are individually taken into account and can be changed by the user.

The initial version of EcoTransIT was published in 2003 with a regional scope limited to Europe. The version published in 2010 was expanded to a global scope. For the first time, EcoTransIT World (ETW) enabled the calculation of environmental impacts of worldwide freight transport chains. For this purpose, the routing logistics of the tool as well as the information about environmental impacts of all transport modes (in particular sea and air transport) were expanded. In the meantime, the methodology was updated

considering new sources, data and knowledge. In this context the requirements of the new European standard EN 16258: 2012 “Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services” were also taken into account.

Thus, ETW offers a ‘best-practice’ standard of carbon foot-printing and green accounting to the whole sector – compliant with international standards like the European standard EN 16258.

The internet version of ETW as well as the integrated route planner for all transport modes has been realized by IVE Hannover. The methodology, input data and default values for the ecological assessments of the transport chains are developed and provided by ifeu Heidelberg and INFRAS Berne. ifeu and INFRAS ensure that the ETW methodology is always up-to-date and in accordance with the international standards.

The present report “Methodology and Data Update” documents the methodology and the data currently embedded in ETW.

1.2 Accordance with EN 16258

Since the very first beginning EcoTransIT World has been provided a harmonized, independent methodology for the calculation of GHG emissions and air pollutants. The overall methodology and the approaches for each transport mode were very similar to the suggestion from the new European standard EN 16258 - which was published by the British Standards Institution (BSI) as BS EN 16258, by the German Institute for Standardisation (Deutsches Institut für Normung, DIN) as DIN EN 16258 and by Association française de normalisation (AFNOR) as NF EN 16258 at the end of 2012. Thus, the adaptation of the ETW methodology to the requirements of the European standard was feasible. The calculation of energy consumption and greenhouse gas (GHG) emissions (as CO_2 equivalents) by **ETW** is **fully in accordance with EN 16258**.

One methodological principle of the new standard is that in a first step the final energy consumption (litre Diesel, kWh electricity) of each part of the transport services (so-called leg) have to be calculated and in a second step these values have to be transferred into standardized energy consumption (MJ) and CO_2 equivalent emissions (kg CO_2e) on a Tank-to-Wheels (TTW) and Well-to-Wheels (WTW) basis (see chapter 3.3). The new standard contains the necessary **conversion factors** respectively **default values** for these calculations (e.g. MJ/litre or kg CO_2e/litre diesel). ETW uses the conversion factors for fuels included in EN 16258 without changes (see chapter 7.1 in the annex of this report). For electricity the standard EN 16258 does not contain conversion factors as these are dependent on the mix of the generating plants which produced the electricity. The European standard only includes general rules for calculation of conversion factors for electricity. ETW uses own calculated conversion factors for electricity for trains which are in line with these general requirements of EN 16258 (see chapter 6.6).

In accordance with EN 16258 the final energy consumptions, the load factor or share of empty trips for the transport service can be measured or calculated by using default values. In general, ETW uses only default values for the calculation of energy consumption and GHG emissions since measured values can only be provided by the users themselves. The default values used by ETW are based on well-established data

bases, statistical data and literature reviews. The data sources for default values suggested by EN 16258 were considered. Therefore, ETW uses only default values being in accordance with new European Standard.

Furthermore, ETW allows users to change vehicle sizes, emission standards, load factors and shares of empty trips based on own data or measurements. In these cases, the user of ETW has to be ensured that the used figures are in accordance with the European standard. Fuel consumption figures as well as conversion factors can't be changed by the user. Fuel consumption data can only be replaced by business solutions of ETW after evaluation by the scientific partners ifeu or INFRAS (see chapter 2).

In normal cases the goods considered with ETW do not fit exactly with the capacity of the chosen vehicles, trains, vessels or airplanes so that the energy consumption or emissions have to be allocated to the transport service considered. The European standard recommends carrying out the allocation using the product of weight and distance (e.g. tonne kilometres). Where this is not possible, then other physical units (e.g. pallet spaces, loading meters, number of container spaces) can be used instead of weight. ETW always uses the **allocation unit tonne kilometres**. Only for **transport of containers** the **allocation unit TEU kilometres** (= twenty-foot equivalent unit) is considered. The allocation methodologies used by ETW are also in accordance with the European standard.

Furthermore, the European standard describes requirements for the declaration of the results of the calculation: the **declaration** must disclose the well-to-wheels energy consumption and greenhouse gas emissions as well as the tank-to-wheels energy consumption and greenhouse gas emissions for the transport service considered. In addition, the sources used for the distance, load utilisation, empty trip percentage and energy consumption parameters must be identified. This report documents the default values used for the calculations in ETW and delivers additional information for declarations in accordance with EN 16258. Since the report is comprehensive and detailed, ETW provides a short declaration which includes all important information required (e.g. data sources used). The short declaration is provided by the ETW internet tool for each calculation carried out by the user. One example of this brief declaration is given in the annex of this report (see chapter 7.2).

Thus, the results for energy consumption and GHG emissions calculated with ETW are in compliance with the standard EN 16258:2012. Moreover, the European standard points out the following points, if the user wants to compare results calculated with different tools: "Please consult this standard to get further information about processes not taken into account, guidelines and general principles. If you wish to make comparisons between these results and other results calculated in accordance with this standard, please take particular care to review the detailed methods used, especially allocation methods and data sources. "Last but not least" it has to be mentioned that one of the triggers for the European standard was that France planned to legalize oblige transport operators to show their customers the CO2 emissions produced by the transport service. However, it was not clear which methods should be used for determining the emissions. For this reason, in 2008 France made a standardisation application to the European Committee for Standardisation (CEN). In the interim the French Decree No. 2011-1336 on "Information on the quantity of carbon dioxide emitted during transport" was published. It stipulates that, by 1st of October 2013 at the latest, CO2

values of commercial passenger and freight transport which begin or end in France must be declared to the customer. This decree basically uses the same methodology as the European standard. However, there are also significant differences from the standard EN 16258. Instead of energy consumption and GHG emissions only CO2 emissions have to be calculated. This possibility is also provided by ETW. Furthermore, the French decree use different conversion factors compared to the EN 16258. They are not comparable so it is not possible to use the conversion factors of the European standard and the French decree at the same time. The ETW internet tool provides only results based on the conversion factors based on EN 16258. But in ETW business solutions the conversion factors included in the French decree can also be used so that ETW can also provide results in accordance with the French decree (see chapter 2).

2 ETW business solutions

The use of the standard online application ETW on the website www.ecotransit.org is free of charge if being applied for single shipments without further customizing. Please respect the copyright of ETW and cite "EcoTransIT® World" as their source.

For professional users, ETW offers Business Solutions which provide standardized and individualized interfaces for different customer issues. Actually over 30 companies from the whole transport sector using the ETW Business Solutions in multifarious ways.

2.1 Additional features compared to the website www.ecotransit.org

The ETW Business Solution enables valuable additional features which are not available on the global website of ETW. These features are:

- Calculation of container sea shipments via the Clean Cargo Working Group (CCWG) methodology, including
    - calculation of EC, GHG emissions and SOx based on CCWG trade lane emission factors
    - adjustable allocation factor (Default 70%) and flexible distance correction factor (Default 15%)
    - sophisticated trade lane mapping
    - usage of SCAC based emission factors (only for CCWG members)
- Automatically flight number analyses via OAG.com interface:
    - enables plane type identification via flight number (inclusive belly or freighter detection)
    - optional stop-over identification or fleet mix determination
- Additional vehicle classes, like over 230 different plane types or additional truck and train classes
- Automatically conversion of the truck load to the respective load factor (FTL, LTL, FCL) including the usage of the respective vehicle type
- Consideration of individual transport distances per leg for all transport types
- Unit conversion tables (e.g. pallets to tons)
- Country depending transport type selection for pre- and post-carriages
- Output split per country or vehicle type (can be used e.g. for result manipulation forward to the French decree)
- LocationEditor: Inclusion and correction of new or customer-specific locations
- LogViewer: Analyse web frontend for company-own calculations
- Participating within the EWI to initiate new working groups, methodology issues and help to steer ETW

All features can be adjusted or enlarged on individual basis towards to the company own needs.

2.2 Available Interfaces

The ETW Business Solutions provides standardized or customized interfaces. The calculation results can be utilized in any desired form like to fill the corporate data warehouses, realize specific environmental reports, regional inventories, establish carbon reporting or provide carbon accounting benchmarks efficiently.

So far ETW provides the following products:

- SOAP XML web service (WSDL)
- Transport list calculation (CSV file) via website up- and download
- Individualized calculation front-end on the customers' website
- Any other individual usage of ETW

2.3 Soap-xml web service

The SOAP XML web service enables the calculation of single requests on the base of a WSDL web service. The request can include all modes including an unlimited amount of via points on base of the ETW characteristics. The SOAP XML web service includes several request types, like calculation requests, flight number requests, location and vehicle requests and many more. Due to these request types it is possible to create a complete external calculation website which uses only SOAP XML requests/ responses.

2.4 Transport list calculation

Within the interface of the transport list calculation the user can upload request files (xml or csv) including huge numbers of transport services and download response files (csv, xml, pdf, kml or rtf) including calculation results. Within the so-called mass calculation every transport service will be calculated separately. The upload and download can be done via a login and password secured website or via a sFTP interface.

2.5 ETW on customer website

ETW can be included on customers' websites. The integration can be realized via a so called iframe or by the customer IT itself by using the SOAP XML web service.

2.6 Methodology support included

All ETW Business Solutions include a consulting package which automatically enables methodology support done by our scientific partners.

In principle almost, every development/ adjustment to the customers' needs can be done within the ETW Business Solutions. The effort for such an individual solution depends on the respective specification. For more information, do not hesitate to contact us[1].

[1] Contact email: info@ecotransit.org

Figure 1: Different kinds of interfaces

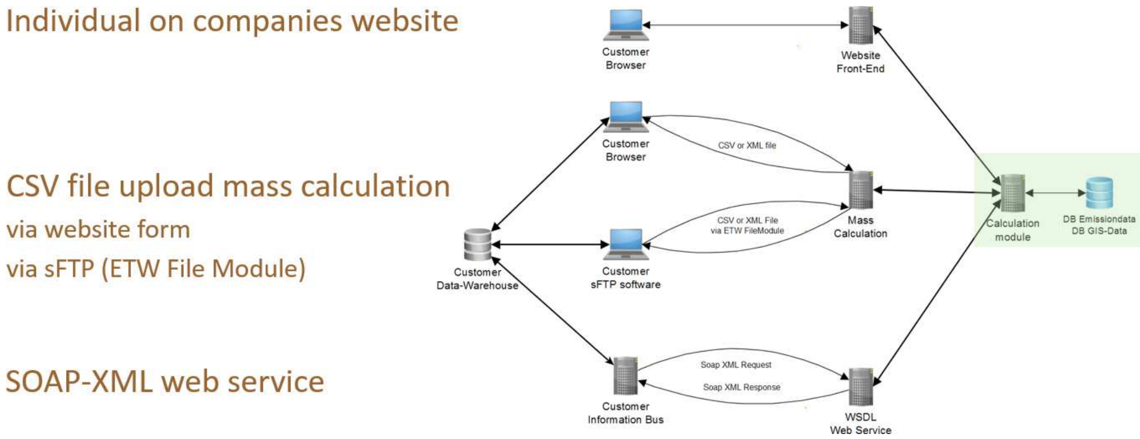
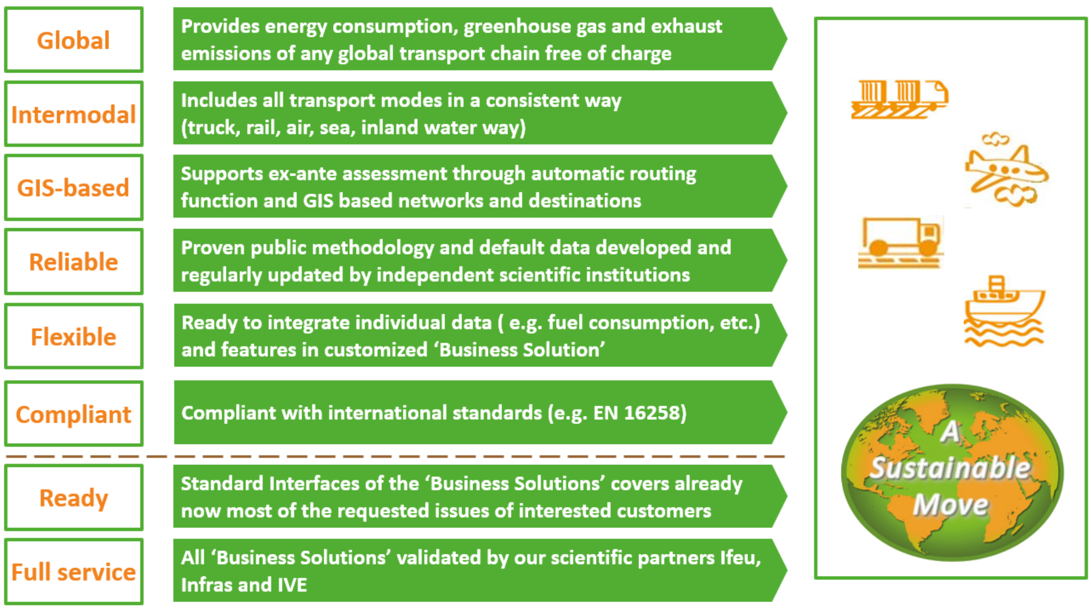


Figure 2: Benefits of the ETW Business Solutions



3 System boundaries and basic definitions

The following subchapters give an overview about the system boundaries and definitions used in ETW. In comparison to the European standard EN 16258 “Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services” ETW allows also the quantification of other emissions like air pollutants for transport chains. Nevertheless, ETW considers all requirements of EN 16258 independent of the environmental impact category considered. The system boundaries as well as definitions are chosen in such a way that they are in accordance with the new European standard.

3.1 Transport service and vehicle operation system

ETW allows the calculation of different environmental impact categories (see next subchapter) for a single transport from A to B or for complex transport chains using different transport modes. In the context of the European standard EN 16258 these transport cases are called **transport services**. According to EN 16258 a transport service is a “service provided to a beneficiary for the transport of a cargo […] from a departure point to a destination point”. The EN 16258 methodology requires that the transport service has to be broken down into sections in which the cargo considered travels on a specified vehicle, i.e. without changing vehicle. This section of route is also called **leg** in the standard. The level of energy consumption and emissions for the consignment under consideration must be determined for each leg and then added to give an overall result. ETW works exactly in this way. For each leg the quantification is done separately and the overall sum is calculated for the entire transport service. Therefore, ETW fulfils these requirements of EN 16258.

Additionally, EN 16258 demands that energy consumption and the GHG emissions for each leg have to be quantified using the so-called **Vehicle Operation System (VOS)**. VOS is the term which the standard uses to denote the round-trip of a vehicle in which the item in question is transported for a section of the route. The VOS does not necessarily have to be an actual vehicle round-trip. It can also consist of all vehicle round-trips for one type of vehicle or of one route or leg or even of all vehicle round-trips in a network in which the transport section in question lies or would lie (for future transport services). In the end the energy consumption for the entire VOS needs to be determined and then allocated to the transport leg and the individual consignment under consideration.

In accordance with EN 16258 the energy consumption of a VOS can be measured or be calculated by using default values. As mentioned in chapter 1.2 the internet tool of ETW only uses default values particularly for energy consumption of trucks, trains, ships and airplanes. Therefore, the VOS established for the calculation for ETW is the entire round trip of these vehicles or vessels. To consider the energy consumption for a single transport service the fuel or electricity consumption of the vehicles or vessels are allocated to the shipment by using the units’ tonne kilometres or TEU kilometres. The transport distance is calculated by the integrated route planner of ETW (see chapter 5). The weight of the shipment or the number of TEU is calculated by using the maximum payload capacity, the load factor and share of additional empty trips (see chapter 4.2). Similar to energy consumption **ETW considers the load factor and additional share of empty trips for the entire VOS**. Thus, the **ETW definition of VOS fulfils all requirements of the EN 16258**. However, it must be noted that specific energy consumption

values per tonne kilometre or TEU kilometre used in ETW already take account of the load factors and empty trips and link the energy consumption calculation directly to the allocation step – so, instead of two separate steps mentioned in the EN 16258 (calculation of energy consumption and afterwards allocation to the single shipment), ETW combine both steps. But the results are identical independent of combining the two steps or not.

3.2 Environmental impacts

Transportation has various impacts on the environment. These have been primarily 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 freight has impacts within all these categories. However, only for some of these categories it is possible to make a comparison of individual transport services on a quantitative basis. Therefore, in ETW the selection of environmental performance values had to be limited to a few but important parameters. The selection was made 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 World

Abbr.	Description	Reasons for inclusion
PEC	Primary energy consumption (= Well-to-Tank energy consumption)	Main indicator for resource consumption
CO_2	Carbon dioxide emissions	Main indicator for greenhouse effect
CO_2e	Greenhouse gas emissions as CO_2-equivalent. CO_2e is calculated as follows (mass weighted): $CO_2e = CO_2 + 25 * CH_4 + 298 * N_2O$ CH_4: Methane N_2O: Nitrous Oxide For aircraft transport the additional impact of flights in high distances can optionally be included (based on RFI factor)	Greenhouse effect
NOx	Nitrogen oxide emissions	Acidification, 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
Particles	Exhaust particulate matter from vehicles and from energy production and provision (power plants, refineries, sea transport of primary energy carriers), in ETW particles are quantified as PM 10	Human toxicity, summer smog

Thus, the categories **land use**, **noise** and **depletion of the ozone layer** were not taken into consideration. In reference to electricity-driven rail transport, the risks of nuclear power generation from radiation and waste disposal were also not considered. **PM emissions** are defined as exhaust emissions from combustion; therefore, PM emissions from abrasion and twirling are also not included in ETW.

In accordance with EN 16258 energy consumption and GHG emissions measured as CO_2 equivalents can be calculated with ETW. The definitions used by ETW are similar to the definitions of EN 16258.

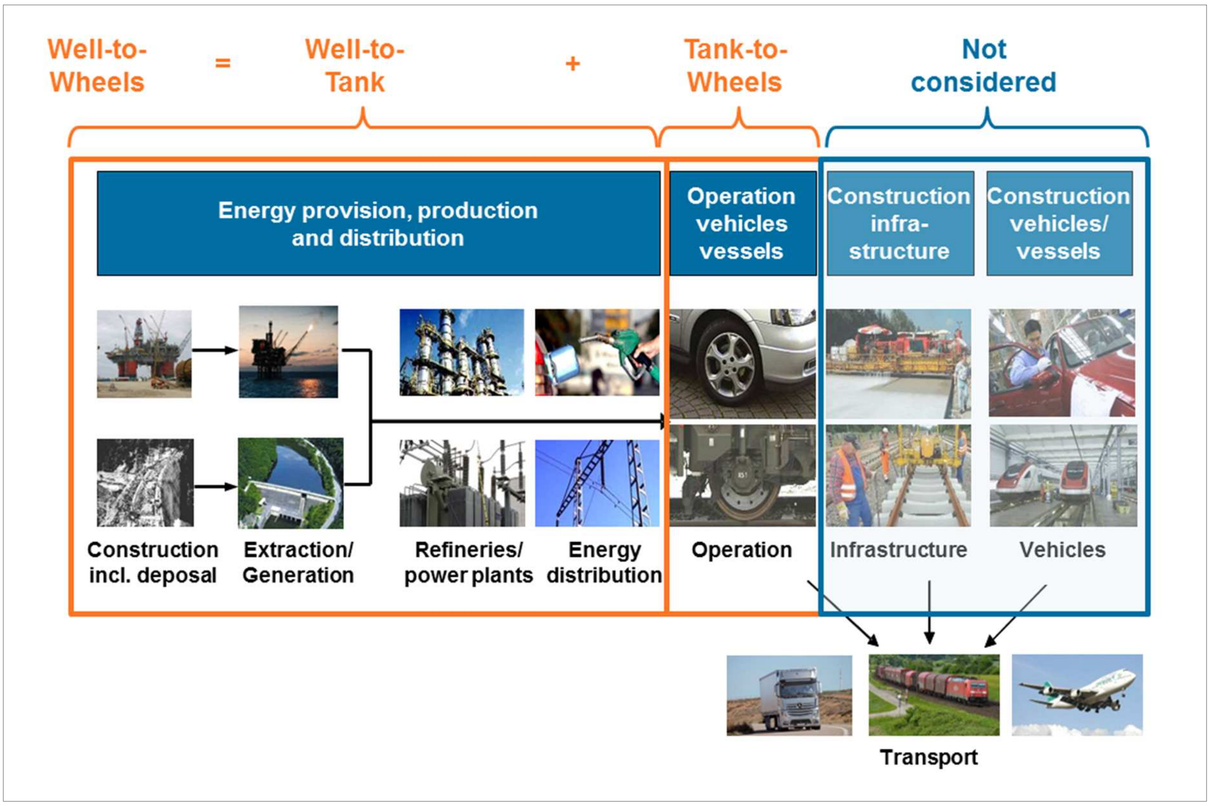
3.3 System boundaries of processes

In ETW, only environmental impacts linked to the operation of vehicles and to fuel or energy production are considered. Therefore, the following **are not included**:

- The production and maintenance of vehicles;
- The construction and maintenance of transport infrastructure;
- Additional resource consumption like administration buildings, stations, airports, etc...

All emissions directly caused by **the operation** 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 3 System boundaries of processes /own figure adapted from SBB/



In ETW, two process steps and the sum of both are distinguished:

- **Final energy consumption** and **vehicle emissions** (= operation; **Tank-to-Wheels/TTW**),
- **Upstream energy consumption** and **upstream emissions** (= energy provision, production and distribution; **Well-to-Tank/WTT**),
- **Total energy consumption** and **total emissions**: Sum of operation and upstream figures (**Well-to-Wheels/WTW**).

The new European standard EN 16258 requires the calculation and declaration of energy consumption and GHG emissions of transport services on TTW as well as WTW basis. ETW provides both figures for energy consumption and GHG emissions. In this context attention should be paid to fact that WTW energy consumption is also very often referred to as primary energy consumption, TTW energy consumption as final energy consumption.

3.4 Transport modes and propulsion systems

Transportation of freight is performed by different transport modes. Within ETW, the most important modes using common vehicle types and propulsion systems are considered.

They are listed in the following table.

Table 2 Transport modes, vehicles and propulsion systems

Transport mode	Vehicles/Vessels	Propulsion energy
Road	Road transport with single trucks and truck trailers/articulated trucks (different types)	Diesel fuel
Rail	Rail transport with trains of different total gross tonne weight	Electricity and diesel fuel
Inland waterways	Inland ships (different types)	Diesel fuel
Sea	Ocean-going sea ships (different types) and ferries	Heavy fuel oil (HFO) / marine diesel oil (MDO) / marine gas oil (MGO)
Aircraft transport	Air planes (different types)	Kerosene

3.5 Spatial differentiation

In ETW worldwide transports are considered. Therefore, environmental impacts of transport can vary from country to country due to country-specific regulations, energy conversion systems (e.g. energy carrier for electricity production), traffic infrastructure (e.g. share of motorways and electric rail tracks) and topography.

Special conditions are also relevant for international transports by sea ships. Therefore a spatial differentiation is necessary. For sea transport, a distinction is made for different trade lanes and areas (Sulphur Emission Control Areas/SECA). On the contrary, for aircraft transport, the conditions relevant for the environmental impact assessments are similar all over the world.

Road and rail

For road and rail transport, ETW distinguishes between Europe and other countries. In this version of ETW, it was not possible to find accurate values for the transport systems of each country worldwide. For this reason, we defined seven world regions and within each region, we identified the most important countries with high transport performance and considered each one individually. For all other countries within a region, we defined default values, normally derived from an important country of this region. In further versions, the differentiation can be refined without changing the basic structure of the model. The following table shows the regions and countries used.

Table 3 Differentiation of regions and countries for road and rail transport

ID	Region	Country	Code	ID	Region	Country	Code
101	Africa	default	afr	514	Europe	Iceland	IS
102	Africa	South Africa	ZA	515	Europe	Ireland	IE
201	Asia and Pacific	default	asp	516	Europe	Israel	IL
202	Asia and Pacific	China	CN	517	Europe	Italy	IT
203	Asia and Pacific	Hong Kong	HK	518	Europe	Latvia	LV
204	Asia and Pacific	India	IN	519	Europe	Lithuania	LT
205	Asia and Pacific	Japan	JP	520	Europe	Luxembourg	LU
206	Asia and Pacific	South Korea	KR	521	Europe	Malta	MT
301	Australia	default	aus	522	Europe	Netherlands	NL
302	Australia	Australia	AU	523	Europe	Norway	NO
401	Central and South America	default	csa	524	Europe	Poland	PL
402	Central and South America	Brazil	BR	525	Europe	Portugal	PT
501	Europe	default	eur	526	Europe	Romania	RO
502	Europe	Austria	AT	527	Europe	Slovakia	SK
503	Europe	Belgium	BE	528	Europe	Slovenia	SI
504	Europe	Bulgaria	BG	529	Europe	Spain	ES
505	Europe	Cyprus	CY	530	Europe	Sweden	SE
506	Europe	Czech Republic	CZ	531	Europe	Switzerland	CH
507	Europe	Denmark	DK	532	Europe	Turkey	TR
508	Europe	Estonia	EE	533	Europe	United Kingdom	GB
509	Europe	Finland	FI	601	North America	default	nam
510	Europe	France	FR	602	North America	United States	US
511	Europe	Germany	DE	701	Russia and FSU	default	rfs
512	Europe	Greece	GR	702	Russia and FSU	Russian Federation	RU
513	Europe	Hungary	HU				

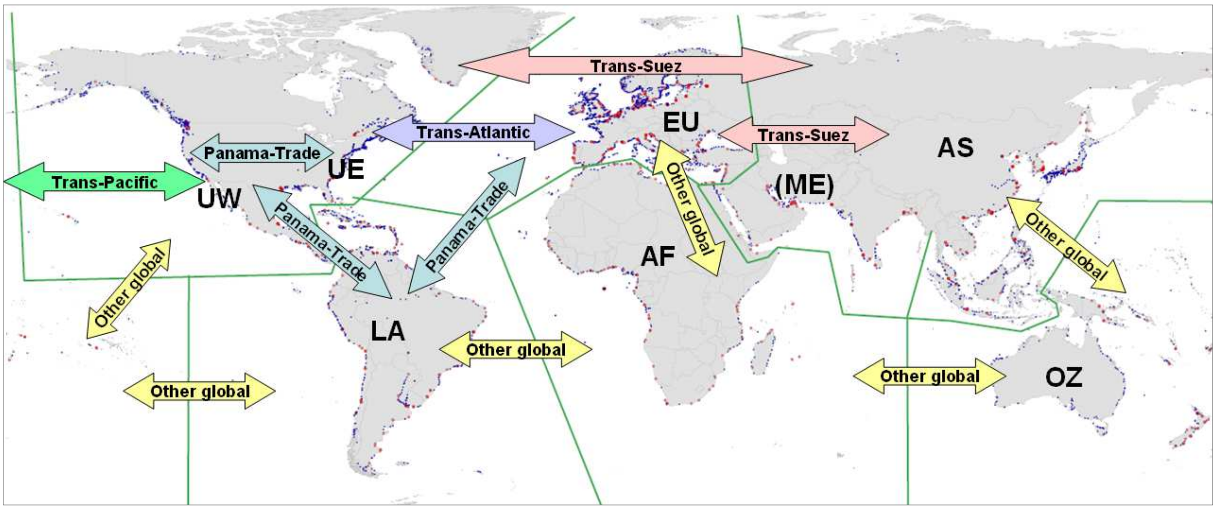
Significant influencing factors are the types of vehicles used, the type of energy, the share of biofuel blends and the conversion factors used. Wide variations result particularly from the national mix of electricity production.

Differences may 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 ETW, it was not possible to determine specific values for railway transport for each country. Therefore, a country specific differentiation of the specific energy consumption of cargo trains was not carried out.

Sea and inland ship

For ocean-going vessels, a different approach was taken because of the international nature of their activity. The emissions for sea ships were derived from the Third IMO Greenhouse Gas Study /IMO 2015/. For each intercontinental (e.g. North America to Europe) or major inter-regional (North-America to South-America) trade lane the common size of deployed ships was analysed, using schedules from ocean carriers. The trade lane-specific emission factors were aggregated from IMO ship types and size classes using the trade lane-specific vessel sizes. Figure 3 shows the connected world regions and the definition of ETW marine trade lanes. The regions considered include UW – North America / West coast, UE – North America / East Coast, LA – South America, EU – Europe, AF – Africa, AS – Asia and OZ – Oceania.

Figure 4: ETW division of the world oceans and definition of major trade lanes.



For inland ships, three ship types are differentiated that are used by default on a given CEMT river class /CEMT 1992/. European rivers are categorized in three size classes (CEMT classes I-IV, class V, and class VI and above) and vessels are allocated to classes according to their ability to navigate specific rivers. For waterways outside Europe, the CEMT classification is not available. Class V is therefore used per default outside Europe.

Overview of country and mode specific parameters

The following table summarizes all countries/regions and mode-specific parameter. For aircraft only, mode specific parameters are considered.

Table 4 Parameter characterisation

	Country/region specific parameter	Mode specific parameter
Road	Fuel specifications: - Sulphur content - Share biofuels Emission regulation Topography Available vehicles Default vehicles for long-distance/feeder	Truck types: - Final energy consumption - Emission factors (TTW): NOx, NMHC, PM
Rail	Fuel specifications: - Sulphur content - Share biofuels Energy and emission factors of upstream process Topography type depending energy consumption Available train types Default vehicles for long-distance/feeder Diesel tracks	Train type, weight and energy type: Final energy consumption (functions) Emission factors for diesel traction (TTW): NOx, NMHC, PM
Inland Ship	Fuel specifications: - Sulphur content - Share biofuels CEMT waterway class determines: - default ship type and thus emission factors in port and on-river - Optional ship types depending on waterway capacity Origin/destination determines default emission standard in Standard input mode	Ship type Cargo type (container/bulk) Emission standard Final energy consumption Emission factors (TTW) NOx, NMHC, PM
Sea Ship	Origin and destination determine the route and thus: - Distance within/outside Emission Control Area (ECA) determines fuel type (HFO/MDO) and respective set of emission factors at sea - Origin/destination port location (within ECA, or subject to other regulation/incentive) determines fuel type (HFO/MDO) and respective set of emission factors in port Choice of trade lane determines aggregated emission factors at sea (based on the distribution of ship sizes on the respective trade lane)	Chosen vessel type (liquid/dry bulk, container, general cargo, RoRo) and size class, determines emission factors at sea Speed adjustment option Final energy consumption (TTW) Emission factors (TTW): NOx, NMHC, PM
Aircraft	-	Aircraft type: - Final energy consumption (TTW) - Emission factors (TTW): NOx, NMHC, PM - Design range
	Fuel dependent values	
All Modes	Energy conversion factors (WTT and TTW) from EN 16258 CO2e-conversion factors (WTT and TTW) from EN 16258 CO2-conversion factors (WTT and TTW) compatible with EN 16258 Upstream emission factors (WTT) for fuels see chapter 6.6.1: NOx, NMHC, PM Upstream energy and emission factors (WTT) for electricity production from national electricity production mixes (see chapter 6.6.2): CO_2, CO_2e, NOx, NMHC, PM	

4 Basic definitions and calculation rules

This chapter gives an overview of basic definitions, assumptions and calculation rules for freight transport used in ETW. The focus will be on the common rules for all transport modes and the basic differences between them. Detailed data and special rules for each transport mode are described in chapter 6. In general, the calculation rules and methodologies used by ETW are in accordance with the European standard EN 16258.

4.1 Main factors of influence on energy and emissions of freight transport

The energy consumption and emissions of freight transport depends on various factors. Each transport mode has special properties and physical conditions. The following aspects are of general importance for all modes of transport:

- Vehicle/vessel type (e.g. ship type, freight or passenger aircraft), size and weight, payload capacity, motor concept, energy, transmission,
- Capacity utilisation (load factor, empty trips),
- Cargo specification (mass limited, volume-limited, general cargo, pallets, container),
- Driving conditions: number of stops, speed, acceleration, air/water resistance,
- Traffic route: road category, rail or waterway class, curves, gradient, flight distance,
- Total weight of freight and
- Transport distance.

In ETW, parameters with high influence on energy consumption and emissions can be changed in the extended input mode by the user. Some other parameters (particularly the transport distance) are selected by the routing system. All other parameters, which are either less important or cannot be quantified easily (e.g. weather conditions, traffic density and traffic jam, number of stops) are included in the average environmental key figures. The following table gives an overview on the relevant parameters and their handling (standard input mode, extended input mode, routing).

Independent of the possibility that user can change values ETW includes so called standard values or default values for all parameters. The default values used by ETW will be presented in the next chapters. All default values are chosen in such a way, that they are in line with the European standard EN 16258. Or in other words: If users calculate energy consumption and CO_2e emissions based on default values included in ETW the results fulfil always the requirements of EN 16258.

Table 5 Classification and mode (standard, extended, routing) of main influence factors on energy consumption and emissions in ETW

Sector	Parameter	Road	Rail	Sea ship	Inland Ship	Aircraft
Vehicle, Vessel	Type, size, payload capacity	E	E	E	E	E
	Drive, energy	A	E	A	A	A
	Technical and emission standard	E	A	A	E	A
Traffic route	Road category, waterway class	R			R	
	Gradient, water/wind resistance	A	A	A	A	A
Driving Conditions	Speed	A	A	E	A	A
	No. of stops, acceleration	A	A	A	A	A
	Length of LTO/cruise cycle					R
Transport Logistic	Load factor	E	E	E	E	E
	Empty trips	E	E	E	E	E
	Cargo specification	S	S	S	S	S
	Intermodal transfer	E	E	E	E	E
	Trade-lane specific vessels			R		
Transport Work	Cargo mass	S	S	S	S	S
	Distance travelled	R	R	R	R	R

Remarks:
A = included in average figures,
S = selection of different categories or values possible in the standard input mode,
E = selection of different categories or values possible in the extended input mode,
R = selection by routing algorithm,
empty = not relevant

4.2 Logistics parameters

Vehicle size, payload capacity and capacity utilisation are the most important parameters for the environmental impact of freight transports, which quantify the relationship between the freight transport and the vehicles/vessels used for the transport. Therefore, ETW gives the possibility to adjust these figures in the extended input mode for the transport service selected.

Each 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 for example coal, ore, oil or some chemical products. Typical products with volume as the limiting factor are vehicle parts, clothes and consumer articles. Volume freight normally has a specific weight on the order of 200 kg/m^3 and below /Van de Reyd and Wouters 2005/. It is evident that volume goods need more transport vessels and in consequence more wagons for rail transport, more trucks for road transport or more container space for all modes. Therefore, more vehicle weight per tonne of cargo has to be transported and more energy will be consumed. At the same time, higher cargo weights on trucks and rail lead to increased fuel consumption.

Marine container vessels behave slightly differently with regard to cargo weight and fuel burnt. The vessels' final energy consumption and emissions are influenced significantly

less by the weight of the cargo in containers due to other more relevant factors, such as physical resistance factors and the uptake of ballast water for safe travelling. The emissions of container vessels are calculated on the basis of transported containers, expressed in twenty-foot equivalent units (TEU). Nonetheless the cargo specification is important for intermodal on- and off-carriage as well as for the case where users want to calculate gram per tonne-kilometre performance figures.

4.2.1 Definition of payload capacity

In ETW payload capacity is defined as mass related parameter.

Payload capacity [tonnes] = maximum mass of freight allowed

For marine container vessels capacity is defined as number of TEU:

TEU capacity [TEU] = maximum number of containers allowed in TEU

This definition is used in the calculation procedure in ETW, however it is not visible because the TEU-based results are converted into tonnes of freight (see also chapter 4.2.2):

Conditions for the determination of payload capacity are different for each transport mode, as explained in the following clauses:

Truck

The payload capacity of a truck is limited by the maximum vehicle weight allowed. Thus the payload capacity is the difference between maximum vehicle weight allowed and empty weight of vehicle (including equipment, fuel, driver, etc.). In ETW, trucks are defined for five total weight classes. For each class an average value for empty weight and payload capacity is defined.

Train

The limiting factor for payload capacity of a freight train is the axle load limit of a railway line. International railway lines normally are dimensioned for more than 20 tonnes per axle (e.g. railway class D: 22.5 tonnes). Therefore, the payload capacity of a freight wagon has to be stated as convention.

In railway freight transport a high variety of wagons are used with different sizes, for different cargo types and logistic activities. However, the most important influence factor for energy consumption and emissions is the relationship between payload and total weight of the wagon (see chapter 4.2.2). In ETW a typical average wagon is defined based on wagon class UIC 571-2 (ordinary class, four axles, type 1, short, empty weight 23 tonnes, /Carstens 2000/). The payload capacity of 61 tonnes was defined by railway experts of the EcoTransIT World Initiative (EWI). The resulting maximum total wagon weight is 84 tonnes and the maximum axle weight 21 tonnes. It is assumed that this wagon can be used on all railway lines worldwide. In ETW the standard railway wagon is used for the general train types (light, average, large, extra-large and heavy).

For dedicated freight transports (cars, containers, several solid bulks and liquids) special wagon types are used. Empty weight and payload capacity for these wagon types come from transport statistics of major railway companies /DB Schenker 2012, SNCF Geodis 2012/. In ETW average values for these special wagon types are used.

All values for empty weight and payload capacity of wagon types used in ETW are given in Table 7.

Ocean going vessels and inland vessels

The payload capacity for bulk, general cargo and other non-container vessels is expressed in dead weight tonnage (DWT). Dead weight tonnage (DWT) is the measurement of the vessel's carrying capacity. The DWT includes cargo, fuel, fresh and ballast water, passengers and crew. Because the cargo load dominates the DWT of freight vessels, the inclusion of fuel, fresh water and crew can be ignored. Different DWT values are based on different draught definitions of a ship. The most commonly used and usually chosen if nothing else is indicated is the DWT at scantling draught of a vessel, which represents the summer freeboard draught for seawater /MAN 2006/, which is chosen for ETW. For container vessels the DWT is converted to the carrying capacities of container-units, expressed as twenty-foot equivalent (TEU).

Aircraft

The payload capacity of airplanes is limited by the maximum zero fuel weight (MZFW). Hence the payload capacity is the difference between MZFW and the operating empty weight of aircrafts (including kerosene). Typical payload capacities of freighters are approximately from 13 tonnes (for small aircrafts) up to 130 tonnes (for large aircrafts). Only a few very small freighters provide a capacity lower than 10 tonnes (e.g. Cessna 208b Freighter, ATR 42-300F, ATR 72-200F). Passenger airplanes have a limited payload capacity for freight approximately between 1-2 tonnes (for medium aircrafts) and 23 tonnes (for large aircrafts such as the Boeing 777). Small passenger aircrafts have partially only a payload capacity for belly freight of 100 kg. For more details, see chapter 6.5.

Freight in Container

ETW allows the calculation of energy consumption and emissions for container transport in the extended input mode. Emissions of container vessels are calculated on the basis of the number of containers-spaces occupied on the vessel, expressed in "Number of TEUs" (Twenty Foot Equivalent Unit). To achieve compatibility with the other modes, the net-weight of the cargo in containers is considered as capacity utilisation of containerized transport (see 4.2.2).

Containers come in different lengths, most common are 20' (= 1 TEU) and 40' containers (= 2 TEU's), but 45', 48' and even 53' containers are used for transport purposes. The following table provides the basic dimensions for the 20' and 40' ISO containers.

Table 6: Dimensions of the standard 20' and 40' container.

	L*W*H [m]	Volume [m³]	Empty weight	Payload capacity	Total weight
20' = 1 TEU	6.058*2.438*2.591	33.2	2,250 kg	21,750 kg	24,000 kg
40' = 2 TEU	12.192*2.438*2.591	67.7	3,780 kg	26,700 kg	30,480 kg
Source: GDV 2010					

The empty weight per TEU is for an average closed steel container between 1.89 t (40' container) and 2.25 t (20' container). The maximum payload lies between 13.35 t per TEU (40' container) and 21.75 t per TEU (20' container). Special containers, for example for carrying liquids or open containers may differ from those standard weights.

Payload capacity for selected vehicles and vessels

In the extended input mode, a particular vehicle and vessel size class and type may be chosen. For land-based transports the size classes are based on commonly used vehicles. For air transport the payload capacity depends on type of chosen aircraft. For marine vessels the size classes were chosen according to common definitions for bulk carriers (e.g. Handysize). For a better understanding, container vessels were also labelled e.g. "handysize-like."

The following table shows key figures for empty weight, payload and TEU capacity of different vessel types used in ETW. For marine vessels, it lists the vessel types and classes as well as the range of empty weight, maximum DWT and container capacities of those classes. The emission factors were developed by building weighted averages from the list of individual sample vessels. Inland vessel emission factors were built by aggregating the size of ships typically found on rivers of class IV to VI.

Table 7 Empty weight and payload capacity of selected transport vessels

Vehicle/ vessel	Vehicle/vessel type	Empty weight [tonnes]	Payload capacity [tonnes]	TEU capacity [TEU]	Max. total weight [tonnes]
Truck	<=7.5 tonnes	4	3.5	-	7.5
	>7.5-12 tonnes	6	6	-	12
	>-12-20 tonnes	7.5	11	-	20
	>20-26 tonnes	9	17	1	26
	>26-40 tonnes	14	26	2	40
	>40-60 tonnes	19	41	2	60
Train	Standard wagon *	23	61	-	84
	Car wagon **	28	21 (10 cars)	-	59
	Chemistry wagon **	24	55	-	79
	Container wagon **	21	65	2,6	86
	Coal and steel wagon **	26	65	-	91
	Building material wagon **	22	54	-	76
	Manufactured product wagon **	23	54	-	77
	Cereals wagon**	20	63	-	83
Sea Ship	General cargo	<850	<5,000	<300	
	Feeder ***	840-3,090	5000-14,999	300-999	
	Handysize-like ***	2,500-7,200	15,000-34,999	1,000-1,999	
	Handymax-like ***	5,800-12,400	35,000-59,999	2,000-3,499	
	Panamax-like ***	10,000-16,500	60,000-79,999	3,500-4,699	
	Aframax-like ***	13,300-24,700	80,000-119,999	4,700-6,999	
	Suezmax-like ***	20,000-41,200	120,000-199,999	>7,000	
	VLCC (liquid bulk only)	33,300-53,300	200,000-319,999		
	ULCC (liquid bulk only)	53,300-91,700	320,000-550,000		
Inland Ship	Neo K (class IV)	110	650		
	Europe-ship (class IV)	230	1,350		
	RoRo (class Va)	420	2,500	200	
	Tankship (class Va)	500	3,000		
	JOWI ship (class VIa)	920	5,500		
	Push Convoy	1,500	9,000		
Aircraft (only Freighter)	Boeing 737-300SF	43.6	19.7	-	63.3
	Boeing 767-300F	86.5	53.7	-	140.2
	Boeing 747-400F	164.1	113.0	-	276.7
	Boeing 777-200F	156.2	102.9		347.5
	Airbus A330-200F	109.0	65.0		233.0

Remarks: Max. total weight for Ship = DWT (Dead Weight Tonnage), for Aircraft: Empty weight includes fuel; Max. total weight = Take-off weight.
*type specific values, used for general train type
**average values from transport statistics
***Seagoing vessels are either bulk carriers with payload capacity in tonnes or container vessels with payload capacity in TEU. The nomenclature such as “Handysize” is usually only used for bulk carriers

4.2.2 Definition of capacity utilisation

In ETW the capacity utilisation is defined as the ratio between freight mass transported (including empty trips) and payload capacity. Elements of the definition are:

Abbr.	Definition/Formula	Unit
M	Mass of freight	[net tonne]
CP	Payload capacity	[tonnes]
LF_{NC}	Load Factor: mass of weight / payload capacity $LF_{NC} = M / CP$	[net tonnes/tonne capacity]; [%]
ET	Empty trip factor: Additional related to loaded distance allocated to the transport. ET = Distance empty / Distance loaded	[km empty/km loaded], [%]

With these definitions capacity utilisation can be expressed with the following formula:

Abbr.	Definition/Formula	Unit
CU_{NC}	Capacity utilisation = Load factor / (1 + empty trip factor) $CU_{NC} = LF_{NC} / (1+ET)$	[%]

Capacity utilisation for trains

For railway transport, there is often no statistically available figure for the load factor. Normally railway companies report net tonne kilometre and gross tonne kilometre. Thus, the ratio between net tonne kilometre and gross tonne kilometre is the key figure for the capacity utilisation of trains. In ETW, capacity utilisation is needed as an input. For energy and emission calculations, capacity utilisation is transformed to net-gross-relation according the following rules:

Abbr.	Definition	Unit
EW	Empty weight of wagon	[tonne]
CP	Payload capacity	[tonnes]
CU_{NC}	Capacity utilisation	[%]
Abbr.	**Formula**	
CU_{NG}	Net-gross relation = capacity utilisation / (capacity utilisation + empty wagon weight / mass capacity wagon). $CU_{NG} = CU_{NC}/(CU_{NC} + EW/CP)$	[net tonnes/gross tonnes]

In ETW, empty wagon weight and payload capacity of rail wagons are defined for different wagon types. These values are used (see chapter 4.2.1, Table 7).

4.2.3 Capacity Utilisation for specific cargo types and transport modes

The former chapter described capacity utilisation as an important parameter for energy and emission calculations. But in reality, capacity utilisation is often unknown. Some possible reasons for this include:

- Transport is carried out by a subcontractor, thus data is not available

- Number of empty kilometres, which has to be allocated to the transport is not clear or known
- Number of TEU is known but not the payload per TEU (or inverse)

For this reason, in ETW three types of cargo are defined for selection, if no specific information about the capacity utilisation is known:

- Bulk goods (e.g. coal, ore, oil, fertilizer etc.)
- Average goods: statistically determined average value for all transports of a given carrier in a reference year
- Volume goods (e.g. industrial parts, consumer goods such as furniture, clothes, etc.)

The following table shows some typical load factors for different types of cargo.

Table 8 Load factors for different types of cargo

Type of cargo	Example for cargo	Load factor [net tonnes / capacity tonnes]	Net-gross-relation [net tonnes / gross tonnes]
Bulk	hard coal, ore, oil	100%	0.72
	waste	100%	0.72
	bananas	100%	0.72
Volume	passenger cars	30%	0.44
	vehicle parts	25-80%	0.40-0.68
	seat furniture	50%	0.57
	clothes	20%	0.35
Remarks: Special transport examples, without empty trips Source: Mobilitäts-Bilanz /ifeu 1999/			

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

Bulk (heavy): 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, requires the return transport of empty wagons or vessels. 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.

Average and Volume (light): For average and volume goods, the load factor with regard to the actual transport trip varies sharply. Due to the diversity of goods, a typical value cannot be determined. Therefore, default values must be defined to represent the transport of average and volume goods. For the empty trip factor of average and volume goods it can be assumed that they 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.

Capacity utilisation of containerized sea and intermodal transport: For containerized sea transport the basis for calculating emissions is the number of container spaces occupied on a vessel. The second important information then is the net-weight of the cargo carried in one container. The bulk, average and volume goods have been translated into freight loads of one TEU. The net weight of a fully loaded container reaches at maximum 16.1 tonnes per TEU, corresponding to 100 % load. In accordance with the Clean Cargo Working Group (CCWG) the net weight of average goods is defined at 10.0 tonnes per TEU [CCWG 2014]. It is assumed that the net weights of volume and bulk goods are 6.0 respectively 14.5 tonnes per TEU. For intermodal transport – the continuing of transport on land-based vehicles in containers – the weight of the container is added to the net weight of the cargo. Table 9 provides the values used in ETW as well as the formula for calculating cargo loads in containers. For more details, see appendix chapter 0.

Table 9 Weight of TEU for different types of cargo

	Container [tonnes /TEU]	Net weight ([tonnes/TEU]	Total weight [tonnes/TEU]
Bulk	2.00	14.50	16.50
Average	1.95	10.00	11.95
Volume	1.90	6.00	7.90
Sources: CCWG 2014; assumptions ETW.			

Capacity utilisation of road and rail transport for different cargo types

The average load factor in long distance road transport with heavy trucks was about 55 % in Germany in 2013 /KBA 2013/ and 58% in 2001 /KBA 2002/. These values also include empty vehicle-km. The share of additional empty vehicle-km in road traffic was about 11 % in 2013 and 17 % in 2001). The average load for all trips (loaded and empty) was about 50 % in 2013 and 2001. The share of empty vehicle-km in France was similar to Germany in 1996 (/Kessel und Partner 1998/).

The load factor for the “average cargo” of different railway companies are in a range of about 0.5 net-tonnes per gross-tonne /Railway companies 2002a/. For dedicated freight transports the value range between 0.3 and 0.66 net-tonnes per gross-tonne /DB Schenker 2012, SNCF Geodis 2012/. According to /Kessel und Partner 1998/ Deutsche Bahn AG (DB AG) the 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 specialized rail: cars. The share of additional empty trips for dedicated trains ranges from 20 % to 100 % (see Table 10).

ifeu calculations have been carried out for a specific train configuration, based on the assumption of an average load factor of 0.5 net-tonnes per gross tonne. 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 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 is 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 road and rail transport. The empty trip factor is estimated to be 10 % for road transport and 20 % for rail transport.

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.

For railway transport of dedicated cargo average load factors and empty trip factors come from transport statistics of major railway companies /DB Schenker 2012, SNCF Geodis 2012/.

All assumptions and average values used in ETW as default are summarized in Table 10.

Table 10 Capacity utilisation of road and rail transport for different types of cargo

	Load factor LF_{NC}	Empty trip factor ET	Capacity utilisation CU_{NC}	Relation Nt/Gt CU_{NG}
Train wagon General cargo				
Bulk	100%	80%	56%	0.60
Average	60%	50%	40%	0.52
Volume	30%	20%	25%	0.40
Dedicated cargo				
Car	85 %	50 %	57 %	0,30
Chemistry	100 %	100 %	50 %	0,53
Container	50 %	20 %	41 %	0,56
Coal and steel	100 %	100 %	50 %	0,56
Building materials	100 %	100 %	50 %	0,55
Manufactured products	75 %	60 %	47 %	0,52
Cereals	100 %	60 %	63 %	0,66
Truck				
Bulk	100%	60%	63%	
Average	60%	20%	50%	
Volume	30%	10%	27%	
Source: DB Cargo, SNCF Geodis, ifeu estimations				

Capacity utilisation for container transport on road and rail

ETW enables the possibility to define a value for t/TEU. At the website this value is active if a container transport (freight unit TEU) is selected. In this case the load factor for trucks and trains will be calculated automatically.

The corresponding **formula for the truck** is

$$LF_{Truck} = (Container_{brutto} * Container\ amount_{vehicle}) / payload\ capacity_{truck}$$

The gross weight of a container is the sum of net weight [t/TEU] and the container weight itself (compare Table 9). The maximum payload of a truck is declared within Table 7.

At trains the load factor will only be calculated for container trains. The corresponding **formula for the trains** is

$$LF_{Container\ Train} = (Container_{brutto} * Container\ amount_{wagon}) / payload\ capacity_{container\ wagon}$$

The gross weight of a container is the sum of net weight [t/TEU] and the container weight itself (compare Table 9). The payload capacity [tonnes] of a container wagon is declared within Table 7.

Capacity utilisation of ocean-going vessels for different cargo types

Capacity utilisation for sea transport is differentiated per vessel type. Most significantly is the differentiation between bulk vessels and container vessels, which operate in scheduled services. The operational cycle of both transport services lead to specific vessel utilisation factors. Furthermore, the vessel load factor and the empty trip factor have been combined to the vessel capacity factor for reasons to avoid common mistakes. It is assumed that performance of ocean-going vessels sailing under laden conditions (when carrying cargo) and ballast conditions (when empty) are relatively similar. The cargo weight of ocean-going vessels only influences the energy consumption to a minor extend, in particular compared to other modes of transport. Reasons are the need to reach a certain draft for safety reasons, which is adjusted by taking up or discharging ballast water and the dominance of other factors that determine the vessels' fuel consumption, namely wave and wind resistance. Wave resistance exponentially increases with speed, which makes speed as one of the most important parameters. While for bulk carriers the difference between laden and ballast conditions might be recognisable, it should be acknowledged that container carriers carry cargo in all directions and always perform with both cargo and ballast water loaded. For container vessels the nominal TEU capacity (maximum number of TEU units on-board) is considered the full load.

The combined vessel utilisation for bulk and general cargo vessels is assumed to be between 48 % and 61 % and follows the IMO assumptions /IMO 2009/. Bulk cargo vessels usually operate in single trades, meaning from port to port. In broad terms, one leg is full whereas the following leg is empty in normal cases. However, cycles can be multiangular and sometimes opportunities to carry cargo in both directions may exist. The utilisation factors are listed in Table 11.

Table 11 Capacity utilisation of sea transport for different types of ships

Vessel types	Trade lane / size class	Capacity utilisation factor
BC (dry, liquid and GC)	Suez trade	49%
	Transatlantic trade	55%
	Transpacific trade	53%
	Panama trade	55%
	Other global trade	56%
	Intra-continental trade	57%
	Great lake	58%
Bulk carrier dry	Feeder (5,000 - 15,000 dwt)	60%
	Handysize (15,000 - 35,000 dwt)	56%
	Handymax (35'000 - 60,000 dwt)	55%
	Panamax (60,000 - 80,000 dwt)	55%
	Aframax (80'000 - 120,000 dwt)	55%
	Suezmax (120,000 - 200,000 dwt)	50%
Bulk carrier liquid	Feeder (5,000 - 15,000 dwt)	52%
	Handysize (15,000 - 35,000 dwt)	61%
	Handymax (35'000 - 60,000 dwt)	59%
	Panamax (60,000 - 80,000 dwt)	53%
	Aframax (80'000 - 120,000 dwt)	49%
	Suezmax (120,000 - 200,000 dwt)	48%
	VLOC(+) (>200,000 dwt)	48%
General cargo (GC)	All trades, all size classes	60%
Container vessel (CC)	All trades, all size classes	70%
RoRo vessels	All trades, all size classes	70%
Ferries (RoPax vessels)	All ferry routes	64%

Note: BC = bulk carrier, GC = general cargo, CC = container cargo vessel.
Sources: IMO 2009; Seum 2010; Scandria 2012; CCWG 2014

Ships in liner service (i.e. container vessels and car carriers) usually call at multiple ports in the sourcing region and then multiple ports in the destination region (see Figure 5). It is also common that the route is chosen to optimize the cargo space utilisation according to the import and export flows. For example, on the US West Coast a particular pattern exists where vessels from Asia generally have their first call at the ports of Los Angeles or Long Beach to unload import consumer goods and then travel relatively empty up the Western Coast to the Ports of Oakland and other ports, from which then major food exports leave the United States. Combined utilisation factors for container vessels (net load of container spaces on vessels and empty returns) used in ETW is 70% independent of vehicle sizes and trade lanes (see Table 11). This figure equates to the utilisation factor for container ships used by the Second IMO GHG Study 2009 /IMO 2009/. The Clean Cargo Working Group recommends alike to use this value to recalculate their CO_2 emission values of the container ships considering real utilisation factors /CCWG 2014/.

Figure 5: Sample Asia North America Trade Lane by Hapag Lloyd AG[2]

Capacity utilisation of inland vessels for different cargo types

The methodological approach to inland vessels is in line with the approach for calculating ocean-going vessels. The cargo load factor and the empty trip factor are also combined to a vessel utilisation factor.

The dominant cargo with inland vessels is bulk cargo, although the transport of containerized cargo has been increasing. For bulk cargo on inland vessels, the principle needed to reposition the inland vessel applies. Thus, empty return trips of around 50 % of the time can be assumed. However, no good data is available from the industry. Therefore, it was assumed that the vessel utilisation is 45 % for all bulk inland vessels smaller class VIb (e.g. river Main). Class Va RoRo and class VIb vessels were estimated to have a 60 % vessel utilisation.

Container inland vessels were assumed to have a vessel utilisation of 70 % in analogy with the average container vessel utilisation cited in /IMO 2009/. This reflects less than full loads of containers as well as the better opportunity of container vessels to find carriage for return trips in comparison with bulk inland vessels.

Capacity utilisation of air freight

Since mainly high value volume or perishable goods are shipped by air freight, the permissible maximum weight is limited. Therefore, only the volume goods category is considered; other types of goods (bulk, average) are excluded. Table 12 shows the capacity utilisation differentiated by short, medium and long haul (definition see Table 12) /BEIS 2016; Lufthansa 2014; EUROCONTROL 2013a; ICAO 2012/. Similar to container ships the utilisation factor refers to the whole round trip of the airplane and includes legs with higher and lower load factors as well as empty trips (like ferry flights). The utilisation factors used for airplane by ETW are included in Table 12. The values for freight refer to the maximum weight which can be transported by freighter or

[2] Internet Site from 01/10/2014.

passenger aircraft. The utilisation factors for passenger presented in Table 12 provide information about the seats sold. The latter is used for the allocation of energy consumption and emissions between air cargo and passenger (see chapter 6.5).

Table 12 Capacity utilisation of freight and passenger for aircrafts

	Freight (freighters and passenger aircrafts	**Passenger** (only passenger aircrafts)
Short haul (up to 1,000 km)	50%	65%
Medium haul (1,001 – 3,700 km)	70%	70%
Long haul (more than 3,700 km)	70%	80%
Sources: BEIS 2016; Lufthansa 2014; EUROCONTROL 2013a; ICAO 2013.		

4.3 Basic calculation rules

In ETW the total energy consumption and emissions of each transport mode are calculated for vehicle usage (TTW) and the upstream process (WTT; see chapter 3.3). Thus, several calculation steps are necessary:

1. Final energy consumption (TTW energy consumption) per net tonne-km
2. Energy related vehicle emissions per net tonne km (TTW)
3. Combustion related vehicle emissions per net tonne km (TTW)
4. Energy consumption and emission factors for upstream process per net tonne km (WTT)
5. Total energy consumption and total emissions per transport (WTW)

The following subchapters describe the basic calculation rules for each step. For each transport mode the calculation methodology can differ slightly. More information about special calculation rules and the database are given in Chapter 6.

4.3.1 Final energy consumption per net tonne km (TTW)

The principal **calculation rule** for the calculation of final energy consumption is

Final energy consumption per net tonne km =
* specific energy consumption of vehicle or vessel per km
/ (payload capacity of vehicle or vessel * capacity utilisation of vehicle or vessel)

The corresponding **formula** is

$$ECF_{tkm,i} = ECF_{km,i,} / (CP * CU)$$

Abbr.	Definition	Unit
$ECF_{tkm,i}$	Final energy consumption (TTW) per net tonne km for each energy carrier i	[MJ/tkm]
i	Index for energy carrier (e.g. diesel, electricity, HFO)	
$ECF_{km,i,}$	Final energy consumption of vehicle or vessel per km; normally depends on mass related capacity utilisation	[MJ/km]
CP	Payload capacity	[tonne]
CU	Capacity utilisation	[%]

Explanations:

- Final energy consumption (TTW) is the most important key figure for the calculation of total energy consumption and energy related emissions of transport. For the following calculation steps, final energy consumption must be differentiated for each energy carrier because different sets of emission factors and upstream energy consumption have to be considered for each energy carrier.
- Final energy consumption depends on various factors (see chapter 4.1). In particular, it should be pointed out that e.g. final energy consumption per kilometre for trucks also depends on capacity utilisation and thus the denominator of the formula.
- As mentioned in chapter 3.1, energy consumption values per tkm combine the steps calculation of energy consumption on a vehicle, train, vessels or airplanes basis and allocation of energy consumption to one single shipment. In the European standard EN 16258 these steps are described consecutively. Nevertheless, the steps can be done in an integrated manner. To fulfil the requirements of EN 16258 it is more important that the VOS is defined in accordance with the European standard and considers the entire round-trips including empty runs. ETW fulfils these requirements without exceptions.
- The formula above refers to a typical case, which is usual for trucks (final energy consumption per vehicle km). For other modes, the calculation methodology can be slightly different (see explanations in chapter 6). However, for all modes the same relevant parameters (final energy consumption of vehicle/vessel, payload capacity and capacity utilisation) are needed.

4.3.2 Energy related emissions per net tonne km (TTW)

The principle calculation rule for the calculation of energy related vehicle emissions is

TTW Vehicle emissions per net tonne-km =
specific energy consumption of vehicle or vessel per net tonne km
* energy related vehicle emission factor per energy carrier

The corresponding formula is

$$EMV_{tkm,i} = ECF_{tkm,i,} * EMV_{EC,i}$$

Abbr.	Definition	Unit
$EMV_{tkm,i}$	Vehicle emissions (TTW) per net tonne km for each energy carrier i	[g/tkm]
i	Index for energy carrier (e.g. diesel, electricity, HFO)	
$ECF_{tkm,i}$	Final energy consumption (TTW) per net tonne km for each energy carrier i	[MJ/tkm]
$EMV_{EC,i}$	Energy related vehicle emission factor (TTW) for each energy carrier i	[g/MJ]

Explanations:

- The formula is used for all emission components which are directly correlated to final energy consumption (TTW CO_2 and SO_2 emissions) and for combustion related emissions of fuel driven trains and ships (see chapter 6.2 to 0). The formula is also used for the calculation of standardized TTW energy consumptions in MJ. In this case the energy related energy factors are used (e.g. MJ per litre diesel). To fulfil the requirements of EN 16258 the energy factors of the European standard EN 16258 are used by ETW (see chapter 7.1 in the annex).
- Based on the European standard the CO_2 equivalents are also calculated by multiplication of the TTW energy consumption with energy related TTW emission factors (e.g. kg CO_2e per litre diesel). For this calculation step the emission factors respectively conversion factors of the European standard EN 16258 are used without changes. The used values are documented in chapter 7.1 in the annex).
- The CO_2 emission factors used by ETW (e.g. kg CO2/litre diesel) are based on the same sources like the CO2 equivalent emission factors included in the European standard EN 16258. Therefore, CO2 emission quantifications can't be in accordance with EN 16258 since only CO2 equivalent calculations are required by European standard. Nevertheless, ETW allows the calculation of CO2 emissions based on the same methodology and the same data sources as the European standard EN 16258.

4.3.3 Combustion related emissions per net tonne km (TTW)

The principal **calculation rule** for the calculation of TTW NOx, NMHC and particles emissions (so called combustion related emissions) is

TTW Emissions per net tonne km =
* specific emission factor of vehicle or vessel per km
/ (payload capacity of vehicle or vessel * capacity utilisation of vehicle or vessel)

The corresponding **formula** is

$$EMV_{tkm,i} = EMV_{km,i,} / (CP *CU)$$

Abbr.	Definition	Unit
$EMV_{tkm,i}$	Vehicle emissions consumption (TTW) per net tonne km for each energy carrier i	[g/tkm]
i	Index for energy carrier (e.g. diesel, electricity, HFO)	
$EMV_{km,i,}$	Combustion related vehicle emission factor (TTW) of vehicle or vessel per km; normally depends on mass related capacity utilisation	[g/km]
CP	Payload capacity	[tonne]
CU	Capacity utilisation	[%]

Explanations:

- The formula is used for vehicle/vessel emissions of truck and aircraft operation.
- For rail and ship combustion related emission factors are derived from emissions per engine work, not per vehicle-km. Thus, they are expressed as energy related emission factors and calculated with the formula in chapter □.

4.3.4 Upstream energy consumption and emissions per net tonne km (WTT)

The principle calculation rule for the calculation of vehicle emissions is

WTT Upstream energy consumption or emissions per net tonne-km =
specific energy consumption of vehicle or vessel per net tonne km
* energy related upstream energy or emission factor per energy carrier

The corresponding formulas are

$$EMU_{tkm,i} = ECF_{tkm,i,} * EMU_{EC,I}$$

$$ECU_{tkm,i} = ECF_{tkm,i,} * ECU_{EC,i}$$

Abbr.	Definition	Unit
$EMU_{tkm,i}$	Upstream emissions (WTT) for each energy carrier i	[g/tkm]
$ECU_{tkm,i}$	Upstream energy consumption (WTT) for each energy carrier i	[MJ/tkm]
i	Index for energy carrier (e.g. diesel, electricity, HS)	
$ECF_{tkm,i}$	Final energy consumption (TTW) per net tonne km for each energy carrier i	[MJ/tkm]
$EMU_{EC,i}$	Energy related upstream emission factor (WTT) for each energy carrier i	[g/MJ]
$ECU_{EC,i}$	Energy related upstream energy consumption (WTT) for each energy carrier i	[MJ/MJ]

Explanations:

- Formulas for upstream energy consumption and emissions are equal but have different units.
- Formulas are equal for all transport modes; upstream energy consumption and emission factors used in ETW are explained in chapter 6.6.

- For the calculation of WTT energy and WTT CO_2 equivalent the emission factors of the new European standard are used for ETW. Only for electricity EN 16258 doesn't provide emission factors. Therefore, ETW calculates own emission factors for electricity in accordance to the European standard. The methodology as well as used values is documented in the chapters 6.6 and 7.1.

4.3.5 Total energy consumption and emissions of transport (WTW)

The principal calculation rule for the calculation of vehicle emissions is

WTW energy consumption or emissions per transport =
Transport Distance
* mass of freight transported
* (TTW energy consumption or vehicle emissions per net tonne km
+ WTT energy consumption or emissions per net tonne km)

The corresponding formulas are

$$EMT_i = D_i * M * (EMV_{tkm,i} + EMU_{tkm,i})$$

$$ECT_i = D_i * M * (ECF_{tkm,i} + ECU_{tkm,i})$$

Abbr.	Definition	Unit
EMT_i	WTW emissions of transport	[kg
ECT_i	WTW energy consumption of transport	[MJ]
D_i	Distance of transport performed for each energy carrier i	[km]
M	Mass of freight transported	[net tonne]
$EMV_{tkm,i}$	TTW Vehicle emissions for each energy carrier i	[g/tkm]
$ECF_{tkm,i}$	TTW energy consumption for each energy carrier i	[MJ/tkm]
$EMU_{tkm,i}$	WTT (upstream) emission factors for each energy carrier i	[g/tkm]
$ECU_{tkm,i}$	WTT (upstream) energy consumption for each energy carrier i	[MJ/tkm]
i	Index for energy carrier (e.g. diesel, electricity, HS)	

Explanations:

- Transport distance is a result of the routing algorithm of ETW (see chapter 5).
- WTW energy consumption and emissions also depend on routing (e.g. road categories, electrification of railway line, gradient, distance for airplanes). This correlation is not shown as variable index in the formulas due to better readability.
- Mass of freight is either directly given by the client or recalculated from number of TEU, if TEU is selected as input parameter in the extended input mode of ETW.
- Using the formula described above for the calculation of WTW energy consumption and WTW CO2 equivalent emissions of transport services fulfils the requirements of EN 16258. Therefore, the methodology is in accordance with the European standard.

4.4 Basic allocation rules

ETW is a tool which takes the perspective of a shipper – the owner of a freight that has to be transported – that want to estimate the emissions associated with a particular transport activity or a set of different transport options. Within the European standard EN 16258 the transport activity is also called as **transport service**. But ETW may be also used by carriers – the operators and responsible parties for operating vehicles and vessels – to estimate emissions for example for benchmarking. The calculation follows principles of life cycle assessments (LCA) and carbon footprints.

The major rule is that the shipper (freight owner) and carrier take responsibility for the vessel utilisation factor that is averaged over the entire journey, from the starting point to the destination as well as the return trip or the entire loop respectively. This allocation rule has been common practice for land-based transports in LCA calculations and is applied also to waterborne and airborne freight. Thus, even if a shipper may fill a tanker to its capacity, he also needs to take responsibility for the empty return trip which would not have taken place without the loaded trip in the first place. Therefore, a shipper in this case will have to apply a 50 % average load over the entire return journey. This fundamental ecological principle considered by ETW is also a general requirement from EN 16258. Only by considering the average load factor for the entire journey (as **vehicle operation system** named by the EN 16258) CO_2 calculations fulfil the European standard.

Similarly, other directional and trade-specific deviations, such as higher emissions from head winds (aviation), sea currents (ocean shipping) and from river currents (inland shipping) are omitted. These effects, which are both positive and negative depending on the direction of transport, cancel one another out and the shipper needs to take responsibility for the average emissions. It is the purpose of ETW to provide the possibility of modal comparisons and calculations of transport services consisting of different transport modes. This also requires that all transport modes are equally treated. Thus, average freight utilisation and average emissions without directional deviations are generally considered.

In ETW energy and emissions are calculated for transport services of a certain amount of a homogeneous freight (one special freight type) for a transport relation with one or several legs. For each leg one type of transport vessel or vehicle can be selected. These specifications determine all parameters needed for the calculation:

- **Freight type:** Load factor and empty trip factor (can also be user-defined in the extended input mode)
- **Vehicle/vessel type:** Payload capacity (mass related), final energy consumption and emission factors.
- **Transport relation:** road type, gradient, country/region specific emission factors.

For the calculation algorithm it is not relevant whether the freight occupies a part of a vehicle/vessel or one or several vessels. Energy consumption and emissions are always calculated based on the capacity utilisation of selected freight type and the corresponding specific energy consumption of the vessel. These assumptions avoid the need of different allocation rules for transports with different freight types in the same

vehicle, vessel or train. Therefore, no special allocation rules are needed for road and rail transport. This approach is also in accordance with EN 16258. The European standard requires that the same allocation rules shall be used for the same vehicles.

For passenger ferries and passenger aircrafts with simultaneous passenger and freight transport (belly freight) allocation rules for the differentiation of passenger and freight transport are necessary. These rules are explained in the related chapters. The approaches selected for ETW are also in line with the requirements of the European standard EN 16258.

5 Routing of transports

5.1 General

For the calculation of energy consumption and environmental impacts ETW has to determine the route between origin and destination for each selected traffic type. Therefore, ETW uses a huge GIS database including worldwide locations and networks for streets, railways, aviation, sea and inland waterways.

Figure 6 Networks of ETW

Name	Type	Attributes
Road	Network	Road classes, Ferry, Country code
Railway	Network	Electrification, European freight corridors, Ferry, Country code
Ocean shipping	Network	Cannel, ECA areas
Inland waterways	Network	Water classes, Country code, ECA areas
Air routing	Direct	No network needed, routing on the base of the great circle formula between the airport locations

Figure 7 Locations of ETW

Name	Type	Attributes
City and District names	Location	City name, District name, Country, Location classes, (Translations)
Zip codes	Location	Country code/ Zip code, City name, Country code
Stations (UIC-Codes)	Location	Station name, UIC-Code/ station code, Country code
UN-/Locodes	Location	UN-/Locode, Location name, Country Code, Ports classes, Inland locations
Airports (IATA-Codes)	Location	IATA-Code, Airport name, Country code, Airport classes
Longitude/ Latitude	Location	No location layer or attributes are needed

5.2 Routing with resistances

Depending on the transport type and the individual settings ETW routes the shortest way in consideration of network attributes (resistances). These network attributes are e.g. street classes at the road routing or cannels at the ocean routing. If there is a motorway between the origin and the destination the truck will probably use it on its route according to the principle of "always using the path of lowest resistance" defined within ETW. Technically, a motorway has a much lower resistance (factor 1.0) than a city-street (factor 5). Thus, a route on a highway has to be more than five times as long as a city-street before the local street will be preferred. These resistances are used for almost every transport type.

5.2.1 Road network resistances

The street network is divided into different street categories, which are used for the routing as resistances.

Table 13 Resistance of street categories

Street category	Resistance
Highway (Category 0)	1.0
Large country road (Category 1)	1.3
Small country road (Category 2)	1.5
Large urban road (Category 3)	1.67
Urban road (Category 4)	2.5
Small urban road (Category 5-7)	3.33

Additionally, there are ferry routes within the street network. These ferry routes work like virtual roads where the whole truck is put on the ferry. ETW has different resistances for ferry routes included.

Table 14 Resistance for ferries in the road network

Ferry handling	Resistance
Standard	5.0
Preferred	1.0
Avoid	100.0

5.2.2 Railway network resistances

Railways have the attributes of electrified or diesel line and dedicated freight corridor. If an electrified train is selected, diesel lines can also be used but they get a higher resistance than electrified lines. This is needed if there is no electrified line available or to circumnavigate possible data errors concerning the electrification of the railway net.

The attribute freight corridor is used as a railway highway. Lines with this attribute will be used with preference.

Table 15 Resistance for the railway network

Attribute	Resistance
Freight corridor	1,0
Non-freight corridor	1,8
Diesel tracks at electrified calculation	4,0

Additionally, there are ferry routes within the rail network. These routes work like virtual tracks where the whole train is put on the ferry. ETW has different resistances for ferry routes included.

Table 16

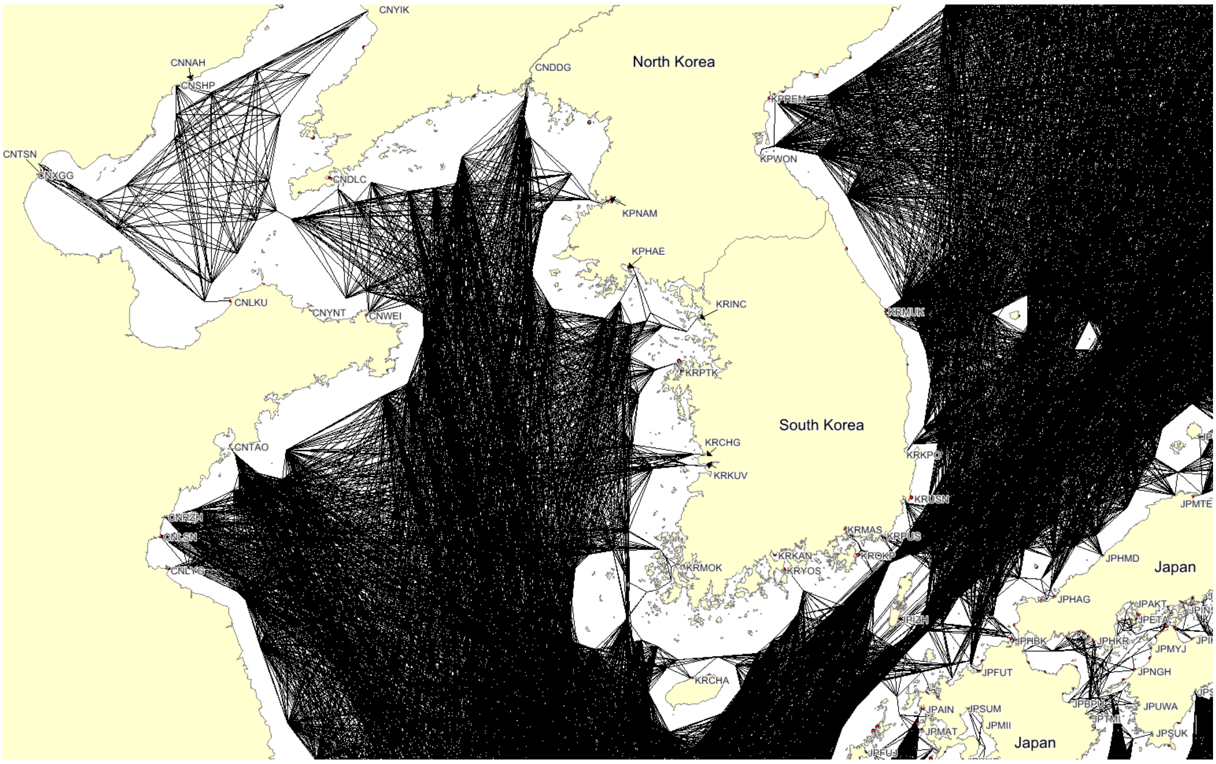
Resistance for ferries in the railway network

Ferry handling	Resistance
Standard	5,0
Preferred	1,0
Obstruct	100,0

5.3 Sea ship routing

A sea ship normally takes the direct and shortest way between two sea-ports[3], harbours, although it often deviates slightly from direct routes due to weather and ocean drift conditions. Therefore, a very large and flexible network is needed. The solution to this is a huge amount of so-called sea nodes, which were placed everywhere in the world close to the coast or around islands. Every sea node is connected with every other sea node as long it does not cross a country side. The result of these connections is a routable sea network.

Figure 8 Sea network area around Korea /IVE mbh 2014/



Canals and certain sea bottlenecks, e.g. the Kattegat strait, are considered as size restricted passages (by draft, length and width) in this network. Every canal and bottleneck

3 Container vessels and car carriers often operate as liner traffic and call at multiple ports on a scheduled route. The routing differs from ocean carrier to ocean carrier and may lead to longer distances between a loading and discharging port. Those schedules are not considered in EcoTransIT World today.

has the attributes of “maximum dead weight tonnes” (DWT) and “maximum TEU capacity” for vessels and is limited to for the classified ship types.

The Suez, Panama and Kiel canals are also included as restricted canals in the ETW sea ship network. Whereas through the Suez Canal even the largest container vessel can pass, the bulk carriers are restricted to 200,000 DWT, which represents the Suez-Max class ships. The Panama-Canal is restricted to bulk carriers up to 80,000 DWT and container carriers up to 4,700 TEU capacity, the Kiel Canal-is restricted to bulk carriers up to 60,000 DWT and container vessels up to 3500 TEU capacity. Additionally, there are small sea areas, like the Kattegat strait between Denmark and Sweden and the entrance to the Great Lakes, next to Montreal, Canada, which are handled as canals and restricted as well (80000 DWT and 4700 TEU for the Kattegat and 60000 DWT and 3500 TEU for the entrance to the Great Lakes).

Ports are considered if they have significant marine traffic. Every port is located and allocated to a specific geographic region (compare Figure 4). On the base of the combination of start and destination location enables the determination of the respective trade lane. For example, on the transatlantic trade, connecting Europe with North America, ETW selects bulk vessels between 35000 and 80000 DWT and container vessels with a TEU capacity of 2000 to 4700 TEU as default ships. If the starting point and destination belong to the same geographic region, an “intra-continental” vessel size is selected. Within Europe an “intra-continental Europe” vessel size is used.

5.3.1 Routing inland waterway ship

The inland waterway network consists an attribute for the inland waterway class. Depending on the ship size and the respective waterway class a waterway can be used or not. Whereas the euro barge can only be used on inland waterways above the class IV (standard European inland waterway), bigger barges need at least waterway class V or higher. Compare also with chapter 6.4.1.

5.4 Aviation routing

In ETW a validation exists if the selected airport is suitable for the flight (compare chapter 5.5). Therefore, all airports are categorized. Depending of the airport category destinations of different distances can be reached.

Table 17 Airport size and reach

Airport size	Reach
Big size	over 5000 km
Middle size	Over 5000 km (but not overseas)
Small size	maximum 5000 km
Very small size	maximum 2500 km

After the selection of the airport, EcoTransIT calculates the distance between the two airports. If the closest airport allows the distance of the flight, it will be selected. If the limit is exceeded, the next bigger airport will be suggested and so on.

The air routing is not based on a network. The calculation of the flight distance uses the Great Circle Distance (GCD). By definition it is the shortest distance between two

points on the surface of a sphere. GCD is calculated by using the geographical coordinates of the two airports which are selected by the EcoTransIT user.

However, the real flight path is longer than the GCD due to departure and arrival procedures, stacking, adverse weather conditions, restricted or congested airspace /Kettunen et al. 2005, Gulding et al. 2009, Reynolds 2009/. Therefore the European standard EN 16258 as well as the European Emission Trading System (ETS) prescribed adding a blanket supplement of 95 km to the GCD for each leg of flight. This approach is also adopted by ETW. Based on this requirement the real flight distance is calculated by using the following formula:

Real flight distance = GCD + 95 km

In ETW airplanes have a maximum reachable distance (so called maximum design range). If the distance between the airports exceeds this distance ETW cannot calculate the emissions for this specific airplane and the error message “Route not found” will be applied. To avoid this error the user has the possibilities to insert a stop-over as via point in the transport chain or to calculate with a hybrid plane.

A hybrid airplane is a mixture of the belly freight airplane B747-400 and the freighter B747-400F (see chapter 5.5). The maximum design range of this hybrid plane is 8,230 kilometres. If the flight distance exceeds this range an additional virtual stopover is automatically included for each 8,230 kilometres. If stopovers are considered for each of the legs a blanket supplement of 95 km is added to the GCD.

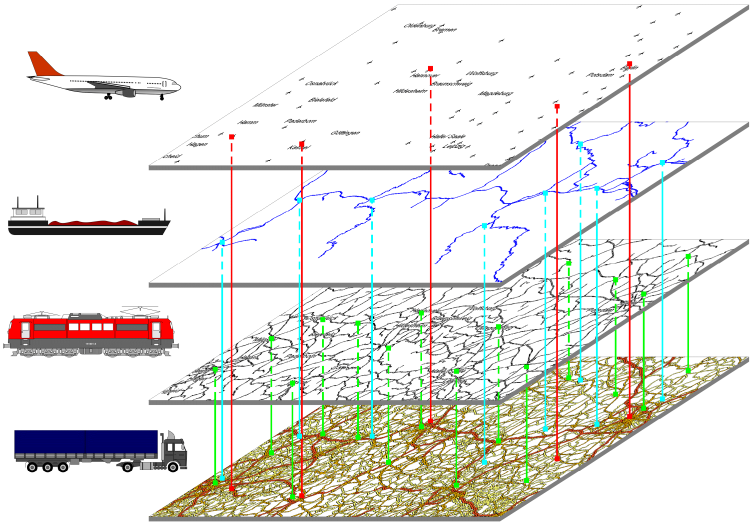
5.5 Determination of transport points within combined transport chains

The routing is available on the different networks for road, railway, ocean, inland waterways and air routes. Depending on the selected mode, ETW determines a route on the respective transport type network.

All networks are connected with so-called transfer points. These transfer points enable the change of a network. Thus, it is possible to calculate complex transport chains with ETW.

Furthermore, ETW has an algorithm to determine the probable transfer point of the transport chain. This is needed if the user wants to calculate a sea shipping transport and defines zip codes as origin and destination (instead of two UN-/Locodes for the ports). In this case, ETW has to determine the closest situated suitable ports to the origin and destination. After the determination of these transfer points and the routing, algorithm locates the routes (in the normal case on the street network) to these transfer point ports. Finally, the main routing between the two ports will be applied on the base of the ocean sea shipping network.

Figure 9 Principle of nodes between different networks



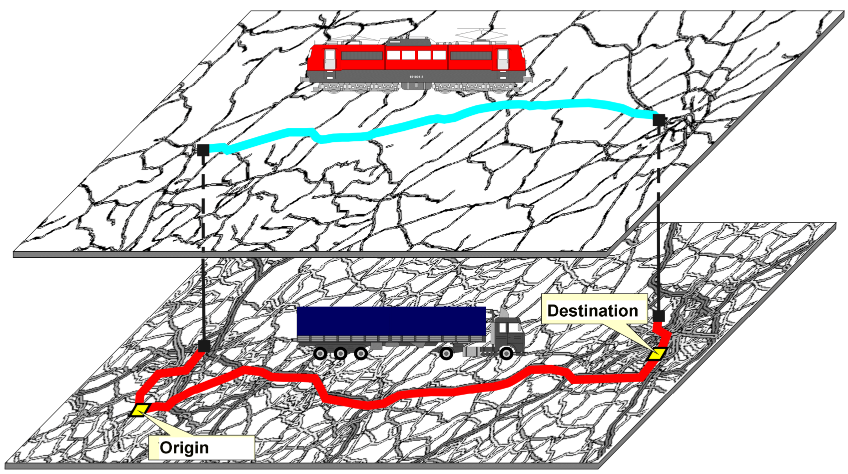
If a detection of a transfer point is needed, ETW determines the geographically nearest transfer points (as-the-birds-fly) to the respective origin and/or destination. The selection of the transfer points is also influenced by the size range of the respective airport or harbour. Thus a container based Suez trade will always start and end with a large classified harbour or a medium haul flight needs at least medium classified airports.

The automatically determination of transfer points could create unrealistic routes because the located transfer point need not be the most suitable choice and could e.g. create needless detours. To avoid this, it is recommended to define the transfer points as via nodes and select directly by this way the correct transport chain.

5.5.1 Definition of side tracks for rail transports

If a transfer point is a station the feeder transport will be calculated regular as a truck transport. The attribute “side-track available” enables the calculation as a train transport (instead the truck). This could be needed if a shipper has a railway connection (side track) which is e.g. not within the ETW GIS-data. In this case, EcoTransIT determines the route on the base of the street network but calculates it as a railway transport.

Figure 10: Route selection in road and rail network from origin to destination



6 Methodology and environmental data for each transport mode

Within the next chapters the methodology for the calculation of energy consumption and emissions of freight transport as well as the data sources used are presented for each mode of transport in detail. The methodology for the calculation of energy consumption and CO_2 equivalent emissions are in accordance with the European standard EN 16258. As required by the standard all used data sources and allocation methodologies are documented in the following chapters.

6.1 Road transport

6.1.1 Classification of truck types

ETW is focused on international long-distance transports. These are typically accomplished using truck trains and articulated trucks. Normally, the maximum gross tonne weight of trucks is limited, e.g. 40 tonnes in most European countries, 60 tonnes in Sweden and Finland and 80,000lbs in the United States on highways. For feeding or special transports, other truck types are used. In ETW, the gross weight classes for all vehicle sizes used for cargo transport are as follows:

Table 18 Truck size classes in ETW

EU/Japan	EPA
Truck >3.5-7.5t	Truck >8,500-16,000lbs
Truck >7.5-12t	Truck >16,000-26,000lbs
Truck >12-20t	Truck >26,000-44,000lbs
Truck >20-26t	Truck >44,000-60,000lbs
Truck >26-40t	Truck >60,000-80,000lbs
Truck >44-60t	Truck >100,000lbs

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 (EURO I - EURO VI) are used. The Pre-EURO I-standard is no longer relevant for most long-distance transports, and therefore it is not included.

The European emission standard is used in most countries worldwide for emission legislation. Other relevant standards are the US EPA emission regulations and the Japanese standards. The following table shows the emission standards used in ETW.

Table 19 Emission standards in ETW

EU	EPA	Japan
Euro-I (1992)	EPA 1994	JP 1994
Euro-II (1996)	EPA 1998	JP 1997
Euro-III (2000)	EPA 2004	JP 2003
Euro-IV (2005)	EPA 2007	JP 2005
Euro-V (2008)	EPA 2010	JP 2009
Euro-VI (2013)	n.a.*	JP 2016

* voluntary NOx standard from CARB 2015 is not implemented due to the lack of CARB 2015 certified diesel engines

6.1.2 Final energy consumption and vehicle emission factors (TTW)

The main sources for final energy consumption and vehicle emission factors is the "Handbook emission factors for road transport" (HBEFA) /INFRAS 2014/ for trucks with EU emission limits and the MOVES model for EPA standard /EPA 2014/.

The influence of the **load factor** is modelled according to the Handbook of Emission Factors /INFRAS 2014/. 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 driving characteristics and the gradient.

Energy consumption and emissions also depend on the driving pattern. Two typical driving patterns, one for highway traffic and one for traffic on other (mainly extra urban) roads, are considered by ETW. Traffic on urban roads has a small fraction in long distance transport and is therefore included in the other roads.

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", and "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 be determined between the countries of Germany and Switzerland. However, for these analyses, the entire traffic on all roads has been considered.

The share of gradients for the different countries in international road transports can only be estimated. No adjustments will be made for the "hilly countries" such as Germany (and all others except the following named), while energy consumption and emissions are assumed 5 % lower for the "flat countries" (Denmark, Netherlands and Sweden) and 5 % higher for the "mountainous countries" Switzerland and Austria. For all regions outside Europe the values for "hilly" are used.

The energy and emission factors of road transport for ETW are derived from the Handbook of Emission Factors (HBEFA 3.2) /INFRAS 2014/ for trucks with Euro standards. For the determination of values for trucks in North America several sources were analysed:

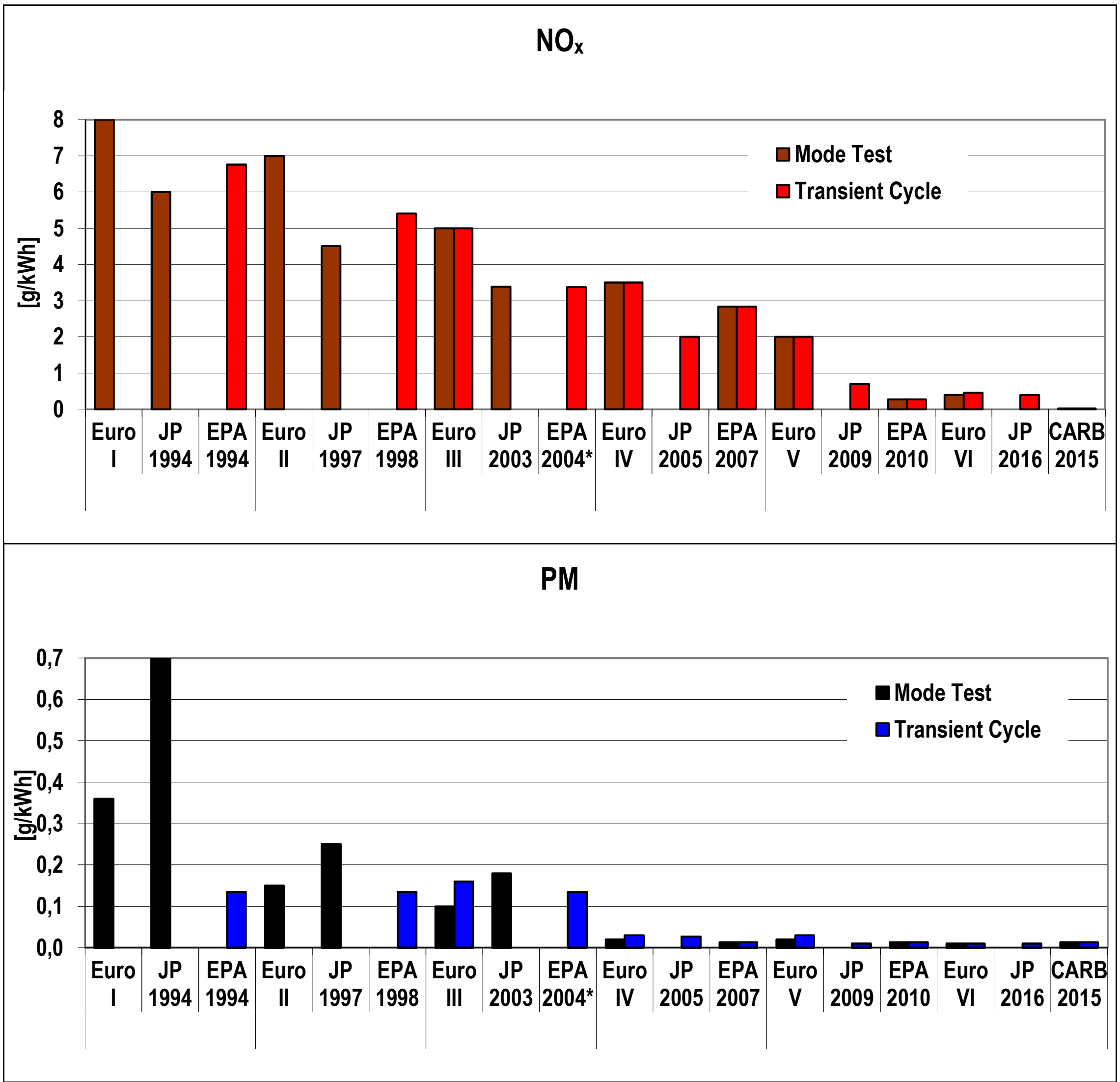
- emission limit values for the EPA standard compared with the EU standard /Dieselnet 2014/
- the emission model MOVES2014 to compare emission factors and energy consumption of trucks by road type, registration year and size /EPA 2014/
- further statistical data (/USCB 2004/, /USDOT 2007/, /USDOE 2009/) on truck size classification, average utilisation and energy consumption

Comparison of Emission standards

A comparison of the U.S., EU and Japanese emission limit values provides insight into the potential difference between the trucks exhaust emission characteristics for these countries. (See

Figure 11)

Figure 11 EU, Japanese and U.S. Emission Limit Values for Heavy Duty Diesel Vehicles by Emission Standard and Testing Procedure



* combined limit value of 3.38 g/kWh NMHC+NOx. Remark: CARB 2015 is a voluntary NOx standard
Source: /Dieselnet 2016/

Default emission standards and fuel quality for the regions

Although most countries have adopted the EU or similar emission standards to some degree, emission regulation still differs greatly between different countries and regions. Therefore, each country/ region is assigned its own default emission standard.

Users of ETW can choose newer emission standards than the default value. It must be noted, that the sulphur content of the diesel fuel restricts several exhaust gas treatment technologies for newer emission standards /UNEP 2007/.

- Diesel oxidation catalysts (DOC), commonly used for Euro III engines and onwards, work with sulphur levels up to 500 ppm.
- Selective catalytic reduction (SCR) requires a fuel with less than 50 ppm sulphur. SCR is a key technology for vehicles for Euro IV and higher.
- Diesel particulate filters need sulphur free fuels (< 15 ppm) and are primarily used in

Euro VI vehicles.

The sulphur content of diesel fuel is assumed according to the valid legislation. Direct emission factors for SO_2 are derived from the sulphur content of the fuel. For Europe, the value is 10 ppm (= 0.47 kg/TJ). In several countries this value is a lot higher, reaching 5000 ppm or even 8000 ppm in Iran.

In the previous version of ETW, Euro V was used as default emissions standards world-wide /ifeu / INFRAS / IVE 2014/. Based on the above considerations, all default values were updated. All EU countries are assigned EURO V as the default emission standard, since vehicles using this standard are already widely adopted in the European market. For all other countries we assume comparable regional standards (introduced around 2008) or at least EURO II (see table below).

Table 20 Sulphur content of diesel fuel [ppm] and default emission standards for trucks

Region	Code	Sulphur content [ppm]	default emission standard	emission legislation / latest standard
Africa	AFR	5000	EURO II	-
	ZA	500	EURO II	-
Asia and Pacific	ASP	5000	EURO II	-
	CN	50	EURO III	EURO IV
	HK	10	EURO IV	EURO V
	IN	350	EURO II	EURO III
	JP	10	JP 2009	JP 2016
	IR	8000	EURO II	-
	KR	50	EURO III	EURO IV
Australia	AU	10	EURO IV	EURO V
Middle East	MIE	5000	EURO II	-
World	WRLD	5000	EURO II	-
Central and South America	CSA	5000	EURO II	-
	BR	500	EURO III	EURO V
	CL	15	EURO III	EURO V
	MX	500	EURO II	EURO III/IV
Europe	EUR	500	EURO II	-
	BA	350	EURO II	-
	EU 28	10	EURO V	EURO VI
	ME	10	EURO II	-
	RS	10	EURO III	EURO III
	TR	10	EURO IV	EURO VI
	CH	10	EURO V	EURO VI
	IL	10	EURO V	EURO V
North America	CA	15	EPA 2007	CARB 2015
	US	15	EPA 2007	CARB 2015
Russia and FSU	FSU 15	500	EURO II	-

	RU	50	EURO III	EURO IV
Remarks: CN: nation-wide sulphur values; some regions have lower limit values. CARB 2015 is an optional standard.				
Sources: /UNEP 2016/; dieselnet.com; integer.com; transportpolicy.net; energy.gov.il; trend news agency 2013				

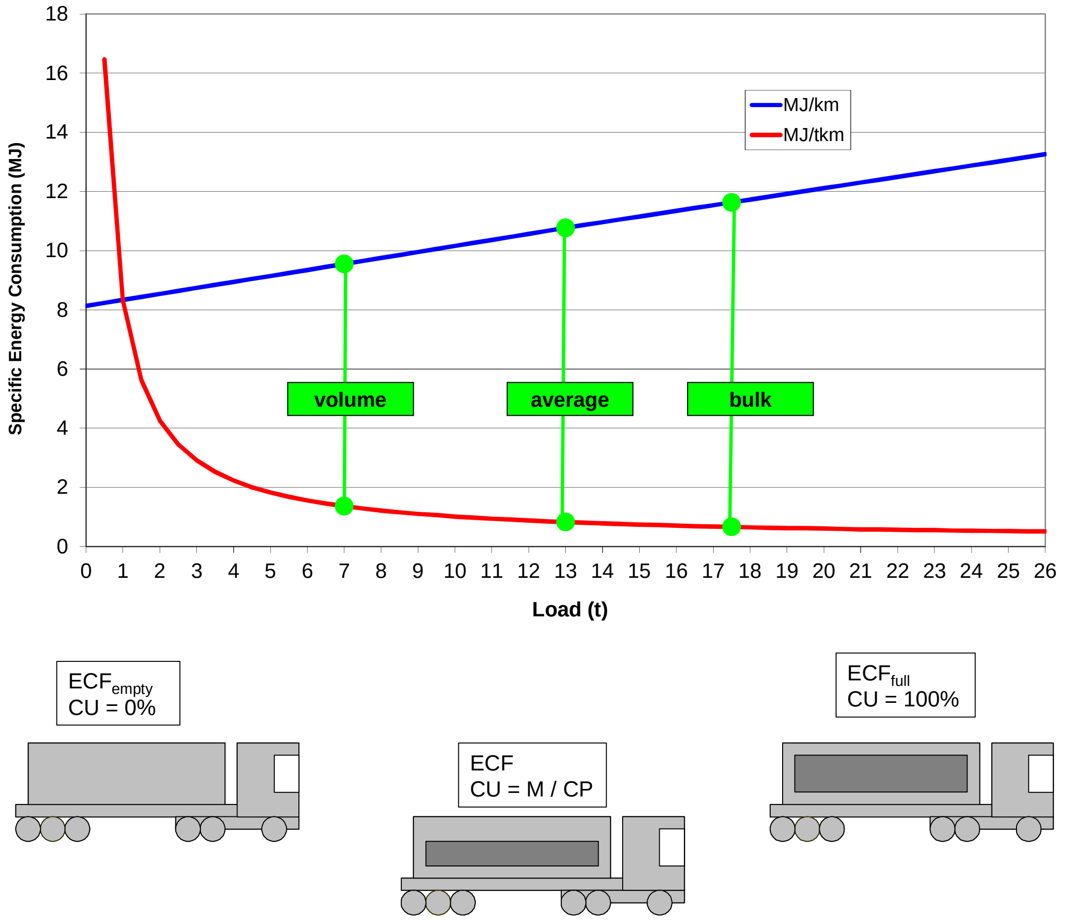
6.1.3 Final energy consumption and vehicle emissions (TTW)

For road transport with trucks, the general calculation rules described in chapter 4.3 are applied. A speciality is the dependence of final energy consumption and vehicle emissions from load weight:

The energy consumption and emissions of a truck depend on the specific energy consumption of the vehicle per kilometre and increases with higher load weights. Thus, the energy consumption per kilometre is a function of the capacity utilisation.

The following figure shows an example for the energy consumption per vehicle-km as a function of load weight, including values for freight types.

Figure 12: Energy consumption for heavy duty trucks (40 t vehicle gross weight, Euro-V, motorway, hilly) as a function of load weight



$$ECF = ECF_{empty} + (ECF_{full} - ECF_{empty}) * CU$$

Definitions:

ECF	Final energy consumption with actual load (g/km)
ECF_{empty}	Final energy consumption without load (g/km)
ECF_{full}	Final energy consumption with full load (g/km)
M	Mass of freight (t)
CP	Payload capacity (t)
CU	Capacity utilisation (weight load / load capacity)

Remark: Load for volume/average/bulk goods including empty trips

Source: Handbook Emission Factors for Road Transport 3.2 (INFRAS 2014)

For the calculation of energy consumption and emissions per net tonne km, the basic calculation rules are applied (see chapter 4.3).

Table 21 shows one set of TTW energy and emission values. For the calculation of TTW CO_2- and CO_2e-emissions the default values of EN 16258 are applied (see Table 52 in the appendix, chapter 7.1)

Table 21 Energy consumption and emissions (TTW) of selected trucks with different load factors in Europe (Motorway, average gradient for hilly countries)

Vehicle Type		full 100%	average 50%	empty 0%
Energy Consumption (MJ/km)				
Truck Euro VI	>3,5-7,5t	5.1	4.9	4.7
	>7,5-12t	7.1	6.6	6.1
	>12-20t	8.5	7.8	7.0
	>20-26t	10.6	9.1	7.8
	>26-40t	13.3	10.9	8.2
	>44-60t	19.0	14.5	9.9
NOx-Emissions (g/km)				
Truck >26-40t	Euro-I	10.49	8.74	6.78
	Euro-II	10.71	9.08	7.21
	Euro-III	8.10	6.45	5.05
	Euro-IV	3.75	3.15	3.16
	Euro-V	2.39	2.09	2.19
	Euro-VI	0.27	0.25	0.35
NMHC-Emissions (g/km)				
Truck >26-40t	Euro-I	0.461	0.423	0.435
	Euro-II	0.297	0.289	0.289
	Euro-III	0.263	0.266	0.274
	Euro-IV	0.030	0.025	0.022
	Euro-V	0.039	0.035	0.033
	Euro-VI	0.025	0.024	0.023
PM-Emissions (g/km)				
Truck >26-40t	Euro-I	0.322	0.264	0.238
	Euro-II	0.163	0.141	0.122
	Euro-III	0.146	0.139	0.135
	Euro-IV	0.036	0.033	0.031
	Euro-V	0.038	0.035	0.033
	Euro-VI	0.004	0.003	0.003
Source: Handbook Emission Factors for Road Transport 3.2 (INFRAS 2014)				

6.1.4 Alternative fuel trucks

Worldwide the vast majority of the trucks uses diesel as fuel. Due to the potential emission reductions and lower fuel costs some fleet managers invested into alternative fuels recently. In 2014 around 200,000 heavy or medium-heavy trucks in Europe (most of them in Eastern Europe) and 350,000 heavy or medium-heavy trucks in China were using CNG or LNG according to the natural gas vehicle association (NGVA). Electric trucks are even less common but have a growing importance (see Table 22).

Table 22 Market situation for trucks with alternative fuels

Drivetrain	Market share worldwide	Examples for pioneer markets	Examples for truck manufacturers
Diesel	Market leader	worldwide	all
CNG	Niche	China, USA, Sweden	e.g. IVECO, MAN, Daimler, SCANIA, Renault, Volvo, Cummins Westport, Freightliner
LNG	Niche	China, USA, Netherlands, Spain	IVECO, SCANIA, Cummins Westport, Freightliner
Dual Fuel (CNG/LNG - Diesel)	Niche	China, USA, UK	MAN, Cummins Westport
Battery electric	Niche	Germany, Austria	MAN, IVECO, Daimler (test)
Overhead catenary	Pilot phase	Sweden, Germany, USA	Siemens (test), Scania
Fuel cell	Pilot phase	Germany, USA	Daimler, Volvo
Source: ifeu analysis			

Having already a niche market, the truck types given in Table 23 are included in EcoTransIT. LNG trucks are common for heavy trucks (>26 t GW) while battery trucks are used for smaller size classes (<26 t). Being a rather young technology, only gas-powered trucks with Euro V or Euro VI standard are considered. For dual fuel, truck manufacturers so far have hesitated in bringing Euro VI dual fuel trucks on the market due to the challenge of keeping the emission limits /DLR et al. 2015/.

Table 23 Truck types with alternative fuels in EcoTransIT

Drivetrain	Size (gross vehicle weight)	Emission standard
CNG	3,5-40 t	EEV/Euro V Euro VI
LNG	26-40 t	EEV/Euro V Euro VI
Dual Fuel (LNG/Diesel)	26-40 t	EEV/Euro V
Electric (Battery)	3,5-26 t	-

Availability of refuelling infrastructure

CNG and LNG trucks require a dedicated refuelling infrastructure which is not yet available in a similar amount to diesel stations or not available at all in some countries[4]. Also, fast charging stations for battery vehicles, especially trucks, are not yet common. Therefore, the operation of trucks with alternative fuels is limited to certain routes and applications at the moment. EcoTransIT has no information on the spatial availability of alternative fuel stations and ETW users have to check availability by themselves. It has to be noted, that extra distances for refuelling might also increase the emissions.

Table 24 gives the number of CNG and LNG stations in the countries with the highest density of these stations per 1000 km². The number of CNG stations is in most countries

[4] However, the installation of a fuel infrastructure is supported by some countries, e.g. in the EU for CNG and LNG within the next decade in order to fulfill the alternative fuel infrastructure directive (2014/94/EU).

higher than for LNG stations. However, the CNG stations are often designed for light duty vehicles and the availability for trucks can be much lower.

When calculating a transport chain EcoTransIT provides the number of refuelling stations in a starting country. But as mentioned above, the exact availability for a specific transport chain (or route) has to be checked from other source, e.g. www.gibgas.de for the EU or www.afdc.energy.gov for the USA.

Table 24 Availability of CNG and LNG refuelling stations in the top 10 countries respectively (ranked by the number of stations per 1000 km²)

Fuel	Region	Country	Stations	Stations per 1000 km²
CNG	Europe	Netherlands	194	5.72
	Europe	Switzerland	167	4.18
	Europe	Italy	1,022	3.47
	Europe	Germany	892	2.56
	Europe	Austria	205	2.49
	Europe	Luxembourg	6	2.32
	Europe	Czech Republic	173	2.24
	Europe	Belgium	56	1.85
	Asia and Pacific	South Korea	196	1.63
	Asia and Pacific	Iran	2,360	1.54
LNG	Europe	Netherlands	16	0.47
	Asia and Pacific	China (including Hong Kong)	3,500	0.38
	Europe	United Kingdom	14	0.06
	Europe	Spain	25	0.05
	Europe	Portugal	4	0.04
	Europe	Italy	6	0.02
	Europe	Sweden	6	0.01
	Europe	France	7	0.01
	Europe	Germany	3	0.01
	North America	United States	76	0.01
Source: EU: NGVA, 2017 data; Non-EU: NGV Global, 2014 data				

Specific energy consumption and emissions of alternative fuel trucks (TTW)

Only a few measurements are available already for alternative fuel trucks. In the HBEFA emission factors for those truck types are currently not available but planned to be included in the next HBEFA version 4. Due to the current lack of information, instead of detailed energy consumption and emission factors (i.e. per size class, road type, load), average correction factors compared to similar diesel trucks are applied (see Table 25).

CNG and LNG trucks have higher specific energy consumptions than diesel, mainly due to the lower energy efficiency of the stoichiometric spark ignition engine used for most gas trucks. Based on a review of literature and fleet park operator's data in /DLR et al. 2015/ a 24% higher energy consumption compared to diesel trucks is assumed. Dual fuel trucks use compression ignition (diesel) engines and are therefore assumed to have the same fuel efficiency than diesel trucks. The average ratio of natural gas (LNG) to

diesel in energy consumption of dual fuel trucks for ETW is 60:40, based on /DLR et al. 2015/ and own assumptions.

Less information is available on real world air pollutant emissions (NOx, NMHC and PM) of gas trucks. It is assumed that the emissions are similar to the diesel trucks, except that Euro V CNG and LNG trucks have lower PM emissions, which are similar to Euro VI diesel trucks. This is due to the fact that spark ignited gas engines have very low PM emissions, even without using particle filters /TNO 2017/. The SOx emissions depend on the sulphur content, which is assumed to be 3.5 ppm and therefore lower than for diesel /TNO 2011/.

Battery electric trucks' TTW energy consumption is considered to be 44% lower than for diesel trucks /CE DELFT 2013/. Electric trucks have zero tailpipe emissions.

Table 25 TTW emission factors of alternative fuel compared to diesel trucks

Vehicle Type (fuel, size, emission standard)	EC	NOx	NMHC	PM
CNG, all size classes, Euro V	+24%	similar		Euro VI
CNG, all size classes, Euro VI	+24%	similar		
LNG, all size classes, Euro V	+24%	similar		Euro VI
LNG, all size classes, Euro VI	+24%	similar		
Dual Fuel (LNG/Diesel), all size classes, Euro V	similar			
Electric (Battery), all size classes	-44%	-100% (no tailpipe emissions)		
Source: (DLR et al. 2015), ifeu assumptions				

It has to be mentioned that the given assumptions provide only a rough picture and include uncertainties which can be hardly quantified at the moment. With increasing market entrance of alternative fuel trucks and availability of measurement data the emission factors should be reviewed.

Furthermore, the processes for energy generation greatly differ for the different truck types (see chapter 6.6 on WTT emissions). These emissions have to be included for an adequate comparison of emissions, especially for electric trucks. Emissions from vehicle construction are not yet within the scope of EcoTransIT, but can have a relevant share of lifecycle emissions, i.e. for batteries.

6.2 Rail transport

The main indicator for calculating energy and emissions of rail transport is the energy consumption of the total train depending on the gross tonne weight of the train and the relation of net-tonne weight to gross tonne weight. In ETW this was taken into consideration by using different general train types, defined by the gross tonne weight of the train and different freight types (average, bulk, volume). In addition to this general approach, the actual version of ETW allows to use special train types for dedicated transport tasks.

6.2.1 Train Types

6.2.1.1 General train types

European railway companies have 1,000 t as a typical average gross weight for international trains /UIC 2009/. The maximum gross weight for international traffic is up to 2,000 tonnes.

In several countries outside Europe the typical gross tonne weight is significantly higher e.g. Australia, Canada, China, USA. Typical train weights in these countries are about 4,000 tonnes and more. For this reason, ETW must cover a wide range in regards to train weight.

Table 26 Definition of general train types in ETW

Train type	Gross tonne weight train	Empty weight wagon	Capacity wagon	LF	ETF
Light	500 t	23 t	61 t	Bulk: 100 % Average: 60% Volume: 30%	Bulk: 80 % Average: 50%Volume: 20%
Average	1000 t				
Large	1500 t				
Extra Large	2000 t				
Heavy	5000 t				
Source: ETW definitions and assumptions					

6.2.1.2 Train types for dedicated transport tasks

For dedicated freight transports (cars, container, several solid bulks and liquids) special trains and wagon types are used. Typical train configurations come from transport statistics of major railway companies /DB Schenker 2012, SNCF 2012/. In ETW average values for these train types are used. They mainly reflect the European situation.

Table 27 Definition of dedicated train types in ETW

Train type	Gross tonne weight train	Empty weight wagon	Capacity wagon	LF	ETF
Car	700 t	28 t	21 t	85 %	50 %
Chemistry	1200 t	24 t	55 t	100 %	100 %
Container	1000 t	21 t	65 t	50 %	20 %
Coal and steel	1700 t	26 t	65 t	100 %	100 %
Building materials	1200 t	22 t	54 t	100 %	100 %
Manufactured products	1200 t	23 t	54 t	75 %	60 %
Cereals	1300 t	20 t	63 t	100 %	60 %
Source: DB Cargo, SNCF, ifeu assumptions					

6.2.2 Final energy consumption (TTW)

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

topology. For ETW, the function was updated with new values and a special survey for heavy trains (>2,000 tonnes).

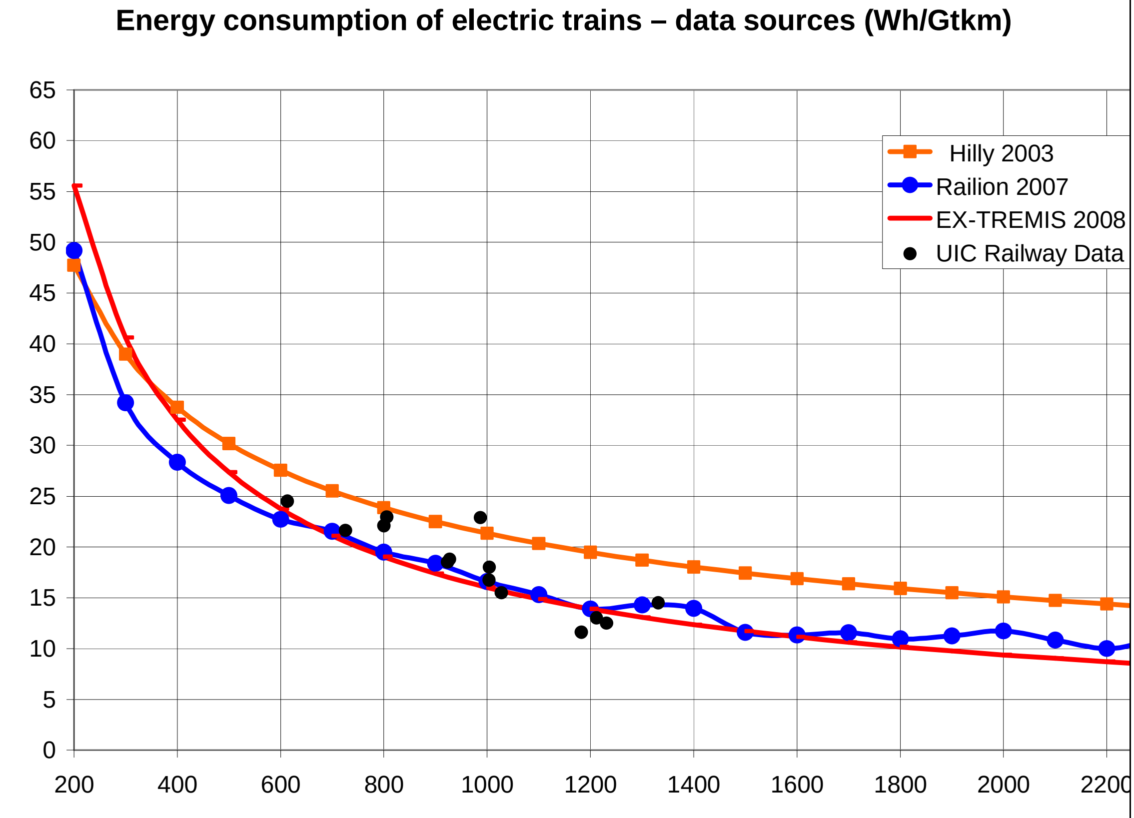
The following energy consumption data for trains were available:

- Average annual consumption of typical freight transport by different companies, e.g. data from UIC energy statistics (last update 2007) /UIC 2009/.
- Analysis of energy consumption of more than 200,000 rides of freight trains by Railion in 2007 in different production types and train weight classes /Railion 2007/.
- Survey of train rides at the Gotthard line by SBB, mainly model calculations; values between 17 and 23 Wh/Gtkm /SBB 2006/.
- Canada: statistics about annual average energy consumption of freight trains. In 2003 the average energy consumption of diesel freight trains was recorded as 33 Wh/Gtkm and 61 Wh/Ntkm (average train weight in UIC-statistic 2007: about 5000 gross tonnes) /EPS 2005/.
- China: average energy consumption of extra-large double deck container and normal trains: Diesel 27 Wh/Gtkm, Electric 10 Wh/Gtkm (train weight about 4000 gross tonnes) /ifeu 2008/.
- US Track1: statistics about annual energy consumption of freight trains; in 2006 the average energy consumption of diesel freight trains was recorded as 66 kWh/Ntkm (average train weight in UIC-statistic 2007: about 5000 gross tonnes) /USDOT 2008/.
- The EX-TREMIS study, which is a kind of “official” dataset for Europe, proposed a function for rail freight transport, which is similar to EcoTransIT methodology /TRT 2008/.

The following diagram shows some of the values mentioned above, compared to the former function of EcoTransIT (hilly). The following conclusions can be stated:

- Nearly all values reside below the former EcoTransIT function.
- The function of EX-TREMIS stays very close to the Railion values in a range from 600 to 1800 gross tonnes.
- Some values from UIC statistics are higher than the Railion values, but the majority are in line with it.

Figure 13: Energy consumption of electric trains – data sources



Source: Railion, UIC, ifeu

ETW function includes the following assumptions:

- For train weights between 600 and 1800 gross tonnes, the Railion values correlate well with the function of EX-TREMIS and most of the UIC-values. Therefore, the following function correlated to these values was calculated:

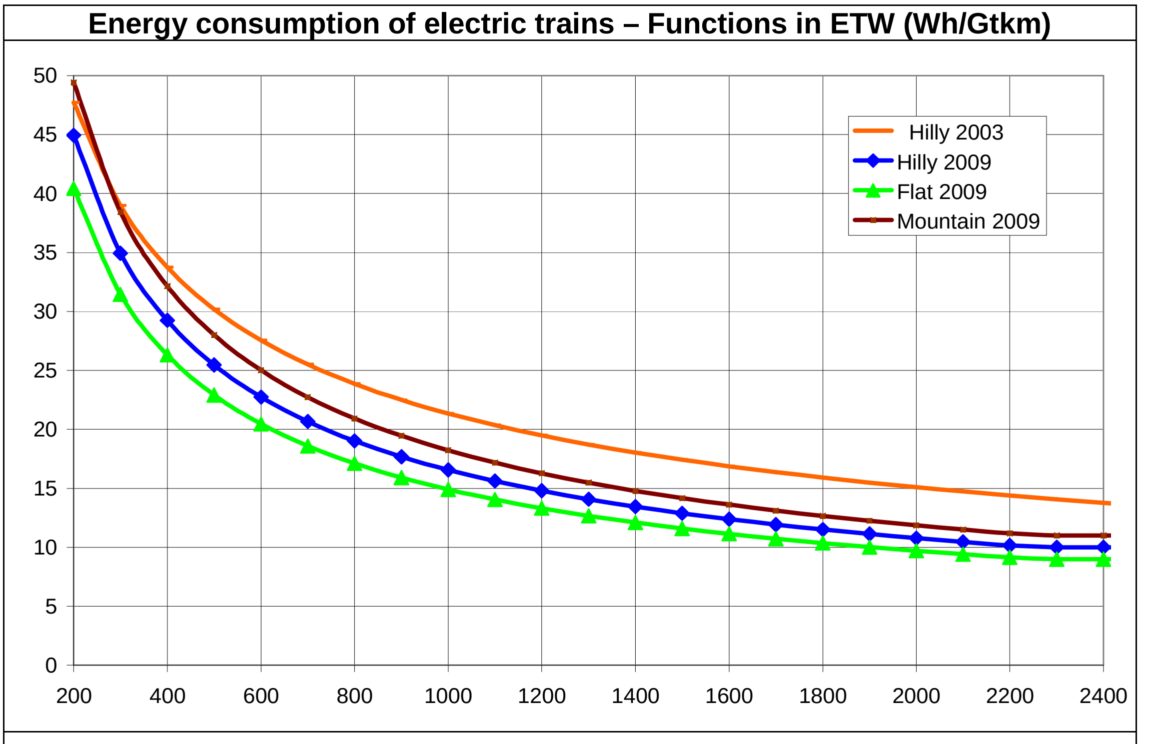
$$EC_{spec}\ [Wh/Gtkm] = 1200 * GTW^{-0,62}$$

(EC_{spec}: specific Energy Consumption, GTW: Gross Tonne Weight)

- Below 600 gross tonnes, the diffusion of the values is higher. This means a higher uncertainty of the values. We propose to use the same function as for the middle weight trains in order to define the function as simply as possible.
- Above 1500 gross tonnes, the Railion values show no significant reduction of specific energy consumption with growing train weight. This general trend is confirmed by values of heavy trains (4000 gross tonnes and more) for Canada, China and USA. Therefore, we propose to use the function until 2200 gross tonnes (specific energy value: 10 Wh/Gtkm) and keeping it constant for larger trains.
- The function is valid for “hilly” countries. For flat countries, the values of the function are multiplied by 0.9, for mountainous countries the factor is 1.1.

The following figure shows the resulting new functions compared to the EcoTransIT “Hilly 2003” function.

Figure 14 Functions for the energy consumption of electric trains



Source: EPS, Railion, TRT, UIC, USDOT, ifeu

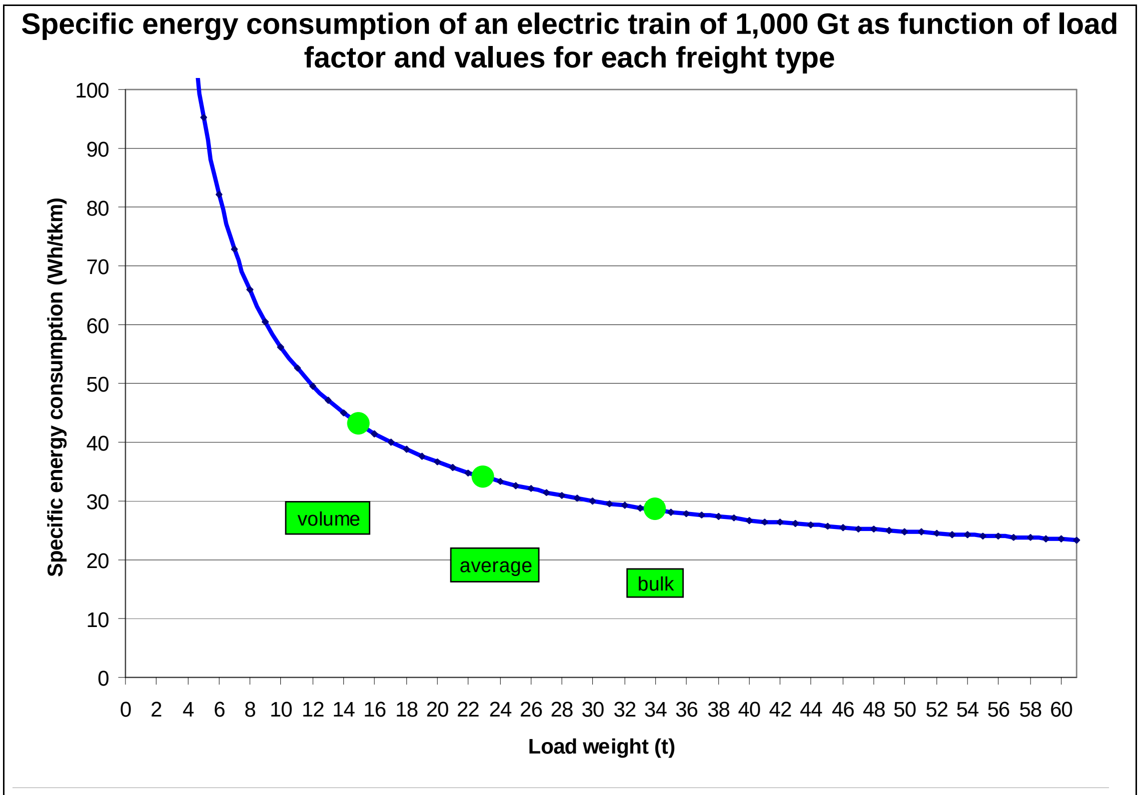
The specific energy consumption per net tonne km is calculated for each train type with the following formula:

Specific energy consumption [Wh/Ntkm] =
Energy consumption of train [Wh/Gtkm] /
Relation Nt/Gt of freight (including empty trip factor)

Relation Nt/Gt = 0.40 for volume freight
0.52 for average freight
0.60 for bulk freight

The following figure shows the specific energy consumption as a function of the net tonnes/gross tonne relation for a 1000-tonne electric train and the values for each freight type.

Figure 15 Specific energy consumption of an electric train of 1,000 Gt as function of load factor and values for each freight type



Remark: Load for volume/average/bulk goods including empty trips

Source: EPS, DB Cargo, TRT, UIC, USDOT, ifeu

The following table shows the specific energy consumption of the default electric trains for each freight type.

Table 28 Specific final energy consumption for selected electric trains

Train Type	Final Energy Consumption			
	Train	Freight		
		Bulk	Average	Volume
Unit	Wh/Gtkm	Wh/Ntkm		
General trains				
Light Train (500t)	25.5	42.7	49.5	63.9
Average Train (1000t)	16.6	27.8	32.2	41.5
Large (1500t)	12.9	21.6	25.0	32.3
Extra Large (2000t)	10.8	18.1	20.9	27.0
Heavy (>2000t)	10.0	16.8	19.4	25.1
Dedicated trains				
Car	20.7		69.3	
Chemistry	14.8		27.7	
Container	16.6		29.5	
Coal and steel	11.9		21.5	
Building materials	14.8		26.8	
Manufactured products	14.8		28.2	
Cereals	14.1		21.2	
Source: DB Cargo, SNCF, ifeu assumptions				

6.2.3 Energy consumption of diesel trains

The available energy data for diesel traction ranges between 2.6 and 9.7 g/gross tonne km /Railways companies 2002/. New statistics show a similar range /UIC 2009/. The statistical uncertainties can be attributed to the unreliable allocation of the fuel consumption to different users (passenger and goods transport, shunting, etc.). Therefore, the primary energy consumption of diesel traction is estimated on the basis of the primary energy consumption of electric 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 electric traction (including electricity generation).

So, the same functional dependence as that of electric traction is taken and has to be divided by the efficiency of the diesel-electric conversion for final energy consumption of 37 %. (See Chapter 6.6.1).

The following table shows the resulting specific energy consumption per Gtkm and Ntkm for different diesel trains and freight types. Some available values of heavy trains from China and statistical averages for Canada and USA are added. The values of North American railways are higher than values from energy function (similar to the large train in the formula). For this reason, additional energy consumption for North American railways could be possible, but we propose to use this formula also for North America as well on account of the small North American database available.

Table 29 Specific final energy consumption for diesel trains

Train Type	Final Energy Consumption			
	Train	Freight		
		Bulk	Average	Volume
Unit	Wh/Gtkm	Wh/Ntkm		
Light Train (500t)	68.8	115.5	133.7	172.6
Average Train (1000t)	44.8	75.2	87.0	112.3
Large (1500t)	34.8	58.4	67.6	87.3
Extra Large (2000t)	29.1	48.9	56.6	73.1
Heavy (>2000t)	27.0	45.4	52.5	67.8
Values of heavy trains	**Average (not specified)**			
China 2008	27			
Canada 2003	33		61	
US Track 1 2006			66	
Source: DB Cargo, ifeu EPS 2005, USDOT				

Table 30: Emission standards for diesel trains (NOx, NMHC, PM)

Standard	Manufacture year	HC	NOx	PM
International UIC (g/kWh)				
UIC 1	<=2002	0,8	12	
UIC 2	2003-2008	0,8	9,5	0,25
European Union, P>560 kW (g/kWh)				
Stage IIIa	2009-2011	0,5	6,0	0,2
Stage IIIb/V	>=2012	0,2	3,8	0,025
US-EPA, line-haul (g/bhp.hr)				
Non-regulated	<1973	0,5	13,5	0,34
Tier 0	1973-1992	1,0	8,0	0,22
Tier 1	1993c-2004	0,6	7,4	0,22
Tier 2	2005-2011	0,3	5,5	0,10
Tier 3	2012-2014	0,3	5,5	0,10
Tier 4	>2015	0,1	1,3	0,03
Source: www.dieselnet.com				

6.2.4 Emission factors for diesel train operation (TTW)

Similar to diesel engines for road and inland ship transport, the emission performance of locomotive engines strongly depends on the engine technology. In the past years the UIC, the EU and US implemented emission limits for new engines in several stages, thus reducing specific emissions for newer engines. This fact should be considered in ETW by providing different emission factors by emissions stage, like already available for road and inland ship transport.

The following table lists the relevant emission stages and emission factors of the UIC, the European Union and the US-EPA.

Determination of emission factors for ETW

For ETW these values can be transformed to fuel-related emission factors. Typical energy consumption values for locomotive engines are about 210 g/kWh [IFEU, 2003], therefore this value is used for the transformation.

For ETW a PM value for UIC 1 is added, based on engine data from engines with manufacture year 1997 and before from [IFEU, 2003]. Table 31 shows the resulting emission factors used in ETW.

Table 31: Emission factors for diesel locomotives (freight transport) in ETW available in the expert mode

Standard	Manufacture year	HC	NOx	PM
International: UIC (g/kg)				
UIC 1	<=2002	3,8	57,1	1,56
UIC 2	2003-2008	3,8	45,2	1,19
European Union, >560 kW (g/kg				
Stage IIIa	2009-2011	2,4	28,6	0,95
Stage IIIb/V	>=2012	1,0	18,1	0,12
US-EPA, line-haul (g/kg)				
Non-regulated	<1973	4,1	73,8	1,53
Tier 0	1973-1992	7,8	44,0	0,97
Tier 1	1993c-2004	4,5	41,0	0,97
Tier 2	2005-2011	2,2	30,2	0,48
Tier 3	2012-2014	2,2	18,6	0,37
Tier 4	>2015	0,5	4,8	0,11
Source: www.dieselnet.com; own assumptions				

Country specific regulations and default values

The emissions values in Table 31 can be compared with existing data from railway companies and the recent default values of EcoTransIT (see Table 32). The comparison shows, that the former ETW-values have a level between UIC 1 and UIC 2 and the average cargo fleet of DB in 2015 lies between UIC 2 and Stage IIIa. Other data could not be evaluated so far.

Table 32: Emission factors for diesel locomotives (freight transport) from different sources

Standard	Manufacture year	HC	NOx	PM
Average values (g/kg), different sources				
ETW 2010	All	4,6	48,3	1,30
DB 2016	All	2,6	42	0,96

Due to the lack of a sophisticated survey we propose a simple approach for default values in ETW:

- For USA and Canada, the Tier 2 standard is used as default value
- For Germany the DB 2016 value is used
- For other EU 27 countries the emission factors of the UIC 2 standard are applied
- For all other countries the UIC 1 standard is assumed.

For future improvement we recommend to ask the UIC for country specific emission factors, which can be used as default values.

Option: particle filter

Several locomotives are equipped with a particle filter, which reduces PM-emissions considerably. For this reason, the extended mode in ETW gives an additional option to choose a particle filter. As default a value of 0.012 g PM/kg is used.

6.3 Sea transport

6.3.1 Overview

The sea transport emission factors in ETW are largely based on the findings of the Third Greenhouse Gas study of the International Maritime Organization (IMO) /IMO 2015/. Basically, fuel consumption and emission factors for main engine, auxiliary engine and boiler were derived in a bottom-up approach from IMO data for individual ship categories and size classes and validated using worldwide fuel consumption and CO_2 emissions for 2012 from /IMO 2015/. These factors were then aggregated to

a) the vessel types and size classes available in the Extended input mode of ETW (Table 39), and
b) the world trade lanes, which are automatically assigned based on the chosen origin and destination, for the Standard mode of ETW.

The resulting fuel consumption and emission factors are further adjusted to a default or user-specified speed reduction and cargo utilization.

The following vessel types are differentiated:

- General Cargo Vessels
- Dry Bulk Carriers
- Liquid Bulk Carriers
- Container Carriers
- Roll-on-Roll-off vessels

Other vessels are not included in ETW because of their differing cargo specifications and lower relevance for the likely ETW user. Those vessel types include LNG and LPG gas carriers as well as car carriers. Ferries are not included in this section of the report because they are treated like extensions of the road network and are thus presented in the chapter on land transport.

6.3.2 Derivation of basic fuel consumption and emission factors

The basic fuel consumption and emission factors are derived for each IMO ship type and size class, separately for main engine, auxiliary engine, and boiler, based on the methodology used in the Third IMO Greenhouse Gas Study from 2015 (see /IMO 2015, p. 43ff/ for ship types and associated parameters).

In order to account for emissions in port and return journeys, fuel consumption is modelled separately for main engine, auxiliary engine, and boiler, for a virtual one-year period in the standard assumption. The results are normalized to one tonne-kilometre (i.e. expressed in g/tkm). If reduced vessel speeds are modelled, the vessel's activity extends the one-year period in order to deliver the same transport services (see Chapter 6.3.4).

The fuel consumption in g/tkm of the main engine is derived based on the following formula:

$$FC_{ME} = \sum_{A} (Sh_A \times SFC_A \times (NP \times LF_{DS}/DS)/(DWT \times CU))$$

With FC_{ME} = Fuel consumption of the main engine in g/tkm

Sh_A = Share of vessel stock per engine age group A [%] based on age distribution[5]. The engine age groups are listed in Table 33.

SFC_A = Specific fuel consumption in g/kWh per engine age group A /IMO 2015/. The respective values are displayed in Table 33.

NP = Average nominal power for the ship type and size class [kW] /IMO 2015/.

LF_{DS} = Load factor at design speed with clean hull and in calm weather (90% MCR for all ships based on /IMO 2009/)

DS = Design speed /IMO 2015/.

DWT = Average payload capacity in dead weight tonnes /IMO 2015/

CU = Cargo utilization [%] based on /IMO 2009/

For ships classes with up to 15 MW average installed power, the specific fuel consumption values for MSD (medium-speed diesel) engines in Table 33 are applied, and for larger ships the values for SSD (slow-speed diesel) engines /Williams et al. 2008/.

[5] Separate age distributions for ships up to 50'000 dwt and above 50'000 dwt were derived from a sample of 4616 vessels from the Lloyds Register of Ships /Lloyds 2009/.

Table 33: Main engine fuel consumption factors (values in g/kWh; IMO 2015, p. 109).

Engine age group	Engine rating		
	SSD	MSD	HSD
Before 1983	205	215	225
1984–2000	185	195	205
post-2001	175	185	195

The fuel consumption in g/tkm of auxiliary engine and boiler is calculated as follows:

$$FC_{A,B} = ((d_{sea} \times 24 \times L_{sea}) + (d_{port} \times 24 \times L_{port})) \times n \times SFC_{A,B}$$

With $FC_{A,B}$ = Fuel consumption of the auxiliary engine or boiler in g/tkm

d_{sea} = Number of days at sea per year /IMO 2015/

L_{sea} = Auxiliary engine/boiler load at sea [kW] /IMO 2015/

d_{port} = Number of days in port per year

L_{port} = Auxiliary engine/boiler load in port [kW], /IMO 2015/

n = Number of auxiliary engines /IMO 2015/ (for boilers: n = 1)

$SFC_{A,B}$ = Specific fuel consumption of the auxiliary engine or boiler in g/kWh (Table 34).

Table 34: Auxiliary engine/boiler fuel consumption factors (values in g/kWh; IMO 2015, p. 109).

Engine type	Fuel type	
	HFO	MDO
Auxiliary engine	225	225
Steam boiler	305	300

Emission factors in g/g fuel for the different pollutants considered in ETW, differentiated by main engine and auxiliary engine/boiler as well as fuel type (HFO or MDO) and engine rating, are based on /IMO 2015/ and can directly be multiplied with the fuel consumption factors derived above. They are listed in Table 35 for the main engine and Table 36 for auxiliary engines and boilers.

For NO_x, SO_x and PM, the emission factors depend on the sulphur content of the fuel used. For HFO, the sulphur content is assumed to be 2.51% /IMO 2015/, and for MDO, 0.1% (limit valid from 1st of January 2015; see also Chapter 0).

Table 35: Main engine emission factors (values in g/g fuel; IMO 2015).

Pollutant	IMO Tier	Engine rating	Fuel type	Emission factor [g/g fuel]
NO_x	0	SSD	HFO	0.09282
	1	SSD		0.08718
	2	SSD		0.07846
	0	MSD		0.06512
	1	MSD		0.06047
	2	MSD		0.05209
SO_x	All	SSD		0.04908
	All	MSD		0.04910
PM	All	SSD		0.00699
	All	MSD		0.00639
NMHC	All	SSD		0.00308
	All	MSD		0.00233
CO_2	All	SSD		3.11000
	All	MSD		3.11000
CO_2eq	All	SSD		3.15000
	All	MSD		3.15000
NO_x	0	SSD	MDO	0.05817
	1	SSD		0.05463
	2	SSD		0.04917
	0	MSD		0.04081
	1	MSD		0.03789
	2	MSD		0.03264
SO_x	All	SSD		0.00176
	All	MSD		0.00176
PM	All	SSD		0.00068
	All	MSD		0.00062
NMHC	All	SSD		0.00308
	All	MSD		0.00233
CO_2	All	SSD		3.21000
	All	MSD		3.21000
CO_2eq	All	SSD		3.24000
	All	MSD		3.24000

Table 36: Auxiliary engine/boiler emission factors (values in g/g fuel; IMO 2015).

Pollutant	IMO Tier	Engine rating	Fuel type	Emission factor [g/g fuel]
NO_x	0	MSD	HFO	0.06476
	1	MSD		0.05727
	2	MSD		0.04934
SO_x	All	MSD		0.04908
PM	All	MSD		0.00603
NMHC	All	MSD		0.00176
CO_2	All	SSD		3.21000
	All	MSD		3.21000
CO_2eq	All	SSD		3.24000
	All	MSD		3.24000
NO_x	0	MSD	MDO	0.04058
	1	MSD		0.03589
	2	MSD		0.03092
SO_x	All	MSD		0.00176
PM	All	MSD		0.00059
NMHC	All	MSD		0.00176
CO_2	All	SSD		3.21000
	All	MSD		3.21000
CO_2eq	All	SSD		3.24000
	All	MSD		3.24000

6.3.3 Aggregation to ETW size classes and trade lanes

Depending on the input mode (Standard or Extended), different aggregation levels or fuel consumption and emission factors are required in ETW.

In the Standard mode, the user only specifies origin and destination of the cargo, as well as the cargo type (bulk or containers). Based on this, the appropriate trade lane/cargo type combination (see Table 37) is automatically chosen. Consequently, average fuel consumption and emission factors representative for the chosen trade lane have to be applied.

In the Extended input mode, the user can choose ship type and size, as well as the goods type and the handling (see Table 39). Hence, the fuel consumption and emission factors for the ship types and size classes available in the Extended input mode of ETW have to be available.

a) Trade lanes

For the aggregation to trade lanes, the fuel consumption and emission factors are calculated as a tkm-weighted average of the ships operating on the respective trade lane based on their size. The required input activity data (mileage, capacity, cargo utilization) are based on /IMO 2009, 2015/. Table 37 lists all region pairs considered by ETW and defines the trade lanes. The associated aggregated size classes are listed in Table 38. The Standard mode does not differentiate liquid and dry bulk.

Table 37: Overview of region pairs and respective trade lanes considered by ETW.

From / To	EU - Europe	NA - North Am.	LA - Latin Am.	AF - Africa	AS - Asia	OZ - Oceania
EU - Europe	Intra-continental Europe	Transatlantic trade	Other global trade	Other global trade	Suez trade	Other global trade
NA - North Am.	Transatlantic trade	Intra-continental (non Europe)	Panama trade	Other global trade	Transpacific trade	Other global trade
LA - Latin Am.	Other global trade	Panama trade	Intra-continental (non Europe)	Other global trade	Other global trade	Other global trade
AF - Africa	Other global trade	Other global trade	Other global trade	Intra-continental (non Europe)	Other global trade	Other global trade
AS - Asia	Suez trade	Transpacific trade	Other global trade	Other global trade	Intra-continental (non Europe)	Other global trade
OZ - Oceania	Other global trade	Other global trade	Other global trade	Other global trade	Other global trade	Intra-continental (non Europe)

Table 38: Default vessel categories depending on cargo type and trade lane

Vessel types	Trade lane	Aggregated size class
BC (liquid, dry, and General Cargo)	Suez trade	Aframax / Suezmax
BC (liquid, dry, and General Cargo)	Transatlantic trade	Handymax / Panamax
BC (liquid, dry, and General Cargo)	Transpacific trade	Handymax / Panamax / Aframax / Suezmax
BC (liquid, dry, and General Cargo)	Panama trade	Handymax / Panamax
BC (liquid, dry, and General Cargo)	Other global trade	Handysize / Handymax / Panamax / Aframax
BC (liquid, dry, and General Cargo)	Intra-continental trade	Feeder / Handysize / Handymax
CC	Suez trade	4,700 – 7,000 (+) TEU
CC	Transatlantic trade	2,000 – 4,700 TEU
CC	Transpacific trade	1,000 – 7,000 (+) TEU
CC	Panama trade	2,000 – 4,700 TEU
CC	Other global trade	1,000 – 3,500 TEU
CC	Intra-continental trade non EU	500 – 2,000 TEU
CC	Intra-continental trade EU	500 – 2,000 TEU
Great Lake BC		< 30,000 DWT

Note: BC = bulk carrier, GC = general cargo ship, CC = container vessel

The ship size ranges per trade lane are based on a sample analysis of transport services of ocean carriers[6]. Size differentiation can be particularly found in container trade,

6 The following carrier schedules were analysed to develop the vessel size groupings per major trade lane: a) Container carriers: NYK Line, OOCL, Hyundai Merchant Marine, APL, CMA-CGM, Hapag Lloyd; b) Bulk carriers: Sea bulk, Polar, AHL Shipping

whereas bulk transport depends more on the type of cargo and distance sailed. The major container trades are distinctive in terms of volumes and goods; therefore, different vessel sizes are deployed on those trades. For example, the Europe – Asia container trade is dominated by large container ships above 5,000 TEU. North America is linked with Asia with a broader range of vessels, usually above 3,000 TEU. In both trade lines ultra-large container vessels are used (above 14,500 TEU), too. In the Europe – North America trades the bulk numbers of container vessels are between 2,000 and 4,700 TEU. Europe trades with the African and Latin American continent are dominated by vessels between 1,500 and 4,000 TEU capacity. For other trade lanes, an average "international" emission factor was formed and several intra-continental emission factors were developed (see Table 38).

A similar approach was used for bulk vessels. However, the distinction here is based on certain size restrictions in particular regions. Some installations in the world sea infrastructure restrict the size of the vessels. The most important ones were considered in developing the vessel size classes for bulk vessels. These are the Suez Canal, the Panama Canal, and the entrance to the Baltic Sea. The Suez Canal does not pose a restriction to even the largest container ships. However, bulk carriers are limited to approximately 200,000 DWT. The Panama Canal poses both restrictions for bulk carriers (ca. 80,000 DWT) and container ships (ca. 4,300 TEU with some vessels up to 5,000 TEU capacity). However, it is currently under construction – after its expansion, it is expected to accommodate container ships of up to 13,000 TEU. The Baltic Sea entrance is limited to bulk vessels of maximum 120,000 DWT in general. However, the ports in the Baltic Sea are mostly served by smaller feeder vessels[7]. Furthermore, the Baltic Sea as well as the North Sea are so-called Emission Control Areas (ECAs) with limits on fuel sulphur at sea and in port /Sustainable Shipping 2009/ (see Chapter 0 for the consideration of ECAs).

b) Size classes in the extended input mode of ETW

The vessel types and size classes available in the Extended input mode of ETW are listed in Table 39. The ETW vessel types are identical to the ship types in /IMO 2015/, but the size class boundaries differ in some cases. For this aggregation, an equal distribution of dead-weight tonnage within the IMO size classes is assumed. The aggregation is carried out (as for the trade lines) by tkm-weighted averaging of all emission factors by the ETW size classes. with the input activity data (mileage, capacity, cargo utilization) based on /IMO 2009, 2015/.

Company. Additionally, ship tracking websites like www.marinetraffic.com were consulted.

7 Personal communication Port of Oslo.

Table 39: Vessel types and sizes that can be selected in the Extended input mode of ETW.

Vessel types (and cargo handling)	Trade and Vessel category names	Aggregated size class
GC	Coastal	< 5,000 DWT
BC / GC (dry)	Feeder	5,000 – 15,000 DWT
BC / GC (dry)	Handysize	15,000 – 35,000 DWT
BC (dry)	Handymax	35,000 – 60,000 DWT
BC (dry)	Panamax	60,000 – 80,000 DWT
BC (dry)	Aframax	80,000 – 120,000 DWT
BC (dry)	Suezmax	120,000 – 200,000 DWT
BC (liquid)	Feeder	5,000 – 15,000 DWT
BC (liquid)	Handysize	15,000 – 35,000 DWT
BC (liquid)	Handymax	35,000 – 60,000 DWT
BC (liquid)	Panamax	60,000 – 80,000 DWT
BC (liquid)	Aframax	80,000 – 120,000 DWT
BC (liquid)	Suezmax	120,000 – 200,000 DWT
BC (liquid)	VLCC (+)	> 200,000 DWT
CC	Feeder	<1,000 TEU
CC	like Handysize	1,000 – 2,000 TEU
CC	EU SECA like Handysize	1,000 – 2,000 TEU
CC	like Handymax	2,000 – 3,500 TEU
CC	like Panamax	3,500 – 4,700 TEU
CC	like Aframax	4,700 – 7,000 TEU
CC	like Suezmax	7,000 – 14,500 TEU
CC	ULCV	>14,500 TEU
Global average CC	World	over all ships
RoRo	RoRo small	< 5000 DWT
RoRo	RoRo large	>= 5000 DWT
(BC = bulk carrier; CC = container vessel; GC = general cargo ship; RoRo = Roll-on/roll-off ship; VLCC = very large crude carrier; ULCV = ultra-large container vessel)		

6.3.4 Adjustments for speed and cargo utilization

Ship speed is one of the most sensitive parameters in the calculation of fuel consumption and emissions of sea transport. Due to the over-proportional reduction in fuel consumption compared to the service speed, “slow steaming” has become a widespread practice in sea transport – in 2012, the average ratio of operating speed to design speed 75% /IMO 2015/. Cargo utilization, on the other hand, is sensitive since ETW calculates shipment-specific emissions, and obviously these are reduced the more goods the emissions can be divided by.

In the Standard mode, the operating speed and the cargo utilization are determined by trade lane and corresponds to the tkm-weighted averages per IMO ship type and size class /IMO 2009, 2015/. In the Extended input mode, the user can adjust speed and cargo utilization of sea transport. The speed adjustment is expressed in percent reduction relative to the chosen ship’s design speed. The cargo utilization is expressed in percent of capacity.

Regardless of whether inputs are default or user-specified, the fuel consumption and

emission factors in ETW are adjusted based on the equations described in the following paragraphs.

a) Adjustment for speed

The main engine load is adjusted based on the speed reduction relative to design speed (based on /IMO 2009, 2015/):

$$LF_{act} = (V_{act}/V_{Des})^3 \times 0.9 \times 1.09 \times 1.15$$

With LF_{act} = Load factor given actual speed [%]

V_{act} = Actual speed [km/h]

V_{Des} = Design speed [km/h]

The constant 0.9 corresponds to the engine load at design speed (with clean hull and calm weather). The factor 1.09 accounts for hull roughness and the factor 1.15 for wave resistance in average conditions /IMO 2015/.

Once the engine load under the actual speed is known, the fuel consumption and emission factors are adjusted. The adjustment is carried out according to the following formula. It adds up the fuel consumption (or emissions, respectively) of main engine, auxiliary engine and boiler, and accounts for the parabolic dependency of specific fuel consumption on engine load /IMO 2015, Jalkanen et al. 2012/ as well as for the additional time at sea due to slower speed:

$$F_{adj} = (F_M \times LF_{act}/0.9) \times \left(0.455 \times {LF_{act}}^2 - 0.71 \times LF_{act} + 1.28\right) \times (1/(1 - V_{act}/V_{Des})) + \left(F_{A.Sea} + F_{B,Sea}\right) \times (1/(1 - V_{act}/V_{Des})) + (F_{A,Port} + F_{B,Port})$$

With F_{adj} = Speed-adjusted fuel consumption or emission factor [g/tkm]

F_M = Fuel consumption or emission factor of the main engine [g/tkm]

$F_{A.Sea}$= Fuel consumption or emission factor of the auxiliary engine at sea [g/tkm]

$F_{B.Sea}$= Fuel consumption or emission factor of the boiler at sea [g/tkm]

$F_{A.Port}$= Fuel consumption or emission factor of the auxiliary engine in port [g/tkm]

$F_{B,Port}$= Fuel consumption or emission factor of the boiler in port [g/tkm]

b) Adjustment for cargo utilization

The speed-adjusted fuel consumption and emission factors are adjusted for the deviation of cargo utilization from the default using:

$$F_{final} = F_{adj} \times (CU_{Def}/CU_{act})$$

With F_{final} = Cargo utilization-adjusted final fuel consumption or emission factor [g/tkm]

CU_{Def} = Default cargo utilization (/IMO 2009/, tkm-weighted average for the respective trade lane or ETW ship type and size; see Table 40) [%]

CU_{act} = Actual cargo utilization [%]

Table 40: Default parameters used in ETW per trade lane (Standard mode) or vessel type/size class (Extended mode).

Vessel type (and cargo handling)	Trade (Standard mode) / Size class (Extended mode)	Days at sea	Design speed [km/h]	Default speed [km/h]	Default cargo utilization [%]
BC (liquid/dry/general)	Suez trade	200	29.0	22.3	55%
BC (liquid/dry/general)	Transatlantic trade	182	28.2	22.2	54%
BC (liquid/dry/general)	Transpacific trade	194	28.7	22.1	54%
BC (liquid/dry/general)	Panama trade	182	28.2	22.2	54%
BC (liquid/dry/general)	Other global trade	186	28.3	22.0	52%
BC (liquid/dry/general)	Intra-continental trade	172	27.3	21.3	53%
CC	Suez trade	248	47.9	30.2	70%
CC	Transatlantic trade	236	44.6	29.8	70%
CC	Transpacific trade	245	47.0	30.1	70%
CC	Panama trade	236	44.6	29.8	70%
CC	Other global trade	236	44.6	29.8	70%
CC	Intra-continental trade non EU	210	39.4	27.3	70%
CC	Intra-continental trade EU	190	30.6	23.0	70%
Great Lakes BC	-	238	26.3	19.7	58%
GC	Coastal	161	21.5	16.1	60%
BC (dry)	Feeder	167	25.9	19.6	56%
BC (dry)	Handysize	171	28.4	21.7	55%
BC (dry)	Handymax	173	28.6	21.9	52%
BC (dry)	Panamax	188	28.5	22.1	52%
BC (dry)	Aframax	191	28.5	22.0	53%
BC (dry)	Suezmax	199	28.4	21.7	56%
BC (liquid)	Feeder	173	25.5	20.6	62%
BC (liquid)	Handysize	175	26.8	21.8	59%
BC (liquid)	Handymax	184	28.0	22.8	62%
BC (liquid)	Panamax	214	30.6	24.8	64%
BC (liquid)	Aframax	204	29.8	23.5	58%
BC (liquid)	Suezmax	211	30.2	23.3	57%
BC (liquid)	VLCC (+)	232	29.8	23.5	50%
CC	Feeder	190	30.6	23.0	70%
CC	like Handysize	200	36.1	25.7	70%
CC	like Handymax	219	42.5	28.6	70%
CC	like Panamax	236	44.6	29.8	70%
CC	like Aframax	244	46.1	30.1	70%
CC	like Suezmax	250	48.9	30.2	70%
CC	ULCV	251	46.3	27.4	70%
CC	World	236	45.1	29.4	70%
RoRo	RoRo small	146	19.8	16.3	70%
RoRo	RoRo large	209	34.4	26.3	70%
Global average CC	World	210	33.3	24.7	58%

6.3.5 Consideration of emission control areas (ECAs)

Emissions from sea vessels are regulated in Annex VI of the “International Convention on the Prevention of Pollution from Ships”, also known as MARPOL. Annex VI defines two sets of emission and fuel quality requirements: on one hand global requirements, and on the other hand more stringent requirements applicable in so-called Emission Control Areas (ECAs). An ECA can be designated for SO_x, PM, or NO_x, or all three pollutants, subject to a proposal from a Party to Annex VI.

Existing Emission Control Areas include /Dieselnet 2015/:

- Baltic Sea (SO_x, adopted: 1997; entered into force: 2005)
- North Sea (SO_x, 2005/2006)
- North American ECA, including most of US and Canadian coast (NO_x & SO_x, 2010/2012).
- US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NO_x & SO_x, 2011/2014).

The fuel sulphur limits inside and outside ECAs are depicted in Figure 15. ECA-specific NO_x emission limits enter into force from 2016 but are not yet considered in ETW.

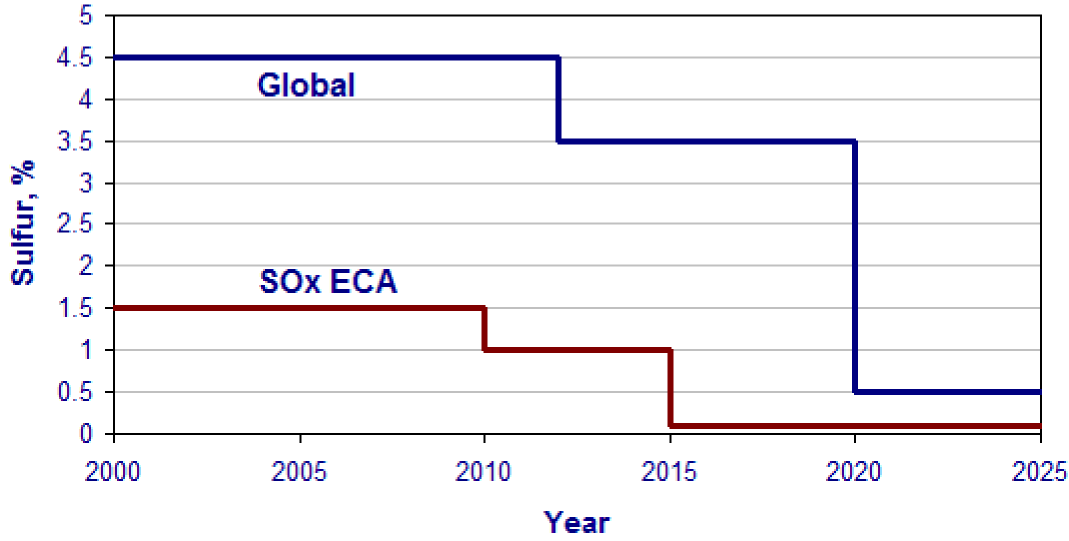
Different options exist to comply with the emission limits in ECAs. Currently the most widespread is to use Marine Diesel Oil (MDO), which has a sulphur content of 0.1% (compare Chapter 6.3.2). Other options are to use scrubber, an after-treatment technology that uses sea water to wash SO_2 out of the exhaust gas, or to switch to LNG instead of diesel. However, the latter two options are not very widespread: as of January 2015, only 0.6% of the world fleet was fitted with scrubbers /Fathom 2015/, and even fewer ships used LNG.

In ETW, it is therefore currently assumed that all ships comply with ECA emission limits (as well as special emission limits in ports) by switching to MDO. This is implemented by splitting the journey travelled into the distance within and outside ECAs. For the distance within ECAs, the fuel consumption and emission factors for MDO (Marine Diesel Oil) are applied, and for the distance outside, the factors for HFO (Heavy Fuel Oil; see Table 34 – Table 36).

Besides ECAs, stricter emission limits also apply to certain ports, e.g. all ports in Europe and California. Ports in other parts of the world have voluntary fuel switch programs, which offer incentives like reduced port fees for using lower-sulphur fuels. The maximum allowed sulphur level in these programs varies. As a simplified assumption, MDO (with 0.1% sulphur content) is assumed to be used in ports with stricter emission limits or voluntary fuel switch programs, i.e.:

- All ports in Europe
- All ports in California
- Seattle, New York, New Jersey, Houston (USA)
- Vancouver (Canada)
- Hong Kong
- Singapore

Figure 16 MARPOL Annex VI fuel sulphur limits (source: Dieselnet 2015).



6.3.6 Allocation rules for seaborne transport

The emissions of ocean-going vessels are averaged over the entire return journeys, taking the load factors and empty returns into account. All emissions are allocated to the freight carried.

For bulk vessels the allocation unit is tonne-kilometre (tkm). All emissions are allocated to the product of transported tonnes of freight and distance travelled. The emissions of container vessels are calculated on a container-kilometre basis (TEU-km). tkm and TEU-km are converted to each other using the container weights presented in Table 9 for volume, average and bulk goods.

6.3.7 Ferry transport

Ferry transport is a special case within ETW as it represents a “hybrid” mode of transport, i.e. it is road or rail transport on a ship. ETW handles ferry routes as an extension of the road and rail network. The user of the web interface cannot choose “ferry” as a mode, but ferry transport is chosen automatically when the mode is road or rail and the most advantageous route leads via a ferry route (compare Chapter 5.2). In the extended mode, the user can choose whether to explicitly avoid or prefer ferry routes. The description of ferry transport is placed in the sea transport chapter in this report since the basic methodology and source of the pollutant emission factors is the same as for sea transport (see Chapter 6.3.2).

The allocation of the energy consumption between passenger and goods transport is a tricky and controversial issue. Different allocation methodologies have been proposed (e.g. /Kristensen 2000/ or /Kusche 2000/); the decision which is the most appropriate cannot be made objectively but remains a convention. In conformity with the European norm (EN) 16258, ETW allocates the energy consumption to freight according to the share of deck area dedicated to vehicles.

The final fuel consumption per gross tonne-kilometre of cargo (i.e. allocated to each tonne of cargo inside the ferry including the vehicle, i.e. train or truck, in g/tkm) is

calculated based on the following equation:

$$FC_{cargo,\ gross} = \left(\left(FC_{Ferry} \times S_{Freight} \right) / (CC \times CU) \right)$$

All input parameters for this equation have been derived based on two studies from the Baltic and Mediterranean Seas, i.e. /Scandria 2012/ and /Holmegaard and Hagemeister 2011/. Their values are displayed in Table 41**.**

Table 41: Parameters for the calculation of final fuel consumption of cargo on ferries.

Parameter	Description	Unit	Value
FC_{cargo}	Final fuel consumption per gross tonne kilometre	g/tkm	14.1
FC_{Ferry}	Total fuel consumption of the ferry (main and auxiliary engines)	g/km	86,971
$S_{Freight}$	Share of freight in terms of deck area dedicated to vehicles	%	54%
CC	Cargo capacity of the ferry [t]	t	5,218
CU	Cargo capacity utilization of the ferry	%	64%

The fuel consumption per net tonne-kilometre (i.e. allocated only to the weight of goods transported inside the train or truck) is calculated by dividing the fuel consumption per gross tonne-kilometre by the ratio of the weight of the goods transported to the weight of the vehicle including the goods transported (compare Chapters 6.1 and 6.2):

$$FC_{cargo,\ net} = FC_{cargo,\ gross} / \left(m_{cargo} / m_{(vehicle+cargo)} \right)$$

where:

$FC_{cargo,\ net}$ = final fuel consumption per net tonne kilometre [g/tkm]

$FC_{cargo,\ gross}$ = final fuel consumption per net tonne kilometre [g/tkm]

m_{cargo} = mass of cargo on the vehicle (truck, train) [t]

$m_{(vehicle+cargo)}$ = mass of the vehicle (truck, train) including cargo [t]

The same pollutant emission factors in g/g fuel have based on /IMO 2015/ are used as for other sea transport (see Chapter 6.3.2), assuming a share of 65% of the main engine in total fuel consumption (based on /IMO 2015/).

6.4 Inland waterway transport

6.4.1 Overview

The methodology for inland waterway transport has been updated compared to previous versions of ETW (see /ifeu, INFRAS, IVE 2014/). The main focus was to consider up to date fuel consumption and emission factors data and update ETW where necessary.

Inland vessels are modelled in a bottom-up approach similar to ocean-going vessels (see Chapter 6.3). However, instead of applying tkm-weighted average fuel consumption and emission factors for aggregate ETW classes, three representative ship types are provided:

- The Europa ship, representative for ships with up to 1500 t capacity, and used by default on rivers of CEMT Classes I-IV[8];
- The “Grossmotorschiff”, representative for ships with 1500 – 3000 t capacity, and used by default on rivers of Class V;
- The Jowi class, representative for capacities >3000 t, used by default on rivers of Class VI and above.

This approach is more appropriate given the lack of activity data on inland navigation (especially outside Europe), which would have added uncertainty to any tkm-weighted aggregation; for Europe, a comparison of mean fuel consumption factors with tkm-weighted aggregated classes has shown that the three ship types listed above represent their size classes well.

The resulting fuel consumption and emission factors are further adjusted to a default or user-specified cargo utilization.

6.4.2 Inland waterways in ETW

The majority of waterways available in ETW are located in Europe. All European waterways class IV and above are included in ETW (Figure 17). Most prominent are the rivers Danube, Elbe, Rhine, and Seine[9], which are (at least in sections) classified as CEMT class VI. Other rivers and canals in Europe are classified as class V or smaller. The distinction between inland waterways up to class IV and above is important because the size and carrying capacity of inland barges significantly increases on class V and larger rivers.

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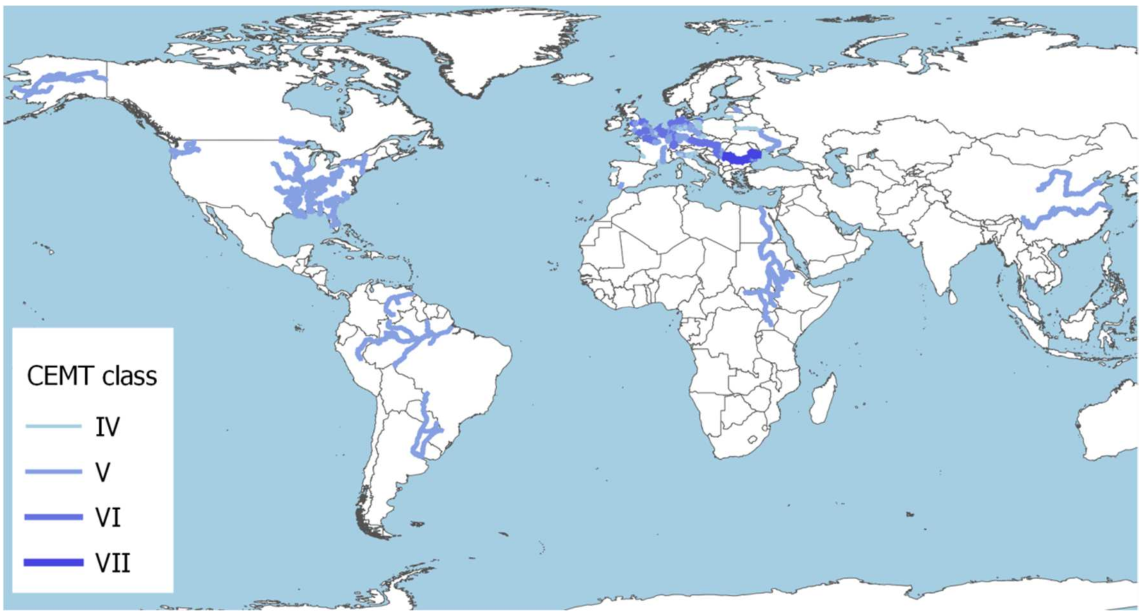
8 Large navigable waterways are classified by the CEMT standard created by the European Conference of Ministers of Transport (**C**onférence **E**uropéenne des **M**inistres des **T**ransports) in 1992 /CEMT 1992/. The standard specifies the maximum measures (length, bean, draught, tonnage) for ships to be able to navigate on rivers of each class.

9 There are other smaller sections that are technically “inland waterways” but are treated as part of the ocean network in ETW. Those include the Weser up to Bremerhaven or the North-Baltic-Channel.

Figure 17: European inland waterways and their classification

Worldwide, approximately 50 countries have navigable waterways of more than 1000 km length. Inland freight navigation is underdeveloped in many countries /BVB 2009/. Besides Europe, mainly the USA and China exhibit significant inland waterway transport performance /Amos et al. 2009/. ETW enables inland waterways calculation on the largest global waterways, such as the Yangtze, Mississippi or Amazon rivers. The CEMT classification is not available on non-European waterways; therefore, the class V is assigned per default to all waterways outside Europe (Figure 18).

Figure 18: Worldwide inland waterways in ETW.



6.4.3 Derivation of basic fuel consumption and emission factors

As for sea transport, fuel consumption is modelled separately for main and auxiliary engine for a virtual one-year period in order to account for emissions in port and return journeys and normalized to one tonne- or TEU-kilometre.

The fuel consumption of the main engine is calculated as follows:

$$FC_M = ((P \times LF_{CU})/V)/(CU \times Cap) \times SFC$$

With FC_M = Fuel consumption of the main engine [g/tkm or g/TEU-km]

P = Installed power [kW] /Panteia 2013/

LF_{CU} = Load factor at default cargo utilization /ifeu and INFRAS 2013/

V = Speed [km/h] /ifeu and INFRAS 2013/

CU = Default cargo utilization /ifeu and INFRAS 2013/

Cap = Capacity (dead weight tonnage or TEU) /Panteia 2013/

SFC = Specific diesel consumption in g/kWh (200 g/kWh for all ships based on /ifeu and INFRAS 2013/)

The input data related to the inland vessel fleet (nominal power, capacity) are sourced from /Panteia 2013/ and correspond to averages of the EU fleet. Load factors, cargo utilization is based on the German TREMOD model /ifeu and INFRAS 2013/. The load factor at default cargo utilization is calculated from ship type- and size class-specific load factors at full or empty load and for up- and downstream travel, respectively, that were derived for TREMOD from empirical data on energy consumption from German river sections /ifeu and INFRAS 2013, BMVBS 2011/:

$$LF_{CU} = LF_{empty} + \left(LF_{empty} - LF_{full}\right) \times CU$$

With LF_{CU} = Load factor at default cargo utilization

LF_{empty} = Average load factor at empty load

LF_{full} = Average load factor at full load

The average load factors at empty/full load are calculated as the arithmetic average of the respective up- and downstream load factors.

The fuel consumption of the auxiliary engine is assumed to be 5% of the consumption of the main engine, as in TREMOD /ifeu and INFRAS 2013/.

Technical data on the three inland barge types provided in ETW are listed in Table 42.

Table 42 Inland vessel technical parameters

Vessel type	Default for CEMT river class	Length [m]	Beam [m]	Installed power [kW]	Average speed [km/h]	Capacity		Default cargo utilization	
						DWT (bulk)	TEU (Con-tainer)	Bulk	Con-tainer
Europa ship	I - IV	85	9.5	737	10.5	1'350	100	60%	60%
"Grossmotorschiff"	V	110	11.4	1'178	10.5	2'500	200	50%	60%
JOWI class	VI+	135	17.34	2'097	10.5	5'300	450	50%	60%

The emission factors for inland vessels have been updated compared to /ifeu, INFRAS, IVE 2014/). Similar to diesel engines for road and rail transport, the emission performance of inland vessel engines strongly depends on the engine technology. In the past years the EU and US implemented emission limits for new engines in several stages, thus reducing specific emissions for newer engines. This fact should be considered in ETW by providing different emission factors by emissions stage, like already available for road transport.

Table 43 lists the emission stages and emission factors available for ETW. The factors have been derived from measurements and literature data for European ships in /ifeu and INFRAS 2013/. For the more recent stages US Tier 3 and US Tier 4, values have been derived from the emission limits and certification data by the EPA in 2014 and 2015 for category 1 and 2 engines /EPA 2015/.

Table 43 Inland vessel engine emission factors

Emission stage (manufacture year)	NOx (g/kWh)	NMHC (g/kWh)	PM (g/kWh)
conventional (1970-2002) / US Tier 1	11,67	0,52	0,32
CCNR I (2002-2006)	9,00	0,39	0,12
CCNR II/ EU IIIA / US Tier 2 (>2006)	7,00	0,29	0,12
US Tier 3	5,10	0,28	0,12
US Tier 4	1,4	0,06	0,03
Source: /ifeu and INFRAS 2013/, /EPA 2015/, dieselnet.com, ifeu assumptions			

According to evaluations in /ifeu and INFRAS 2013/ it was estimated that the average engine age for German and Dutch ships in 2011 was around 20 years. It can further be estimated that currently more than half of the transport performance in Germany is carried out by ships with no type approved engines (thus older than 2002). Also, most countries outside Europe or the US have no regulation for inland ship engines. Thus, the stage “conventional (1970-2002) / US Tier 1” is used as default value. For Germany, which may be representative for Western Europe, this will result in slightly higher emissions than for the average fleet. However, expert users can calculate emissions with newer emission stages if they have detailed knowledge of the ship or engine age.

6.4.4 Allocation rules for inland waterway transport

For inland waterway navigation, the same allocation rules as for ocean transport apply (see Chapter 6.3.6).

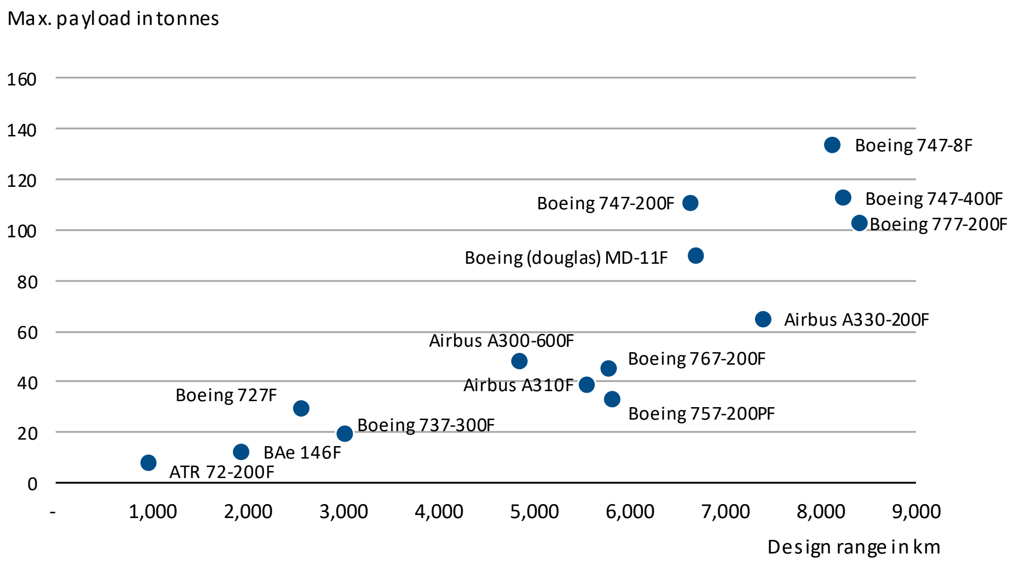
6.5 Air transport

6.5.1 Type of airplanes and load factor

The type and model of airplanes (e.g. Boeing 747-400, B777F) used for air cargo has a high impact on GHG emissions and air pollutants. On the one hand the type gives the information about the capacity of the airplane and age of the turbine used. On the other hand, the aircraft type delivers information if air cargo is transported in dedicated freighters (only for freight) or together with passengers in aircrafts (so-called belly freight). This information is important for the allocation methodology (see subchapter 6.5.3). In the extended input mode of ETW 42 dedicated freighter and some 200 passenger aircraft types are available for selection. For the full list of aircraft type refer to the table the appendix 7.4.

Each aircraft is characterised by both a maximum possible design range and a maximum payload (maximum freight weight). Large passenger aircrafts can fly without stopovers more than 10,000 km, whereas smaller ones have maximum ranges of 2,000 to 3,000 km /Lang 2009/. Aside from that, larger aircrafts can transport more freight than smaller ones. The maximum payload capacity of larger aircrafts is much higher. ETW includes a wide range of small, medium and large aircrafts covering the whole possible spectrum of operating distances and payloads, which is shown exemplarily for selected freighter aircraft in Figure 19. ETW considers only the so-called design range of the aircrafts, which is the maximum range for the case if the whole structural payload is utilised /Hünecke 2008/. Beyond this range the payload has to be reduced due to the additional fuel needed for the longer flight. This possibility is not considered by ETW.

Figure 19 Design ranges and maximum payload capacities of selected dedicated air freighters



Within the extended input mode ETW provides only aircrafts suitable for the flight distance between the selected airport pair. If the trip distance is longer only those aircrafts are offered by ETW that are able to fly this distance. The longer the flight, the fewer the types of aircrafts provided (see Figure 19). Additionally, the aircraft are distinguished between dedicated freighter and passenger aircrafts. The characteristics of all freighter and passenger aircrafts included in EcoTransIT are available in Table 55 in the annex. In the extended input mode of ETW, all aircraft types are available and may be chosen by the user.

In the standard input mode of ETW, an own selection of airplanes is not possible. Rather, ETW use the airplanes of Table 44 depending on the flight distance (up to 1,000 km short haul aircraft; over 1,000 km up to 3,700 km medium haul aircraft; more than 3,700 km long haul aircraft). Because to the users of the standard input mode it is usually unknown whether a dedicated freighter or passenger aircraft is used, ETW uses a mix of both aircraft types. This mixed aircraft type is called “hybrid aircraft”. Worldwide around 60% of air cargo is transported by freighter /e.g. IATA 2013; Airbus 2013/. This share is used for the hybrid aircrafts of EcoTransIT independent of flight distance. Thus, if a user of the standard input mode selects airports EcoTransIT calculates firstly the distance of the flight (e.g. 5,200 km). In the next step EcoTransIT identifies the freighter and the passenger aircrafts fitting to the flight distance (in this case Boeing 747-400F and Boeing 747-400). In the last step energy consumption and emissions are calculated for both aircraft types and mixed by the share 60% freighter and 40% belly freight. In the standard mode EcoTransIT shows only the mixed result of this hybrid aircraft.

Table 44 Characteristics of selected aircrafts

Type	Distance Group	Type of aircraft	IATA Aircraft code	Design Range (km)	Max. Payload (t)	Typical Seats (number)
Freighter	Short haul	Boeing 737-300SF	73Y	3,030	19.7	
Freighter	Medium Haul	Boeing 767-200F	76X	5,790	45.0	
Freighter	Long haul	Boeing 747-400F	74Y	8,250	113.0	
Belly Freight	Short haul	Embraer 190	E90	3,330	1.4	98
Belly Freight	Medium Haul	Airbus 320	320	5,700	2.4	150
Belly Freight	Long haul	Boeing 747-400	744	13,450	16.8	416
Sources: Lang 2007; Lang 2009; LCAG 2014.						

Mainly high value volume or perishable goods are shipped by air freight and the permissible maximum weight is limited. Therefore, only the category volume goods are included within the ETW tool – independent of using standard or extended input mode. Other types of goods (bulk, average) are not available for air cargo. The load factors used for volume goods differentiated by short, medium and long haul are contained in chapter 4.2.3.

6.5.2 Energy consumption and emission factors (Tank-to-Wheels)

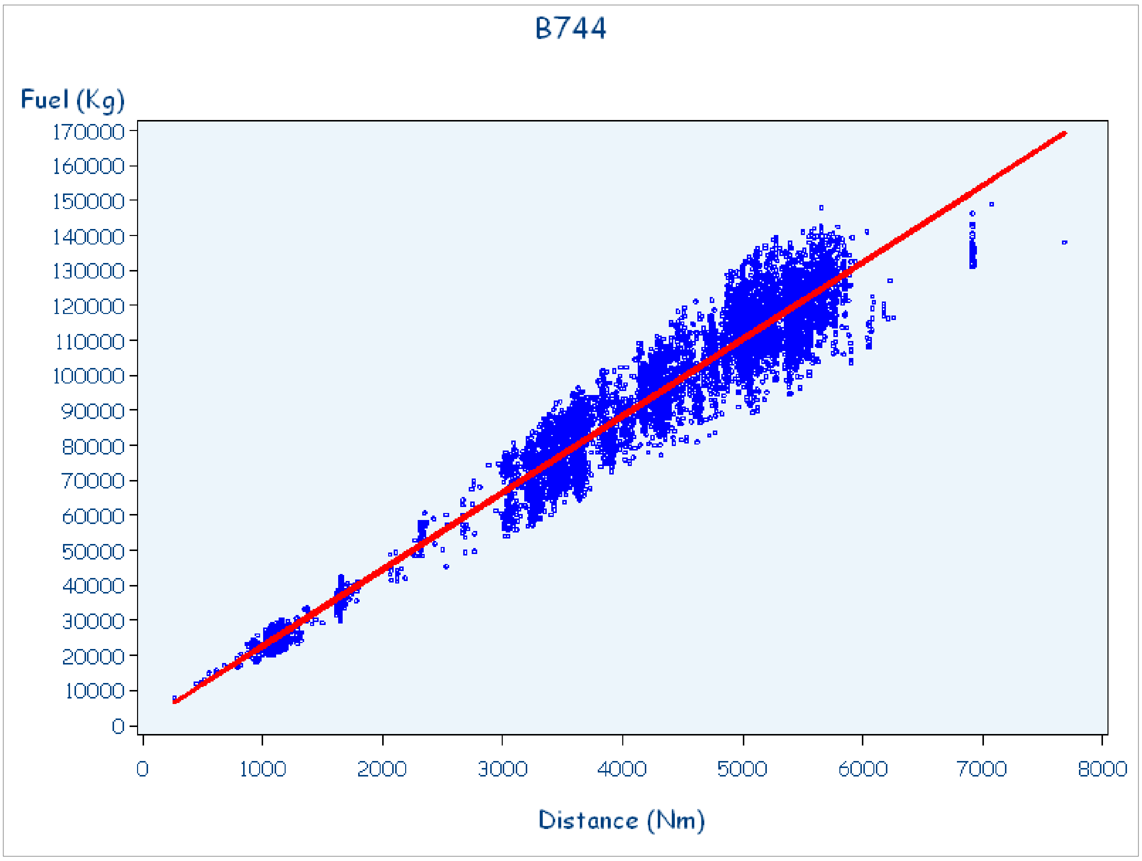
Specific TTW energy consumption and TTW emissions of air cargo transportation depend heavily on the length of the flight. This is caused by different energy needs and emissions in different phases of flight (e.g. take-off or climb). Due to the data sources used by ETW this dependency from flight distance is considered for air pollutants like NOx, NMHC and PM. For fuel consumption the data source used (EUROCONTROL "Small Emitters Tool", see below) only considers a linear correlation between energy consumption and flight distance. This simplification is legitimate since most air cargo flights are long haul flights where take-off and landing phases don't dominate the overall energy consumption of the whole flight. Furthermore, energy consumption and emissions depend on utilisation of the capacity of aircrafts (utilisation of payload capacity). Whereas this dependency is considered by road transport, this was not able for aircrafts due to lack of available data. But the possible error is small and therefore justifiable.

The basis of fuel consumption for the different airplanes considered by ETW is the EUROCONTROL "Small Emitters Tool"[10] which has been developed on behalf of the European Commission for reporting under the European Emissions Trading Scheme (ETS) /EUROCONTROL 2009 and 2015/. This data source is updated yearly and covers a wide range of aircrafts and aircraft families including many newer ones /BEIS 2016/. The Small Emitters Tool covers more than 400 different aircraft types including turboprop engines. EUROCONTROL gathers, on a regular basis and from volunteer aircraft operators in Europe, samples of actual fuel-burn data for their flights performed in a specific year (e.g. 2015). Based on this fuel-burn data a linear regression is carried out for each aircraft type in the sample to consider the fuel dependency from distance flown (see for example in Figure 20) /EUROCONTROL 2009/. In total measured energy consumptions are available for around 85 different aircraft types in the Small Emitters Tool.

In a second step the Small Emitters Tool uses conclusions by analogy for aircraft families. That means that for aircrafts without measured fuel-burn data the energy consumption of other aircraft types of the same family is used (e.g. fuel-burn data from B747-400 for B747-300). In these cases, the measured data are adjusted by using a correction factor based on the MTOW (maximum take-off weight) ratio /EUROCONTROL 2009/. This approach is used for around 30 airplanes. In a third step data from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (formerly called the EMEP CORINAIR Emission Inventory Guidebook) is used for around 30 airplanes /EEA 2013/2015/. Last but not least for the remaining aircraft types (around 270) the average fuel consumption per flight kilometre is calculated based on linear regression model based on the available data considering the MTOW of each airplane /EUROCONTROL 2009/.

10 See also http://www.eurocontrol.int/small-emitters-tool.

Figure 20 TTW energy consumption of the Small Emitters Tool is based on a linear regression of fuel-burn data collected in Europe – example of a Boeing 747-400 /EUROCONTROL 2009/



Since the Small Emitters Tool contains only fuel-burn data for one aircraft model (e.g. Boeing 747-400), the data is used for both dedicated freighter and passenger aircrafts (see Table 45: Boeing 747-400F). Most of the energy consumption data of the 32 freighter and passenger aircrafts considered in ETW are based on measured fuel-burn data collected in context of the Small Emitters Tool. Only for three aircrafts conclusions by analogy from other family models are used (Boeing 777-200/200ER, Boeing 777F and Boeing (McDonnell Douglas) MD-90). For four further aircraft types the method of linear regression based on all available data is applied (Boeing 727F, Boeing 747-8F, Boeing 747-8i and Boeing 787-8). Table 45 shows exemplarily the TTW energy consumptions for the six airplanes used for calculation of the "hybrid aircrafts" in the standard input mode of ETW relating to discrete travel distances. These energy consumption values are completely based on measured fuel-burn data from the Small Emitter Tool. For distances between the discrete mission distances given in Table 45 (e.g. between 4,630 and 5,556 km) the fuel consumptions of the aircrafts are calculated by linear interpolation.

Table 45 TTW fuel consumption of selected freighter and passenger aircrafts depending on flight distances

Distance (km)	Dedicated freighter			Passenger aircrafts		
	Boeing 737-300SF (kg)	Boeing 767-200F (kg)	Boeing 747-400F (kg)	Embraer 190 (kg)	Airbus 320 (kg)	Boeing 747-400 (kg)
232	1,570	2,119	5,744	1,366	1,527	5,744
463	2,285	3,383	8,381	1,912	2,217	8,381
926	3,714	5,911	13,655	3,004	3,597	13,655
1,389	5,143	8,439	18,928	4,096	4,977	18,928
1,852	6,572	10,967	24,202	5,188	6,357	24,202
2,778	9,431	16,023	34,749	7,371	9,118	34,749
3,704	12,289	21,079	45,296	9,555	11,878	45,296
4,630		26,135	55,843		14,638	55,843
5,556		31,191	66,389		17,399	66,389
6,482		36,248	76,936		20,159	76,936
7,408			87,483			87,483
8,334			98,030			98,030
9,260						108,577
10,186						119,124
11,112						129,671
12,038						140,218
12,964						150,765
13,890						161,312
Source: EUROCONTROL Small Emitters Tool /EUROCONTROL 2015/						

CO_2, CO_2 equivalents and SO_x depend directly on the amount of kerosene consumed by the airplanes. For CO_2-equivalent the emission factors of the European standard EN 16258 are used without changes (se e

Table 46 and Table 52). The CO_2 emission factor used by ETW is based on the same sources than the CO_2 equivalent emission factor included in the European standard so that the CO_2 emissions calculation of ETW is comparable with the approach of EN 16258. For SO_x an emission factor of 0.84 g per kg kerosene is applied for ETW /EEA 2013/2015/. This value is based on data from EUROCONTROL. On national level the values can be much lower. For example, in Germany an emission factor of 0.4 g SO_2 per kg kerosene in 1998 and 0.2 g SO_2 per kg kerosene in 2009 is used /Öko-Institut 2010; ifeu and Öko-Institut 2012/.

Table 46: Fuel-based emission factors for CO_2, CO_2e and SO_x (TTW) for kerosene (jet A and jet A1)

	g/kg fuel
Carbon dioxide (CO_2)	3.15
Carbon dioxide equivalents (CO_{2e})	3.18
Sulphur dioxide emissions (SO_x)	0.84
Sources: EEA 2013/2015; EN DIN 2012; Öko-Institut 2010.	

NO_x, NMHC and PM are air pollutants which are independent from the fuel consumption of the aircrafts. For these air pollutants ETW uses emission factors of the EMEP/EEA Air Pollutant Emission Inventory Guidebook /EEA 2013/2015/. This guidebook provides detailed emission factors for NO_x, HC and PM of around 75 different aircraft types with regard to discrete mission distances. The data of the EMEP/EEA Guidebook is applied in different national inventories (e.g. see /ifeu and Öko-Institut 2012/ for Germany/ as well as for several emission calculation tools (e.g. see /ICAO 2012/). In this context, it has to be taken into account that the EMEP/EEA data is based on an average fleet. The calculated values may be 10% below or above the real emissions of individual aircrafts calculated for a concrete city pair /ICAO 2012/. Nevertheless, EMEP/EEA data is the most comprehensive publicly available data source for NO_x, HC and PM emissions of aircrafts.

For ETW the emission data of the EMEP/EEA Guidebook are used directly without changes /EEA 2013/2015/. Table 47 shows the results for the aircraft type Boeing 747-400 according to the flight distance. Since the emission values are also given only for discrete mission distances, emissions for flight distances between those listed in the Table 47 are calculated by linear interpolation. In some cases, the data from the EMEP/EEA Guidebook doesn't cover the maximum ranges of the airplanes. For these cases the emission values were extrapolated to cover the whole ranges needed for the ETW calculations. These extrapolation steps were done by using a polynomial regression. Because the EMEP/EEA Guidebook only includes distance related emission factors for hydrocarbons in total (HC), NMHC emissions have to be calculated afterwards. Therefore, it was assumed that the NMHC emissions for the Landing and Take-Off cycle (so-called LTO cycle, <1,000 m altitude) be 90% of total HC emissions, while during cruise only NMHC is emitted /EEA 2013/2015/. The NMHC values in Table 47 consider already this adjustment step.

Table 47 NOx, HMHC and PM emissions of aircraft type Boeing 747-400 (freighter)

Distance (km)	NO_X (kg)	NMHC (kg)	PM (kg)
232	126	2.8	0.6
463	171	3.1	0.9
926	227	3.7	1.5
1,389	290	4.2	2.1
1,852	353	4.6	2.6
2,778	472	5.8	4.2
3,704	607	6.5	5.0
4,630	734	7.4	6.2
5,556	863	8.3	7.4
6,482	988	9.1	8.6
7,408	1.126	10.3	9.8
8,334	1.248	11.2	11.0
9,260	1.373	12.1	12.1
1,186	1.506	13.0	13.3
1,112	1.783	15.0	15.9
12,038	2.239	17.9	19.9
12,964	2.509	19.9	22.5
13,890	2.930	22.8	26.4
Sources: EEA 2013/2015; INFRAS calculations.			

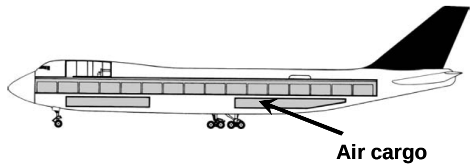
6.5.3 Allocation method for belly freight

The energy consumption and emissions of dedicated freighters are simply allocated per leg (airport pair) by using the quotient of air cargo weight considered and the total payload within the aircraft. The latter is the product of maximum payload capacity (CP) and the capacity utilisation (CU). For belly freight the energy consumption has to be split between air cargo and passenger. For the allocation of emissions between passenger and freight different approaches are principally possible /EN 16258; ICAO 2012/. ETW uses the approach used (and required) by the European Standard EN 16258. In accordance with EN 16258 a weight of 100 kg (= 0.1 t) per passenger is assumed. Figure 21 contains the concrete formula to allocate the energy consumption and emissions of passenger aircrafts.

Figure 21 Allocation rules for dedicated freighter and passenger aircrafts in accordance with EN 16258

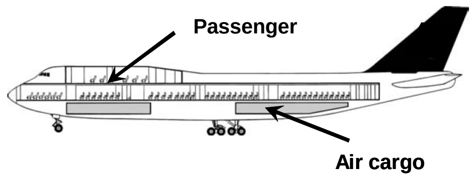
Dedicated freighter

$$\frac{m_{cargo}}{(CP \times CU_{cargo})}$$



Passenger aircraft

$$\frac{m_{cargo}}{(CP \times CU_{cargo} + n_{seats} \times 0{,}1\,t \times CU_{passanger})}$$



Legend:

m_{cargo} = weight of air cargo considered [tons]

CP = maximum payload of cargo [tons]

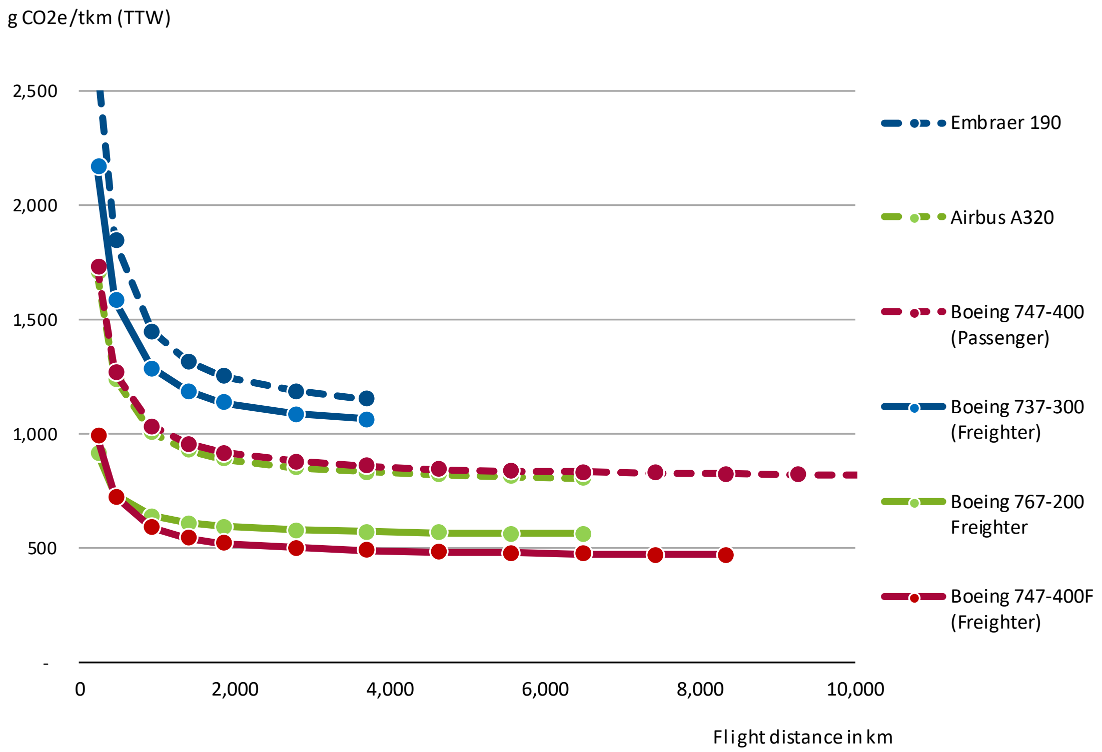
CU_{cargo} = capacity utilisation [%]

$n_{passenger}$ = number of seats offered [number]

$CU_{passenger}$ = capacity utilisation passenger [%]

The approach required by EN 16258, which is used for belly freight, leads to higher fuel consumption and emissions of air cargo carried by passenger aircrafts compared to that of freighters. As Figure 22 shows, for aircrafts used for the standard input mode of ETW, the CO_2 emissions of belly cargo is 20 to 80% higher as air cargo transported by dedicated freighters. Additionally, the figure shows that the specific CO_2 emissions of smaller aircrafts (e.g. B737-300SF) are much higher than those of larger aircrafts which are used for long-haul flights (e.g. B 747-400F). In this context it has to be noted, that small aircrafts are only used for short-haul trips up to 1.000 km, medium sized aircrafts for medium-haul trips between 1.000 and 3.700 km, while big aircrafts are only used for long-haul flights over 3.700 km within ETW.

Figure 22 Specific TTW CO_2 emissions of selected freighter and passenger aircrafts in g/tkm used for the ETW standard input mode /EUROCONTROL 2015; INFRAS calculations/



6.6 Energy consumption and emissions of the upstream process (WTT)

Additional to the emissions caused directly by operating the vehicles (Tank-to-Wheels/TTW) emissions and energy consumption of the **generation of final energy (fuels, electricity)** are taken into account by ETW (Well-to-Tank/WTT). The impacts of building the infrastructure for extraction and generation of the different energy carrier are also included. Considering Tank-to-Wheels energy consumption and GHG emissions as well as Well-to-Wheels energy consumption and GHG emissions (sum of TTW and WTT) is a requirement of the European standard EN 16258. ETW provides TTW as well as WTW data not only for energy consumption and GHG emissions, but also for all air pollutants. Therefore, ETW provides emission data always in the same system boundaries required by EN 16258.

The main energy carriers used in freight transport processes are liquid fossil fuels such as diesel fuel, kerosene, heavy fuel oil 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 (including construction and disposal of power stations)
- Energy distribution (transforming and catenary losses)

Energy chain of fuel production:

- Exploration and extraction of primary energy (crude oil) and transport to the entrance of the refinery
- Conversion within the refinery
- In the case of natural gas compression (CNG) or cooling and liquefaction (LNG)
- Energy distribution (transport to service station, filling losses)

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

6.6.1 Exploration, extraction, transport and production of liquid fuels

The greenhouse gas emission factors and the energy demand for the construction and disposal of refineries, exploration and preparation of different input fuels, the transport to the refineries, the conversion in the refinery and transport to the filling station are taken from EN 16258 (see Table 52 in the annex). The other emission factors are from three different data sources: [ifeu / INFRAS / LBST 2015], [ifeu 2015] and the ecoinvent database (version 3.2 using the cut- off approach) [ecoinvent 2013]. For each fuel supply chain, the data source that best represented the EN 16258 values concerning fuel properties (lower heating value), greenhouse gas emissions and energy demand was chosen.

The following table shows the specific factors for the upstream emissions (WTT).

Table 48 Emission factors for energy production of liquid fuels (WTT)

Fuel	NOx kg/TJ	SO_2 kg/TJ	NMHC kg/TJ	PM kg/TJ
Gasoline	36.3	27.8	53.0	1.4
Diesel, MDO, MGO	38.4	30.9	24.9	1.5
Biodiesel	81.1	29.2	5.8	2.5
Kerosene	38.4	30.9	24.9	1.5
Heavy fuel oil	38.8	87.1	32.4	7.0
CNG	28.1	3.9	0.9	0.8
LNG	21.9	42.6	6.0	3.1

Source: heavy fuel oil [ecoinvent 2013]; biodiesel [ifeu 2015] and all others [ifeu / INFRAS / LBST 2015]
Assumptions: CNG average pipeline transport distance 4000 km; LNG imported by ship from Katar to the EU

6.6.2 Electricity production

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 actuality be traced to a particular power plant.

The preferred method to estimate emission factors for electricity production on a general (not company specific) level is to use the average electricity split per year and country. This approach is recommended by the European standard EN 16258.

Single companies often buy electricity on the marked (e.g. green electricity) with different energy mixes and therefore different emission factors. The EN 16258 allows the use of such values on a company level. However, they cannot be used in the public version of ETW, because in many cases there is no information available about the company which runs the train on the selected destination or about the electricity used by a company. To be consistent, it is not possible to combine national and company specific values in the same emission balance, because double counting of emissions from the same energy source cannot be avoided. This also violates the rules of EN 16258.

Therefore, the marked based electricity mix can only be used in the business solution of ETW. In this case, the company is responsible for the quality of the emission values and fulfilling the recommendations of EN 16258. The public version consequently uses the national production mix for the emission calculation of all modes and processes.

The emission values for the national electricity production are calculated using the UMBERTO based "master network". This model has been maintained by ifeu since 2001 and can be used to model the impacts of electricity mixes in Germany and other European or non-European countries. The model consists of basic power plants and raw material upstream processes. The percentage of electricity from the different plants as well as fuel supply, plant efficiency, exhaust gas treatment and electricity losses are varied for the different regions. Data on the regional electricity mixes (values are shown in Table 49) stems from EUROSTAT and the International Energy Agency (IEA) and the reference year is 2013.

Table 50 shows the emission values at pantograph for the different countries/ regions.

Table 49 Energy split of electricity consumption

Region	Ref. year	Source	Coal	Oil	Gas	Nu-clear	Re-newa-bles	other
Africa	2013	IEA	34,9%	9,9%	35,5%	1,9%	17,8%	0,0%
South Africa	2013	IEA	93,6%	0,1%	0,0%	5,6%	0,7%	0,0%
Asia (excl. China)	2013	IEA	50,8%	5,2%	22,5%	3,3%	18,0%	0,3%
China (incl. Hong Kong)	2013	IEA	73,9%	0,1%	2,5%	2,0%	21,2%	0,2%
Hong Kong	2013	IEA	74,8%	0,4%	24,5%	0,0%	0,3%	0,0%
India	2013	IEA	71,9%	1,9%	5,5%	2,9%	17,7%	0,1%
Japan	2013	IEA	28,5%	13,4%	43,0%	0,9%	13,4%	0,8%
South Korea	2013	IEA	38,2%	4,0%	30,0%	26,0%	1,7%	0,1%
Australia	2013	IEA	64,1%	1,4%	21,3%	0,0%	13,2%	0,0%
Non-OECD Americas	2013	IEA	2,4%	12,4%	18,8%	1,7%	64,7%	0,0%
Brazil	2013	IEA	2,5%	3,9%	13,2%	2,5%	77,9%	0,0%
Chile	2013	IEA	40,5%	7,2%	15,1%	0,0%	37,2%	0,0%
Mexico	2013	IEA	10,6%	16,0%	55,5%	4,0%	14,0%	0,0%
EU 28	2013	EUROSTAT	26,6%	1,9%	16,5%	27,1%	26,7%	1,2%
Austria	2013	EUROSTAT	6,5%	1,1%	13,3%	0,0%	77,6%	1,5%
Belgium	2013	EUROSTAT	3,7%	0,2%	28,3%	51,7%	13,6%	2,5%
Bosnia and Herzegovina	2013	IEA	56,6%	0,2%	0,2%	0,0%	43,0%	0,0%

Region	Ref. year	Source	Coal	Oil	Gas	Nu-clear	Re-newa-bles	other
Bulgaria	2013	EUROSTAT	42,7%	0,5%	5,2%	34,1%	17,5%	0,0%
Croatia	2013	EUROSTAT	17,3%	1,6%	14,5%	0,0%	66,5%	0,0%
Czech Republic	2013	EUROSTAT	47,6%	0,1%	4,9%	36,3%	11,0%	0,2%
Denmark	2013	EUROSTAT	40,1%	1,0%	9,5%	0,0%	44,9%	4,5%
Estonia	2013	EUROSTAT	86,1%	1,0%	2,8%	0,0%	9,7%	0,4%
Finland	2013	EUROSTAT	19,3%	0,3%	10,2%	33,3%	35,9%	1,0%
France	2013	EUROSTAT	3,8%	0,4%	3,5%	74,4%	17,3%	0,7%
Germany	2013	EUROSTAT	44,5%	1,1%	12,5%	15,6%	24,3%	1,9%
Greece	2013	EUROSTAT	44,9%	9,2%	18,5%	0,0%	27,3%	0,1%
Hungary	2013	EUROSTAT	20,4%	0,2%	18,2%	51,6%	8,8%	0,8%
Ireland	2013	EUROSTAT	27,8%	0,8%	48,7%	0,0%	22,3%	0,5%
Israel	2013	IEA	53,5%	3,6%	41,8%	0,0%	1,0%	0,0%
Italy	2013	EUROSTAT	15,5%	5,3%	38,6%	0,0%	39,0%	1,5%
Latvia	2013	EUROSTAT	0,0%	0,0%	41,2%	0,0%	58,7%	0,0%
Lithuania	2013	EUROSTAT	0,0%	5,0%	54,2%	0,0%	39,7%	1,1%
Luxembourg	2013	EUROSTAT	0,0%	0,0%	76,7%	0,0%	18,1%	5,1%
Montenegro	2013	EUROSTAT	34,4%	0,0%	0,0%	0,0%	65,6%	0,0%
Netherlands	2013	EUROSTAT	24,4%	1,2%	57,5%	2,8%	10,3%	3,7%
Norway	2013	EUROSTAT	0,0%	0,0%	1,9%	0,0%	97,8%	0,3%
Poland	2013	EUROSTAT	83,6%	1,1%	4,4%	0,0%	10,8%	0,0%
Portugal	2013	EUROSTAT	23,0%	3,3%	14,0%	0,0%	58,5%	1,1%
Romania	2013	EUROSTAT	27,2%	0,9%	14,9%	19,8%	37,1%	0,0%
Serbia	2013	EUROSTAT	71,3%	0,0%	0,8%	0,0%	27,8%	0,0%
Slovakia	2013	EUROSTAT	11,4%	1,6%	10,5%	54,5%	21,8%	0,2%
Slovenia	2013	EUROSTAT	29,1%	0,0%	3,0%	34,0%	33,8%	0,0%
Spain	2013	EUROSTA	14,5%	4,9%	20,7%	20,1%	39,3%	0,4%

Region	Ref. year	Source	Coal	Oil	Gas	Nu-clear	Re-newa-bles	other
		T						
Sweden	2013	EUROSTAT	0,6%	0,3%	0,8%	42,6%	53,7%	2,0%
Switzerland	2013	IEA	0,0%	0,1%	1,1%	36,7%	58,9%	3,2%
Turkey	2013	EUROSTAT	25,5%	0,7%	44,1%	0,0%	29,6%	0,0%
United Kingdom	2013	EUROSTAT	36,9%	0,6%	27,3%	19,0%	15,0%	1,2%
Non-OECD Eurasia	2013	IEA	23,1%	1,0%	39,7%	16,3%	19,8%	0,2%
United States	2013	IEA	39,5%	0,6%	27,1%	19,2%	13,1%	0,5%
Canada	2013	IEA	9,6%	1,0%	10,0%	15,3%	64,1%	0,0%
Middle East	2013	IEA	0,0%	33,1%	63,5%	0,6%	2,9%	0,0%
Islamic Republic of Iran	2013	IEA	0,0%	26,0%	65,9%	2,0%	6,1%	0,0%
Former Soviet Union	2013	IEA	21,0%	0,7%	43,6%	16,6%	18,0%	0,2%
Russian Federation	2013	IEA	14,7%	0,8%	49,9%	16,3%	18,0%	0,3%
World	2013	IEA	40,1%	4,2%	22,2%	10,6%	22,5%	0,4%

Table 50 Energy and emission factors of the electricity supply for railway transport (WTT at pantograph) in 2013

Region	Energy factor (MJ/ MJ)	CO_{2e} (g/ MJ)	$CO_{2,\,fossil}$ (g/ MJ)	NO_x (g/MJ)	SO_2 (g/ MJ)	NMHC (g/ MJ)	PM10 (g/ MJ)
Africa	3,93	305	293	0,962	1,081	0,036	0,104
South Africa	3,83	368	348	1,023	0,773	0,016	0,187
Asia (excl. China)	4,28	372	347	0,793	0,805	0,019	0,111
China (incl. Hong Kong)	3,55	332	306	0,873	0,758	0,011	0,125
Hong Kong	3,72	345	317	0,856	0,682	0,016	0,117
India	3,90	360	336	0,813	1,170	0,014	0,136
Japan	2,71	219	205	0,578	0,411	0,028	0,052
South Korea	3,28	214	202	0,808	0,746	0,025	0,094
Australia	3,35	318	307	0,404	0,476	0,014	0,052
Non-OECD America	2,18	96	90	0,164	0,169	0,014	0,016
Brazil	1,79	59	55	0,112	0,092	0,008	0,011
Chile	2,56	195	184	0,731	0,404	0,024	0,039
Mexico	3,58	236	222	0,333	0,434	0,030	0,040
EU2 8	2,62	137	130	0,319	0,345	0,011	0,041
Austria	1,30	55	50	0,088	0,041	0,005	0,013
Bosnia	3,47	330	325	0,248	1,310	0,007	0,080
Belgium	2,72	65	62	0,119	0,059	0,006	0,019
Bulgaria	3,99	249	242	0,259	0,915	0,009	0,071
Switzerland	2,07	4	4	0,016	0,017	0,002	0,006
Czech Republic	3,41	220	213	0,248	0,610	0,007	0,054
Germany	2,46	189	180	0,245	0,230	0,011	0,028
Denmark	1,51	143	133	0,410	0,217	0,011	0,035
Estonia	3,53	392	385	0,329	1,537	0,009	0,096

Region	Energy factor (MJ/ MJ)	CO_{2e} (g/ MJ)	$CO_{2, fossil}$ (g/ MJ)	NO_x (g/MJ)	SO_2 (g/ MJ)	NMHC (g/ MJ)	PM10 (g/ MJ)
Spain	2,14	101	95	0,237	0,235	0,012	0,033
Finland	2,28	88	80	0,237	0,099	0,008	0,023
France	3,39	28	26	0,077	0,060	0,004	0,017
United Kingdom	2,69	181	168	0,430	0,225	0,012	0,044
Greece	2,75	252	246	0,230	0,651	0,014	0,044
Croatia	2,07	103	99	0,305	0,314	0,008	0,032
Hungary	3,67	139	133	0,182	0,304	0,008	0,031
Ireland	2,08	161	157	0,272	0,171	0,008	0,019
Israel	3,27	277	262	0,911	0,895	0,031	0,116
Italy	2,17	152	142	0,351	0,194	0,020	0,030
Lithuania	2,76	162	147	0,329	0,098	0,024	0,025
Luxembourg	2,14	123	117	0,160	0,022	0,012	0,013
Latvia	2,03	90	81	0,200	0,032	0,013	0,014
Montenegro	2,38	166	163	0,125	0,663	0,004	0,041
Netherlands	2,12	165	158	0,255	0,184	0,012	0,030
Norway	1,22	4	4	0,005	0,010	0,001	0,002
Poland	3,03	324	302	0,629	0,883	0,012	0,116
Portugal	1,77	119	115	0,368	0,352	0,014	0,030
Romania	2,88	165	160	0,160	0,537	0,008	0,039
Serbia	3,34	332	326	0,250	1,308	0,007	0,080
Sweden	2,21	11	9	0,052	0,026	0,002	0,009
Slovenia	2,74	123	120	0,108	0,351	0,004	0,027
Slovakia	2,97	82	77	0,144	0,190	0,007	0,026
Turkey	2,90	221	209	0,294	0,200	0,018	0,029
Non-OECD Eurasia	3,97	245	226	0,431	0,504	0,020	0,069
United States	2,98	198	189	0,294	0,269	0,012	0,031
Canada	2,11	66	63	0,084	0,095	0,005	0,011
Middle East	4,60	308	289	0,430	0,495	0,048	0,047
Iran	3,95	253	245	0,377	0,434	0,041	0,042
Former Soviet Union	3,99	242	221	0,492	0,314	0,023	0,066
Russian Federation	4,02	229	210	0,414	0,257	0,024	0,050
World	3,43	255	243	0,823	0,801	0,025	0,094

6.7 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. Therefore, the trans shipping processes are classified in container, liquid, bulk and other cargo. On the basis of assumptions and previous ifeu-studies, the energy use of the different transfer processes is estimated. All processes are performed with electricity. In addition to final energy consumption stated below, country specific energy and emission factors for electricity generation are used to produce Well-to-Wheels-values.

The European standard EN 16258 doesn’t considers up to now approaches for the calculations of energy consumption and GHG emission caused by intermodal transfers.

This means that results for energy consumption and GHG emissions of transport services must not include intermodal transfers to be in accordance with EN 16258. Results for intermodal transfers are only additionally declared.

In the following the approaches for intermodal transfers of containers, liquid, bulk and other cargo are explained more in details:

Container: The energy used by a handling container in a rail cargo transport centre was estimated by /ifeu°2000/ with 4.4 kWh/TEU and transfer process. In previous studies /ISV1993, ifeu1999/ a lower value (2.2°kWh/°TEU+transfer) for rail was assessed. For container transfer in ship cargo transport centres, these studies searched out an energy factor twice than rail /ISV°1993/. Because of high uncertainties, the value of 4.4 kWh/TEU+transfer is assumed for all carriers.

Liquid cargo: In /ISV°1993/ a very detailed calculation of the energy demanded by transhipping diesel was carried out. For different carriers the values range from 0.3 to 0.5 kWh/t, for which is why 0.4 kWh/t as average energy use is assessed.

Bulk cargo: The results of early ifeu-estimations searching out the energy use of unloading corn from different means of transport were used in /ISV°1993/. For bulk cargo transfer the previous value 1.3 kWh/t is also used in EcoTransIT.

Other cargo: In this category all cargo, which is not container, liquid or bulk cargo is summarized. Thus, the value for energy use of transhipping cargo of this category has the highest uncertainty. On basis of /ISV°1993/ a factor of 0.6 kWh/t for this category is taken.

6.8 Biofuel shares

Environmentally sustainable biofuels are an option to reduce GHG emissions but require little adaption in the vehicle technology. The European Standard EN 590 permits biodiesel blends with up to 7% of FAME[11] and 30% for hydrotreated vegetable oil (HVO[12]). Various technical options exist to use biofuels, e.g. as blends in conventional diesel vehicles (B5, B7, B20, B30) or as pure biodiesel vehicles (B100). According to /ePure, 2016/ in the EU 28 biodiesel incorporation in the diesel pool has fluctuated over the last 5 years and reached 5.1% (low heating value) in 2014.

EcoTransIT includes defaults for the average share of Biodiesel (incl. HVO) in Diesel (MJ/MJ):

- EU: 5%
- Non-EU: 1%

For the countries in Table 51 country-specific biofuel shares are used. The numbers reflect the actual share of biofuels in energy content and can vary from official data on the share of renewable energy sources (RES). The latter is an instrument for reporting

[11] Fatty Acid Methyl Ester

[12] Hydrotreated Vegetable Oils

in the context of the EU renewable energy directive (RED) and follows a unique calculation rule (including electricity, other alternative fuels and multiple counting factors).

Table 51 Share of biodiesel in total diesel in selected EU countries (MJ/MJ)

Fuel Type	France (2014)	Germany (2014)	Sweden (2014)	Finland (2014)	Norway (2016)
HVO	0.3 %	0.8 %	9 %	16.5 %	-
FAME	6.6 %	4.9 %	8 %	0.5 %	-
UCOME*	0.4 %		-	-	-
Total (used in EcoTransIT)	**7.3 %**	**5.7 %**	**17 %**	**17 %**	**10.5 %**

Source /ePure, 2016/, /IEA, 2015/, /Sbb, 2017/, Eurostat, own calculations; * Used Cooking Oil Methyl Ester

7 Appendix

7.1 EN 16258: Default conversion factors

Table 52 EN 16258 default values for fuels and gases

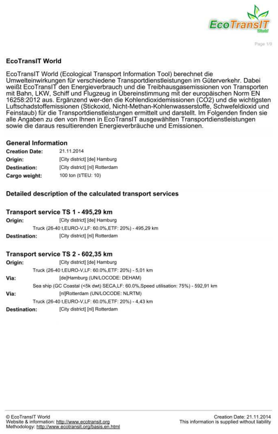
	density (d)	Energy factor MJ/kg		CO2e-factor kgCO_2e/kg	
Fuel type description	**kg/l**	**TTW**	**WTW**	**TTW**	**WTW**
Gasoline	0.745	43.2	50.5	3.25	3.86
Ethanol	0.794	26.8	65.7	0.08	1.56
Diesel	0.832	43.1	51.3	3.21	3.9
Bio-diesel	0.890	36.8	76.9	0.08	2.16
Liquefied Petroleum Gas (LPG)	0.550	46.0	51.5	3.10	3.46
Compressed Natural Gas (CNG)	x	45.1	50.5	2.68	3.07
Aviation Gasoline (AvGas)	0.800	44.3	51.8	3.13	3.76
Jet Gasoline (Jet B)	0.800	44.3	51.8	3.13	3.76
Jet Kerosene (Jet A1 and Jet A)	0.800	44.1	52.5	3.18	3.88
Heavy Fuel Oil (HFO)	0.970	40.5	44.1	3.15	3.41
Marine Diesel Oil (MDO)	0.900	43.0	51.2	3.24	3.92
Marine Gas Oil (MGO)	0.890	43.0	51.2	3.24	3.92
Liquedfied natural gas (LNG)* - **not EN 16258**	x	45.1	56.2	2.68	3,62

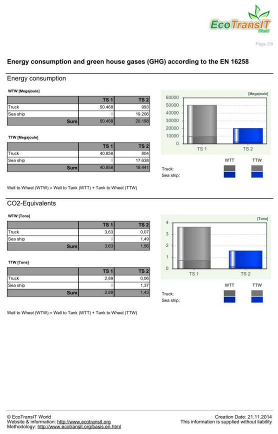
* The EN 16258 does not contain default values for liquefied natural gas (LNG). For EcoTransIT, similar TTW values as for CNG are assumed (both fuels contain mainly methane). The WTT values base on ifeu / INFRAS / LBST 2015. The values are higher than for CNG due to higher energy intensity, especially for liquefaction.

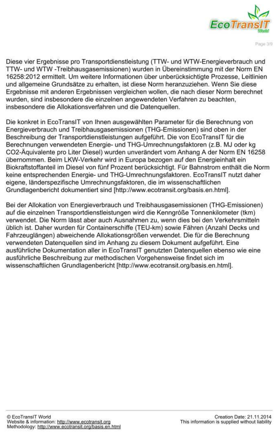
Table 53 Default values for carbon dioxide consistent with EN 16258

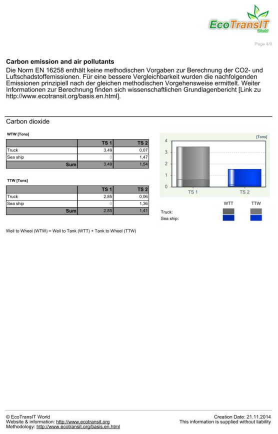
	CO2-factor kgCO_2/kg	
Fuel type description	**TTW**	**WTW**
Gasoline	3.17	3.78
Ethanol	0.00	0.75
Diesel	3.16	3.84
Bio-diesel	0.00	0.62
Liquefied Petroleum Gas (LPG)	3.02	3.37
Compressed Natural Gas (CNG)	2.54	2.78
Aviation Gasoline (AvGas)	3.10	3.74
Jet Gasoline (Jet B)	3.10	3.74
Jet Kerosene (Jet A1 and Jet A)	3.15	3.85
Heavy Fuel Oil (HFO)	3.11	3.38
Marine Diesel Oil (MDO)	3.21	3.89
Marine Gas Oil (MGO)	3.21	3.89

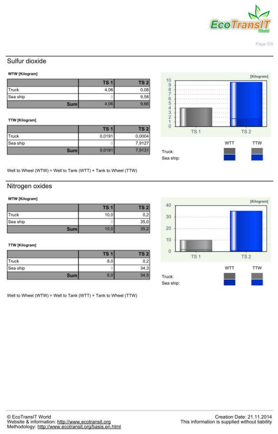
7.2 Example for an ETW declaration in accordance with EN 16258

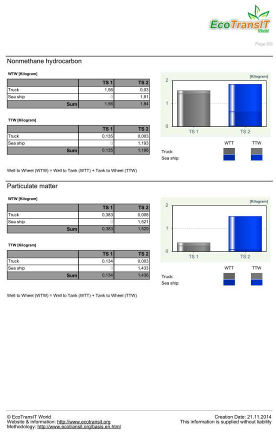


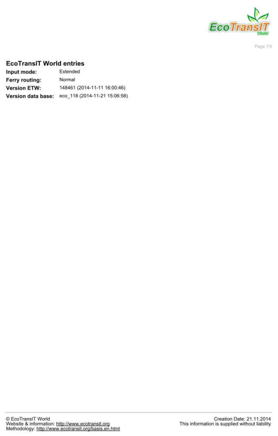


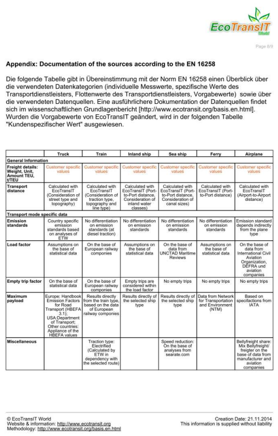


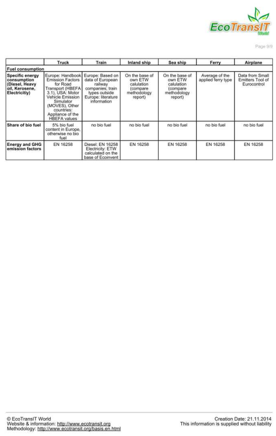












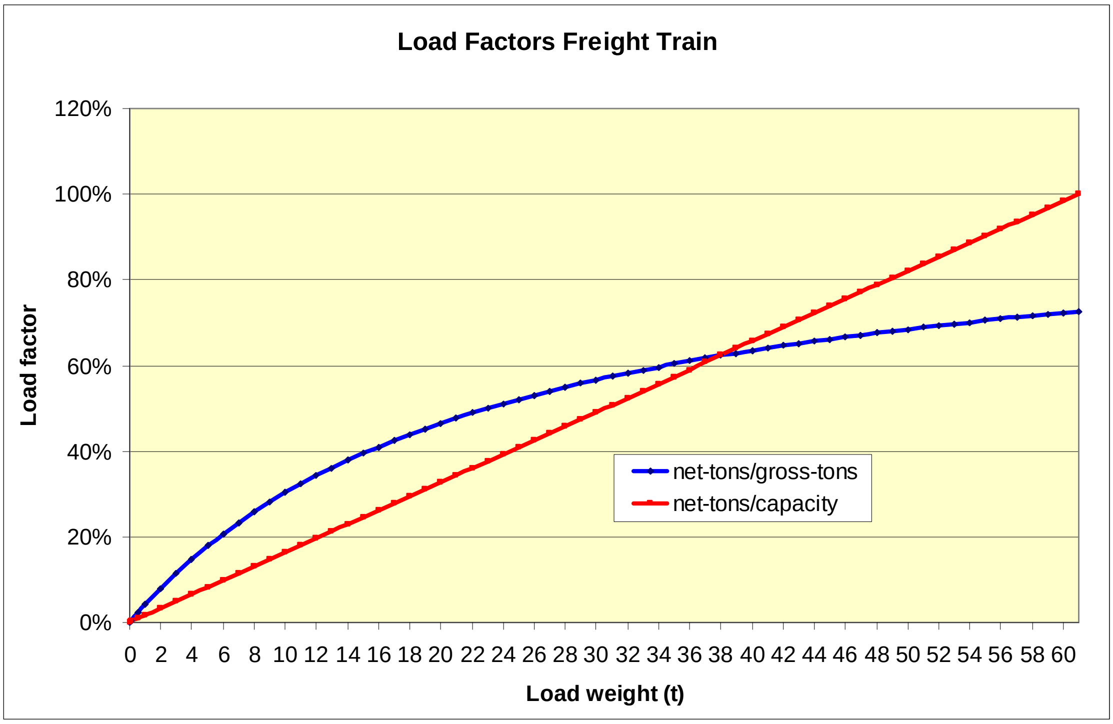
7.3 Additional information to load factors

In this chapter some explanations about the load factor of trains and containers are given in addition to chapter 4.2.2.

7.3.1 Train

The load factor for trains is originally defined as the relation of net tonnes / gross tonne. For a better comparison with road and ship transport the values are transformed to the relation freight load/capacity. The following figure shows a comparison of the load factors for freight trains, based on the average wagon defined in ETW (see chapter 4.2.1: empty weight: 23 tonnes, payload capacity: 61 tonnes).

Figure 23 Load factors for freight trains



7.3.2 Container

Many cargoes shipped in containers are light weight consumer goods[13]. The emissions per TEU-km are allocated to the net-load of the container. Since emissions of container vessels are calculated on a g/TEU-km basis and energy consumption of the ship only marginally depends on the load of the container, volume and average weight cargo is responsible for higher emissions on a per tonne-kilometre basis than heavy weight cargo.

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13 Container vessels' carrying capacity by weight is usually achieved if all container spaces are used and containers weigh no more than 12 gross tonnes for large container vessels and 15 tonnes gross for small container vessels. Thus, container vessels cannot be fully loaded with only heavy weight containers.

Three container load classes and an average empty TEU weight are provided as default values (see Table 54).

Average cargo:

In accordance with the Clean Cargo Working Group (CCWG) the net weight of average goods is be defined by 10.0 tonnes per TEU /CCWG 2014/. Cargo is transported in 20' and 40' containers in the ratio of approximately 2 to 5, i.e. 2 TEU to 10 TEU[14]. Thus, for each lift[15] an average of 1.7 TEUs is loaded. The average empty weight of a TEU is 1.95 tonnes[16].

Volume cargo:

For determining the default volume cargo load of one TEU a convention was used. It is assumed that light weight cargo (volume cargo) tends to be transported in 40' containers. Generally, a maximum load of 90 % of the capacity is assumed due to imperfect fit of the cargo in the container. Then the light weight is assumed to be using 50 % of the carrying capacity. Thus, a 40' Container filled 45 %[17] to its weight carrying capacity is assumed to represent a light weight cargo container. These results in 6.0 tonnes/TEU and an average empty container weight of 1.9 tonnes.

Heavy weight cargo:

The default heavy weight TEU load is derived similarly. Here 90 % of the maximum carrying capacity of the containers is assumed to represent the heavy weight cargo. In order to determine the average heavy weight, the use of 20' and 40' containers for heavy weight cargo need to be determined. Applying the 1.7 ratio 40' to 20' container results in approximately 5x 40' containers and 2x 20' containers or 12 TEUs. In the set of 12 TEUs and 7 containers, a ratio of 3x 40' containers filled with volume weight cargo and 2x 40' containers plus 2x 20' containers filled with heavy weight cargo result in the overall average weight of 10.5 tonnes. The heavy weight containers are then filled with 14.5 tonnes per TEU on average[18] and an average empty container weight of 2.0 tonnes. A theoretical model container vessel is assumed to be loaded with

- x-number of average loaded containers (20' and 40')
- plus, x-time the mix of 2x 20' plus 2x 40' heavy load and 3x 40' light weight load.

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14 A ratio of 1.7 was determined by comparing lifts and TEUs handled from port statistics.

15 Lift is an expression from container terminals and describes the number of containers loaded on-board of vessels.

16 Calculated from a mix of 20' and 40' containers.

17 50 % of the container weight capacity utilised to a maximum of 90 %.

18 Assuming a maximum utilisation by weight of 90 %.

Table 54: Container net-cargo weights for EcoTransIT cargo categories (net weight)

Light weight cargo	Average cargo	Heavy weight cargo
6 metric tonnes/TEU	10 metric tonnes/TEU	14.5 metric tonnes/TEU

If goods are transported as weight restricted cargo, users should be careful not to over-estimate the pay load of the container. Even if a 20’ container can carry more than 21 tonnes of cargo, the on-carriage vehicle may not be able to carry that weight. The maximum gross weight of a 20’ container of 24 tonnes requires an on-road truck >32 tonnes gross vehicle weight, usually used to pull flat beds. This represents a special transport because only one 20’ container could be carried on the flat bed that is capable of carrying 2 TEUs. If containers are further transported by road, it is recommended not to exceed 18 tonnes per TEU for heavy weight cargo.

For intermodal transport – the continuing of transport on land-based vehicles – the weight of the container is added to the net-weight of the cargo. Table 9 on page 15 provides the values used in ETW.

7.4 Detailed data of aircrafts included in EcoTransIT

Table 55 Design range, payload and seats of selected types of aircrafts

Type	Aircraft Code	Type of Aircraft	Design Range [km]	Max. Pay-load [t]	Typical Seats [number]
Freighter	ABY	Airbus 300-600F	4,850	48.1	
Freighter	31Y	Airbus 310-300F	5,560	39.1	
Freighter	33X	Airbus 330-200F	7,400	65.0	
Freighter	ATY	ATR 72-200F	960	7.8	
Freighter	14F	BAe 146-300QT	1,930	12.5	
Freighter	M1F	Boeing (McDonnell Douglas) MD-11F	6,700	89.6	
Freighter	72F	Boeing 727F	2,570	29.5	
Freighter	73Y	Boeing 737-300SF	3,030	19.7	
Freighter	74X	Boeing 747-200F	6,640	111.0	
Freighter	74Y	Boeing 747-400F	8,250	113.0	
Freighter	74N	Boeing 747-8F	8,130	133.9	
Freighter	75F	Boeing 757-200PF	5,830	32.8	
Freighter	76X	Boeing 767-200F	5,790	45.0	
Freighter	77X	Boeing 777-200F	8,410	102.9	
Belly	319	Airbus 319	3,300	1.7	124
Belly	320	Airbus 320	5,700	2.4	150
Belly	321	Airbus 321	5,500	2.8	185
Belly	332	Airbus 330-200	12,500	17.5	253
Belly	333	Airbus 330-300	10,500	21.0	295
Belly	346	Airbus 340-600	13,900	22.0	380
Belly	388	Airbus 380-800	15,000	20.0	525
Belly	M90	Boeing (McDonnell Douglas) MD-90	3,860	3.0	153
Belly	734	Boeing 737-400	4,010	3.5	147
Belly	738	Boeing 737-800	3,590	4.0	162
Belly	744	Boeing 747-400	13,450	16.8	416
Belly	74H	Boeing 747-8i	14,820	17.4	467
Belly	752	Boeing 757-200	7,220	3.8	200
Belly	763	Boeing 767-300	10,310	13.7	218
Belly	772	Boeing 777-200/200ER	9,700	19.0	305
Belly	77W	Boeing 777-300ER	14,490	23.0	365
Belly	788	Boeing 787-8	14,200	15.8	242
Belly	E90	Embraer 190	3,330	1.4	98

8 References

General

Borken 1999 Borken, J., Patyk, A., Reinhardt, Guido A., ifeu: Basisdaten für ökologische Bilanzierungen – Einsatz von Nutzfahrzeugen in Transport, Landwirtschaft und Bergbau; Verlag Vieweg, ISBN 3-528-03118-2; Braunschweig/Wiesbaden 1999

Carstens 2000 Stefan Carstens, Hans Ulrich Diener: Güterwagen Band 2, Gedeckte Wagen - Sonderbauart. MIBA-Verlag, Nürnberg 2000; citation in: http://en.wikipedia.org/wiki/Covered_goods_wagon

DB Schenker 2012 Internal survey: key values of freight transport from railway transport statistics, 2012

EN DIN 2012 EN DIN 16258:2012 – Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (passenger and freight), 21.11.2012

ePure 2016 Overview of the biofuel policies and markets across the EU-28. No.June.

GDV 2010 Containerhandbuch / Container Handbook. Gesamtverband der Deutschen Versicherungswirtschaft e.V. http://www.containerhandbuch.de/

IEA 2015 IEA advanced Motor fuels Annual report - Sweden.

ifeu / INFRAS / IVE 2014 EcoTransIT World - Ecological Transport Information Tool for Worldwide Transports. Methodology and Data Update. Commissioned by EcoTransIT World Initiative (EWI). Berne – Hannover – Heidelberg, 4th December 2014.

ifeu 1999 Knörr, W. et al.: Mobilitäts-Bilanz – Energieverbrauch und Emissionen im Personen- und Güterverkehr mit verschiedenen Verkehrsmitteln; Erstellung verschiedener Materialien und Tools im Auftrag der DB AG; 1998 - 2000; Veröffentlichung der "Mobilitäts-Bilanz" und der Software „Reisen und Umwelt" im Okt. 1999

KBA 2013 KBA and BAG: Verkehr deutscher Lastkraftfahrzeuge; VD5, Dezember 2013

KBA 2002 Güterkraftverkehr deutscher Lastkraftfahrzeuge; Reihe 8, Heft 12, Dezember 2001

Kessel und Partner 1998 Kienzler, H.-P.: Kapazitätsauslastung und Leerfahrten im Gütertransport; VDA Materialien zur Automobilindustrie, Heft 16; Frankfurt am Main 1998

Sbb 2017 Auto diesel sales exceeded 3 billion litres in 2016. pp. 1–5.

SNCF Geodis 2012 Internal survey: key values of freight transport from railway transport statistics, 2012

Van de Reyd and Wouters Van de Reyd, J.K.R., Wouters, M.V.L.J.: Air Cargo Density Research. Delft 2005

Road transport

Dieselnet 2014 DieselNet - Online information service on clean diesel engines and diesel emissions: Summary of worldwide emission standards, http://www.dieselnet.com, last visit October 10th, 2014

CE DELFT 2013 Zero emissions trucks: an overview of state-of-the-art technologies and their potential.

dieselnet.com Online information service on clean diesel engines and diesel emissions: Summary of worldwide emission standards, http://dieselnet.com/standards/, last visit in April 2016

DLR / LBST / IFEU / DBFZ 2015 Identifizierung von Hemmnissen der Nutzung von LNG und CNG im schweren Lkw-Verkehr sowie Möglichkeiten zu deren Überwindung. Berlin, München, Heidelberg, Leipzig.

energy.gov.il Ministry of national infrastructure, energy and water resources (Israel): Fuel and the Environment, http://energy.gov.il/English/Subjects/Subject/Pages/Gxms-MniFuelAndTheEnvironment.aspx, last visit in April 2016

EPA 2014 Motor Vehicle Emission Simulator (MOVES), Version 2014a, by EPA Office for Transportation and Air Quality, retrieved from, http://www.epa.gov/otaq/models/moves/**EPA 2009** Motor Vehicle Emission Simulator (MOVES), Version 2009/12/21, by EPA Office for Transportation and Air Quality, retrieved from, http://www.epa.gov/otaq/models/moves/

INFRAS 2014 Keller, M. et al, INFRAS, et al: Handbook Emission Factors for Road Transport, Ver. 3.2, Bern 2014

integer.com Industry Insight – International Diesel Emissions Regulation https://www.integer-research.com/industry-insight/emissions-legislation/, last visit in April 2016

NGV Global Current Natural Gas Vehicle Statistics - Natural Gas Vehicle Knowledge Base. http://www.iangv.org/current-ngv-stats/ (23.05.2017).

NGVA European map of CNG & LNG filling stations - get directions. http://www.ngva.eu/get-directions (05.07.2017).

TNO 2011 Environmental and Economic aspects of using LNG as a fuel for shipping in The Netherlands.

TNO 2017 Emissions testing of two Euro VI LNG heavy-duty vehicles in the Netherlands: tank-to-wheel emissions

transportpolicy.net Fuels: Diesel and Gasoline in the US, Australia and Canada, http://transportpolicy.net/index.php?title=Australia:_Fuels:_Diesel_and_Gasoline http://transportpolicy.net/index.php?title=Canada:_Fuels:_Diesel_and_Gasoline http://transportpolicy.net/index.php?title=US:_Fuels:_Diesel_and_Gasoline last visit in April 2016

trend news agency 2013 Iranian dangerous fuels with 180 to 8000 ppm sulphur, trend news agency 2013, http://en.trend.az/iran/2106825.html**,** last visit in April 2016

UNEP 2007 Opening the door to cleaner vehicles in developing and transition countries: the role of low sulphur fuels. UNEP (PCFV) 2007 http://www.unep.org/transport/pcfv/pdf/sulphurreport.pdf last visit in April 2016

USCB 2004 U.S. Census Bureau - 2002 Economic Census: Vehicle Inventory and Use Survey (VIUS); EC02TV-US, Washington DC, 2004

USDOE 2009 U.S. Departement of Energy: Transportation Energy Data Book, Edition 28, 2009

USDOT 2007 U.S. Departement of Transport – Federal Highway Administration: Development of Truck Payload Equivalent Factor (TPEF), Columbus, 2007

Rail transport

DB 2008 Deutsche Bahn AG, Bahn-Umwelt-Zentrum: Energy and emission figures 2008

DB Schenker 2012 Internal survey: key values of freight transport from railway transport statistics, 2012

EPS 2005 Railway Association of Canada and Environment Canada: Locomotive Emissions Monitoring Program 2003; Environmental protection series: EPS 2/TS/17; 2005

IFEU 2003: Erarbeitung von Basisemissionsdaten des dieselbetriebenen Schienenverkehrs unter Einbeziehung möglicher Schadstoffminderungstechnologien – Weiterführung und Auswertung des UBA-FuE-Vorhabens 299 43 111. Im Auftrag der Deutschen Bahn AG, Heidelberg.

ifeu 2008 Sectoral analysis of motorised traffic in China; commissionned by Kreditanstalt für Wiederaufbau (KfW); Heidelberg, 2008

Railway companies 2002 Different internal statistics DB, DSB, SBB, SJ, SNCB, SNCF und TI about railway operation data, energy consumption, train configuration etc., 2002

SBB 2006 Enotrac AG: Simulationsrechnungen für Re 420 und Re 620; unpublished; March 2006

SNCF Geodis 2012 Internal survey: key values of freight transport from railway transport statistics, 2012

TRT 2008 TRT Trasporti e Territorio Srl: EX-TREMÌS (Exploring non road Transport EMISsions in Europe): Development of a Reference System on Emission Factors for Rail, Maritime and Air Transport; Final Report; commissionned by JRC-IPTS; Milan, 19 June 2008

UIC 2005 UIC/CER: Rail Diesel Study (EU funded) - WP1: Status and future development of the diesel fleet; Final Report; 21.07.2005

UIC 2007 UIC Statistic

UIC 2009 UIC Energy and CO2 Database; 2009

USDOT 2008 Energy Intensity of Class I Railroad a Freight Service

Inland ship and Marine transport

Amos, P., Dashan, J., Tao, N., Junyan, S., Weijun, F. 2009 Sustainable Development of Inland Waterway Transport in China. Prepared for the World Bank and the Ministry of Transport (MOT), People's Republic of China. World Bank and Waterborne Transport Institute of MOT. http://siteresources.worldbank.org/EXTPRAL/Resources/china.pdf [accessed on 02.02.2016]

BMVBS 2011 Kompendium Nutzen-Kosten-Analyse (NKA) für Investitionen an Binnenschifffahrtsstraßen, Ausgabe 2011. Bundesministerium für Verkehr, Bau und Stadtentwicklung, Unterabteilung Wasserstraßen, Berlin.

BVB 2009 The power of inland navigation. The future of freight transport and inland shipping in Europe 2010 – 2011. Published by the Dutch Inland Shipping Information Agency (BVB).

CEMT 1992 Resolution No. 92/2 on New Classification of Inland Waterways. Conférence Européenne des Ministres des Transports (CEMT). Athens. http://www.international-transportforum.org/IntOrg/acquis/wat19922e.pdf [accessed on 02.02.2016]

Dieselnet 2015 Emission Standards International: IMO Marine Engine Regulations. https://www.dieselnet.com/standards/inter/imo.php [accessed on 02.02.2016]

EPA 2015 Marine Spark-Ignition Engine Certification Data, year 2014 and 2015. https://www3.epa.gov/otaq/certdata.htm#marineci (23.03.2016).

Fathom 2015 Marine Scrubbers: The Guide 2015. The Comprehensive Resource for Marine SOx Scrubbers. Fathom Maritime Intelligence, Windsor.

Holmegard and Hagemeister 2011 Environmental Performance Evaluation of Ro-Ro Passenger Ferry Transportation. Proceedings from the Annual Transport Conference at Aalborg University, ISSN 1603-9696, www.trafikdage.dk/artikelarkiv [accessed on 26.11.2017].

ifeu and INFRAS 2013 Aktualisierung der Emissionsberechnung für die Binnenschifffahrt und Übertragung der Daten in TREMOD. Im Auftrag des Umweltbundesamtes, FKZ 3711 45 105. Institut für Energie- und Umweltforschung (ifeu) und INFRAS, Heidelberg und Bern. https://www.ifeu.org/verkehrundumwelt/pdf/ifeu%202014_Bericht%20Binnenschifffahrt%20TREMOD.pdf [accessed on 02.02.2016]

IMO 2015 Third IMO Greenhouse Gas Study 2014. Executive Summary and Final Report. International Maritime Organization (IMO), London. http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf [accessed on 01.02.2016]

IMO 2009 Second IMO Greenhouse Gas Study 2009. International Maritime Organisation (IMO) London, UK.

Jalkanen, J.-P., Johansson, L., Kukkonen, J., Brink, A., Kalli, J., Stipa, T. 2012 Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon dioxide. Atmospheric Chemistry and Physics 12, 2641-2659, 2012. http://www.atmos-chem-phys.org/12/2641/2012/acp-12-2641-2012.pdf [accessed on 02.02.20126]

MAN 2006 Basic Principles of Ship Propulsion. Technical Paper by MAN DW.

Panteia 2013 Contribution to impact assessment of measures for reducing emissions of inland navigation. European Commission (EC). http://ec.europa.eu/transport/modes/inland/studies/doc/2013-06-03-contribution-to-impact-assessment-of-measures-for-reducing-emissions-of-inland-navigation.pdf [accessed on 02.02.2016]

Scandria 2012 Benchmarking of ferry and RoRo transport for the development of "green corridors for freight transport". Baltic Sea Region Project #26 "Scandinavian-Adriatic Corridor for Growth and Innovation". Ministry of Energy, Infrastructure and State Development, Mecklenburg-Vorpommern

Sustainable Shipping 2009 Emission Control Areas (ECAs) – What you need to know. A Sustainable Shipping Briefing Paper, August 2009.

Williams, E., Lerner, B., and Murphy, P. 2008 Determination of Emission Factors from Commercial Marine Vessels. 17th International Emission Inventory Conference, Portland OR, June 03, 2008. http://www3.epa.gov/ttnchie1/conference/ei17/session4/williams_pres.pdf [accessed on 01.02.2016]

Ferries

Bäckström 2003 Bäckström, S.: Internal description of the proposed NTM-methodology and comments to the proposal for EcoTransIT; February 2003

Kristensen 2000 H.O. H. Kristensen (Danish Shipowners Association: Energy consumption and exhaust emissions for various types of marine transport compared with trucks and private cars; paper presented at ENSUS 2000 conference - newcastele 4-6 September 2000

Kusche 2000 Kusche, J.: Transport-Ökobilanz von Deutschland nach Schweden; Diplomarbeit, Berlin 2000

TT-Lines 2009 Internal values for energy consumption, capacity and load factor from TT Lines, 2009

Aircraft transport

Airbus 2013 Airbus (Ed.): Future payloads - freight forecast 2013 - 2032; Blagnac Cedex (France) 2013

Atmosfair 2009 Atmosfair (Ed.): The atmosfair emission calculator. Methodological background. Berlin: 2009

BEIS 2016 Department for Business, Energy and Industrial Strategy (DBEI): 2016 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors / Hill, N.; Watson, R. (Ricardo-AEA); James, K. (WRAP). Report on behalf of the for Business, Energy and Industrial Strategy (BEIS). London: 2016

EEA 2013/2015 EEA (European Environment Agency): EMEP/EEA Air pollutant emission inventory guidebook 2013. Technical guidance to prepare national emission inventories. EEA Technical report No 12/2013. Aviation annex (1.A.3.a) updated July 2015, Copenhagen: 2013/2015

EUROCONTROL 2009 Astorino, A.: EUROCONTROL ETS Support Facilities and Fuel Estimator tool. Presentation. Brussels: 2009

EUROCONTROL 2013a EUROCONTROL: Standard Inputs for EUROCONTROL Cost Benefit Analyses. Edition Number: 6.0. Edition Date: September 2013. Brussels: 2013

EUROCONTROL 2015 EUROCONTROL: Small emitters tool: Version 5.05 dated 2015.12.26. Brussels: 2015

Hünecke 2008 Hünecke, K.: Die Technik des modernen Verkehrsflugzeuges. Stuttgart: Motorbuch Verlag 2008

Graßl/Brockhagen 2007 Graßl, H; Brockhagen, D.: Climate forcing of aviation emissions in high altitudes and comparison of metrics. An update according to the Fourth Assessment Report, IPCC 2007. Hamburg: 2007

IATA 2013 International Air Transport Association (IATA): Cargo e-Chartbook – Q2 2013.

ICAO 2012 International Civil Aviation Organisation (ICAO): ICAO Carbon Emissions Calculator. Version 5. Montreal: 2012

ifeu 2010 Knörr, W. (ifeu-Institut): EcoPassenger: Environmental Methodology and Data. Final Report. Commissioned by International Union of Railways (UIC). Heidelberg: 2010

ifeu/Öko-Institut 2012: Knörr, W.; Schacht, A. (ifeu); Gores, S. (Öko-Institut): Entwicklung eines Modells zur Berechnung der Energieeinsätze und Emissionen des zivilen Flugverkehrs – TREMOD AV. UBA-Texte, No. 48/2012. Dessau: 2012

IPCC 1999 Intergovernmental Panel on Climate Change (IPCC): Aviation and the Global Atmosphere. A Special Report of IPCC Working Groups I and III in collaboration with the Scientific Assessment Panel to the Montreal Protocol on Substances that Deplete the Ozone Layer. Cambridge: University Press, 1999.

IPCC 2006 Intergovernmental Panel on Climate Change (IPCC): Datenbank für Emissionsfaktoren vom IPCC. 2006. See http://www.ipcc-nggip.iges.or.jp/EFDB/main.php.

Lang 2007 Lang, G.: Passagierflugzeuge – Das aktuelle Typenbuch. München: Scont-Verlag, 2007

Lang 2009 Lang, G.: Flugzeuge – Die bekanntesten Passagierflugzeuge der Welt. Fränkisch-Crumbach: Edition XXL, 2009

Lufthansa 2014 Deutsche Lufthansa AG (Ed.): Geschäftsbericht 2013. Frankfurt/M.: 2014.

LCAG 2014 Lufthansa Cargo (Ed.): Pallets, Container and Fleet. Frankfurt/M.: 2014

Öko-Institut 2009 Graichen, J.; Gores, S.; Herold, A.: Überarbeitung des Emissionsinventars des Flugverkehrs. Final report on behalf of the Umweltbundesamtes. Berlin: 2009

Piano 2008 Piano$_x$: Aircraft Emissions and Performance User's Guide. Woodhouse Eaves (UK): 2008

UBA 2008 Umweltbundesamt (2008): Klimawirksamkeit des Flugverkehrs. Aktueller wissenschaftlicher Kenntnisstand über die Effekte des Flugverkehrs. Dessau: März 2008.

Energy supply

EN 16258 „Methode zur Berechnung und Deklaration des Energieverbrauchs und der Treibhausgasemissionen bei Transportdienstleistungen (Güter- und Personenverkehr)“ 2013

Eurostat 2015 Yearly Energy Statistics – 2013 data

IEA 2015 IEA Energy Statistics – 2013 data

ifeu 2015 Fehrenbach et al. (ifeu): Aktualisierung der Eingangsdaten und Emissionsbilanzen wesentlicher biogener Energienutzungspfade (BioEm), 2015

ifeu / INFRAS / LBST 2015 Klimaschutzbeitrag des Verkehrs im Kontext des Energiekonzeptes der Bundesregierung bis 2050. UFOPLAN 2013 FKZ 3712 45 100.

UNEP 2016 Partnership for Clean Fuels and Vehicles – Diesel Fuel Sulphur Levels: Global Status January 2016; http://www.unep.org/transport/new/pcfv/about.asp last visit April, 2016

Directive 2004/8/EC Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC

ecoinvent 2013 ecoinvent Version 3.2: Weidema, B.P.; Bauer, Ch.; Hischier, R.; Mutel, Ch.; Nemecek, T.; Reinhard, J.; Vadenbo, C.O.; Wernet, G, 2013, The ecoinvent database: Overview and methodology, Data quality guideline for the ecoinvent database version 3, www.ecoinvent.org

Intermodal transfer

ifeu 2000 Knörr, W. et. al, ifeu and SGKV (Studiengesellschaft für den kombinierten Verkehr e.V).: Comparative Analysis of Energy Consumption and CO_2 Emissions of Road Transport and Combined Transport Road/Rail; comissioned by IRU (International Road Union) and BGL (Bundesverband Güterkraftverkehr Logistik und Entsorgung e.V.); Geneva/Frankfurt a.M. 2002

ISV 1993 Systemvergleich für unterschiedliche verkehrliche Prozessabläufe/Transportketten hinsichtlich Energieeinsatz und klimarelevanter Emissionen (im Güterverkehr). Bearbeitet von ISV (Uni Stuttgart), IER (Uni Stuttgart), ISB (Uni Hannover) und ifeu im Auftrag der Enquête-Kommission "Schutz der Erdatmosphäre" des Deutschen Bundestages, 1993.

9 Expressions and abbreviations

Gtkm	Gross tonne kilometre hauled	Tonne kilometre of freight including empty wagon (vehicle, vessel) weight; for railways: train without locomotive
Ntkm	Net tonne kilometre:	Tonne kilometre of freight; also: tkm
tkm	Tonne kilometre	Tonne kilometre of freight; also: Ntkm (in distinction to Gtkm)
Gt	Gross tonnes t	Tonnes of freight including empty wagon (vehicle, vessel) weight; for railways: train without locomotive
Nt	Net tonnes	Tonnes of freight
T	Tonne	Metric tonne, unit used in ETW for the freight mass
RFI	Radiative Forcing Index	Takes into account the climate effects of other GHG emissions (in particular nitrogen oxides, ozone, water, soot, sulphur), especially for emissions in high altitudes. (>9km)
	Payload	Load weight of freight
CP	Payload capacity	Mass related capacity of a vehicle/vessel for freight
LF	Load factor	Relation of net tonnes and tonne capacity of a vehicle/vessel without empty trip factor
CU	Capacity utilisation	Relation of net tonnes and tonne capacity of a vehicle/vessel including the empty trip factor
ET	Empty trip factor	Relation of vehicle/vessel-km running empty and km loaded
D	Distance	Transport distance in km
Km	Kilometre	
M	Mass of freight	
EC	Energy consumption	
ECT	Total energy consumption	Sum of final energy consumption and upstream energy consumption
ECF	Final energy consumption	Energy consumption of vehicle/vessel
ECU	Upstream energy consumption	Energy consumption for production and delivery of final energy
EGR	Exhaust Gas Recirculation	Technology to reduce emissions of diesel engines
EMT	Total emissions	Sum of vehicle and upstream emissions
EMV	Emissions vehicle	Direct emissions from vehicle operation
EMU	Upstream Emissions	Emissions of upstream process
HFO	Heavy fuel oil	Fuel for marine vessels
MDO	Marine diesel oil	
MGO	Marine Gas oil	
SCR	Selective Catalytic Reduction	Technology to reduce emissions of diesel engines
TEU	Twenty-foot equivalent	Unit for container transport
TTW	Tank-to Wheels	Energy consumption and emissions from vehicle operation
WTT	Well-to-Tank	Energy consumption and emissions from upstream processes
WTW	Well-to-Wheels	Energy consumption and emissions from vehicle operation and upstream processes