Calculating GHG emissions for freight forwarding and logistics services in accordance with EN 16258

– Terms, Methods, Examples –

DSLV
Deutscher Speditions- und Logistikverband e.V.

CLECAT
european association for forwarding, transport, logistics and customs services

Calculating GHG emissions for freight forwarding and logistics services
(April 2012)

Authors: Dipl.-Ing. **Martin Schmied**,
INFRAS – Forschung und Beratung,
Mühlemattstrasse 45, 3007 Bern, Switzerland
(E-Mail: Martin.Schmied@infras.ch)

and

Dipl.-Wirtschafts-Ing. **Wolfram Knörr**
ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH,
Wilckens Straße 3, 69120 Heidelberg, Germany
(E-Mail: Wolfram.Knoerr@ifeu.de)

Editor: Dipl.-Ing. **Christa Friedl**,
Wissenschaftsjournalistin
Krefeld, Germany
(E-Mail: Christa.Friedl@web.de)

Translation: **Lynda Hepburn**, BSc, MSc, MITI
Freelance science translator
7/2 Shandon Street, Edinburgh EH11 1QH, United Kingdom
(E-mail: lynda@summittranslations.co.uk)

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Introduction by CLECAT, the European Association for Forwarding, Transport, Logistics and Customs Services

Transport is responsible for over 30% of final energy consumption. Management and reduction of energy consumption in transport are key societal challenges in relation to climate change and security of supply. Standardization provides tools to support the various stakeholders in managing those challenges.

CLECAT is therefore pleased to present to its members and other interested parties the English edition of the DSLV guide '*Calculating GHG emissions for freight forwarders and logistics services'*, which provides for a practical tool for logistics service providers that seek to make use of the CEN standard in order to determine their environmental footprint and seek ways to reduce it. Anyone with experience in the measuring of the carbon footprint of logistics knows that this can be complicated, not the least because up to now there has been no standard way of doing it. The publication of the CEN standard EN 16258, covering a "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)" earlier this year was therefore welcomed by CLECAT. We are convinced that a standardised calculation methodology will benefit industry, facilitate communication on the results and enable comparisons of energy consumptions and GHG emissions of different transport operations realised by companies.

The CEN standard provides for a common approach and framework for the calculation and declaration of energy consumption and emissions for transport services irrespective of the level of complexity. The standard includes standardised procedures for calculating emissions for the transport of individual consignments and partial loads and methods for determining data for subcontractors. However, the standard remains complex and theoretical. We are therefore pleased to support our members with implementation guidelines providing further operational details.

It is quite clear that industry will benefit from being pro-active in this area as climate change will not go-away but remain an important transport policy issue. Ambitious targets have been set at EU level to cut GHG emissions by 2020 and 2050. However, sectorial GHG-emissions have not been set but this is likely to happen in the future.

Significant efforts have already been made by industry to improve the energy efficiency of freight transport. These gains in energy efficiency have however not been sufficient to outweigh the growth in emissions caused by larger transport freight volumes, due to a strong increase in global trade and the further integration of the enlarged EU. A mere transfer of goods transport from the road to alternative modes of transport will not be sufficient to mitigate large quantities of GHG emissions, and will have just as little effect as an increased use of biofuels, because the potential of both measures in its own right is too limited. It is the combination of a number of measures taken by industry that will eventually lead to a significant reduction in GHG emissions.

Companies are increasingly seeking to reduce their footprint which is suiting both economic and environmental objectives. Even when the motivation to reduce energy consumption may initially be economic, improved efficiencies in the supply chain have positive effects on the environment. Only with a uniform standard can industry understand how and where the optimum emission savings can be made in their supply chains.

At the same time CLECAT is of the opinion that governments should continue to look at technology development, strengthened research into new technology and fuels, increased use of information technology and integrated mobility management as well as a wide variety of non-technology policy tools with potential to improve economic efficiency and reduce emissions.

Simply measuring emissions is not an end in itself. As in every other sector, the calculation of GHG emissions in goods transport and logistics is the first step to understanding and subsequently reducing emissions. This will support in further advancing reduction or avoidance strategies.

A standard is not set in stone and will need to be reviewed on a regular basis. At the same time, voluntary initiatives such as Green Freight Europe, will need to integrate the standard in its system. Also, we hope that individual Member States and in particular France who has been in the driving seat at European level, and the first to make the measuring of emissions in transport mandatory, will bring the values included in its legislation in line with the European standard.

We would like to thank the DSLV for offering CLECAT the opportunity to publish the updated English version of the guidelines. Special thanks are also due to the German Federal Environmental Agency and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety for providing the funding for the research and the publication of the guidelines.

Nicolette van der Jagt
Director General
CLECAT

Introduction by the German Federal Environment Agency (Umweltbundesamt)

Freight traffic is essential for supplying companies with raw materials and upstream products, and consumers with durable and consumable goods. It is an important requirement for production based on a division of labour and for a broad range of goods. The closer the trade links between regions and the further apart these regions lie, the more freight transport takes place.

The total freight transport volume in Germany – as a product of the quantity and distance transported – rose by around 22 percent between 2000 and 2010 and will probably continue to increase over the next few decades. In a forecast to the year 2025, the Federal Ministry of Transport, Building and Urban Development therefore assumes a growth in road freight transport services of 79 percent compared to 2004. One disadvantage of this development is the increase in the negative environmental effects of freight transport – in particular the production of environmentally damaging carbon dioxide (CO2). The freight transport sector needs to make a larger contribution to reducing CO2 emissions than it has in the past. One fundamental requirement when developing initiatives to reduce emissions in logistics companies is to know the scope and origin of the company's CO2 emissions. This shows where and how the energy consumption and therefore the emissions can be reduced most efficiently. This produces not only direct cost-savings but also a competitive advantage when the commitment to the environment is relayed to the clients.

In order to provide assistance for freight forwarding and logistics companies in their climate protection endeavours, the BMU and UBA have initiated a research project on emission monitoring, the results of which have been incorporated in this guide.

After all, you can only manage what you know.

Jochen Flasbarth
President of the German Federal Environment Agency

1 Guide to the guide

The purpose of the guide

The calculation of greenhouse gas emissions is nothing fundamentally new. For a number of years many businesses, including companies from the freight forwarding and logistics sector, have been recording carbon dioxide (CO_2) values for products and services. However, the calculation methods applied differ, the reliability of the results is often doubtful and evaluation of the results not always easy.

A few examples:

Biofuels are often assessed as though they did not produce any greenhouse gas emissions at all. This assumption is wrong, because growing, harvesting and transporting the plants used for producing the fuels uses energy and therefore creates emissions just like the actual manufacture of the biofuels.

When calculating emissions, some companies disregard the empty trip component of the vehicles used. As a result, the calculated values only show part of the reality.

Calculations for air transport are often difficult to compare when cargo and passengers are transported in the same aircraft, as the exact allocation of the calculated emissions often does not follow a consistent methodology.

The new EN 16258 Standard

In order to achieve more **accuracy, transparency** and **consistency** in the calculation of energy consumption and greenhouse gas emissions in the logistics sector, a new standard has been developed over the last few years by the European Committee for Standardization (CEN: French Comité Européen de Normalisation). This guide presents the contents, suggested calculation methods and requirements of the new standard **"Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services"**. It therefore shows exactly how carriers, forwarders or logistics companies can calculate energy consumption and greenhouse gas emissions in compliance with the new standard.

Anyone who has never before been involved with carbon footprints for transport services will realise that producing them can be complicated and time-consuming. The guide helps to make the calculations as easy as possible and to keep the effort to a necessary minimum. Small and medium-sized businesses will find it easiest to implement the new standard. Such companies usually have exact records of their diesel consumption and can calculate the greenhouse gas emissions associated with this without much effort. This guide explains how this is done, what **equations** to use and what **background information** is required for them.

Layout of the guide

The layout of the guide is explained with the help of a flow diagram showing background information and calculation aids:

- Companies which wish to calculate their energy consumption and greenhouse gas emissions must be aware of basic relationships, terms and standards. **Chapters 3, 4 and 5** contain the **basic information on climate protection and carbon footprints**.
- **Chapter 5** also presents an overview of the new standard **"Methodology for calculation and declaration of energy consumption**

and greenhouse gas emissions of transport services" (EN 16258). This standard forms the basis for all explanations and sample calculations in this guide, in as far as they concern transport services.

- The practical application starts in **Chapter 6**. Carriers or freight forwarders who know their own fuel and energy consumption or can calculate it themselves will find fixed **conversion factors and equations** which can be used to determine energy consumption and greenhouse gas emissions for a specific transport route in conformity with the EN 16258 standard. This chapter is therefore a starting point for the standard-compliant calculation of energy consumption and greenhouse gas emissions, particularly for small and medium-sized companies, because they usually have accurate figures for the energy consumption of the mode of transport which they use.
- **Chapter 7** deals with the standard-compliant **allocation**: how are the calculated consumption and emissions divided between individual consignments?
- **Chapter 8** describes the different **methods for determining energy consumption** (measurement and calculation) which are permitted by the standard EN 16258.
- **Chapter 9** describes the different options for **measuring energy consumption** which are specified by the new standard.
- If there are no available measured values for energy consumption and load utilisation for the mode of transport, then this can be calculated with the aid of a **distance-based approach**. **Chapter 10** explains how this is done – divided into lorry, train, ship and aircraft.
- **Chapter 11** describes **distance-based calculations** once more in particular detail for **lorries**.
- Energy is used and greenhouse gas emissions created not only by vehicles but also by **buildings, warehouses and handling**. **Chapter 12** provides aids to calculation.
- Finally, **Chapter 13** describes how to **correctly evaluate and report the results**.

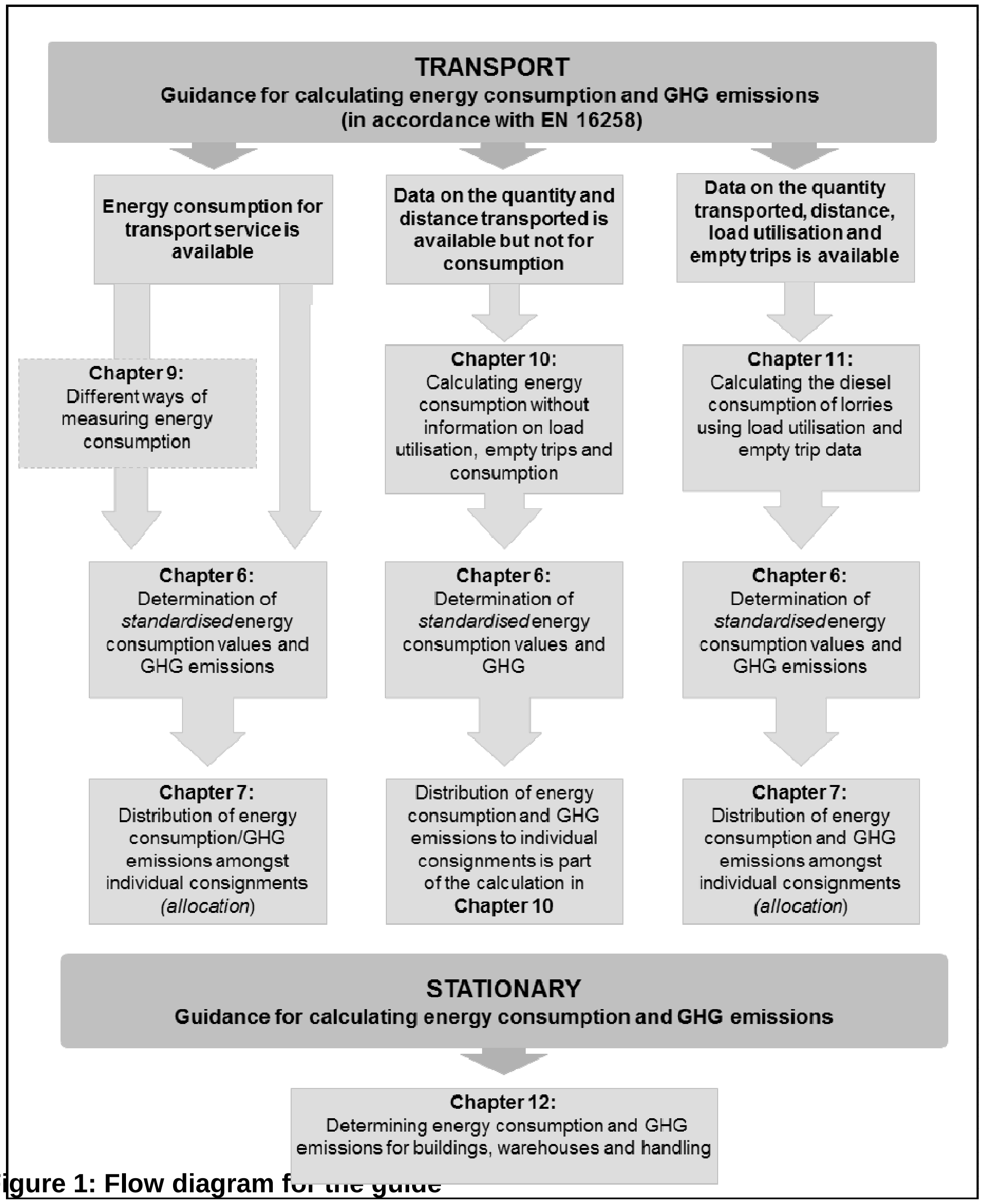

Figure 1: Flow diagram for the guide

EN 16258 as a basis

It is also important to know:

- This guide is based on the new European standard EN 16258. Where the standard contains clear provisions, these are used for the calculations in this guide. If the standard leaves options for selection, these are described and recommendations made. However, the important point to remember is that the standard in its present form focuses exclusively on transport. Calculation of energy consumption and emissions for buildings, warehouses and handling are not governed by the current version of the standard. However, the calculation methods for these areas presented in Chapter 12 correspond in essence to the provisions of the standard, even if they are not explicitly dealt with there. According to the standard EN 16258 the results may well be calculated but must be presented separately from the results for transport calculated in compliance with the standard. The methods used must be clearly described.

- The specifications, conversion factors and sample calculations in this guide apply in principle to Europe. However, intercontinental transport by air and ship can also be calculated using the instructions in this guide – the specifications apply anywhere in the world.
- The practical section of each chapter contains one or more simple **sample calculations** which apply the instructions of the standard EN 16258 and illustrate how to proceed. It should be noted that, if rounded intermediate results are presented, these will be used for further calculation.
- This guide is obviously unable to take into account all possible transport services and calculation cases – this applies particularly to rail, ship and air modes of transport. For descriptions of the detailed procedure for these modes of transport and especially lorry transport, reference must be made to more detailed literature.

Benefit for the reader

In a nutshell: the guide provides **two types of benefits**. First it demonstrates on the basis of **sample calculations** how to determine reliable and realistic figures for consumption and greenhouse gas emissions which are in accordance with the new standard EN 16258. Secondly, it supplies **standard values for the calculation**, e.g. conversion factors for fuels and electricity, specific energy consumption figures, data for different fuels and means of transport, factors for the climatic effect of greenhouse gases and refrigerants. These standard values are also referred to as default values and comply with the requirements of the new standard. Last but not least, the guide attaches great importance to a simple but often forgotten message: a result is only ever as good as its data source. The more values which are directly measured for a specific transport service, the better the result will represent reality. However, in practice, values are very often simply not available. For this reason the guide indicates ways in which a useable and standard-compliant result can be attained with the help of values from databases.

Whichever method is used, **what is important is that the selected procedure can be understood by the reader of the final results (internally or externally). For this reason the route taken to reach the result must be stated. Numerical values can only be turned into unambiguous statements when it is clear which methods were used and under what constraints they were determined. Only then is an evaluation of the results, a comparison of values and the correct selection of climate protection measures possible. It is not without reason that the new standard EN 16258 requires the calculation method and the default values in particular to be clearly shown.**

An overview of the most important conversion factors

Factors for converting energy consumption data into the **standardised energy consumption unit MJ** and into **greenhouse gas emissions** (**for fuels based on the specifications in the standard EN 16258**):

	Energy consumption			***Greenhouse gas emissions (as CO2e = CO2 equivalents)***		
	Unit	***direct (TTW)***	***total (WTW)***	***Unit***	***direct (TTW)***	***total (WTW)***
Diesel	MJ/l	35.9	42.7	kg/l	2.67	3.24
Diesel D5 (5 vol.-% biofuel)	MJ/l	35.7	44.0	kg/l	2.54	3.17
Compressed natural gas	MJ/kg	45.1	44.4	kg/kg	2.68	3.07
Liquefied petroleum gas	MJ/l	25.3	50.5	kg/l	1.70	1.90
Jet kerosene	MJ/kg	44.1	52.5	kg/kg	3.18	3.88
Heavy fuel oil (HFO)	MJ/kg	40.5	44.1	kg/kg	3.15	3.41
Marine diesel/gas oil	MJ/kg	43.0	51.2	kg/kg	3.24	3.92
Traction current EU-27	MJ/kWh	3.6	10.8	kg/kWh	0	0.468
Electricity EU-27	MJ/kWh	3.6	10.2	kg/kWh	0	0.424

Average consumption values per tonne kilometre divided **according to mode of transport and vehicle types:**

Mode of transport/ Vehicles	**Energy**	**Unit**	**Volume goods**	**Average goods**	**Bulk goods**
Lorry < 7,5 t GVW	Diesel	l/tkm	0.140	0.078	0.063
Lorry 7,5-12 t GVW	Diesel	l/tkm	0.108	0.061	0.050
Lorry 12-24 t GVW	Diesel	l/tkm	0.063	0.036	0.029
Lorry 24-40 t GVW	Diesel	l/tkm	0.038	0.023	0.020
Train (electric traction)	Electricity	kWh/tkm	0.042	0.032	0.028
Train (diesel traction)	Diesel	l/tkm	0.011	0.009	0.008
Container ship	HFO	kg/tkm	0.0089	0.0051	0.0037
Bulk ship	HFO	kg/tkm	x	x	0.0017
Barge	Diesel	l/tkm	x	x	0.0088
Dedicated freighter	Kerosene	kg/tkm	0.148	x	x
Belly freigth	Kerosene	kg/tkm	0.258	x	x

Well-to-wheels greenhouse gas emissions per tonne kilometre calculated using the table above (in accordance with EN 16258):

Mode of transport/ Vehicles	**Energy**	**Unit**	**Volume goods**	**Average goods**	**Bulk goods**
Lorry < 7,5 t GVW	Diesel	g CO_2e/tkm	454	253	204
Lorry 7,5-12 t GVW	Diesel	g CO_2e/tkm	350	198	162
Lorry 12-24 t GVW	Diesel	g CO_2e/tkm	204	117	94
Lorry 24-40 t GVW	Diesel	g CO_2e/tkm	123	75	65
Train (electric traction)	Electricity	g CO_2e/tkm	20	15	13
Train (diesel traction)	Diesel	g CO_2e/tkm	36	29	26
Container ship	HFO	g CO_2e/tkm	30	17	13
Bulk ship	HFO	g CO_2e/tkm	x	x	6
Barge	Diesel	g CO_2e/tkm	x	x	29
Dedicated freighter	Kerosene	g CO_2e/tkm	574	x	x
Belly freigth	Kerosene	g CO_2e/tkm	1,001	x	x

2 Climate protection and carbon footprints in logistics

When government, the media and environmental protection organisations warn about the consequences of climate change and global warming, they are referring to the greenhouse effect of human (anthropogenic) origin which is the aim of strategies for reducing or avoiding emissions. On the other hand, it is often forgotten that without a – natural – greenhouse effect there would be no life on earth. If it were not that certain gases in the atmosphere convert part of the solar radiation into heat, the average temperatures would not be plus 15 °C but minus 18 °C. Trace gases with a greenhouse effect such as carbon dioxide (CO_2), ozone, nitrous oxide and methane therefore guarantee that the earth is habitable in the first place.

The anthropogenic greenhouse effect

Nevertheless, over the last century, **increasing amounts of greenhouse gases have been released into the atmosphere** from the operation of power plants and industrial processes but also from transport. Burning not only oil, gas and coal but also biomass inevitably produces carbon dioxide, as the carbon in the energy source combines with the oxygen in the air. This is a fixed chemical law.

Both the environmental effects and social consequences of prolonged climate change are dramatic, the **resulting economic costs** considerable. According to the Stern report published at the end of 2006, the annual costs for limiting the global rise in temperature to 2 °C are around 1% of the global gross domestic product. It would be even more expensive if the community of states did nothing. Climate change could then lead to annual losses of 5 to 20% of the global gross domestic product.

Logistics at the centre of climate policy

As it seems impossible to avoid an increase in the average global temperature, the community of states has agreed to **limit the further increase in temperature to 2 °C** and to reduce anthropogenically generated **greenhouse gas emissions by 50% globally by 2050** in order to avoid severe consequences for the environment. An above-average contribution (up to 80-95%) is expected from the industrialised nations.

The European Union has made an initial commitment to reducing greenhouse gas emissions by 20% by the year 2020 (in comparison with 1990) – though without specifying the actual contributions from different sectors. However, goods traffic is already the focus of political activity. European policy in particular is increasingly linking legislation for (goods) traffic with environmental legislation. Environmental costs play an important role, especially in the discussions on internalising external costs for goods traffic. However, there is currently no decision as to whether greenhouse gas emissions will ever become a measure for a possible charge in the form of taxes or duties.

Aside from this, all branches of industry are now discussing how they can reduce their outputs of greenhouse gases. The **logistics sector** has also been part of this discussion for a long time.

It is likely that logistics processes will also form part of a climate protection strategy for the transport industry – regardless of whether it will be implemented by the service provider themselves or by sub-contractors. Increasing numbers of freight forwarders and logistics companies are therefore addressing the issue of how to make tangible reductions in emissions –

either because they want to position their company as a pioneer in this area or because they wish to be prepared for possible transport industry and government requirements. However, a key driving force for transport service providers is to reduce dependence as far as possible on increasingly expensive oil through wide-ranging economies.

The value of standardised calculations

Anyone who wishes to successfully protect the climate must first **record** the **greenhouse gas emissions** which they produce as accurately and reliably as possible. Because "*you cannot manage what you cannot measure*" certainly applies here.

If the amount and source of the greenhouse gas emissions produced during the manufacture of a product or from services are determined, then this is referred to as carbon dioxide (CO_2) or **greenhouse gas footprints**.

However, up until now there were no consistent **standards for the calculation of greenhouse gas emissions from logistics services** – with the result that every company did this in different ways. The European standard ***EN 16258* "*Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services*",** which is published by the German Institute for Standardization (Deutsches Institut für Normung, DIN) as **DIN EN 16258** and by the British Standards Institution (BSI) as **BS EN 16258** should produce standardisation in the calculation methodology. This guide therefore takes up the new standard and demonstrates how greenhouse gas emissions for transport processes can be determined in a standardised manner**.**

A standardised calculation is necessary in the first place to create a reliable picture of the emissions produced. It also assists in targeting financial resources to those areas where the greatest amount of energy and therefore most emissions can be saved. Companies which record their emissions over a period of any length using the same methods can also present clear and credible evidence of the success of their efforts to protect the environment.

Many companies in the transport industry assume that a standardised calculation of greenhouse gas emissions will aid the selection of their logistics service provider. At first glance, low values of CO_2 per transported tonne and kilometre appear to promise climate-friendly transport. Caution must be urged about such a simple approach. **Comparisons of standardised CO_2 characteristic values from different service providers are only possible if the transport services have the same defined boundary values.**

Even when they have been calculated in a standard manner, CO_2 characteristic values are generally not convincing enough on their own. A parcel carrier with a very fast delivery service may utilise the capacity of their vehicle less well than a competitor who collects and combines consignments and only delivers after several days. Even an ultra modern fleet cannot compensate for the higher emissions of partially loaded vehicles. The faster supplier may then have a poorer CO_2 characteristic value than the slower competitor – even if the company is otherwise very committed to environmental and climate protection.

It is more meaningful if forwarders judge their logistics service providers by the general progress the companies have made in terms of climate protection. Standardised and standard-compliant calculations of CO_2 and greenhouse gas characteristic values can be important indices of this. They can aid the objective assessment of the logistics service provider's efforts towards protecting the climate.

But one thing should be kept firmly in mind: measuring greenhouse gas emissions on their own is not an end in itself. In some cases it is more crucial to eliminate obvious energy guzzlers and inefficiency without having first carried out exact emission measurements. Simply measuring greenhouse gas emissions without avoiding these or at least reducing them does not contribute to climate protection.

3 Before you start – the most important principles

Forwarding and logistics activities cover far more than merely transport from A to B. Goods have to be handled, rearranged and/or put into temporary storage. So fuel, electricity, heat or refrigerant are not only required for transport: greenhouse gas emissions occur along the entire logistics chain and need to be taken into account in a carbon footprint. Only then will a full picture be obtained. Generally, storage and handling account for the minor component of emissions – but in some cases they can be very important. What is essential for every calculation is the question of what exactly needs to go into the equation. This is what experts call **defining the system boundaries**.

Direct and indirect emissions

Every transport service creates greenhouse gas emissions – the **direct emissions**. These are dependent on the type of vehicle, the load, the distance and the amount of fuel used. But the production of power and fuels, the manufacture of vehicles and construction of streets and the maintenance of the transport network also use energy and cause greenhouse gases – the **indirect emissions.**

Indirect emissions from the **production of fuels** play an important role when producing the carbon inventory for logistics services. For example, for diesel all emissions – from extraction of the crude oil via its transport to the refinery, the actual distillation of the diesel and its transport to the filling station – have to be included. For electrically operated modes of transport such as trains, the carbon footprint requires information on the generation of the necessary power.

The **new Standard EN 16258 "*Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services*"** stipulates that **indirect energy consumption and emissions from the energy processes must be taken into account**. In this context the standard refers to well-to-tank and well-to-wheels emissions (see box). This guide therefore presents calculation methods for both direct emissions and for total emissions. The same applies to energy consumption. According to the standard EN 16258, indirect energy consumption and indirect emissions which arise from the manufacture, maintenance and disposal of vehicles or traffic infrastructure are to be explicitly excluded from the calculation.

Definitions of energy consumption and emissions in accordance with EN 16258

- **Well-to-tank** (energy processes): Recording energy consumption and all indirect emissions from fuel provision from the well to the vehicle tank. Energy consumption includes losses during the production of the energy sources e.g. in high-voltage lines.
- **Tank-to-wheels** (vehicle processes): Recording all direct emissions from vehicle operation. Consumption here is referred to as final energy consumption.
- **Well-to-wheels** (vehicle and energy processes): The sum of well-to-tank and tank-to-wheels, i.e. direct and indirect emissions. Consumption here is referred to as primary energy consumption which, besides the end energy consumption, includes all losses from the upstream chain.

Energy consumption and greenhouse gas emissions

Logistics processes generally create emissions from the consumption of fuels or electricity. These can be calculated directly from consumption using fixed conversion factors. It is therefore a good idea – and a requirement of the standard EN 16258 – to show **energy consumption** for the transport service along with the greenhouse gas emissions in a comparable energy unit. In this guide all energy consumption values are therefore converted into the standard energy unit megajoules.

Carbon dioxide (CO_2) is the greenhouse gas (GHG) which has the most extensive effects. CO_2 and greenhouse gas (GHG) are therefore often used synonymously. According to the Kyoto Protocol, there are five **additional greenhouse gases** besides carbon dioxide which are important: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The last-named trace gases are often not the product of the combustion of oil, gas or fuels but result from industrial processes, or they reach the environment directly when used (e.g. fluorocarbons as refrigerants).

In the past many freight forwarders have only calculated the CO_2 emissions which they produce. However, currently applicable standards demand the **determination of all greenhouse gas emissions** without exception, because similar quantities of some gases heat the atmosphere far more than does carbon dioxide. This guide therefore shows the total quantities in the form of what is known as **CO_2 equivalents**. The Global Warming Potential (GWP) is a deciding factor for the CO_2 equivalents: the greater the GWP, the more the gas contributes to global warming. A kilogramme of the refrigerant R-404A, for example, produces CO_2 equivalent emissions of 3.9 t – roughly corresponding to the amount which is produced by burning around 1,300 l of diesel.

For lorry transport there is only a slight difference – about 1-2% – between straight CO_2 emissions and equivalents. In contrast, for electrical power generation, the increase can be 4 to 10%, depending on the generation method.

Table 1: Global Warming Potential (GWP) for selected greenhouse gases

Greenhouse gas	**Chemical formula**	**GWP factor (100 a)**
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide (laughing gas)	N_2O	298
Refrigerant R-134A	CH_2FCF_3	1,430
Refrigerant R-404A	R-143a(52%)+R-125(44%)+R-134a(4%)	3,922

Sources: IPCC 2007; own calculations.

Load weight

The energy consumption and emissions depend on the total weight of the load (gross weight). If goods are transported on pallets or in packaging, the weight of the cargo supports such as pallets or packaging must be taken into account when determining energy consumption. Calculation of emissions therefore always requires information on how the item was transported and how heavy the cargo supports and transport packaging was. In the allocation of energy consumption and emissions to individual consignments in what follows, the standard EN 16258 stipulates that the weight of cargo supports must only be taken into account if they are a fixed part of the load (e.g. cargo loaded onto pallets by the client).

Transport services are often calculated on the basis of what is known as **chargeable weight** – a type of weight per unit volume on which the cargo area of the goods is based. As differing calculation principles are often used it is not so easy to convert from chargeable weight to **actual weight**. However, accurate calculation of energy consumption and emissions always requires actual weights in order to reach the correct results.

4 Standards and norms – what framework is there?

A series of standards and norms must be complied with when calculating the greenhouse gas emissions caused by logistics operations. The choice of standard depends on the **aim of the calculation**. If greenhouse gas emissions as an absolute quantity are to be determined for the **whole company**, then this is referred to as **Corporate Carbon Footprinting**. Different requirements and standards apply to this corporate carbon footprinting than to footprinting for individual transport services. The emissions from individual transport services can be important as part of the footprinting for an **individual product** – i.e. **Product Carbon Footprinting**. However, **carbon footprints can also be created for selected transport services** as such.

Table 2: Comparison of current standards and norms

	Corporate Carbon Footprinting	**Product Carbon Footprinting**	**Transport services footprinting**
Standards and norms	ISO 14064-1 and GHG Protocol[1)]	PAS 2050; GHG Protocol[2)] ISO Standard (development), (ISO 14040 ff.)	Standard EN 16258[2)]
System boundaries	Activities by own company obligatory; inclusion of subcontractors optional	Total value-added chain, irrespective of whether own or third party processes	Total transport chain, irrespective of whether own vehicles or vehicles belonging to subcontractors
Environmental parameters	All greenhouse gases (as CO_2 equivalents)	All greenhouse gases (as CO_2 equivalents)	All greenhouse gases (as CO_2 equivalents) + energy consumption
Emissions from the manufacture of energy sources (e.g. diesel)	Manufacture of electricity used by own company: yes Other energy sources: optional	must be included	must be included
Permitted methods for allocating emissions to individual consignments	no provisions	preferably physical variables (e.g. weight) but monetary values permitted	only physical variables (weight preferred, but also number of pallets, load metres, TEU etc.)

[1)] The details in the table relate to the "Corporate Accounting and Reporting Standard" of the GHG Protocol. – [2)] "Product Life Cycle Accounting and Reporting Standard".

Source: Öko-Institut data.

Corporate carbon footprint

To draw up the complete **carbon footprint of a freight forwarding company** first requires the emissions from the transport services carried out. This does not require the emissions from each single transport service: as a rule the total emissions from all transport journeys are adequate. So if the total fuel consumption of the lorry fleet is known, the total emissions of all transport services can be calculated directly (see chapter 6). The distribution of the emissions from a vehicle to each individual consignment, also known as **allocation**, is not necessary in the context of corporate carbon footprints.

The **methodical principles** are specified in the **ISO standard 14064-1** or the "**Corporate Accounting and Reporting Standard**" of the **Green-**

house Gas Protocol which cover the same material to a large extent. The GHG Protocol is a standard used by many companies which, unlike the ISO 14064-1, does not have to be certified by an external auditor. In both standards not only CO_2 emissions but CO_2 equivalents are calculated (see Chapter 4).

What is covered by the calculations: Scope 1, Scope 2, Scope 3

Both **standards for creating corporate carbon footprints** require a clear **definition of the system boundaries**, i.e. an unambiguous specification of which parts of the company are included in the inventory. The standards distinguish between direct emissions which arise from the combustion of fuels from the company's own vehicles or from gas or heating oil in the company or are due to the release by the company itself of substances which impact on the environment (**Scope 1**), and indirect emissions. Indirect emissions are produced through the supply of electricity, district heating and process heat (**Scope 2**) and also from the services of sub-contractors, from the buying and disposal of products, from the production of fuels or from business trips or journeys to work by staff (**Scope 3**).

Table 3: Allocation of individual areas of importance for the environment to Scope 1 to 3 of the GHG Protocol

	Scope 1	Scope 2	Scope 3
Energy consumption from company's own lorries, cars, locomotives, ships, aircraft	X		
Liquefied petroleum gas/ compressed natural gas and fuel oil consumption of company's own offices/warehouses	X		
Refrigerant losses from company's own offices, warehouses and lorries	X		
Power consumption by company's own offices/warehouses/cargo handling equipment		X	
District heating consumption of company's own offices/warehouses		X	
Business trips, journeys to work by staff			X
Transport services by sub-contractors (lorry, rail, ship, plane)			X
Third party warehouses and cargo handling equipment			X
Energy consumption and emissions for energy sources (e.g. diesel)			X
Energy consumption and emissions for products (e.g. paper manufacture)			X
Source: own figure.			

Companies which compile GHG inventories in accordance with ISO 14064-1 or the Corporate Accounting and Reporting Standard of the GHG Protocol must calculate Scope 1 and 2, while reporting Scope 3 emissions is optional. The transport services which were not carried out by the company itself but by contracted carriers or sub-contractors come under **Scope 3** – a significant proportion for many freight forwarders. Excluding these emissions would give a very incomplete picture. Scope 3 also covers greenhouse gas emissions which arise from extracting the crude oil, producing the diesel in the refinery and from all supply transport services e.g. to filling stations.

The GHG Protocol also recognised that omitting the Scope 3 emissions can often give a very incomplete picture for corporate carbon footprints. The GHG Protocol has just published an amendment "**Corporate Value Chain (Scope 3) Accounting and Reporting Standard**" which defines the requirements for including these emissions in the footprint. Anyone applying this amendment to the GHG Protocol has to report on a large part of their Scope 3 emissions. This also includes transport services by subcontractors.

Product Carbon Footprints

Product Carbon Footprints are based on the calculation of greenhouse gas emissions along the whole life cycle of a product or service. If two products or services are to be compared with one another, then it must be ensured that this is based on the **same usage**. Therefore, when comparing two different lamps, it is not the lights which are compared but the delivery of a specific light output over a specific time period. The life cycle of a product therefore includes the total value-added chain and ranges from the manufacture and transport of the raw materials and upstream products via the manufacture and distribution of the products all the way to their use and disposal.

In comparison with the **total emissions of a product, those from the transport component** are normally of lower importance. However, in contrast to corporate carbon footprints, the emissions produced during transport must be calculated and apportioned to the individual consignment (the product being transported) **(allocation).**

The "**Product Life Cycle Accounting and Reporting Standard**" in the **GHG Protocol** recommends that allocations are made as far as possible using physical units (e.g. weight or the number of pallets). If no relevant data are available, then the allocation can also be carried out using monetary values. To date, allocation using monetary values is not usual for transport services and is also not planned for calculating transport services for the new standard EN 16258.

Carbon footprints for individual transport services – EN 16258

Up until now there have been no specific standards for the **carbon footprinting of transport services themselves or for individual consignments**. The new standard **EN 16258** "**Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services**" provides the first description of methodology, system boundaries, allocation and data sources which can be used by freight forwarders in a targeted approach. The standard is published by the German Institute for Standardization (Deutsches Institut für Normung DIN) as DIN EN 16258 (in German) and by British Standards Institution (BSI) as BS EN 16258 (in English). Like every European (EN) or DIN standard it has no legally binding character. Its application is optional.

This guide refers to the new standard EN 16258 for the calculation of energy consumption and greenhouse gas emissions by transport services, and adheres to the calculation procedures suggested there. Only the description of the calculation methods for buildings, warehouses and handling in Chapter 12 refer to the GHG Protocol as standard, as the new norm does not contain any regulations on this.

The contents of the standard EN 16258 "Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services"

- The standard provides guidelines for a systematic approach when calculating energy consumption and greenhouse gas emissions for passenger and goods transport. The standard also contains guides on declaration, i.e. in which form the values are to be notified to third parties.
- The standard only gives guidelines for the transport service itself, not for stationary services such as handling or storage (see Chapter 12).
- The greenhouse gas emissions are calculated as CO_2 equivalents. In addition, energy consumption must be calculated and presented in a standard way in MJ.
- It is not permissible to show only the energy consumption and the direct emissions of the vehicle (tank-to-wheels), the object is to take account of the energy consumption and greenhouse gas emissions arising from the production of the energy sources such as diesel (well-to-tank). The standard contains appropriate conversion factors for this (see Chapter 6). On the other hand, the standard makes no allowance for the manufacture, maintenance and disposal of vehicles or the transport infrastructure.
- The standard stipulates that the calculation of energy consumption and emissions for each leg of the journey along which the specified item is transported must be done separately. Each leg must be calculated in such a way that empty trips are also included in a proportional manner.
- The 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 metres, number of container spaces) can be used instead of weight. Physical units can also be used for allocation on their own without distance. However, monetary units are not permissible for allocation. The variable used for allocation must be specified with the result (see Chapter 7).
- Four variables need to be shown for energy consumption and greenhouse gas emissions for the transport service under consideration: tank-to-wheels and well-to-wheels energy consumption and tank-to-wheels and well-to-wheels greenhouse gas emissions (see Chapter 4). Besides these results, information must also be declared on the methods used. In particular, the variables used for allocation and the use of values which are not measured but taken from databases (called default values) must be specified.
- The standard itself does not prescribe any external certification or verification of the calculation.

Basic procedure in accordance with EN 16258

The standard EN 16258 gives a detailed description of the procedure to be used for calculating the energy consumption and greenhouse gas emissions for transport services where, according to the standard, a **transport service** is the transport of goods from the sender to any recipient. The calculation requires this transport service to be broken down into sections in which the item in question travels on a specified vehicle, i.e. without changing vehicle. This **section of route** is also called a **leg** in the English version of 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.

The energy consumption and the emissions for the leg are determined using what is known as a **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. Energy consumption and emissions first have to be determined for larger networks in order to calculate average characteristic values for these networks (e.g. greenhouse gas emission per tonne kilometre) which are then applied to the individual consignment. This is already common procedure nowadays.

The calculation of energy consumption and emissions for a transport service (consignment) must be carried out in acc. with standard EN 16258 in **three steps**:

- ***Step 1:*** Splitting the transport service into individual sections without changing mode of transport (legs)
- ***Step 2:*** Calculating energy consumption and emissions per leg:
  - Specifying the Vehicle Operation System (VOS) for this leg (actual vehicle round-trip, routes or vehicle type or for total network; including empty trips)
  - Quantitative determination of total energy consumption for this Vehicle Operation System (e.g. diesel consumption in litres)
  - Conversion of the measured energy consumption into standardised energy consumption (MJ) and greenhouse gas emissions (kg CO_2 equivalents) for this Vehicle Operation System
  - Allocation of standardised energy consumption and greenhouse gas emissions to the transport service
- ***Step 3:*** Addition of the results of all legs of the transport service.

The French CO_2 decree No. 2011-1336

One of the triggers for the European standard EN 16258 was that France planned to legally oblige transport operators to show their customers the CO_2 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 31.12.2013 at the latest, CO_2 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 (see Table 4).

According to the French decree, it is only CO_2 emissions which have to be determined and declared to the customer. The CO_2 conversion factors per litre or kg of fuel must be taken from a decree by the French transport ministry. These conversion factors are based on French sources and do not conform to those in the standard EN 16258 as presented in Chapter 6. Another important difference is that the French decree prescribes which default values are to be used for the specific energy consumption per kilometre travelled by road, rail or ship. The European standard EN 16258 has specifically decided against the requirement for hard and fast values. For goods transport in particular there are too many operational situations which cannot really be calculated with such values.

Due to the large number of differences, this guide cannot go into the calculations which apply to the French decree No. 2011-1336. The **guide** demonstrates instead how **energy consumption and greenhouse gas emissions from transport services can be calculated in conformity with the European standard EN 16258**. The first step of the calculation, how to covert fuel or power consumption into **standardised energy consumption and greenhouse gas emissions** in compliance with the standard is shown in **Chapter 6**. The **allocation**, i.e. the apportionment of these values to individual transport services is explained in **Chapter 7**. The basic **approach** for **determining energy consumption for Vehicle Operation Systems** is described in **Chapter 8**. **Chapter 9** describes various standard-compliant **options for measuring energy consumption**. The two **Chapters 10 and 11** give detailed descriptions of how to proceed if there are no measured values and default values have to be used.

Table 4: A comparison of EN 16258 and the French decree No. 2011-1336

	Standard EN 16258	**French decree No. 2011-1336**
Duty of disclosure	- Not obligatory, optional - However, the transport services customer can demand its usage	- Obligatory for commercially supplied transport services if the start or end points are in France
Mode of transport	- All modes of passenger and goods transport	- All modes of passenger and goods transport
Specific values	- Energy consumption and greenhouse gas emissions (CO_2 equivalents) - Tank-to-wheels and well-to-wheels	- CO_2 emissions - Well-to-wheels; tank-to-wheels optional
System boundaries	- Only transport services, no handling processes or offices - Incl. transport services provided by sub-contractors - No manufacturing, maintenance and disposal of vehicles and transport infrastructure - No refrigerant losses	- Only transport services, no handling processes or offices - Incl. transport services provided by sub-contractors - No manufacturing, maintenance and disposal of vehicles and transport infrastructure - No refrigerant losses
Sources of input data (in increasing order of preference)	- Default values - Fleet value for transport operator (average for fleet) - Specific values for transport operator (average for vehicle or type of route) - Actual measurement for the transport service concerned	- Values in accordance with the decree of the Transport Ministry (default values) (Level 1) - Average fleet values (Level 2) - Average values e.g. for route type, customer, mode of transport (Level 3) - Actual for measured values for transport service (Level 4)
Data source for default values	- Specification for energy and GHG emission factors (e.g. g CO_2e/l) - Otherwise freely selectable (e.g. l/100 km), selection must be justified - Standard includes possible sources	- Only values in acc. with the decree of the Transport Ministry
Allocation parameters	- Recommendation: tonne kilometres - Other allocation variables permitted - Empty trips must be taken into account in a proportional manner	- For trips without change of load: mass, volume, area, loading metres or package - Otherwise the product of these variables and distance - Empty trips must be taken into account
Declaration	- TTW and WTW energy consumption and GHG emissions - Sources for default values and allocation parameters - Deviations from recommendations - No details on the time when information must be supplied	- WTW CO_2 emissions; declaration of TTW CO_2 emissions is optional - Explanation of the calculation method used and the energy sources - Information must be made available at the agreed date or otherwise within two months from the end of the service provision
Certification	- Is optional (by accredited auditor)	- Declaration of conformity must be made by approved body

Source: own figure.

5 Determining standardised consumption values and emissions

Companies who are able to specify their own consumption of diesel, jet kerosene, marine diesel or electricity precisely by means of measurements or from their own calculations can easily determine standardised energy consumption values and greenhouse gas emissions with the aid of fixed conversion factors. According to EN 16258 both values must be shown for the operation of the vehicle (tank-to-wheels) and as a total for operation and energy supply (well-to-wheels). Chapter 7 then describes how to apportion the energy consumption amongst the individual consignments.

Determining energy consumption and greenhouse gas emissions

If measurements are made of the diesel consumption of lorries or ships, the electricity consumption by electrical locomotives or the jet kerosene used by aircraft, then this provides direct data on the final energy consumption and therefore on the **tank-to-wheels energy consumption**. However, if different modes of transport are used in a transport chain then, in an ideal case, the energy consumption values of each individual mode of transport should be added together. However, this can only be done if there is a common physical unit. The standard EN 16258 specifies that litres, kilogrammes and kilowatt hours must therefore be converted into megajoules (MJ) using fixed factors.

The **well-to-wheels energy consumption values** are likewise determined using a conversion factor which also allows for losses in power plants, refineries and power cables. The WTW conversion factor is therefore larger than the TTW conversion factor (see Table 5).

$$E_T = F \times e_T \quad \text{or} \quad E_W = F \times e_W$$

E_T	=	Tank-to-wheels energy consumption in MJ
E_W	=	Well-to-wheels energy consumption in MJ
F:	=	Measured energy consumption (e.g. l, kg or kWh)
e_T	=	Tank-to-wheels energy factor from measured values in MJ
e_W	=	Well-to-wheels energy factor from measured values in MJ

The **greenhouse gas emissions for tank-to-wheels and well-to-wheels** are calculated in a similar way to energy consumption. A specific conversion factor is used to multiply the measured energy consumption for both values (see Table 5).

$$G_T = F \times g_T \quad \text{or} \quad G_W = F \times g_W$$

G_T	=	Tank-to-wheels GHG emissions in kg CO_2 equivalents (CO_2e)
G_W	=	Well-to-wheels GHG emissions in kg CO_2 equivalents (CO_2e)
F:	=	Measured energy consumption (e.g. l, kg or kWh)
g_T	=	Tank-to-wheels GHG emission factors from measured values in kg CO_2e
g_W	=	Well-to-wheels GHG emission factors from measured values in kg CO_2e

The new standard EN 16258 contains the necessary conversion factors for the calculations shown above. These are shown in Table 5. All the sample calculations in this guide are carried out using these conversion factors. The standard stipulates that deviations from these factors are only permitted, e.g. if suppliers provide equivalent values which have been compiled in accordance with the EU Directive 2009/30/EC.

Table 5: Factors for the calculation of energy consumption and greenhouse gas emissions (calculated as CO_2 equivalents) in accordance with EN 16258.

	Standardised energy consumption				**Greenhouse gas emissions (calculated as CO_2 equivalents)**			
	Tank-to-wheels (e_T)		**Well-to-wheels (e_W)**		**Tank-to-wheels (g_T)**		**Well-to-wheels (g_W)**	
	MJ/kg	***MJ/l***	***MJ/kg***	***MJ/l***	***kg CO_2e/kg***	***kg CO_2e/l***	***kg CO_2e/kg***	***kg CO_2e/l***
Petrol	43.2	32.2	50.5	37.7	3.25	2.42	3.86	2.88
Ethanol	26.8	21.3	65.7	52.1	0.00	0.00	1.56	1.24
Petrol E5 (5 vol.% Ethanol)	42.4	31.7	51.4	38.4	3.08	2.30	3.74	2.80
Petrol E10 (10 vol.% Ethanol)	41.5	31.1	52.2	39.1	2.90	2.18	3.62	2.72
Diesel	43.1	35.9	51.3	42.7	3.21	2.67	3.90	3.24
Biodiesel	36.8	32.8	76.9	68.5	0.00	0.00	2.16	1.92
Diesel D5 (5 vol.-% biofuel)	42.8	35.7	52.7	44.0	3.04	2.54	3.80	3.17
Diesel D7 (7 vol.-% biofuel)	42.7	35.7	53.2	44.5	2.97	2.48	3.76	3.15
Compressed natural gas	45.1	n/a	50.5	n/a	2.68	n/a	3.07	n/a
Liquefied petroleum gas	46.0	25.3	51.5	28.3	3.10	1.70	3.46	1.90
Jet kerosene[1)]	44.1	35.3	52.5	42.0	3.18	2.54	3.88	3.10
Heavy fuel oil (HFO)[2)]	40.5	39.3	44.1	42.7	3.15	3.05	3.41	3.31
Marine diesel oil (MDO)	43.0	38.7	51.2	46.1	3.24	2.92	3.92	3.53
Marine gas oil (MGO)	43.0	38.3	51.2	45.5	3.24	2.88	3.92	3.49

[1)] Without allowing for a possible higher effect on the climate from air traffic at cruising height. – [2)] HFO = Heavy fuel oil (heavy fuel oil for ships).

Source: EN 16258.

Sample calculation 1:

Calculation of TTW and WTW energy consumption and TTW and WTW greenhouse gas emissions based on measured diesel consumption values

A lorry needs 406 l of diesel to drive from Paris to Madrid. The calculations in this example are made using the conversion factors for conventional diesel (without biodiesel) in accordance with the standard EN 16258.

TTW energy consumption: $E_T = F \times e_T = 406 \text{ l} \times 35.9 \text{ MJ/l} = 14{,}578 \text{ MJ}$

WTW energy consumption: $E_W = F \times e_W = 406 \text{ l} \times 42.7 \text{ MJ/l} = 17{,}340 \text{ MJ}$

TTW GHG emissions: $G_T = F \times g_T = 406 \text{ l} \times 2.67 \text{ kg } CO_2\text{e/l} = 1{,}084 \text{ kg } CO_2\text{e}$

WTW GHG emissions: $G_W = F \times g_W = 406 \text{ l} \times 3.24 \text{ kg } CO_2\text{e/l} = 1{,}316 \text{ kg } CO_2\text{e}$

Taking account of added biodiesel

In many EU countries biodiesel is added to conventional diesel. This is based on the EU directive 2009/30/EC. Typical fuels in Europe are D5 with up to 5 vol% biodiesel and D7 with up to 7 vol% biodiesel (sold in Germany, for example). All these fuels are sold at the petrol stations without this being specially indicated. In many European countries the customer therefore buys diesel and receives fuel with a percentage of biodiesel (e.g. D7 in Germany). In order to be able to take account of these fuels when calculating energy consumption and emissions in accordance with EN 16258, the standard contains the required **conversion factors for various blending rates** (see Table 6). The blending rates at petrol stations are generally specified in relation to volume. However, at a national level the blending rates are published in relation to energy content. Due to the lower energy density of biodiesel, the percentage by volume is always higher than the energy-related biodiesel percentage (see Table 6).

According to EU guidelines, admixtures of biofuels should reduce well-to-wheels greenhouse gases by at least 35% by 2016, 50% by 2017 and 60% by 2018. The values in Table 5 and Table 6 take account of the current reduction in emissions of 35% – this has the advantage that it is not necessary to know the production path and source material for the biofuels. This approach is in line with the standard EN 16258.

Table 6: Blending rate of biodiesel (volumetric and energetic) and the resulting energy and GHG conversion factors.

Biodiesel percentage in relation to volume (litres)	Biodiesel percentage in relation to energy content	TTW energy conversion factor (e_T)	WTW energy conversion factor (e_W)	TTW GHG conversion factor (g_T)	WTW GHG conversion factor (g_W)
in %	in %	MJ/litre	MJ/litre	kg CO_2e/litre	kg CO_2e/litre
1,0%	0.91%	35.9	43.0	2.64	3.23
2,0%	1.83%	35.8	43.2	2.62	3.21
3,0%	2.75%	35.8	43.5	2.59	3.20
4,0%	3.67%	35.8	43.7	2.56	3.19
5,0%	4.59%	35.7	44.0	2.54	3.17
6,0%	5.51%	35.7	44.2	2.51	3.16
7,0%	6.43%	35.7	44.5	2.48	3.15
8,0%	7.36%	35.7	44.8	2.46	3.13
9,0%	8.29%	35.6	45.0	2.43	3.12
10,0%	9.22%	35.6	45.3	2.40	3.11
20,0%	18.59%	35.3	47.9	2.27	2.98

Source: EN 16258.

The standard EN 16258 does not contain conversion factors for electricity as these are dependent on the mix of the generating plants which produced the electricity. A higher proportion of electricity produced from coal causes higher greenhouse gas emissions, a higher proportion of renewable energy produces lower ones. The standard recommends using the values from the supplier if possible and, if these are not available, average values for the grid used or for the country (e.g. Germany, France or Greece). However, it is advisable to exercise caution when using data from the supplier. Energy labelling values cannot be used for this as they only relate to CO_2 and not to all greenhouse gases and, in addition, they do not include all the stages of the process from extraction of the energy source via its conversion in the power plants to the distribution to the end customer.

Nowadays electricity is predominantly used by public transport companies. The electricity mixes in this context also vary from company to company and so too do the conversion factors. However, the European railway companies have determined specific values for their electricity generation which take account of the different power plant fleets, so that each country has its own conversion factors. This guide uses the values from the emission model EcoTransIT World (www.ecotransit.org). The corresponding TTW and WTW conversion factors for energy consumption and for determining the TTW and WTW greenhouse gas emissions are detailed in the appendix. They comply with the requirements of the standard EN 16258.

Sample calculation 2:

Calculation of TTW and WTW energy consumption values based on electricity consumption

An electric goods train requires around 4,500 kWh of electricity for a journey from Munich to Berlin (conversion factors are taken from the appendix, see Table 23).

The **TTW energy consumption** is calculated as follows:

$$E_T = F \times e_T = 4{,}600 \text{ kWh} \times 3.6 \text{ MJ/kWh} = 16{,}560 \text{ MJ}$$

The **WTW energy consumption** can be determined as follows:

$$E_W = F \times e_W = 4{,}600 \text{ kWh} \times 11.1 \text{ MJ/kWh} = 51{,}060 \text{ MJ}$$

The **TTW and WTW greenhouse gas emissions** can then be calculated as follows:

$$G_T = F \times g_T = 4{,}600 \text{ kWh} \times 0 \text{ kg } CO_2e\text{/kWh} = 0 \text{ kg } CO_2e$$

$$G_W = F \times g_W = 4{,}600 \text{ kWh} \times 0.574 \text{ kg } CO_2e\text{/kWh} = 2{,}640 \text{ kg } CO_2e$$

If the same energy consumption values were measured for a goods train in **Sweden**, then the WTW energy consumption and the WTW greenhouse gas emissions would be significantly lower due to electricity generation for the railway coming exclusively from hydropower (conversion factors are taken from the appendix):

$$E_W = F \times e_W = 4{,}600 \text{ kWh} \times 3.8 \text{ MJ/kWh} = 18{,}400 \text{ MJ}$$

$$G_W = F \times g_W = 4{,}600 \text{ kWh} \times 0.004 \text{ kg } CO_2e\text{/kWh} = 18 \text{ kg } CO_2e$$

Procedure for climate-controlled transport services

Many goods and freight has to be kept cold during transport while some have to be kept warm. This requires **additional energy**. If cooling units are operated by means of the lorry's diesel tank, then the additional consumption is already contained in the fuel consumption of the vehicle and goes directly into the greenhouse gas calculation. If the cooling units are supplied from a separate energy source, then the additional consumption must be recorded separately. TTW and WTW energy consumption values or TTW and WTW greenhouse gas emissions can then be calculated in the way described above.

However, cooling units are also filled with **refrigerant**. In the past, for example, cooling units in lorries often used the refrigerant R-22 which has been replaced by the hydrofluorocarbons R-404A, R-410A and R-134a. R-

404A and R-410A are used in cooling units for larger vehicles for frozen and refrigerated delivery, R-134a in cooling units for smaller vehicles for refrigerated delivery. Refrigerated containers on container ships use R-22, R-134a and R-404A.

Most refrigerants have a strong greenhouse effect if they escape into the atmosphere through leakage or accidents. It is not necessary to include these refrigerant losses in the inventory when calculating energy consumption and greenhouse gas emissions for transport services in compliance with the new standard EN 16258. If their environmental effects are calculated in any case, then the results have to be shown separately from the energy-related emissions determined in accordance with EN 16258.

Even though the standard does not require this, the climatic effect of refrigerant which enters the environment due to losses and leakage can easily be determined using the amount of refrigerant needed for refilling and the GWP factor. The method suggested here follows the recommendations in the GHG protocol for stationary processes (see Chapter 12). The allocation of the greenhouse gas emissions to individual consignments can be done similarly to the allocation of energy-related greenhouse gas emissions as described in Chapter 7:

Direct GHG emissions = amount of refrigerant refilled x GWP factor

For example, for 0.5 kg of refrigerant R-134a released, the following applies:

0.5 kg R-134a x 1,430 kg CO_2e/kg = 715 kg CO_2e/kg

Table 7 shows the **GWP factors for standard refrigerants**:

In order to calculate the total greenhouse gas emissions (similarly to the WTW greenhouse gas emissions as specified in EN 16258) the emissions from manufacturing the refrigerant also need to be included. Calculation of total emissions is done similarly using the total emission factor (see Table 7):

0.5 kg R-134a x 1,533 kg CO_2e/kg = 766.5 kg CO_2e/kg

Table 7: Greenhouse gas emission factors for selected refrigerants

	Direct emissions factor (similar to TTW)	**Total emissions factor (similar to WTW)**
	kg CO_2e/kg	kg CO_2e/kg
Refrigerant R-22	1,810	1,886
Refrigerant R-134A	1,430	1,533
Refrigerant R-404A	3,922	4,025
Refrigerant R-410A	2,088	2,177
Sources: IPCC 2007; Ecoinvent 2009; own calculations.		

Unlike fuels, refrigerants are not transformed into energy when used. The TTW energy consumption is therefore zero. Energy is only consumed when the refrigerant is manufactured. If this energy consumption is allocated to the transport service, it is negligible in comparison with the transport-related energy consumption. This is the reason that no specific conversion factors for refrigerants are shown in this guide.

6 Allocation: consumption and emissions from individual consignments

The person purchasing freight forwarding services is often not interested in the environmental effect of a whole load but in that of the individual consignment they have dispatched. This challenge applies in particular to forwarding groupage services and to extensive general cargo networks. Depending on the organisation of the supply chain, it is not only the energy consumption and greenhouse gas emissions from the lorry which need to be allocated to the individual item but also the values for train, plane and / or ship transport. The new standard EN 16258 contains both principal and specific regulations for this allocation procedure. The principal regulations include:

- The total energy consumption and greenhouse gas emissions of a vehicle must be allocated to the transported goods. This means that **empty trips have** to be added to the transported goods in a **proportional manner**.
- **Marginal accounting is not permitted**. The distribution of energy consumption and emissions for a specific leg of the journey must **always be related to all the loaded goods**. If an extra consignment is loaded then all energy consumption and emissions are allocated to this item in a proportional manner. It is not permitted to allocate only the minor additional consumption of energy to this last consignment. This procedure would result in the goods loaded first being allocated the highest environmental effects.
- If **passengers and goods are conveyed at the same time** (e.g. in a passenger plane or on a ferry), then energy consumption and emissions have to be divided amongst the passengers and freight.
- The selected **distribution factor** for the allocation may not be changed for a specific vehicle or in the course of the transport service.

The **Standard EN 16258** in fact recommends using the **product of the weight of the consignment** and the actual **distance travelled** – i.e. the transport capacity measured in tonne kilometres – as the allocation parameter. As this is not always possible for all transport services, the standard also permits other methods of allocation. Alternatively, for example, the product of distance and other variables such as volume, loading metres, number of pallets or number of standard containers (TEU = twenty-foot equivalent unit) can be used if these variables are the crucial limiting factor for the transport service. If there is no distance information available, then the weight or number of consignments can be used as the allocation factor. This often applies to courier, express or parcel services as in such cases it is almost impossible to determine the transport distance per individual consignment. However, the standard also permits the allocation of energy consumption and emissions using distance alone. Users of the standard therefore have a large choice of possible allocation parameters. However, it is a basic requirement that the chosen **allocation variables must be stated** along with the result. This applies in particular if the allocation parameter recommended by the standard – tonne kilometres – is not used. As the chosen parameter has a major influence on the result (see next sample calculation), users of the standard (e.g. the transport industry) must specify the allocation variables precisely in order to obtain comparable calculation results.

Sample calculation 3:
Allocating energy consumption to an individual consignment

A carrier transports eight pallets with wood briquettes on a 12-t lorry from his warehouse in Antwerp to two customers in Brussels and Leuven. He then drives back empty. The lorry uses a total of 25.7 l. Two consignments are transported

- four pallets of hardwood briquettes from Antwerp to Brussels (50 km)
- four pallets of bark briquettes from Antwerp via Brussels to Leuven (50 + 26 km)

- weight of the consignments:
  - Hardwood briquettes:
    960 kg/pallet + 20 kg weight of pallet = 980 kg total weight/pallet
  - Bark briquettes
    500 kg/pallet + 20 kg weight of pallet = 520 kg total weight/pallet

Case 1: Allocation using the product of weight and distance (transport capacity)

- Hardwood briquettes: 50 km x 3.92 t = 196.0 tkm
- Bark briquettes 76 km x 2.08 t = 158.1 tkm
- Total: 196.0 tkm + 158.1 tkm = 354.1 tkm

Percentage share of **hardwood briquettes**: 196.0 tkm / 341.6 tkm = **55.35%**

Case 2: Allocation using the product of number of pallets and distance

- Hardwood briquettes: 50 km x 4 pallets = 200 pallet-km
- Bark briquettes 76 km x 4 pallets = 304 pallet-km
- Total: 200 pallet-km + 304 pallet-km = 504 pallet-km

Percentage share of **hardwood briquettes**: 200 pallet-km / 504 pallet-km = **39.68%**

The **hardwood briquettes** are therefore assigned a diesel consumption of **14.2 l** (55.35% x 25.7 l) for the **weight-based allocation** and **10.2 l** (39.68% x 25.7 l) for the **pallet-kilometres allocation**. This example illustrates clearly that the chosen allocation method has a major influence on the result.

Special case of collection and distribution services

The standard EN 16258 formulates special recommendations for allocation for collection and distribution transport services. As for other trips, the first step is to determine fuel consumption, TTW and WTW energy consumption and TTW and WTW greenhouse gas emissions for the whole trip and then, in a second step, allocate these to the individual consignments. However, if distance is used for the allocation (e.g. to calculate tonne kilometres), the standard prescribes that, instead of the actual transport distances for the individual goods, the **direct distances** from the start or end points (e.g. terminal) to the loading and unloading points must be used (see sample calculation 4).This enables a fairer allocation of energy consumption and emissions to the individual consignment, because this procedure does not depend on whether the trip is done clockwise or anti-clockwise or whether an item is loaded or unloaded at the beginning or the end.

The standard EN 16258 permits two options for determining the shortest distance: either the **great circle distance** between the terminal and loading or unloading point or the **shortest practicable distance** between the terminal and the loading or unloading point on the transport routes available. It is important to note that the shortest distances may only be used for allocation: fuel consumption must be determined along the route actually taken for the whole trip.

Collection and distribution transport services should also use the product of distance and weight for allocation purposes, as is the case for freight transport in general. For collection and distribution transport services, the standard permits other allocation parameters (e.g. number of consignments, number of stops) to be used in combination with the distance instead of weight. These parameters can also be used alone or in combination (e.g. weight and number of stops) – in other words, without distance (see sample calculation 4). However, as a general rule, the standard permits the use of other allocation parameters (e.g. only the number of consignments) for collection and distribution transport services. The parameters used must, however, be specified in the declaration.

Sample calculation 4:
Allocation for collection and distribution services with a lorry

A lorry uses 8 l of diesel for a collection and distribution trip. The diesel consumption, which applies to the load taken on at the second stop (1.5 t), is calculated from the product of great circle distance and the weight of the consignment as follows:

- Notional transport capacity of all consignments:

  (3 x 4.1 + 1.5 x 7.9 + (2+3) x 10.3 + 3 x 11.5 + 2 x 8.2 + 3.5 x 4.3) tkm = 141.6 tkm
- Transport capacity of consignment: 1.5 t x 7.9 km = 11.85 tkm
- Percentage share of consignment: 11.85 tkm / 141.6 tkm = 8.37%

The amount therefore applicable to the **consignment in question** (2nd stop) **is 0.67 litres** (8.37% x 8 l).

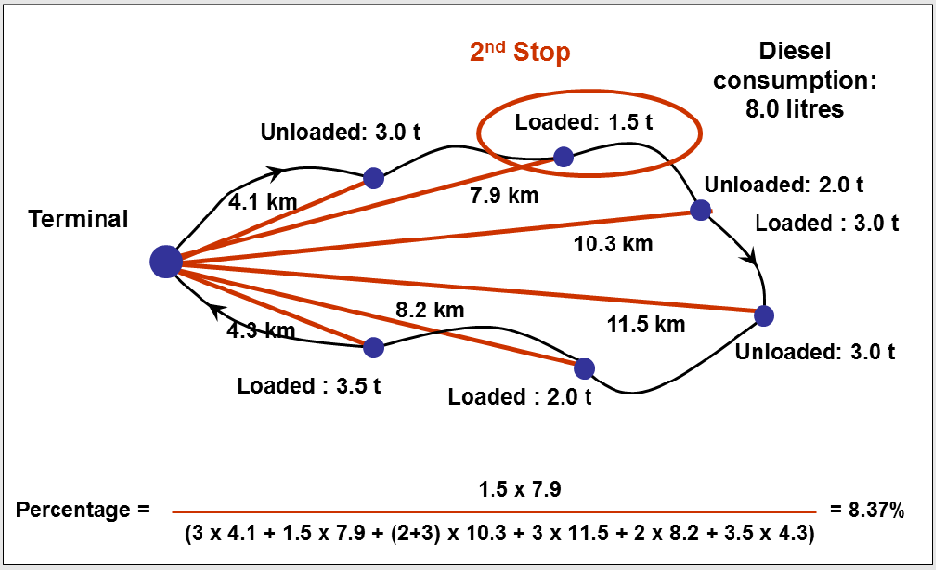

Figure 2: Example of allocation for a collection and distribution service

Besides transport services based on linear distances, EN 16258 permits allocation to be calculated from the weight of consignments alone or other parameters such as number of consignments or number of stops. The combination of these parameters (e.g. weight and number of stops) is also standard-compliant. The results for the example shown in Figure 2 are given in the following table. Depending on the chosen allocation parameters, Consignment 2 has the following diesel consumption percentages (see Table 8):

- Number of consignments: 14.29%
- Number of stops: 16.67%
- Weight: 8.33%
- 50% weight + 50% stops: 12.50%
- Transport service (linear distance): 8.37%

Table 8: Allocation examples for a collection and distribution trip

Stop	Loading/ Unloading	Distances (Great circle distances)	Con-sign-ment weight	Transport service (linear distance)	Allocation based on … Con-sign-ments	Stops	Weight	50% weight + 50% stops	Trans-port service[1)]
		km	*kg*	*tkm*	*%*	*%*	*%*	*%*	*%*
1	Unloaded	4.1	3.0	12.30	14.29%	16.67%	16.67%	16.67%	8.69%
2	**Loaded**	**7.9**	**1.5**	**11.85**	**14.29%**	**16.67%**	**8.33%**	**12.50%**	**8.37%**
3	Unloaded	10.3	2.0	20.60	14.29%	16.67%	11.11%	13.89%	14.55%
	Loaded	10.3	3.0	30.90	14.29%	8.33%	16.67%	12.50%	21.82%
4	Unloaded	11.5	3.0	34.50	14.29%	8.33%	16.67%	12.50%	24.36%
5	Loaded	8.2	2.0	16.40	14.29%	16.67%	11.11%	13.89%	11.58%
6	Loaded	4.3	3.5	15.05	14.29%	16.67%	19.44%	18.06%	10.63%
Total			**18.0**	**141.60**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

[1)] Based on great circle distances.

Sources: Prof. Lohre/FH Heilbronn; own calculations.

Special case of cargo in passenger transport services

Cargo is sometimes carried along with passengers – for example, in air transport (belly freight) or on ferries which take private vehicles and lorries. Belly freight is of considerable importance in practice. The standard EN 16258 states that the allocation between passengers and freight must be done on the basis of percentage by weight. If there are no available weights for passengers and baggage, then passengers are calculated at a flat rate of 100 kilograms per passenger including baggage.

Sample calculation 5:
Allocation of cargo in passenger aircraft

A Boeing 747-400 needs a total of 67,800 kg jet kerosene from Frankfurt to New York. The plane is carrying 350 passengers and 9 t of cargo. The flight distance is 6,300 km.

The **allocation of kerosene consumption to 1 t cargo**:

- Transport capacity passengers + cargo = (350 x 0.1 t + 9 t) x 6,300 km = 277,200 tkm
- Transport capacity 1 t cargo = 1 t x 6,300 km = 6,300 tkm
- Percentage share of 1 t cargo = 6.300 tkm / 277,200 tkm = 2.27%
- Jet kerosene consumption for 1 t cargo = 2.27% x 67,800 kg = 1,539 kg

1 t belly freight in the passenger aircraft is therefore responsible for a kerosene consumption of **1,539 kg**.

7 Calculation methods for transport services – two ways, one aim

Energy consumption and greenhouse gases from transport services can be determined using two basic approaches: either consumption-based or distance-based methods.

Consumption-based method

In the **consumption-based method** the greenhouse gas emissions are calculated with the aid of the measured energy consumption and the energy-specific emission factors. To be comparable, energy consumption must be converted into a standard energy unit (normally megajoules) using clearly defined factors. The standard EN 16258 recommends using the consumption-based method as it provides more precise results than the distance-based method.

The standard divides the consumption-based option into **three different cases.** In the **first case** the measured energy consumption is available for an **actual transport service** – but in reality this only happens in rare cases.

The **second instance** is of greater importance, where **average values are available for the vehicle or route** for the vehicle round-trip (known as a Vehicle Operation System). These values were not measured for this actual transport service but determined over the period of a year, for example.

If these values are also not available then, in the **third instance, average fleet values** which are typical for the transport service under consideration can be used. Care must be taken not to include any fleet values which cover a completely different size of vehicle – e.g. the fleet average for 40-t lorries, if the calculation actually deals with distribution journeys. In all three instances the empty trips have to be included in the calculation.

The methods for measuring energy consumption are described in Chapter 9.

Distance-based method

The consumption-based method which is calculated from measurements of energy consumption for the mode of transport used is, however, not practicable if a large proportion of transport services are made with vehicles belonging to sub-contractors. Obtaining a complete record of their fuel consumption is not realistic. In such cases the **distance-based method** is appropriate. Along with the weight of the consignment this method requires information on the distances travelled or on the tonne kilometres (weight times distance). These values are then linked to consumption or emission factors per vehicle kilometre or per tonne kilometre in order to determine how much energy was used and how much greenhouse gas produced.

The factors can be taken from official databases such as HBEFA, TREMOD or TREMOVE or from publicly accessible calculation tools such as EcoTransIT World. Annual kilometres travelled, transport services and loads, in contrast, have to be calculated specially. The more closely the consumption and emission factors are matched to the mode of transport in question, the more accurate are the calculations. For example, an empty lorry uses less fuel than a fully loaded one. The specified databases therefore contain differing consumption values and emission factors for empty and fully loaded lorries. The values from databases are also known as default values.

The procedure for calculating energy consumption and greenhouse gas emissions for all modes of transport using the distance-based method is shown in Chapter 10. For lorry transport, Chapter 11 describes how to calculate more accurate energy consumption and greenhouse gas emissions for the mode of transport in question using default values.

EN 16258: two methods – four approaches

The standard EN 16258 permits **four approaches for determining consumption data**, where the first three cases correspond to the consumption-based method and the fourth case relates to the distance-based method (see Figure 3):

- Use of **individual measured values** for the actual transport service,
- Use of **vehicle-type or route-type specific values** (e.g. determined over a year) which are referred to as **transport operator specific values** in the standard.
- Use of **average fleet values** (e.g. obtained over a year), which are referred to as **transport operator fleet values** in the standard
- Use of fixed **default values** from databases**.**

One thing applies to all the methods: the data are only as good as the source from which they were taken. In addition to the results it must therefore always be clearly stated which variables have been measured and which are default values from databases. In addition, the source of default values must always be specified in accordance with the standard EN 16258.

Irrespective of which data sources are used and in accordance with the standard EN 16258, the measured or calculated energy consumption values must be converted to the standardised energy unit MJ for better comparability. In addition, the greenhouse gas emissions must be obtained from the energy consumption by means of conversion factors. The standard provides specific conversion factors for all energy sources or describes the method to be used for determining these factors for both conversion stages – standardisation of the energy consumption values and calculation of the greenhouse gas emissions. These conversion factors are presented in Chapter 6.

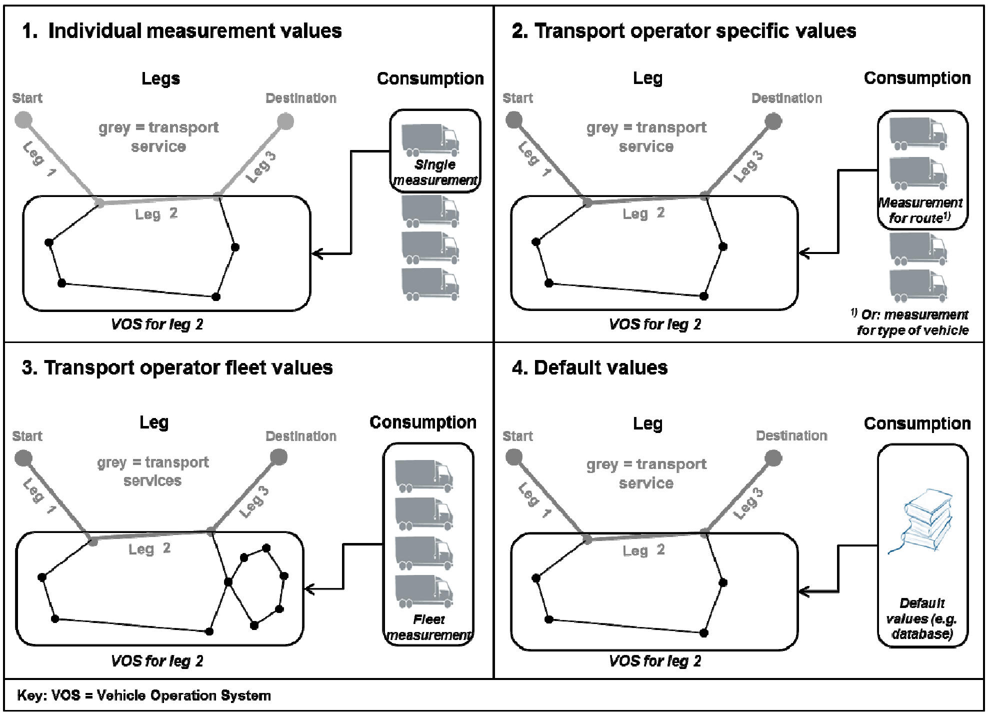

Figure 3: Four approaches for determining consumption data in accordance with the standard EN 16258

8 Measuring energy consumption – what you need to do

In previous sub-chapters it was shown how energy consumption and greenhouse gas emissions for tank-to-wheels and well-to-wheels can be calculated in a standardised way on the basis of energy consumption data and how these values can be allocated to individual consignments. Anyone who measures energy consumption values must ensure that they are recorded in compliance with the standard EN 16258.

The CEN standard specifies that the **total vehicle round-trip** in which the individual consignment is transported, or would be transported in the case of planned consignments, must be taken into account. This vehicle round-trip is referred to as a Vehicle Operation System, **VOS**. This ensures that empty trips for supplying the vehicle or empty trips back to the site are included in the calculation.

Please note therefore that, for a journey with a full load from A to B, the Vehicle Operation System also includes the **empty trip** from B to A. For **container ships** the Vehicle Operation System is the total loop from the port of departure to the receiving terminal and back again, even if the container under consideration is only transported for one leg of the journey. In **collection and distribution transport services** the Vehicle Operation System includes the whole trip. Empty trips must be divided proportionally between all consignments.

EN 16258: Three measurement options

The future standard permits three cases for the measurement of energy consumption and recommends the following sequence:

(1) **Use of individual measured values for the actual transport service (specific measured values):** In this case the fuel consumption is determined exactly for the round-trip on which the consignment is transported. This type of detailed treatment is rather uncommon in practice up to now, as freight forwarders and logistics operators can rarely collect separate energy data for all the modes of transport used.

(2) **Use of transport operator specific values (vehicle-type or route-type values)**: In this case the logistics company measures, for example on an annual basis, the consumption of diesel by the vehicles, ships or aircraft which it uses specifically for the route on which the consignment is transported, and then divides these values between the individual consignments. So what is used is an average energy consumption figure per tonne kilometre or per TEU kilometre e.g. obtained over a year. This method will likely become important in future as it is relatively easy to put into practice. This could lead to the use of vehicle-type average values being used (e.g. the average of all 40-tonne lorries or all B747-400F aircraft) instead of route-type averages.

(3) **Use of transport operator fleet values:** This case is similar to the second one – although here the average values for the whole fleet of a service operator are used and not specifically for one type of vehicle or route. In order to be able to use these values for a single consignment, it must be ensured that the vehicles are typical for the type of transport under consideration. This procedure is standard in

many freight forwarding companies nowadays – although this method gives the most imprecise results as they are not based on any specific data for the individual transport service.

Sample calculation 6:

Measurement of energy consumption in accordance with EN 16258

A diesel powered train transports gravel over a distance of 520 km and travels back to the starting point empty.

Case 1: Diesel consumption for actual train round trip and allocation to <u>1 t gravel</u>:

- Loading: 2,400 t gravel
- Diesel consumption: 6,000 l

Share of diesel consumption per t gravel = (1 t / 2,400 t) x 6,500 l = **2.7 l**

Case 2: Diesel consumption on an annual basis for actual train round trip and allocation to <u>1 t gravel</u>:

- Train round-trips per year: 100
- Loading: 100 x 2,400 t gravel = 240,000 t gravel
- Diesel consumption: 576,000 l

Share of diesel consumption per t gravel = (1 t / (2,400 t x 100)) x 576,000 l = **2.4 l**

Case 3: Diesel consumption on an annual basis for total network and allocation to <u>1 t gravel</u>:

- Total transport capacity of all bulk cargo transport services by the company: 4.73 billion tkm
- Transport capacity for 1 t gravel over 520 km: 520 tkm
- Diesel consumption: 23.04 million l

Share of diesel consumption per t gravel = (520 tkm / 4,730 million tkm) x 23.04 million l = **2.5 l**

This example shows that the method used for measuring energy consumption has an effect on the result. In this example the consumption is highest for the actual train round-trip. However, this can be easily explained. In a single round-trip special effects can arise, e.g. additional stops by a goods train in order to let passenger trains past. With annual values effects like these are averaged out.

At present, an average value per tonne kilometre is often calculated in practice as in case 3 and then used to calculate individual consignments.

9 Reaching your goal quickly without own measured consumption data

If sub-contractors are employed for transport services, then there is usually neither consumption information for their vehicles and vehicle round-trips nor details on the load utilisation or proportion of empty trips. In this case the standard EN 16258 makes provision for using default values, both for energy consumption and for load utilisation and empty trips. The sources of the default values must, however, be stated and their selection justified. In these cases energy consumption values are often determined using the **distance-based approach** in which specific energy consumption values per tonne kilometre are used. These specific values are also used in this chapter of the guide.

However, it must be noted that specific energy consumption values per tonne kilometre already take account of the load utilisation and empty trips made by the vehicle and link the energy consumption calculation to the allocation step (see Chapter 7) – so, instead of two separate steps in the calculation, only one is necessary. Using these specific values also means that the **allocation variable** is also fixed**.** For energy consumption values per tonne kilometre, allocation is carried out using weight**,** while for energy consumption values per TEU km, it is done using the 20-foot standard container (TEU = twenty foot equivalent unit). This chapter uses both options.

Whilst the values for energy consumption of various modes of transport can be taken from databases, values for **load utilisation** and **empty trips** have to be specified. The dilemma is that load utilisation and empty trips have a large effect on the energy consumption. However, both variables usually depend on the type of goods transported. With heavy bulk goods such as ores, coal or mineral oil products in which the transport weight is the limiting factor for the load utilisation, loaded trips are at almost 100% capacity in relation to weight. At the same time it is often a case of unpaired transport journeys with a high percentage of empty trips. In contrast, for volume goods and general cargo, the weight-related load utilisation is around 30 to 40% but the empty trip proportion is lower. In order to be able to allow for these effects, the specific energy consumption values per tonne kilometre will be shown for the three types of goods **bulk goods, volume goods and average goods** in this chapter. This also applies to container transport services.

How is the calculation done?

The following sections provide tables with energy consumption values per tonne kilometre for bulk, average and volume goods for all modes of transport. All these values represent default values and are based on the sources specified in the standard EN 16258. They are therefore all standard-compliant. As the energy values are dependent on the mode of transport and their variables, these are shown separately for lorry, train, ship and aircraft variables. The specific consumption values per tonne kilometre also contain specifications on load utilisation and empty trip percentages which are shown in the following sections specifically for each mode of transport.

To determine the energy consumption for the consignment in question, the specific consumption value per tonne kilometre (tkm) has to be multiplied by the weight of the consignment and the distance travelled by the transport service. For containers, the tables show the specific consumption values per TEU kilometre. For such cases these values have to be multiplied by the distance and the number of TEUs. This is summarised in the following equation:

$$F = W * D * E$$

F	=	energy consumption in l, kg or kWh
W	=	actual cargo weight in t or TEU
D	=	actual transportation distance in km
E	=	specific energy consumption (in l, kg or kWh) per tkm or TEU-km

In order to determine the energy consumption exactly, the following steps have to be followed:

- Determine the **type of goods** (heavy, average or volume goods);
- Identify the **vehicle** used in terms of type and size;
- Select the specific **consumption values** per tkm or TEU-km which match the type of goods and/or the type of vehicle;
- Determine the **actual transportation distance** for the individual consignment. For land-based transport (road, rail, inland shipping) this is the distance actually covered. Special calculation guides apply to air traffic and marine shipping as the actual distance usually deviates from the ideal route;
- Determine the **actual consignment weight** (including packaging or transport aids such as pallets and container weights if appropriate, see Table 9) or number of TEU;
- **Calculate the energy consumption** for the consignment by multiplying the consignment weight by the transportation distances and the specific consumption values per tkm or TEU-km.

The energy consumption values obtained in this way are used to determine the TTW and WTW energy consumption values and the TTW and WTW greenhouse gas emissions using the conversion factors given in the standard EN 16258 and presented in Chapter 6.

Table 9: Container weight for different types of goods

Type of goods	Container weight	Cargo weight	Total weight
	Tonnes/TEU	Tonnes/TEU	Tonnes/TEU
Volume goods	1.9	6.0	7.90
Average goods	1.95	10.5	12.45
Bulk goods	2.0	14.5	16.50

Source: EcoTransIT 2010.

Lorry transport

Lorry transport services use different sizes of vehicles. Consumption values for four size classes of lorries will be provided here covering the permitted range in most European countries, using the web-based emission calculation tool EcoTransIT (www.ecotransit.org). Although exhaust emissions from lorry transport have been drastically reduced in recent years, average fuel consumption has nevertheless remained almost constant since the introduction of Euro 3. For this reason consumption values per tonne kilometre do not currently vary depending on different technical exhaust standards or the age of the vehicle. Only very old lorries have higher consumption values than shown in this chapter.

Table 10: Assumptions for four classes of lorries

	Additional empty trips[1)]	**Lorry < 7.5 t GVW**	**Lorry 7.5-12 t GVW**	**Lorry 12 t GVW**	**Road train/ articulated lorry 24-40 t GVW**
Maximum payload		3.5 t	6.0 t	12.0 t	26.0 t
Freight transport		*– Cargo weight in t per lorry –*			
Volume goods	+10%	1.05 t	1.8 t	3.6 t	7.8 t
Average goods	+20%	2.1 t	3.6 t	7.2 t	15.6 t
Bulk goods	+60%	3.5 t	6.0 t	12.0 t	26.0 t
Container transport		*– Number TEU per lorry –*			
Volume goods	+10%	-	-	1 TEU	2 TEU
Average goods	+10%	-	-	1 TEU	2 TEU
Bulk goods	+10%	-	-	-	1 TEU

[1)] Additional empty trips: percentage of trip which is carried out empty, in relation to the load trip.
Source: EcoTransIT 2010.

The ascents and descents in the **route profile** have a large effect on consumption – increasingly so with heavier vehicles and loads. Consequently, specific consumption values for hilly profile (representative for countries like Germany) are given here and also for journeys on the level (representative for countries like Netherlands). Road cargo traffic often uses motorways. The **calculation is therefore based** on the average fuel consumption on **motorways**. This takes account of averaged proportions of freely flowing and saturated traffic and traffic jams. Fuel consumption on **rural roads** is comparable to that on motorways. If larger percentages of the route lie in **urban areas**, the following **correction factors** can be used:

Table 11: Correction factors for the use of urban roads

Lorry type	**Correction factor**
Lorry < 7.5 t GVW	0.9
Lorry 7.5-12 t GVW	1
Lorry 12-24 t GVW	1.3
Road train/articulated lorry 24-40 t GVW	1.4

Sources: HBEFA 3.1; TREMOD 2010; own calculations.

Table 12 shows characteristic consumption values per tonne kilometre for the specific energy consumption for lorry and container transport. Volume goods result in a higher fuel consumption over one tonne kilometre than do bulk goods.

Table 12: Specific energy consumption E per tkm or TEU-km for lorry transport

	Hilly			Level ground (flat)		
	Volume goods	Average goods	Bulk goods	Volume goods	Average goods	Bulk goods
Freight transport	*– Diesel consumption in litre/tkm –*					
Lorry < 7.5 t	0.140	0.078	0.063	0.139	0.077	0.062
Lorry 7.5 – 12 t	0.108	0.061	0.050	0.105	0.059	0.048
Lorry 12 – 24 t	0.063	0.036	0.029	0.060	0.034	0.027
Articulated lorry 24 – 40 t[1)]	0.038	0.023	0.020	0.033	0.020	0.016
Container transport	*– Diesel consumption in litre/TEU-km –*					
Lorry < 7.5 t	x	x	x	x	x	x
Lorry 7.5 – 12 t	x	x	x	x	x	x
Lorry 12 – 24 t	0.24	0.26	x	0.22	0.24	x
Articulated lorry 24 – 40 t[1)]	0.17	0.19	0.34	0.14	0.16	0.29

[1)] Including road trains.

x = Container transport for this lorry size or this container weight not applicable.

Sources: HBEFA 3.1; TREMOD 2010; own calculations.

Sample calculation 7:
Energy consumption by a lorry transport service

A 40-t articulated lorry transports 8 t of insulation from Milan to Rome.

Determining the parameters for the calculation:

- Lorry class: road train/articulated lorry 24 – 40 t
- Type of goods: volume goods
- Transport weight: 8 t
- Transport distance: 578 km
- Road category: motorway, hilly

Calculating energy consumption:

$$F\,[\text{litre}] = W\,[t] \times D\,[km] \times E\,[l/tkm] =$$
$$8\,t \times 578\,km \times 0.038\,l/tkm = 176\,l$$

Rail traffic

The energy consumption of goods trains is highly dependent on the length and total weight of the train: the longer and heavier the train, the less energy is used per individual tonne transported. The calculation therefore requires specifications for different classes of trains of differing gross weight. A train with average gross weight of 1,000 t can be used as an approximation. Table 13 shows specific energy characteristic values E per tkm or TEU-km, from which the appropriate value can be selected and used in the equation for calculating the energy consumption F.

Table 13: Specific energy consumption E per tkm or TEU-km for goods trains with electric and diesel traction

	Electric traction			Diesel traction		
	Volume goods	Average goods	Bulk goods	Volume goods	Average goods	Bulk goods
Freight transport	***– in kWh/tkm –***			***– in litres/tkm –***		
Train 500 t (short train)	0.064	0.049	0.043	0.017	0.013	0.012
Train 1,000 t (medium train)	0.042	0.032	0.028	0.011	0.009	0.008
Train 1,500 t (long train)	0.032	0.025	0.022	0.009	0.007	0.006
Train 2,000 t (long train)	0.027	0.021	0.018	0.007	0.006	0.005
Container transport	***– in kWh/TEU-km –***			***– in litres/TEU-km –***		
Train 500 t (short train)	0.507	0.622	0.726	0.137	0.169	0.197
Train 1,000 t (medium train)	0.330	0.405	0.472	0.089	0.110	0.128
Train 1,500 t (long train)	0.256	0.315	0.367	0.070	0.085	0.100
Train 2,000 t (long train)	0.214	0.264	0.307	0.058	0.072	0.083
Sources: EcoTransIT 2010; own calculations.						

Sample calculation 8:
Energy consumption by a train transport service

A 20-foot container with 11 t total weight (average goods, see Table 9) is transported by rail from Rotterdam to Basel. The weight of the train is unknown, the rail line is electrified.

Determining the parameters for the calculation:

- Type of train: train 1000 t, electric
- Type of goods: average
- Quantity transported: 1 TEU
- Distance transported: 716 km (determined using EcoTransIT)

Calculating energy consumption:

F [kWh] = W [TEU] x D [km] x E [kWh/TEU-km] =
1 TEU x 716 km x 0.405 kWh/TEU-km = 290 kWh

Sea and inland shipping

Freight transport by ship primarily serves the transport of bulk goods and containers. Ships have various sizes and are designed for a variety of purposes; there can be restrictions on size depending on the route. In sea shipping there are typical sizes of ships depending on the route. There are also maximum limits, e.g. for passage through the Panama Canal.

In general the same physical rules apply to ships as to other modes of transport in terms of **energy consumption**: the larger the ship and loading capacity, the smaller the specific energy consumption per unit load. **Speed** is crucial for the amount of energy consumed by ships, more so than for other modes of transport. This guide gives specific energy values for average fleets divided according to trade routes and comprising different types of ships (see Table 14; for inland shipping see Table 15). In general, a 4% reduction in speed is assumed compared to what is known as the design speed.

Table 14: Specific energy consumption E (heavy fuel oil, HFO) per tkm or TEU-km for different classes of ships

	Energy consumption based on tonne kilometres			Energy consumption based on TEU-kilometres		
	Volume goods	Average goods	Bulk goods	Volume goods	Average goods	Bulk goods
	– in kg/tkm –			*– in kg/TEU-km –*		
Container ship transport						
Average of all trade routes	0.0089	0.0051	0.0037	0.053	0.053	0.053
Asia (4,700 - 7,000+ TEU)	0.0076	0.0044	0.0032	0.046	0.046	0.046
Transpacific (1,000 - 7,000+ TEU)	0.0087	0.0050	0.0036	0.052	0.052	0.052
Transatlantic (2,000 - 7,000+ TEU)[1)]	0.0089	0.0051	0.0037	0.053	0.053	0.053
Other routes (1,000 - 7,000+ TEU)	0.0096	0.0055	0.0040	0.058	0.058	0.058
Intracontinental (500 - 2,000+ TEU)	0.0123	0.0070	0.0051	0.074	0.074	0.074
Bulk goods/tankers						
Asia (80,000 - 200,000 dwt[2)])	x	x	0.0014	x	x	x
Transpacific (35,000 - 200,000 dwt[2)])	x	x	0.0017	x	x	x
Other routes (over 35,000 dwt[2)])	x	x	0.0020	x	x	x

[1)] Including Panama ship class (2,000 – 4,700 TEU). – [2)] dwt = dead weight tonnage = load-bearing capacity of a ship for average summer draught.

Sources: EcoTransIT 2010; own calculations.

Table 15: Specific energy consumption E (diesel) per tkm or TEU-km for different classes of inland ship (average upstream, downstream and canal navigation)

	Energy consumption based on tonne kilometres			Energy consumption based on TEU-kilometres		
	Volume goods	Average goods	Bulk goods	Volume goods	Average goods	Bulk goods
	– in litres/tkm –			*– in litres/TEU-km –*		
Bulk goods ship/tanker						
Europaschiff type (1,300 t[1)])	x	x	0.0116	x	x	x
Big Rhine barge (2,300 t[1)])	x	x	0.0088	x	x	x
Jowi class (5,200 t[1)])	x	x	0.0050	x	x	x
Container ship[2)]						
Elbe push-convoy (140 TEU)	0.0214	0.0122	0.0089	0.128	0.128	0.128
Articulated tug-barge (240 TEU)	0.0166	0.0095	0.0069	0.100	0.100	0.100
Jowi class (430 TEU)	0.0096	0.0055	0.0040	0.058	0.058	0.058

[1)] Maximum payload. – [2)] Average load factor of container positions (TEU loaded): 60 %.

Sources: TREMOD 2010; Contargo 2011; PLANCO 2007; own calculations.

For inland shipping the transport distances correspond to the length of the navigated waterways. For sea shipping the stated shipping routes are used. If the length of the routes is unknown they can be determined using e.g. the web tool EcoTransIT (www.ecotransit.org).

Sample calculation 9:
Energy consumption by a sea transport service

5 tonnes of volume goods are transported by container ship from Singapore to Hamburg (trade route: Suez).

Determining the parameters for the calculation:

- Type of ship: Suez - container ship
- Type of goods: volume goods
- Transported weight: 5 tonnes
- Distance transported: 15,908 km (determined using EcoTransIT)

Calculating energy consumption:

F [kg] = W [TEU] x D [km] x E [kg/TEU]
= 5 t x 15,908 km x 0.0076 kg/tkm = 605 kg HFO

Air transport

Aircraft are primarily used to transport urgent, perishable or very valuable products – usually volume goods – over long distances. The kerosene consumption depends on the **type of aircraft**. A specific feature of air transport is that, due to the high energy expenditure for the take-off phase, the consumption is also distance dependent. Table 16 therefore shows values for different types of aircraft and different **distances**. If the actual flight route lies between the values shown, then the required value must be obtained by linear interpolation.

Air cargo is transported in exclusively cargo aircraft but also in the cargo hold of passenger planes. In the second case the cargo is referred to as additional or **belly cargo**. In the case of belly cargo the energy consumption must be divided between the passengers and cargo. According to the standard EN 16258, passengers (including luggage) are estimated at 100 kg per head. The jet kerosene consumption figures shown in the following table follow this allocation method for belly cargo. For cargo it has been assumed that the aircraft is loaded to 60% by weight for medium distance flights (up to 3,700 km) and to 65% for long-distance flights (over 3,700 km). The passenger load utilisation which is used in the allocation between cargo and passengers is around 70% for medium distance flights and 80% for long-distance flights, based on the number of seats.

The **total consumption of jet kerosene** which applies to an individual air cargo consignment is found by multiplying the specific kerosene consumption by the weight of the consignment and the flight distance. Distances for air traffic are often calculated on the basis of great circle distance, which is approximately a straight line as the shortest connection between two points. However, actual flight routes often deviate from this ideal. Added to this are operational or weather-related diversions. In the monitoring directive on emissions trading in aviation activities, the EU therefore suggests adding a blanket supplement of 95 km for each flight. This approach was adopted in the standard EN 16258.

Table 16: Specific energy consumption E for selected types of aircraft in kg jet kerosene per tkm dependent on the flight route (only volume goods)

Medium distance[1)]			Long distance[1)]		
Distance	**Belly freight (e.g. B757-200)**	**Cargo plane (e.g. B767-300F)**	**Distance**	**Belly freight (e.g. B747-400)**	**Cargo plane (e.g. B747-400F)**
km	kg/tkm	kg/tkm	km	kg/tkm	kg/tkm
1,500	0.290	0.190	3,700	0.257	0.148
2,000	0.273	0.180	4,000	0.255	0.148
2,500	0.264	0.174	6,000	0.254	0.147
3,000	0.258	0.171	8,000	0.259	0.150
3,700	0.254	0.168	10,000	0.267	x[2)]

[1)] Maximum payload and number of seats: B757-200: 4 t, 200 passengers; B747-400: 14 t, 416 passengers; B67-300 F: 53.7 t; B747-400F: 112.6 t. – [2)] Range exceeded.

Sources: EcoTransIT 2010; own calculations.

Sample calculation 10:

Energy consumption by an aircraft transport service

A medical device packed in a crate (0.05 t) is transported as belly cargo in a passenger aircraft from Shanghai to London.

Determining the parameters for the calculation:

- Type of goods: not relevant
- Type of transport: cargo
- Transport weight (inc. packaging): 50 kg, 0.05 t
- Distance transported: 9,219 km (great circle) + 95 km = 9,314 km
- Distance class: long distance

Interpolation of consumption of jet kerosene for flight route:

0.259 kg/tkm + (0.267 - 0.259) kg/tkm x 1,314 km : 2,000 km = 0.264 kg/tkm

Calculating energy consumption:

F [kg] = W [t] x D [km] x E [kg/tkm] =

0.05 t x 9,314 km x 0.264 kg/tkm = 123 kg jet kerosene

10 Detailed distance-based calculations for lorries

If there are no measured consumption values available for the transport service but actual information on the load utilisation and percentage of empty trips by the vehicles, the calculation should use these values. Although the new standard EN 16258 permits default values for consumption, load utilisation or percentage of empty trips e.g. from databases (see also Chapter 10), it also stipulates that the company's own measured values should be used wherever possible. How to make allowances for **measured load utilisation data and percentage of empty trips** is described below specifically for **lorry transport**. This **detailed methodology** continues to be based on consumption values from databases (default values).

Determining diesel consumption for lorries

The specific diesel consumption values for lorries presented in Chapter 10 are based on one tonne kilometre. The fuel consumption for the whole lorry is thus apportioned to the individual consignments using the tonne kilometres and hence the weight and the distance travelled. In the detailed method the calculation of energy consumption and the allocation are divided further in order to enable different load utilisation and allocation methods. This requires **three steps**:

1. Calculating the diesel consumption of the lorry for the whole vehicle round-trip (incl. empty journeys) on which the individual consignment is transported (referred to as a Vehicle Operation System in the standard EN 16258);
2. Allocating the energy consumption to the individual consignment (refer to Chapter 7 for the principles);
3. Calculating TTW and WTW energy consumption and TTW and WTW greenhouse gas emissions as specified in the standard EN 16258 (see Chapter 6).

These steps must be repeated for all legs in which the individual consignment changes vehicle, and added up to produce a total. The following values are needed to obtain an energy consumption calculation which is as accurate as possible:

- Length of the total vehicle round-trip (vehicle kilometres),
- Size of lorry used per leg,
- Maximum load (payload capacity) of the lorry (e.g. 26 t or 34 pallet spaces for a 40-t lorry),
- Average load (payload) of the vehicle for the total round-trip (e.g. 12 t cargo or 20 pallets),
- Type of route travelled (road category, longitudinal gradient characteristics).

The **diesel consumption** of the vehicle round-trip for a lorry is calculated from the average consumption in litres per 100 km and the distance travelled by the lorry **using the following equation.** When determining the vehicle-kilometres travelled, it must be ensured that all journeys which are directly connected to the consignment are included.

	F [l] **= D** [km] **x E** [l/100 km] **/ 100**	
F:	=	Calculated diesel consumption in litres
D	=	Distance covered by the total vehicle round-trip in km (incl. empty trips)
E	=	Specific diesel consumption in litre/100 km

The **specific energy consumption E** is dependent on the lorry (primarily on the size of the vehicle) and its average load utilisation and is calculated as follows:

	E [litre/100 km] **= A** [litre/100 km] **+ B** [litre/100 km] **x N** [t] **/ C** [t]	
E	=	Specific diesel consumption in litre/100 km
A	=	Consumption of empty vehicle in litre/100 km
B	=	Difference of fully loaded vehicle minus empty vehicle in l/100 km
N	=	Payload in tonnes
C	=	Payload capacity in tonnes (maximum payload)

Table 17 shows representative values for the parameters A, B and C which are typical for European countries for four different sizes of lorries. As in Chapter 10, the figures are consumption values for **motorways** and **other rural roads**. The consumption on **urban roads** can be calculated using the **correction factors** in Table 11 (Chapter 10). No distinction has been made according to the emission standards (Euro classes) as their effect on fuel consumption is negligible since the introduction of Euro 3.

Table 17: Parameters A, B and C for typical lorries in Europe

Parameter	Hilly		Level ground (flat)		
	A	B	A	B	C
	l/100 km	l/100 km	l/100 km	l/100 km	Tonnes
Lorry < 7.5 t GVW	13.0	1.4	12.9	1.2	3.5 t
Lorry 7.5-12 t GVW	16.9	3.2	16.6	2.4	6.0 t
Lorry 12-24 t GVW	19.3	4.2	18.7	2.9	12.0 t
Articulated lorry 24-40 t GVW[1)]	22.7	14.4	21.5	8.2	26.0 t

[1)] Including road trains.

Sources: HBEFA 3.1; TREMOD 2010; own calculations.

As the diesel consumption of a lorry depends on its total weight, the weight-related load utilisation is included in the above equation (part of equation: N/C) – irrespective of whether the allocation of consumption to an individual consignment at the next step is made using a different allocation value (e.g. volume, number of pallets, loading metres). This means that the **weight related load utilisation** of the lorry is always required in order to carry out the detailed calculation – irrespective of the allocation value used. Further, it is the **actual weight** and not the chargeable weight which must be used in the calculation. It should also be noted that the **weight of cargo supports** (e.g. weight of pallets) or of packaging must also be taken into account when calculating consumption. However, for the allocation, only cargo supports which are part of the load need to be included (see Chapter 7).

In order to be able to apply the above equation correctly, you either need to calculate the vehicle round-trip separately for each leg where the payload changes, or an average payload for the whole vehicle round-trip must be determined, in which case the distances of all the legs have to be included.

Determining average load

The average load of the vehicle for a complete round trip is required for calculating the specific energy consumption. If several consignments are carried in a round trip, the payloads of each individual consignment have to be added. This is easy when dealing with an actual vehicle round-trip where there is no loading or unloading **and** the payload of all the consignments is known.

If this is not the case, the following procedures are available:

- *Case 1: Payload, distance and total length are known for all the legs of a round trip.*

  The average payload is calculated by multiplying payload and length of leg for each leg, adding the individual legs and dividing by the total length:

Average payload = sum (payload * length of leg) / total length

- *Case 2: No or incomplete information on the vehicle round trip*

  In this case estimated payloads can be used instead. This can be e.g. an average annual value for comparable transport situations for this company. It is important to include the empty trips.

Allocation and calculation of energy consumption and GHG emissions

A further step is required to allocate the consumption to the individual consignment. As the weight of the load is known, it also makes sense to use the weight of the individual consignment for the allocation. The standard EN 16258 actually suggests using the product of the weight and distance (i.e. tonne kilometres) for the allocation. Alternatively, the standard also permits other variables when these are closer to the limiting values of the transport service (e.g. number of pallet places, loading metres). The standard again suggests using the product of the allocation parameter and the distance (e.g. product of number of pallets and distance or loading metres and distance) for the allocation. If this is not possible, the allocation unit itself with distance or even the distance alone can be used to allocate emissions to consignments.

After successfully allocating the diesel consumption to the individual consignment you can then go on to calculate TTW and WTW energy consumption and TTW and WTW greenhouse gas emissions (see Chapter 6).

Sample calculation 11:

Calculating fuel consumption using actual load data

A 12-t lorry delivers a total of eight pallets with wood briquettes on a trip. Four pallets of hardwood briquettes (total weight 0.98 t/pallet) are sent from the warehouse in Antwerp to Brussels (50 km). Four more pallets with bark briquettes (0.52 t/pallet) are taken from the warehouse in Antwerp via Brussels to Leuven (50 km + 26 km). The lorry drives back empty from Leuven to the warehouse (70 km). The route mainly involves motorways without any ascents and descents.

Average payload of the vehicle round trip

The average payload of the round trip can be calculated from the payload of each leg and the length of the legs:

- Leg 1: 4 x 0.98 t + 4 x 0.52 t = 6.00 t

- Leg 2: 4 x 0.52 t = 2.08 t

- Leg 3: Empty trip = 0 t

Average payload = (6.0 t x 50 km + 2.08 t x 26 km)(50 km + 26 km + 70 km) = 2.43 t

Average consumption per 100 km (from Table 17):

E [l/100 km] = a + b x N/C =

16.6 l/100 km + 2.4 l/100 km x 2.43 t / 6.0 t = 17.57 l/100 km

Calculating the total consumption

F [l]= D [km] x E [l/100 km] / 100 =

146 km x 17.57 l/100 km / 100 = 25.7 l

11 Calculations for buildings, warehouses and handling

It is not only vehicles that create emissions in the logistics sector. Buildings, warehouses and handling equipment are also responsible for part of the greenhouse gases, generally as a result of

- **Power consumption** by the handling equipment, terminals, warehouses and offices,
- **Thermal energy consumption** by the terminals, warehouses and offices,
- Consumption of diesel, liquefied petroleum gas or electricity for additional equipment such as **swap body vehicles** or **forklift trucks,**
- **Refrigerant losses** from freezers and cold storage.

GHG Protocol instead of EN 16258

Stationary services are currently not included in the standard EN 16258. However, future editions of the standard will include the handling of goods. Until then the greenhouse gas emissions for these services which are not included in the standard can be recorded but must be presented separately from the standard-compliant results for transport services. The methods used for these calculations should be described as clearly as possible. A good methodological basis is provided by the **Corporate Accounting and Reporting Standard** in the **Greenhouse Gas Protocol** (see Chapter 5).

According to the GHG Protocol, however, there is only an obligation to calculate the **direct greenhouse gas emissions**. But in order to comply with the provisions of the standard EN 16258 for transport services, account must also be taken of **indirect emissions** (i.e. the greenhouse gases produced by the manufacture of energy sources or products like refrigerant). The procedure for calculating the final energy consumption and the direct emissions will be shown as well as that for calculating the overall energy consumption and the total emissions. Construction of the buildings, warehouses and handling devices will not be considered as it is of lower importance for the overall emissions.

Power and heating

The GHG Protocol includes what is known as the **emission factor-based method** for determining greenhouse gas emissions for power and heating – this approach corresponds to the consumption-based methods in the standard EN 16258. The first step is therefore to obtain the energy consumption values which are then multiplied by the relevant emission factors in a second step, in a similar way to the transport calculations. Energy consumption values are determined for the individual buildings, terminals or handling equipment by means of electricity meters, fuel oil invoices or annual bills from the energy provider. In the case of kWh data it should be noted that these often refer to the gross calorific value whereas many emission factors relate to the net calorific value (in Europe the net calorific value is on average 90% of the gross calorific value). It is important to record all energy consumers – including sorting and conveying systems which often make considerable contributions to consumption. Energy consumption and greenhouse gas emissions are therefore calculated as follows:

Energy consumption:

$$E_{direct\ and\ total} = F \times e_{direct\ and\ total}$$

$E_{direct\ and\ total}$	=	final energy consumption (direct) and primary energy consumption (total) in MJ
F	=	measured energy consumption (e.g. kWh electricity, kWh district heating, kWh gas or litre fuel oil)
$e_{direct\ and\ total}$	=	energy conversion factor for final energy consumption (direct) and primary energy consumption (total) in MJ per kWh electricity, kWh district heating, kWh gas or litres fuel oil

Greenhouse gas emissions:

$$G_{direct\ and\ total} = F \times g_{direct\ and\ total}$$

$G_{direct\ and\ total}$	=	direct and total emissions in kg
F	=	measured energy consumption (e.g. kWh electricity, kWh district heating, kWh gas or litre fuel oil)
$g_{direct\ and\ total}$	=	GHG conversion factor for direct and total greenhouse gas emissions in kg CO_2 equivalents per kWh electricity, kWh district heating, kWh gas or litre fuel oil

The necessary **conversion factors** are shown in Table 18. The factors for electricity and district heating depend on the power plant mix of the country in question. The table shows the electricity values for EU-27 and Germany as examples (for further data, please refer to the appendix). The factors include all process steps from the extraction of the energy carriers and their conversion in the power plant to the transport to the end customer. This procedure therefore corresponds to that required by the standard EN 16258 for transport services. The energy supplier's CO_2 emission factors for electricity labelling cannot be used as they only include some of the indirect emissions and, in addition, are only calculated for CO_2.

If a logistics company uses green electricity from renewable sources, this electricity can only be used to reduce emissions in the carbon footprint if it comes from new plants e.g. new wind turbines. This is usually only guaranteed if the electricity is certified (e.g. electricity with labels like the German OK Power). A company which generates power in photovoltaic units can only count this towards reducing emissions if the company uses the power itself. Anyone who merely makes areas available for PV units and then feeds the electricity into the public grid is not allowed to show the green energy as a reduction measure.

Table 18: Factors for energy consumption and greenhouse gas emissions in stationary services

	Energy conversion factors			GHG conversion factors		
	Unit	***Direct energy con-sum-ption (e_{direct})***	***Total energy con-sum-ption (e_{total})***	***Unit***	***Direct emis-sions (g_{direct})***	***Total emis-sions (g_{total})***
Electricity EU-27	MJ/kWh	3.6	10.2	kg CO_2e/kWh	0.000	0.424
Electricity Germany	MJ/kWh	3.6	9.7	kg CO_2e/kWh	0.000	0.583
Electricity photovoltaic	MJ/kWh	3.6	3.7	kg CO_2e/kWh	0.000	0.000
District heating Germany	MJ/kWh_{th}	3.6	4.1	kg CO_2e/kWh_{th}	0.000	0.249
Natural gas: net calorific value	MJ/kWh	3.6	4.1	kg CO_2e/kWh	0.202	0.242
Natural gas: gross calorific value	MJ/kWh	3.2	3.7	kg CO_2e/kWh	0.182	0.218
Heating oil	MJ/kg	35.8	41.7	kg CO_2e/kg	2.67	3.09
Liquefied petroleum gas	MJ/l	25.3	28.3	kg CO_2e/l	1.70	1.90

Note: The values shown include the power loss due to the electricity distribution. The emission value for district heating is related to the thermal consumption in kWh. Energy consumption and emissions due to the construction, maintenance and disposal of the infrastructure are not included (in keeping with the standard EN 16258).

Sources: GEMIS 4.8; EN 16258; own calculations.

Sample calculation 12:
Energy consumption and greenhouse gas emissions from a warehouse

A German warehouse (area 100,000 m²) requires 5.28 million kWh of electricity per year.

- Final energy consumption: 5.28 million kWh x 3.6 MJ/kWh = 19.008 TJ
- Primary energy consumption: 5.28 million kWh x 9.7 MJ/kWh = 51.216 TJ
- Direct GHG emissions: 5.28 million kWh x 0.0 kg CO_2e/kWh = 0 t CO_2e
- Total GHG emissions: 5.28 million kWh x 0.583 kg CO_2e/kWh = 3,078 t CO_2e

Refrigerant losses

In cold stores and freezer warehouses the main refrigerant used – in relation to the volume refrigerated – is ammonia which has virtually no damaging effects on the environment. In contrast, smaller warehouses up to 50,000 m² use refrigerants containing fluorine such as R-134a or R-404A or the chlorine-containing R-22 (which is now banned in new plants). Chlorinated and fluorinated refrigerants are **high impact greenhouse gases** which must not be released into the environment.

The GHG Protocol recommends the Lifecycle Stage Approach for calculating the impact of refrigerant losses on the environment. This takes the **annual quantity refilled** and multiplies it by the specific CO_2 equivalent factor for the chemical. If these quantities are unknown, the losses can be calculated using average leakage rates.

Table 19 shows the conversion factors required for calculating the individual refrigerants. The greenhouse gas emissions from the losses of refrigerant can then be calculated using the following equation:

$$G_{direct\ and\ total} = RL \times g_{direct\ and\ total}$$

$G_{direct\ and\ total}$	=	direct and total emissions in kg
RL	=	refrigerant losses in kg
$g_{direct\ and\ total}$	=	GHG conversion factor for direct and total greenhouse gas emissions in kg CO_2 per kg refrigerant

Table 19: Factors for calculating the greenhouse gas emissions for refrigerant losses

	Direct emission factor (g_{direct})	**Total emission factor (g_{total})**
	kg CO_2e/kg	kg CO_2e/kg
Refrigerant R-22	1,810	1,886
Refrigerant R-134A	1,430	1,533
Refrigerant R-404A	3,922	4,025
Refrigerant R-407A	1,770	1,873
Refrigerant R-410A	2,088	2,177
Refrigerant R-717 (ammonia)	3	5
Sources: IPCC 2007; Ecoinvent 2009; own calculations.		

Sample calculation 13:
Calculating the greenhouse gas emissions from refrigerant losses

Losses of refrigerant in a freezer warehouse amount to 150 kg R-410A per year. The greenhouse gas emissions can be calculated as follows:

- Direct GHG emissions: 150 kg x 2,088 kg CO_2e/kWh = 313.2 t CO_2e
- Total GHG emissions: 150 x 2,177 kg CO_2e/kWh = 326.6 t CO_2e

Energy consumption by additional equipment

Swap body vehicles for swap trailers or **forklift trucks** require diesel, liquefied petroleum gas or electricity. This amount can be of relevance so it should be converted into TTW and WTW energy consumption and TTW and WTW greenhouse gas emissions as in the procedure prescribed in the standard EN 16258 (see Chapter 6). If no energy consumption figures are available, the number of operating hours and the standard consumption per hour can be used for forklift trucks as an alternative. If forklift trucks are loaded using loading stations in the warehouse, then their energy consumption has already been recorded via the warehouse.

Allocation

The GHG Protocol does not give any information about how the electricity consumption for warehouses or handling facilities can be divided amongst individual consignments. This guide recommends using only **physical units** (e.g. weight, number of pallets) for the allocation. As the stationary services are a fixed part of a logistics chain, the **same allocation parameters** should be used as for the transport services in this chain. Other parameters are appropriate if the energy consumption of the stationary services is determined using a different variable. The energy consumption of freezer units is dependent on the weight of the goods. In this case the allocation could be made using the weight of the frozen goods, even if a different allocation variable was used for the transport services. For handling equipment the allocation is usually done using the number of consignments handled. In principle the **parameters** used for allocation **must be declared for stationary services as well as for transport services.**

If goods have to be stored for longer periods, then this part has a higher energy consumption. For this reason **the period of storage** needs to be included in the allocation for warehouse facilities. So, for example, the proportion of energy consumption for a pallet can be calculated using the average number of occupied pallet places per year and the period for which a pallet is stored.

Sample calculation 14:

Allocation of energy consumption to a pallet in the freezer warehouse

Around 80% of the 6,700 pallet spaces in a freezer warehouse are occupied over the course of the year. For example, in the warehouse beef is stored for an average of 21 days and sweet peppers for 150 days. The following proportion of the annual energy consumption therefore applies per pallet of beef or sweet peppers:

- Total pallet-days:
  6,700 pallets x 80% x 365 days = 1,956,400 pallet-days

- ***Beef:***	1 pallet x 21 days = 21 pallet-days
Percentage:	21 pallet-days / 1,956,400 pallet-days = **0.00107%**
- ***Sweet pepper:***	1 pallet x 150 days = 150 pallet-days
Percentage:	150 pallet-days / 1,956,400 pallet-days = **0.00767%**

12 Results – what next

The calculation of energy consumption and greenhouse gas emissions forms the basis for the company's climate protection strategy. Calculating the values is not the end of the work – only the beginning.

How good is my result?

Mistakes can easily be made in calculations. The results of the calculations must therefore be checked to see that they are **plausible** and corrected if necessary before they are made public. This applies in particular to emission and consumption calculations for transport chains in which different modes of transport are used. As a rough guide: aircraft have the highest emissions at 500 to 1,000 g CO_2 equivalents per tonne kilometre; ships have the lowest emissions with around 5 to 30 g CO_2 equivalents per tonne kilometre. If the values obtained lie significantly below or above these, then it is essential to **recheck the calculation process**.

If the energy consumption values are calculated rather than measured, then certain **assumptions**, e.g. about the load utilisation of the vehicles, enter the calculation. Assumptions are not always correct but can have a considerable effect on the result. What are known as sensitivity analyses – in which the assumed values are changed systematically – reveal which input values actually have a crucial effect on the result. Analyses of this kind are recommended the first time a carbon footprint is carried out. If it becomes clear that the assumed values have a marked effect on the result, they should be replaced by measured values for the next carbon footprinting.

EN 16258: Reporting the results and calculation procedure

A value is not very informative on its own For example, the quantity of greenhouse gas emissions per tonne kilometre says nothing about a company's overall environmental performance. In order to understand the values, it must also be known how they were calculated. According to EN 16258, those preparing the carbon footprint must disclose both the well-to-wheels energy consumption and greenhouse gas emissions and the tank-to-wheels energy consumption and greenhouse gas emissions for the transport service in a **declaration**. In addition, it must be clear what **sources** were used for the distance, load utilisation, empty trip percentage and energy consumption parameters: are these specific measured values for the actual transport service? Or are they vehicle-type or route-type values for the transport operator, perhaps determined over a year? Perhaps only the transport operator's average fleet values were used, or even fixed quantities from databases (default values)?

Although the standard EN 16258 allows for short declarations where only the well-to-wheels greenhouse gas emissions have to be stated, these short declarations must nevertheless contain a reference to where the other results of the calculation and the further information on the calculation method are to be found. This is mainly aimed at creating transparency in order to show whether the results are based on measurements or on default values. If default values are used, the source from which they were taken must be stated and the reason for the choice of these particular sources given. The standard EN 16258 also suggests that, in the case of transport chains, the sources used for each leg should be specified – because the data sources may well be different from one leg to another (see Table 20).

Table 20: Template for declaration of kind of sources used for each leg

Categories	Default value	Transport operator fleet value	Transport operator specific value	Specific measured value
Load (e.g. weight, TEU)				
Transport distance of load				
Fuel consumption[1)]				
Fuel consumption per distance[1)]				
Mileages of vehicles[1)]				
Load factors of vehicles[1)]				
Vehicle capacities [1)]				
Empty trips[1)]				

[1)] Refers to vehicle operation system (VOS).

Sources: Annex D of EN 16258; own figure.

If the recommendations in the standard are not followed, then this must be clearly stated in a declaration. This applies particularly to the applied allocation methods, or if there is any deviation from the factors used to convert energy consumption into standardised energy units (e.g. MJ) and into greenhouse gas emissions (in kg) (see Chapter 6) where specific values from the fuel supplier are used. An important point in this context is that the standard EN 16258 only makes provisions for the calculation of transport services. If the energy consumption and greenhouse gas emissions are calculated voluntarily for the buildings, warehouses and handling, then these must be shown separately from the standard-compliant values determined for the transport services (see also Chapter 12).

Incidentally, the standard does not make provision for **certification** of the calculations. Companies can have their calculation certified voluntarily but are then required to comply with the regulations of DIN EN 45011 (in future DIN EN ISO/IEC 17065) i.e. the certification may only be done by accredited certifying bodies.

Implementing climate protection measures

If you have done your calculations correctly, then you have a solid basis for introducing measures to reduce energy consumption and greenhouse gas emissions in your own company. Calculations based on the guide make it possible to correctly evaluate the effect of measures and to apply these measures in places where the most cost-efficient reductions in energy consumption and emissions can be made. Protecting the climate does not come for free: many cost-saving measures incur costs to begin with but pay off due to energy savings in subsequent years. Assessing climate protection from the initial investments leads to the wrong priorities being set. Climate protection is a long-term investment – in sustainable economic management and therefore in the future of the individual company.

A targeted climate protection strategy starts in your own company. Priority measures are those for **avoiding** or at least **reducing greenhouse gases**, for example by optimising routes, reducing empty trips, the introduction of more efficient sizes of vehicles or energy-efficient operation of storage and handling facilities. In second place is the use of **renewable energy**

sources, i.e. from certified green energy or renewable raw materials for heat generation. An additional contribution to climate protection can be made by **offsetting greenhouse gas emissions** (see box). However, this is only plausible if the emissions have been significantly cut in the first place through suitable reduction measures.

Climate or CO_2 offsetting

Climate or CO_2 offsetting is the term used if a company reduces its (unavoidable) greenhouse gas emissions by climate protection projects outside the company. If the quantity emitted is balanced in this way, then this is often referred to as climate or CO_2 neutrality. However, these terms are only partially correct, as carbon footprints do not usually record all the emissions in the upstream chain. If you decide to go down the offsetting route, then the following sequence must be adhered to:

- Wherever possible, emissions of harmful greenhouse gases should be avoided or reduced by means of saving or efficiency measures and through the use of renewable energy.
- The unavoidable emissions are then offset completely through appropriate climate protection projects e.g. in emerging or developing countries.

Offsetting is not true climate protection in all instances. Suitable **compensation projects are those which apply the Gold Standard** developed by WWF and other environmental organisations. This standard ensures that the activities do actually bring about a reduction in greenhouse gas emissions and also contribute to the economic development of the countries. For example, the gold standard currently excludes afforestation projects as it cannot be guaranteed that the trees will remain protected over the years.

Further information on voluntary offsetting and the gold standard can be found in the "Positionspapier Kompensation" by the Öko-Institut and in the "Guides on the Voluntary Offsetting of Greenhouse Gas Emissions" by the German Federal Environment Agency (Umweltbundesamt):

www.oeko.de/oekodoc/1011/2010-071-de.pdf

www.umweltdaten.de/publikationen/fpdf-l/3963.pdf

13 Additional helpful Information

Conversion aids

Table 21: Decimal factors

Name	Factor	Value
Kilo (k)	10^3	1.000
Mega (M)	10^6	1.000.000
Giga (G)	10^9	1.000.000.000
Tera (T)	10^{12}	1.000.000.000.000
Peta (P)	10^{12}	1.000.000.000.000.000

Table 22: Energy conversion factors (final energy)

	MJ	kWh	Litres diesel	kg diesel
1 MJ	1	0.2778	0.0279	0.0233
1 kWh	3.6	1	0.1004	0.0835
1 litres diesel	35.9	10.0	1	0.832
1 kg diesel	43.1	12.0	1.202	1

Note: Conventional diesel without any admixture of biodiesel – in relation to final energy.

Emission factors for electricity for different countries

Table 23: Factors for calculating energy consumption and greenhouse gas emissions for traction current and power from the national grid

Country	Traction current		Electricity from the public mains supply of the country[1]	
	Energy	CO_2e	Energy	CO_2e
	MJ/kWh	*kg/kWh*	*MJ/kWh*	*kg/kWh*
Tank-to-wheels				
All countries	3.6	0.000	3.6	0.000
Well-to-wheels				
Europe (EU-27)	10.8	0.468	10.2	0.424
Austria	4.5	0.119	6.8	0.210
Belgium	13.5	0.393	12.4	0.219
Bulgaria	12.3	0.660	10.5	0.538
Czech Republic	11.2	0.661	11.2	0.681
Denmark	6.2	0.433	10.9	0.471
Estonia	13.8	1.208	9.7	1.012
Finland	9.9	0.480	10.3	0.295
France	13.2	0.077	13.5	0.072
Germany	10.8	0.574	9.7	0.583
Greece	16.0	1.004	9.1	0.801
Hungary	14.5	0.637	13.1	0.481
Ireland	11.9	0.779	7.5	0.526
Italy	9.6	0.749	8.4	0.463
Latvia	5.1	0.160	5.8	0.181
Lithuania	11.9	0.108	7.4	0.390
Netherlands	8.8	0.497	9.2	0.460
Poland	12.5	1.085	10.6	1.005
Portugal	8.9	0.544	7.8	0.399
Romania	9.4	0.556	8.9	0.495
Slovakia	12.1	0.199	10.5	0.370
Slovenia	11.7	0.686	9.4	0.405
Spain	9.2	0.425	8.3	0.363
Sweden	3.8	0.004	8.7	0.058
United Kingdom	10.7	0.621	9.5	0.488

[1] Including loses of electricity grid.

Sources: EcoTransIT 2010; GEMIS 4.8; own calcualtions.

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- **Decree n° 2011-1336 of 24 October 2011 on information on the quantity of carbon dioxide emitted during transport services** (décret no 2011-1336 du 24 octobre 2011 relatif à l'information sur la quantité de dioxyde de carbone émise à l'occasion d'une prestation de transport). Can be downloaded free at: http://legifrance.gouv.fr
- **BMU/BDI Guide on product-related climate protection strategies**: Product-related climate protection strategies: understanding and using Product Carbon Footprints (Produktbezogene Klimaschutzstrategien: Product Carbon Footprint verstehen und nutzen). Joint guide by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federation of German Industry (BDI). (Only available in German)
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- **GEMIS 4.8:** Globales Emissions-Modell Integrierter Systeme (GEMIS). PC computer model for calculating the environmental effects of energy systems; developed by the Öko-Institut and International Institute for Sustainability Analysis and Strategy (IINAS). The PC program can be downloaded free of charge at: www.iinas.org/gemis-de.html
- **GHG Protocol**: Corporate Accounting and Reporting Standards (Corporate Standard). World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Can be downloaded free at: www.ghgprotocol.org
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- **Memorandum Product Carbon Footprint**: Perspectives on compiling and reporting Product Carbon Footprints for international standardisation and harmonisation (Positionen zur Erfassung und Kommunikation des Product Carbon Footprint für die internationale Standardisierung und Harmonisierung). German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, German Federal Environment Agency and Öko-Institut. (Only available in German). Can be downloaded free at: www.bmu.de/files/pdfs/allgemein/application/pdf/memorandum_pcf_lang_bf.pdf
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- **Position paper on carbon offsetting (Positionspapier Klimakompensation)**: Harthan, R.; Brohmann, B.; Fritsche, U.R.; Grießhammer, R.; Seebach, D.; Öko-Institut position paper. Berlin, Darmstadt, Freiburg: 2010. (Only available in German) Can be downloaded free at: http://www.oeko.de/oekodoc/1011/2010-071-de.pdf (only available in German)
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