www.defra.gov.uk

2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting:
Methodology Paper for Emission Factors

October 2010

Department for Environment, Food and Rural Affairs
Nobel House
17 Smith Square
London SW1P 3JR

Tel: 020 7238 6000
Website: www.defra.gov.uk

Information about this publication is available from:

Defra
Area 5C
Ergon House
London

Email: *ghgreporting@defra.gsi.gov.uk*

This document is available on the Defra website and has been produced by Nikolas Hill (AEA) for the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (Defra)

Published by the Department for Environment, Food and Rural Affairs

2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting:
Methodology Paper for Emission Factors

Contents

I. Introduction

General

1. Greenhouse gases can be measured by recording emissions at source by continuous emissions monitoring or by estimating the amount emitted using activity data (such as the amount of fuel used) and applying relevant conversion factors (e.g. calorific values, emission factors, oxidation factors).

2. These conversion factors allow organisations and individuals to calculate greenhouse gas (GHG) emissions from a range of activities, including energy use, water consumption, waste disposal, recycling and transport activities. For instance, a conversion factor can be used to calculate the amount of greenhouse gases emitted as a result of burning a particular quantity of oil in a heating boiler.

3. The 2010 Guidelines to Defra /DECC's Greenhouse Gas (GHG) Conversion Factors for Company Reporting (hereafter the 2010 GHG Conversion Factors) represent the current official set of government emissions factors. These factors are also used in a number of different policies including the UK Government's Quality Assurance Scheme (QAS) for Carbon Offsetting (see: *http://offsetting.decc.gov.uk/*) and Act on CO_2 Calculator (see: *http://actonCO2.direct.gov.uk/home.html*)[1]. This paper outlines the methodology used to update the emission factors for the 2010 GHG Conversion Factors. The new factors are presented at the end of each of the relevant following sections.

4. Significant work was carried out to provide a code for offsetting, culminating in the release of the Carbon Offsetting QAS. As part of the requirements of this work, a standard set of emission factors for each of the sources needed to be developed to calculate the emissions. Existing factors were supplemented by updated/ new factors in the 2008 update (detailed in the accompanying 2008 transport EF methodology paper) and further updated and expanded in 2009. This methodology paper explains how these factors have been updated/ expanded further for the 2010 GHG Conversion Factors.

5. In the 2009 update, emissions factors for the non-CO_2 greenhouse gases methane (CH_4) and nitrous oxide (N_2O) were added, based upon the emission factors used in the UK Greenhouse Gas Inventory (GHGI). These have subsequently been updated in 2010. Values for methane and N_2O are presented as CO_2 equivalents (CO_2e) using GWP factors from the Intergovernmental Panel on Climate Change (IPCC)'s second assessment report (GWP for CH_4 = 21, GWP for N_2O = 310), consistent with reporting under the Kyoto Protocol.

[1] At the time of publication of this paper the Act on CO_2 Calculator was still utilising emission factors from the 2009GHG Conversion Factors. Although not yet confirmed, an update to the 2010 GHG Conversion Factors dataset is anticipated later in 2010.

6. For the first time in 2010, indirect emissions from the fuel cycle have been included. These emissions include those resulting from the extraction of primary fuels (e.g. coal, oil, natural gas) or biomass feedstocks (for bioenergy), the transport, refining, purification or conversion of primary fuels or biomass feedstocks to energy carriers/fuels for direct use by end-users and the distribution of these fuels to end users. These emissions have been added in particular for better comparability / consistency with the emission factors provided for bioenergy (including biofuels), which already included these upstream indirect emissions. **Other indirect emissions are not included**, for example those associated with the manufacture of a product or construction of transport infrastructure or vehicle production and disposal and the factors do not therefore cover such situations.

7. The factors for 2010 GHG Conversion Factors will be set for the next financial year, 2010/2011. It is the intention to continue to review and update them once a year.

8. Further information about the 2010 GHG Conversion Factors and the factors used in the Act on CO_2 Calculator can be found at: *http://www.defra.gov.uk/environment/business/reporting/index.htm*, and *http://actonCO2.direct.gov.uk/dms/091123-Act-on-CO2-calculator-v2-methodlogy-FINAL.PDF*

9. Previous methodology papers are also available from Defra's website at: *http://www.defra.gov.uk/environment/business/reporting/methodology-papers.htm*

Overview of changes since previous update

10. Major changes and updates in terms of methodological approach from the October 2009 version are as follows:
    a. In previous years, emissions factors have only been provided for direct emissions of CO_2, with the other greenhouse gases methane (CH_4) and nitrous oxide (N_2O) added in 2009.
    For the first time in this 2010 update, indirect emission factors (also known as fuel cycle or Well-To-Tank emission factors) associated with the production of fuels have been added for all activities allowing the provision of life-cycle emission factors. Emissions from the production of vehicles or infrastructure are not considered.
    b. Lifecycle emissions factors and calculations for waste, biofuels and biomass have been expanded (as well as updated /amended) and include both direct and indirect emissions. For example in the case of biofuels, these emission factors incorporate emissions associated with the production and transportation of the fuel, as well as the direct emissions from fuel combustion. In addition to indirect emissions, the direct/Scope 1 emissions of CH_4 and N_2O resulting from combustion of these fuels have also been separated out.
    c. The single table for water, biofuel and biomass emission factors from 2009 has been split into three. Emission factors for pure biofuels are provided separately (based on UK averages from the Renewable Fuels Agency for 2009) as well as assistance in calculating the emission

factors for different blends with conventional petrol, diesel or compressed natural gas (CNG) fuels.

d. An entirely new table of emission factors for maritime shipping freight transport has been produced for Annex 7, based on information from the International Maritime Organisation's 2009 report on GHG emissions.

11. More minor methodological changes have been applied to the following areas, which are summarised in greater detail in the relevant later sections:
    a. *Car emission factors:* petrol and diesel vehicles now purely based on data from new car registrations. LPG and CNG vehicles split out and based on updated assumptions;
    b. *Bus emission factors*: now based on data from DfT from the Bus Service Operators Grant;
    c. *Van emission factors:* petrol and diesel vehicles now utilising updated speed-emission curve data and revised payload capacity assumptions. LPG and CNG vehicles split out and based on updated assumptions;

II. Fuel Conversion Factors (Annex 1)

12. The GHG Conversion Factors released in 2007 and 2008 reported CO_2 emission factors only for estimating greenhouse gas emissions. These were subsequently expanded to include direct emissions of CH_4 and N_2O (in CO_2 equivalents – CO_2e) in 2009.

13. The factors are also used in the Act on CO_2 Calculator released in June 2007 and updated with the most recent factors in July 2008 and July 2009.

14. The following sections summarise the approach taken to revise and expand the currently used emission factors to include indirect emission factors.

Summary of changes since previous update

15. The main methodological changes and additions since the previous update include:
    a. Addition of indirect emissions from the fuel cycle (i.e. from the production and distribution of fuels);
    b. Addition of emission factors for CNG (compressed natural gas) and LNG (liquefied natural gas).

New Fuel Emission Factors

Direct Emissions

16. All the fuel conversion factors for direct emissions presented in the 2010 GHG Conversion Factors are based on the default emission factors used in the UK GHG Inventory (GHGI) for 2008 (managed by AEA).

17. The CO_2 emissions factors are based the same ones used in the UK GHGI and are essentially independent of application (assuming full combustion). However, emissions of CH_4 and N_2O can vary to some degree for the same fuel depending on the particular use (e.g. emission factors for gas oil used in rail, shipping, non-road mobile machinery or different scales/types of stationary combustion plants can all be different). The figures presented in Annex 1 of the 2010 GHG Conversion Factors for fuels are based on an activity-weighted average of all the different CH_4 and N_2O emission factors from the GHGI.

18. The standard emission factors from the GHGI have been converted into different energy and volume units using information on Gross and Net Calorific Values (CV) from the Digest of UK Energy Statistics 2009 (DECC), available at: *http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx*

19. Four tables are presented in the 2010 GHG Conversion Factors, the first of which provides emission factors by unit mass, and the second by unit volume. The final two tables provide emission factors for energy on a Gross and Net CV basis respectively. Emission factors on a Net CV basis are higher (see definition of Gross CV and Net CV in the footnote[2] below).

20. It is important to use the correct emission factor, otherwise emissions calculations will over- or under-estimate the results. If you are making calculations based on energy use, you must check (e.g. with your fuel supplier) whether these values were calculated on a Gross CV or Net CV basis and use the appropriate factor. Natural Gas consumption figures quoted in kWh by suppliers in the UK are generally calculated (from the volume of gas used) on a Gross CV basis[3]. Therefore the emission factor in Table 1c (Gross CV basis) should be used by default for calculation of emissions from Natural Gas in kWh, unless your supplier specifically states they have used Net CV basis in their calculations instead.

Indirect Emissions

21. In the 2010 update indirect emission factors for fuels have also been included in the Annexes for the first time. These fuel cycle emissions are the emissions 'upstream' from the point of use of the fuel resulting from the transport, refining, purification or conversion of primary fuels to fuels for direct use by end-users and the distribution of these fuels.

22. In the absence of specific UK-based set of fuel cycle emissions factors information from JEC WTW (2008) were used as a basis for the factors included in the 2010 GHG Conversion Factors[4]. This is the preeminent

[2] Gross CV or higher heating value (HHV) is the CV under laboratory conditions. Net CV or 'lower heating value (LHV) is the useful calorific value in typical real world conditions (e.g. boiler plant). The difference is essentially the latent heat of the water vapour produced (which can be recovered in laboratory conditions).
[3] See information available on Transco website: *http://www.transco.co.uk/services/cvalue/cvinfo.htm*
[4] JEC WTW (2008). Well-To-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context, JRC/EUCAR/CONCAWE, Version 3, 2008 update. Available at: *http://ies.jrc.ec.europa.eu/jec-research-collaboration/downloads-jec.html*

European study carried out in this area that covers a wide variety of fuels. The coverage of the JEC WTW (2008) work includes:

a. Refined conventional road transport fuels: petrol and diesel;
b. Alternative road transport fuels: LPG, CNG and LNG;
c. Other fuels/energy carriers: coal, natural gas, naptha, heating oil and (EU) electricity

23. For fuels covered by the Defra/DECC GHG Conversion Factors where no fuel cycle emission factor was available in JEC WTW (2008), these were estimated based on similar fuels, according to the assumptions in Table 1.

24. The final combined emission factors (in $kgCO_2e/GJ$, Net CV basis) are presented in Table 1. These include indirect emissions of CO_2, N_2O and CH_4 and were converted into other units of energy (e.g. kWh, Therms) and to units of volume and mass using the default fuel properties and unit conversion factors found in Annex 11 and Annex 12 of the 2010 Defra/DECC Conversion Factors.

Table 1: Basis of the Annex 1 indirect / 'fuel cycle' emissions factors for different fuels

Fuel	Indirect EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect Emission Factor	Assumptions
Aviation Spirit	12.51	Estimate	Similar to petrol
Aviation Turbine Fuel [1]	13.34	Estimate	= Kerosene fuel, estimate based on average of petrol and diesel factors
Biofuels	Annex 9		
Burning Oil[1]	13.34	Estimate	= Kerosene, as above
CNG [2]	8.36	JEC WTW (2008)	
Coal (domestic)[3]	15.39	JEC WTW (2008)	Emission factor for coal
Coal (electricity generation)[4]	15.39	JEC WTW (2008)	Emission factor for coal
Coal (industrial)[5]	15.39	JEC WTW (2008)	Emission factor for coal
Coking Coal	15.39	Estimate	Assume same as factor for coal
Diesel	14.18	JEC WTW (2008)	
Electricity	Annex 3		
Fuel Oil [6]	13.34	Estimate	Assume same as factor for kerosene
Gas Oil [7]	14.18	Estimate	Assume same as factor for diesel
LPG	8.00	JEC WTW (2008)	
LNG [8]	20.00	JEC WTW (2008)	
Lubricants	9.43	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Naphtha	9.78	JEC WTW (2008)	
Natural Gas	5.55	JEC WTW (2008)	Natural gas EU mix
Other Petroleum Gas	7.56	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Petrol	12.51	JEC WTW (2008)	
Petroleum Coke	11.45	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Refinery Miscellaneous	8.73	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Wood	Annex 9		

Notes:

(1) Burning oil is also known as kerosene or paraffin used for heating systems. Aviation Turbine fuel is a similar kerosene fuel specifically refined to a higher quality for aviation.

(2) CNG = Compressed Natural Gas is usually stored at 200 bar in the UK for use as an alternative transport fuel.

(3) This emission factor should only be used for coal supplied for domestic purposes. Coal supplied to power stations or for industrial purposes have different emission factors.

(4) This emission factor should only be used for coal supplied for electricity generation (power stations. Coal supplied for domestic or industrial purposes have different emission factors.

(5) Average emission factor for coal used in sources other than power stations and domestic, i.e. industry sources including collieries, Iron & Steel, Autogeneration, Cement production, Lime production, Other industry, Miscellaneous, Public Sector, Stationary combustion - railways and Agriculture. Users who wish to use coal factors for types of coal used in specific industry applications should use the factors given in the UK ETS.

(6) Fuel oil is used for stationary power generation. Also use this emission factor for similar marine fuel oils.

(7) Gas oil is used for stationary power generation and 'diesel' rail in the UK. Also use this emission factor for similar marine diesel oil and marine gas oil fuels.

(8) LNG = Liquefied Natural Gas, usually shipped into the UK by tankers. LNG is usually used within the UK gas grid, however it can also be used as an alternative transport fuel.

III. Electricity Conversion Factors (Annex 3)

Summary of changes since previous update

25. The main methodological changes and additions since the previous update include:
    a. Addition of indirect emissions from the fuel cycle (i.e. from the production and distribution of the primary fuels used in power generation)

26. A detailed summary of the methodology used to calculate individual electricity emission factors is provided in the following subsections.

Direct Emissions from UK Grid Electricity

27. The electricity conversion factors given represent the average carbon dioxide emission from the UK national grid per kWh of electricity used at the point of final consumption (i.e. transmission and distribution losses are included). These factors include only direct carbon dioxide, methane and nitrous oxide emissions at UK power stations and do not include emissions resulting from production and delivery of fuel to these power stations (i.e. from gas rigs, refineries and collieries, etc.).

28. This factor changes from year to year, as the fuel mix consumed in UK power stations changes. Because these annual changes can be large (the factor depends very heavily on the relative prices of coal and natural gas), and to assist companies with year to year comparability, the factor presented is the grid rolling average of the grid conversion factor over the previous 5 years. This factor is updated annually.

29. The electricity conversion factors provided in the 2010 GHG Conversion Factors Annex 3 are based on UK Greenhouse Gas Inventory for 2008 (AEA) according to the amount of CO_2, CH_4 and N_2O emitted from major power stations per unit of electricity consumed from the DECC's Digest of UK Energy Statistics (DUKES) 2009[5]. The source data and corresponding calculated emissions factors are summarised in the following Table 2 and Table 3. The corresponding 5-year rolling average emission factors are presented in Table 4.

Table 2: Base electricity generation emissions data

Year	Electricity Generation (1)	Total Grid Losses (2)	UK electricity generation emissions (3), ktonnes		
	GWh	%	CO_2	CH_4	N_2O
1990	286,404	7.5%	203,991	2.635	5.384
1991	292,468	7.5%	202,899	2.557	5.336
1992	294,741	7.5%	190,845	2.477	5.016
1993	299,296	7.5%	171,646	2.444	4.221
1994	295,452	7.5%	166,709	2.578	4.012
1995	304,791	7.5%	163,520	2.643	3.853
1996	312,430	8.1%	163,163	2.675	3.573
1997	310,660	8.1%	149,691	2.573	3.050
1998	320,317	8.1%	154,764	2.802	3.155
1999	323,213	8.1%	146,639	2.850	2.733
2000	329,345	8.3%	158,233	3.023	3.072
2001	340,525	8.5%	168,600	3.273	3.381
2002	342,299	8.3%	164,271	3.282	3.189
2003	350,385	8.2%	173,323	3.408	3.491
2004	349,092	8.3%	172,664	3.389	3.372
2005	353,481	7.4%	172,641	3.688	3.517
2006	352,075	7.4%	181,718	3.779	3.856
2007	351,088	7.2%	177,429	3.861	3.569
2008	346,225	7.4%	172,861	4.069	3.319

Notes:

(1) Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES (2009) Table 5.6 Electricity fuel use, generation and supply. The total consistent with UNFCCC emissions reporting category 1A1a includes (according to Table 5.6 categories) GWh supplied (gross) from all thermal sources from '*Major power producers*' plus Hydro-natural flow; plus GWh supplied from thermal renewables, hydro-natural flow and other non-thermal sources from '*Other generators*'.

(2) For 1990 to 1995, based upon 1.5% transmission losses and 6% distribution losses from the national grid (DUKES, 2008). For 1996 to 2007, based upon calculated net grid losses from data in DUKES (2008) Table 5.1 Commodity Balances.

(3) Emissions from UK centralised power generation (excluding Crown Dependencies and Overseas territories) listed under UNFCC reporting category 1A1a from the UK Greenhouse Gas Inventory for 2008 (AEA, 2010)

[5] DUKES (2009): http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Table 3: Base electricity generation emissions electricity emissions factors

Year	Emission Factor, $kgCO_2e$ / kWh											
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)			
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total
1990	0.71225	0.00019	0.00583	0.71827	0.05775	0.00002	0.00047	0.05824	0.77000	0.00021	0.00630	0.77651
1991	0.69375	0.00018	0.00566	0.69959	0.05625	0.00001	0.00046	0.05672	0.75000	0.00020	0.00611	0.75631
1992	0.64750	0.00018	0.00528	0.65295	0.05250	0.00001	0.00043	0.05294	0.70000	0.00019	0.00570	0.70589
1993	0.57350	0.00017	0.00437	0.57804	0.04650	0.00001	0.00035	0.04687	0.62000	0.00019	0.00473	0.62491
1994	0.56425	0.00018	0.00421	0.56864	0.04575	0.00001	0.00034	0.04611	0.61000	0.00020	0.00455	0.61475
1995	0.53650	0.00018	0.00392	0.54060	0.04350	0.00001	0.00032	0.04383	0.58000	0.00020	0.00424	0.58443
1996	0.52224	0.00018	0.00355	0.52596	0.04625	0.00002	0.00031	0.04658	0.56849	0.00020	0.00386	0.57254
1997	0.48185	0.00017	0.00304	0.48507	0.04267	0.00002	0.00027	0.04296	0.52452	0.00019	0.00331	0.52802
1998	0.48316	0.00018	0.00305	0.48640	0.04279	0.00002	0.00027	0.04308	0.52595	0.00020	0.00332	0.52947
1999	0.45369	0.00019	0.00262	0.45650	0.03978	0.00002	0.00023	0.04003	0.49347	0.00020	0.00285	0.49652
2000	0.48045	0.00019	0.00289	0.48353	0.04324	0.00002	0.00026	0.04352	0.52369	0.00021	0.00315	0.52705
2001	0.49512	0.00020	0.00308	0.49840	0.04598	0.00002	0.00029	0.04629	0.54110	0.00022	0.00336	0.54469
2002	0.47990	0.00020	0.00289	0.48299	0.04315	0.00002	0.00026	0.04343	0.52306	0.00022	0.00315	0.52643
2003	0.49466	0.00020	0.00309	0.49796	0.04393	0.00002	0.00027	0.04423	0.53860	0.00022	0.00336	0.54218
2004	0.49461	0.00020	0.00299	0.49781	0.04484	0.00002	0.00027	0.04513	0.53945	0.00022	0.00327	0.54294
2005	0.48840	0.00022	0.00308	0.49171	0.03901	0.00002	0.00025	0.03927	0.52741	0.00024	0.00333	0.53098
2006	0.51613	0.00023	0.00340	0.51976	0.04109	0.00002	0.00027	0.04138	0.55723	0.00024	0.00367	0.56113
2007	0.50537	0.00023	0.00315	0.50875	0.03919	0.00002	0.00024	0.03945	0.54455	0.00025	0.00340	0.54820
2008	0.49927	0.00025	0.00297	0.50249	0.04009	0.00002	0.00024	0.04035	0.53936	0.00027	0.00321	0.54284

Table 4: 5-Year Grid Rolling Average electricity emissions factors

Year	5-Year Grid Rolling Average Emission Factor, $kgCO_2e$ / kWh											
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)			
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total
1990	0.71225	0.00019	0.00583	0.71827	0.05775	0.00002	0.00047	0.05824	0.77000	0.00021	0.00630	0.77651
1991	0.70300	0.00019	0.00574	0.70893	0.05700	0.00002	0.00047	0.05748	0.76000	0.00020	0.00621	0.76641
1992	0.68450	0.00018	0.00559	0.69027	0.05550	0.00001	0.00045	0.05597	0.74000	0.00020	0.00604	0.74624
1993	0.65675	0.00018	0.00528	0.66221	0.05325	0.00001	0.00043	0.05369	0.71000	0.00020	0.00571	0.71591
1994	0.63825	0.00018	0.00507	0.64350	0.05175	0.00001	0.00041	0.05218	0.69000	0.00020	0.00548	0.69568
1995	0.60310	0.00018	0.00469	0.60797	0.04890	0.00001	0.00038	0.04929	0.65200	0.00019	0.00507	0.65726
1996	0.56880	0.00018	0.00426	0.57324	0.04690	0.00001	0.00035	0.04727	0.61570	0.00019	0.00462	0.62051
1997	0.53567	0.00018	0.00382	0.53966	0.04493	0.00001	0.00032	0.04527	0.58060	0.00019	0.00414	0.58493
1998	0.51760	0.00018	0.00355	0.52133	0.04419	0.00002	0.00030	0.04451	0.56179	0.00020	0.00386	0.56584
1999	0.49549	0.00018	0.00324	0.49890	0.04300	0.00002	0.00028	0.04329	0.53849	0.00020	0.00352	0.54220
2000	0.48428	0.00018	0.00303	0.48749	0.04295	0.00002	0.00027	0.04323	0.52722	0.00020	0.00330	0.53072
2001	0.47885	0.00019	0.00294	0.48198	0.04289	0.00002	0.00026	0.04317	0.52175	0.00020	0.00320	0.52515
2002	0.47846	0.00019	0.00291	0.48156	0.04299	0.00002	0.00026	0.04327	0.52145	0.00021	0.00317	0.52483
2003	0.48077	0.00020	0.00291	0.48388	0.04322	0.00002	0.00026	0.04350	0.52398	0.00021	0.00318	0.52737
2004	0.48895	0.00020	0.00299	0.49214	0.04423	0.00002	0.00027	0.04452	0.53318	0.00022	0.00326	0.53666
2005	0.49054	0.00021	0.00303	0.49377	0.04338	0.00002	0.00027	0.04367	0.53392	0.00022	0.00329	0.53744
2006	0.49474	0.00021	0.00309	0.49804	0.04241	0.00002	0.00026	0.04269	0.53715	0.00023	0.00335	0.54073
2007	0.49984	0.00022	0.00314	0.50320	0.04161	0.00002	0.00026	0.04189	0.54145	0.00023	0.00340	0.54509
2008	0.50076	0.00023	0.00312	0.50410	0.04084	0.00002	0.00025	0.04112	0.54160	0.00024	0.00337	0.54522

Notes: Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES)

Indirect Emissions from UK Grid Electricity

30. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect / fuel cycle emissions as included in Annex 1). The average fuel cycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel/primary energy used in electricity generation.

31. Average indirect emission factors for electricity have been calculated using Annex 1 indirect emission factors and data on the total fuel consumption by type of generation from Table 5.6, Digest of UK Energy Statistics 2009 (DECC, 2009).The data used in these calculations is presented in Table 5, Table 6 and Table 7, together with the final indirect emission factors for electricity.

Table 5: Fuel Consumed in electricity generation (GWh), by year

	Fuel Consumed in Electricity Generation, GWh					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	**Total**
1990	N/A	N/A	N/A	N/A	N/A	N/A
1991	N/A	N/A	N/A	N/A	N/A	N/A
1992	N/A	N/A	N/A	N/A	N/A	N/A
1993	N/A	N/A	N/A	N/A	N/A	N/A
1994	N/A	N/A	N/A	N/A	N/A	N/A
1995	N/A	N/A	N/A	N/A	N/A	N/A
1996	390,938	45,955	201,929	16,066	204,221	**859,109**
1997	336,614	25,253	251,787	16,066	214,864	**844,584**
1998	347,696	17,793	267,731	16,046	223,092	**872,358**
1999	296,706	17,920	315,548	16,187	210,895	**857,256**
2000	333,429	18,023	324,560	15,743	176,744	**868,499**
2001	367,569	16,545	312,518	12,053	201,678	**910,363**
2002	344,552	14,977	329,442	12,343	194,769	**896,083**
2003	378,463	13,867	323,926	17,703	191,072	**925,031**
2004	364,158	12,792	340,228	16,132	181,366	**914,674**
2005	378,846	15,722	328,372	21,327	190,264	**934,531**
2006	418,018	17,897	308,254	17,412	183,764	**945,345**
2007	382,217	14,639	352,735	14,135	150,312	**914,038**
2008	347,676	20,536	377,216	11,348	129,371	**886,147**

Source: Table 5.6, Digest of UK Energy Statistics 2009 (DECC, 2009), available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Table 6: Fuel consumed in electricity generation as a % of the Total, by year

	Fuel Consumed in Electricity Generation, % Total					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	**Total**
1990	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1991	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1992	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1993	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1994	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1995	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1996	45.5%	5.3%	23.5%	1.9%	23.8%	**100.0%**
1997	39.9%	3.0%	29.8%	1.9%	25.4%	**100.0%**
1998	39.9%	2.0%	30.7%	1.8%	25.6%	**100.0%**
1999	34.6%	2.1%	36.8%	1.9%	24.6%	**100.0%**
2000	38.4%	2.1%	37.4%	1.8%	20.4%	**100.0%**
2001	40.4%	1.8%	34.3%	1.3%	22.2%	**100.0%**
2002	38.5%	1.7%	36.8%	1.4%	21.7%	**100.0%**
2003	40.9%	1.5%	35.0%	1.9%	20.7%	**100.0%**
2004	39.8%	1.4%	37.2%	1.8%	19.8%	**100.0%**
2005	40.5%	1.7%	35.1%	2.3%	20.4%	**100.0%**
2006	44.2%	1.9%	32.6%	1.8%	19.4%	**100.0%**
2007	41.8%	1.6%	38.6%	1.5%	16.4%	**100.0%**
2008	39.2%	2.3%	42.6%	1.3%	14.6%	**100.0%**

Notes: Calculated from figures in Table 5

Table 7: Significance of indirect emissions for different fuels used for electricity generation and the calculated average indirect emission factor, by year

	Indirect Emissions as % Direct CO_2 Emissions, by fuel						Av. Electricity EF CO_2e/kWh		
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	**Weighted Average**	Direct CO_2	Calc Indirect CO_2e	5-yr Rolling Av.
1990	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.71225	0.10224	0.10224
1991	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.69375	0.09958	0.10091
1992	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.64750	0.09294	0.09825
1993	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.57350	0.08232	0.09427
1994	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.56425	0.08099	0.09161
1995	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.53650	0.07701	0.08657
1996	16.5%	17.1%	9.7%	12.5%	14.4%	**14.4%**	0.52224	0.07496	0.08164
1997	16.5%	17.1%	9.7%	12.5%	13.7%	**13.7%**	0.48185	0.06608	0.07627
1998	16.5%	17.1%	9.7%	12.5%	13.6%	**13.6%**	0.48316	0.06583	0.07298
1999	16.5%	17.1%	9.7%	12.5%	13.1%	**13.1%**	0.45369	0.05948	0.06867
2000	16.5%	17.1%	9.7%	12.5%	13.2%	**13.2%**	0.48045	0.06365	0.06600
2001	16.5%	17.1%	9.7%	12.5%	13.5%	**13.5%**	0.49512	0.06664	0.06434
2002	16.5%	17.1%	9.7%	12.5%	13.3%	**13.3%**	0.47990	0.06364	0.06385
2003	16.5%	17.1%	9.7%	12.5%	13.4%	**13.4%**	0.49466	0.06642	0.06397
2004	16.5%	17.1%	9.7%	12.5%	13.3%	**13.3%**	0.49461	0.06569	0.06521
2005	16.5%	17.1%	9.7%	12.5%	13.4%	**13.4%**	0.48840	0.06550	0.06558
2006	16.5%	17.1%	9.7%	12.5%	13.7%	**13.7%**	0.51613	0.07062	0.06637
2007	16.5%	17.1%	9.7%	12.5%	13.3%	**13.3%**	0.50537	0.06727	0.06710
2008	16.5%	17.1%	9.7%	12.5%	13.1%	**13.1%**	0.49927	0.06531	0.06688

Notes: Indirect emissions as % direct CO_2 emissions is based on information from Annex 1 of the Conversion Factors. Weighted average is calculated from the figures for fuels from both Table 6 and Table 7,

IV. Conversion Factors for Process Emissions (Annex 4 and Annex 5)

Summary of changes since previous update

32. No changes have been made since the 2009 update.

Inventory of Likely Process Emissions (Annex 4)

33. Annex 4 provides a matrix of the Kyoto greenhouse gases that are likely to be produced by a variety of the industries in the UK that are most likely to have a significant impact on climate change. This matrix is based upon the Greenhouse Gas Inventory Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) adapted for UK processes by AEA. These process related emissions refer to the types of processes that are used specifically in the UK. Process emissions might be slightly different for processes operated in other countries.

34. Global Warming Potential (GWP) is used to compare the impact of the emission of equivalent masses of different GHGs relative to carbon dioxide. For example, it is estimated that the emission of 1 kilogram of methane will have the same warming impact 1 as 21 kilograms of carbon dioxide. Therefore the GWP of methane is 21. The GWP of carbon dioxide is, by definition, 1.

Global Warming Potentials of Greenhouse Gases (Annex 5)

Greenhouse Gases Listed in the Kyoto Protocol

35. The conversion factors in Table 5a of Annex 5 incorporate (GWP) values relevant to reporting under UNFCCC, as published by the IPCC in its Second Assessment Report, Climate Change 1995. The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. (Eds. J. T Houghton et al, 1996).

36. *Mixed/Blended gases:* GWP values for refrigerant blends are be calculated on the basis of the percentage blend composition (e.g. the GWP for R404a that comprises is 44% HFC125, 52% HFC143a and 4% HFC134a is [2800 x 0.44] + [3800 x 0.52] + [1300 x 0.04] = 3260). A limited selection of common blends is presented in Annex 5.

Other Greenhouse Gases

37. Revised GWP values have since been published by the IPCC in the Fourth Assessment Report (2007) but current UNFCCC Guidelines on Reporting and Review, adopted before the publication of the Fourth Assessment Report, require emission estimates to be based on the GWPs in the IPCC Second Assessment Report. A second table in Annex 5, Table 5b, includes

other greenhouse gases not listed in the Kyoto protocol or covered by reporting under UNFCCC. These GWP conversion factors have been taken from the IPCC's Fourth Assessment Report (2007).

38. *CFCs and HCFCs:* Not all refrigerants in use are classified as greenhouse gases for the purposes of the UNFCCC and Kyoto Protocol (e.g. CFCs, HCFCs). These gases are controlled under the Montreal Protocol and as such GWP values are listed in Table 5b

V. Passenger Surface Transport Emission Factors (Annex 6)

Summary of Changes Since the Previous Update

39. Besides the addition of indirect emission factors (for emissions from the fuel production cycle), the main methodological changes and additions since the previous update include:
    a. Both engine size and market class based emission factors are now entirely based upon time-series new car CO_2 emission data from SMMT (Society for Motor Manufacturers and Traders) [6].
    b. Emission factors for LPG and CNG cars and vans have been split out and revised assumptions used to derive them;
    c. Petrol and diesel van emission factor calculations now utilise updated speed-emission curve data;
    d. Revised payload capacity assumptions have been used to derive figures per tonne-km for vans;
    e. Petrol vans have been disaggregated into Class I, II and III vans.
    f. Local bus emission factors are now based on data from DfT from the Bus Service Operators Grant;
    g. Eurostar emission factors now based on more specific data and assumptions agreed with Eurostar.

40. All other factors have also been updated with more recent data in the latest 2010 GHG Conversion Factors.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

41. Previously, several datasets were identified to help inform the updating of the average CO_2 emission factors for passenger cars, with the most relevant one identified based on SMMT data. This data, presented in Table 8, provides numbers of registrations and averages of the NEDC[7] gCO_2/km

[6] SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry. http://www.smmt.co.uk/
[7] NEDC = New European Driving Cycle, which is used in the type approval of new passenger cars.

figures for new vehicles registered since 1998. This dataset represents a good indication of the actual UK fleet split of vehicle/engine sizes and relative NEDC gCO_2/km by size category. In the updates to the Defra/DECC Conversion Factors carried out for 2007-2009 the SMMT dataset was used in combination with data derived from the speed-emission curves used in UK GHG Inventory. However, for the 2010 update the emission factors by car engine size are based entirely on the SMMT dataset to bring these in better alignment with the corresponding emission factors by car market segment.

Table 8: Average CO_2 emission factors and total registrations from SMMT data for 1997 to 2009 (provided by EST, based on data sourced from SMMT).

Vehicle Type	Engine size	Size label	gCO_2 per km	MPG	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	150.4	43.2	9,727,769	45%
	1.4 - 2.0 l	Medium	186.8	34.8	10,228,366	47%
	> 2.0 l	Large	260.3	25.0	1,873,171	9%
Average petrol car			**183.2**	**35.5**	**21,829,306**	**100%**
Diesel car	<1.7 l	Small	126.2	59.1	1,556,214	18%
	1.7 - 2.0 l	Medium	157.4	47.4	4,987,224	59%
	> 2.0 l	Large	213.4	35.0	1,872,209	22%
Average diesel car			**169.5**	**44.0**	**8,415,647**	**100%**

42. A limitation of the NEDC (New European Driving Cycle – used in vehicle type approval) is that it takes no account of further 'real-world' effects that can have a significant impact on fuel consumption. These include use of accessories (air con, lights, heaters etc), vehicle payload (only driver +25kg is considered in tests, no passengers or further luggage), poor maintenance (tyre under inflation, maladjusted tracking, etc), gradients (tests effectively assume a level road), weather, more aggressive/harsher driving style, etc. It is therefore desirable to uplift NEDC based data to bring it closer to anticipated 'real-world' vehicle performance.

43. In terms of uplifting NEDC based emission factors to 'real-world' values, there are a number of sources of evidence and information to inform a decision on an appropriate value. Results of research by TUEV Nord for the German Environmental Agency[9] have shown that the CO_2 emissions for the NEDC test cycle can vary up to +30% for a specific vehicle type, due to vehicle and driving behaviour variations. The study concludes that on average the CO_2 emissions in real traffic are systematically higher than indicated by the type approval results by a factor in the order of +10-15%. In comparison, the IEA (International Energy Agency) uses a factor of +15-18% in its model calculations to convert from test-cycle to 'real-world' values. This is also similar to the value of +15.5% quoted by Energy Saving Trust (EST) based on information from ARVAL (the UK's biggest fleet operator) on

[8] The SMMT gCO_2/km dataset for 1997 represented around 70% of total registrations, which rose to about 99% by 2000 and essentially all vehicles thereafter.

[9] Investigations for an Amendment of the EU Directive 93/116/EC (Measurement of Fuel Consumption and CO_2 Emission). Study by TUEV Nord Mobilitaet GmbH & Co.KG, Institute for Vehicle Technology and Mobility. Carried out by order of the German Environmental Agency (UBA). November 2005.

observations from the real performance of its vehicles relative to test cycle data. The ARVAL factor provides the only information specific to the UK, although it may be a small over-estimate for private cars in some cases due to the nature of fleet vehicle usage compared to more typical driving styles of the general public.

44. Other information from EST on the impacts of various real-world effects on fuel consumption also provides support for the application of uplift factors. These effects include general maintenance and tyre pressure (increase of 1% for every 3 PSI under pressure), inefficient driving style (eco-driving training has been shown to achieve up to 5-10% reduction in fuel consumption), air conditioning use (increase of 5% for average mixed use; up to 20-25% increase when on full power[10]).

45. Air conditioning (a/c) is a particularly significant component of 'real-world' impacts on fuel consumption, as it is not currently included in the type-approval testing procedures. It is estimated that today around 85% of new cars are sold with air conditioning systems fitted as standard[11], with nearly all medium and large cars having air conditioning as standard equipment[12]. SMMT (Society for Motor Manufacturers and Traders)[13] has estimated that the proportion of the car fleet with a/c units increased from 10% in 1993 to 55% by 2002 further to 70% by 2005[14].

46. An uplift factor of **+15% over NEDC based gCO_2/km** factors was agreed with DfT in 2007 to take into account the combined 'real-world' effects on fuel consumption not already taken into account in the previous factors. [Note: This represents a decrease in MPG (miles per gallon) over NEDC figures of about 13% for petrol cars and 9% for diesel cars]. No new evidence has been identified to suggest this figure should change for the 2010 GHG Conversion Factors.

47. The updated SMMT data was used to update the factors for the 2010 GHG Conversion Factors. The resulting *New 'Real-World'* 2010 GHG Conversion Factors, presented in Table 9, include the +15% uplift factor to take into account the 'real-world' impacts on fuel consumption not captured by drive cycles such as the NEDC in type-approval. The engine size average by fuel type and the overall average figures have been calculated from a mileage weighted average of the petrol and diesel averages, using data from the UK GHG Inventory on the relative % total mileage by petrol and diesel cars. Overall for petrol and diesel, this split in total annual mileage was 64.7% petrol and 35.3% diesel, and can be compared to the respective total registrations of the different vehicle types for 1997-2009, which was 72.2% petrol and 27.8% diesel.

[10] Source: tests carried out by ADEME, France.
[11] From: *www.boschautoparts.co.uk/teACon1.asp?c=2&d=2*
[12] From: *www.eberspacher.com/aircon.php?section=products*
[13] SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry. *http://www.smmt.co.uk/*
[14] From CfIT (Commission for Integrated Transport): *www.cfit.gov.uk/plenaries/0501mfp3.htm*

48. For the 2010 GHG Conversion Factors emission factor for CH_4 and N_2O have also been updated for all vehicle classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 9.

49. Individuals may wish to calculate their carbon emissions for a particular door-to-door journey using Transport Direct[15] - www.transportdirect.info.

Table 9: Revised CO_2 emission factors for cars by engine size for 2010 update

Vehicle Type	Engine size	Size label	Final New 'real-world' 2010 GHG Conversion Factors(1) gCO2 per km: CO_2	CH_4	N_2O	Total	MPG
Petrol car	< 1.4 l	Small	173.0	0.18	0.96	174.1	37.6
	1.4 - 2.0 l	Medium	214.9	0.18	0.96	216.0	30.3
	> 2.0 l	Large	299.4	0.18	0.96	300.5	21.7
Average petrol car			**210.7**	**0.18**	**0.96**	**211.9**	**30.9**
Diesel car	<1.7 l	Small	145.2	0.05	1.66	146.9	51.4
	1.7 - 2.0 l	Medium	181.0	0.05	1.66	182.7	41.2
	> 2.0 l	Large	245.5	0.05	1.66	247.2	30.4
Average diesel car			**195.0**	**0.05**	**1.66**	**196.7**	**38.3**
Car (unknown fuel)	(2)	Small	169.1	0.16	1.10	170.4	40.3
	(2)	Medium	203.8	0.13	1.22	205.1	34.3
	(2)	Large	272.4	0.11	1.34	273.9	26.5
Average car (unknown fuel)	(2)	-	**206.9**	**0.14**	**1.21**	**208.3**	**33.5**

Notes:
(1) Using a +15% uplift factor for NEDC ⇒ 'real-world';
(2) Estimated from the relative vehicle-km data from the UK GHG Inventory

Hybrid, LPG and CNG Passenger Cars

50. CO_2 emission factors generated for medium and large hybrid petrol-electric cars for the 2010 update have also been revised and updated to reflect the availability of additional models on the market. These are based on average emission factors for the main models currently widely available on the UK market for the last 5 years according to the VCA's[16] database. The models included in this calculation and their allocation to the Medium or Large size category are summarised in Table 10. As new / updated hybrid models are becoming more widely available, this data will be updated in future years. The new emission factors for petrol hybrid cars are presented in Table 12.

[15] Note that the emission factors and vehicle size categorisation in Transport Direct are not identical to the Defra conversion factors, as they are used in a different way and for a different purpose. However both figures produce consistent estimates.
[16] The UK Vehicle Certification Agency maintains a car CO_2 database which is available for download at the following location: http://www.vcacarfueldata.org.uk/downloads/

Table 10: Summary of models used in the estimation of emission factors for petrol hybrid cars

Size	Make and Model	Model year	NEDC gCO_2/km	Uplifted gCO_2/km
Medium	TOYOTA Prius T Spirit 1.8 VVT-i hybrid E-CVT	2010	92.00	105.8
	TOYOTA Prius T Spirit with Solar Panel 1.8VVT-i hybrid E-CVT	2010	89.00	102.35
	HONDA Insight 1.3 IMA ES 5 door	2010	105.00	120.75
	HONDA Insight 1.3 IMA ES-T 5 door	2010	105.00	120.75
	HONDA Insight 1.3 IMA S 5 door	2010	101.00	116.15
	HONDA Insight 1.3 IMA SE 5 door	2010	101.00	116.15
	HONDA Civic Hybrid	2010	109.00	125.35
	HONDA Civic Hybrid	2009	109.00	125.35
	TOYOTA Prius	2009	104.00	119.6
	HONDA Civic Hybrid	2008	109.00	125.35
	TOYOTA Prius	2008	104.00	119.6
	HONDA Civic Hybrid	2007	109.00	125.35
	TOYOTA Prius	2007	104.00	119.6
	HONDA Civic Hybrid	2006	109.00	125.35
	TOYOTA Prius	2006	104.00	119.6
	Average		**103.60**	**119.14**
Large	LEXUS GS450h 17" wheels	2010	179.00	205.85
	LEXUS GS450h 18" wheels	2010	180.00	207
	LEXUS RX450h	2010	148.00	170.2
	LEXUS LS600h LWB	2010	219.00	251.85
	LEXUS LS600h SWB	2010	218.00	250.7
	LEXUS GS450h	2009	186.00	213.9
	LEXUS RX400h	2009	192.00	220.8
	LEXUS GS450h	2008	186.00	213.9
	LEXUS RX400h	2008	192.00	220.8
	LEXUS GS450h	2007	186.00	213.9
	LEXUS RX400h	2007	192.00	220.8
	LEXUS GS450h	2006	186.00	213.9
	LEXUS RX400h	2006	192.00	220.8
	Average		**188.92**	**217.26**
All	**Average All**		**143.21**	**164.70**

51. For the 2010 GHG Conversion Factors the assumptions of the emission factors for LPG and CNG vehicles have been split out (whereas previously they were combined) using updated information from the Energy Savings Trust (EST[17]). Previous information from EST indicated that LPG and CNG cars results in 10-15% reduction in CO_2 relative to petrol cars, similar to diesel vehicles. However, updated information on their individual relative performance is summarised in Table 11. New factors for LPG and CNG cars, presented in Table 12, were calculated based on the updated assumptions from EST for reductions in CO_2 emissions relative to the emission factors for petrol cars from the 2010 GHG Conversion Factors dataset. Average emission factors for all vehicle sizes were calculated based on a weighted average using the relative vehicle-km for medium and large cars from the UK GHG Inventory. Due to the significant size and weight of the LPG and CNG fuel tanks it is assumed only medium and large sized vehicles will be available.

[17] *See http://www.energysavingtrust.org.uk/fleet/technology/alternativefuels/*

52. For the 2010 GHG Conversion Factors emission factor for CH_4 and N_2O have also been added for all vehicle classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 12.

Table 11: Assumptions base on information from EST on the performance of LPG and CNG passenger cars relative to petrol and diesel equivalents

	% CO_2 relative to		**EST Source**
	Petrol	Diesel	
LPG	-10%	+5%*	(1)
CNG	-20%	-5%	(2)
CNG (methane emissions only)	+400%		(3)

Notes:
* Derived based on the relative difference for CNG relative to petrol and diesel cars
(1) http://www.energysavingtrust.org.uk/business/Business/Transport-advice/Low-carbon-technology/Alternative-fuels/Liquified-petroleum-gas-LPG
(2) http://www.energysavingtrust.org.uk/business/Business/Transport-advice/Low-carbon-technology/Alternative-fuels/Natural-gas
(3) http://www.afdc.energy.gov/afdc/vehicles/emissions_natural_gas.html

Table 12: New emission factors for LPG and CNG passenger cars for 2010 GHG Conversion Factors

		gCO_2e per km			
Car fuel	**Car size**	**CO_2**	**CH_4**	**N_2O**	**Total**
Petrol Hybrid	Medium	119.1	0.10	0.96	120.2
	Large	217.3	0.13	0.96	218.4
	Average	**164.7**	**0.14**	**0.96**	**165.8**
LPG	Medium	193.4	0.37	1.23	195.0
	Large	269.4	0.37	1.23	271.0
	Average	**214.2**	**0.37**	**1.23**	**215.8**
CNG	Medium	171.9	0.90	1.23	174.0
	Large	239.5	0.90	1.23	241.6
	Average	**190.4**	**0.90**	**1.23**	**192.5**

Emission Factors by Passenger Car Market Segments

53. Emission factors for cars by market segment (according to SMMT classifications) were calculated to be consistent with the previous GHG Conversion Factors by engine size. For the 2010 GHG Conversion Factors, the market classification split was derived using detailed SMMT data on new car registrations between 1997 and 2009 split by fuel[18]. The test-cycle based data was uplifted by 15% to take into account 'real-world' impacts, consistent with the methodology used to derive the car engine size emission factors presented in Table 9. The supplementary market class based emission factors for passenger cars are presented in Table 13.

[18] This data was provided by EST and is based on detailed data sourced from SMMT on new car registrations.

54. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O have also been updated for all car classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 14 to Table 16.

Table 13: Passenger car market class based CO_2 emission factors for 2010 GHG Conversion Factors

Car Market Segment	Example Model	Average in-use CO_2 emission factor for segment, gCO_2 per km		
		Petrol	**Diesel**	**Total**
A. Mini	Smart Fortwo	159.86	103.31	159.30
B. Supermini	VW Polo	172.46	145.08	169.69
C. Lower Medium	Ford Focus	202.50	166.30	192.13
D. Upper Medium	Toyota Avensis	230.01	181.49	209.51
E. Executive	BMW 5-Series	272.68	214.99	247.99
F. Luxury	Bentley Continental GT	347.48	253.33	326.02
G. Sports	Mercedes SLK	254.84	178.63	253.08
H. Duel Purpose 4x4	Land Rover Discovery	289.93	270.68	278.42
I. MPV	Renault Espace	236.16	208.54	221.81
All	**Total**	**210.71**	**194.95**	**206.90**

Table 14: Passenger car market class based CH_4 emission factors for 2010 GHG Conversion Factors

Car Market Segment	Example Model	Average in-use CH_4 emission factor for segment, gCO_2e per km		
		Petrol	**Diesel**	**Total**
A. Mini	Smart Fortwo	0.18	0.05	0.18
B. Supermini	VW Polo	0.18	0.05	0.16
C. Lower Medium	Ford Focus	0.18	0.05	0.15
D. Upper Medium	Toyota Avensis	0.18	0.05	0.13
E. Executive	BMW 5-Series	0.18	0.05	0.11
F. Luxury	Bentley Continental GT	0.18	0.05	0.11
G. Sports	Mercedes SLK	0.18	0.05	0.11
H. Duel Purpose 4x4	Land Rover Discovery	0.18	0.05	0.11
I. MPV	Renault Espace	0.18	0.05	0.12
All	**Total**	**0.18**	**0.05**	**0.14**

Table 15: Passenger car market class based N_2O emission factors for 2010 GHG Conversion Factors update

Car Market Segment	Example Model	Average in-use N_2O emission factor for segment, gCO_2e per km		
		Petrol	**Diesel**	**Total**
A. Mini	Smart Fortwo	0.96	1.66	1.01
B. Supermini	VW Polo	0.96	1.66	1.10
C. Lower Medium	Ford Focus	0.96	1.66	1.16
D. Upper Medium	Toyota Avensis	0.96	1.66	1.22
E. Executive	BMW 5-Series	0.96	1.66	1.34
F. Luxury	Bentley Continental GT	0.96	1.66	1.34
G. Sports	Mercedes SLK	0.96	1.66	1.34
H. Duel Purpose 4x4	Land Rover Discovery	0.96	1.66	1.34
I. MPV	Renault Espace	0.96	1.66	1.28
All	**Total**	**0.96**	**1.66**	**1.21**

Table 16: Passenger car market class based total GHG emission factors for 2010 GHG Conversion Factors

Car Market Segment	Example Model	Average in-use Total GHG emission factor for segment, gCO_2e per km		
		Petrol	**Diesel**	**Total**
A. Mini	Smart Fortwo	161.0	105.0	160.5
B. Supermini	VW Polo	173.6	146.8	170.9
C. Lower Medium	Ford Focus	203.7	168.0	193.4
D. Upper Medium	Toyota Avensis	231.2	183.2	210.9
E. Executive	BMW 5-Series	273.8	216.7	249.4
F. Luxury	Bentley Continental GT	348.6	255.0	327.5
G. Sports	Mercedes SLK	256.0	180.3	254.5
H. Duel Purpose 4x4	Land Rover Discovery	291.1	272.4	279.9
I. MPV	Renault Espace	237.3	210.2	223.2
All	**Total**	**211.9**	**196.7**	**208.2**

Direct Emissions from Taxis

55. New emission factors for taxis per passenger km were estimated in 2008 on the basis of an average of the 2008 GHG Conversion Factors of medium and large cars and occupancy of 1.4 (CfIT, 2002[19]). The emission factors for black cabs are based on the large car emission factor (which is consistent with the VCA[20] dataset based on the NEDC for London Taxis International vehicles) and an average passenger occupancy of 1.5 (average 2.5 people per cab from LTI, 2007[21]).

[19] Obtaining the best value for public Subsidy of the bus industry, a report by L.E.K. Consulting LLP for the UK Commission for Integrated Transport, 14 March 2002. Appendix 10.5.1: Methodology for settlements with <25k population. Available at: *http://www.cfit.gov.uk/docs/2002/psbi/lek/a1051/index.htm*
[20] Vehicle Certification Agency (VCA) car fuel database is available at: *http://www.vcacarfueldata.org.uk/*
[21] *See: http://www.lti.co.uk/news/index.php?p=98*

56. The emission factors per passenger km for taxis presented in Table 17 have been updated to be consistent with the most recent data for the 2010 update. The base emission factors per vehicle km are also presented in Table 18. It should be noted that many black cabs will probably have a significantly different operational cycle to the NEDC, which would likely to increase the emission factor. At the moment there is insufficient information available to take this into account in the current factors.

57. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O have been updated for all taxis. These figures are, as before, based on the emission factors for diesel cars from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 17 and Table 18.

Table 17: Emission factors per passenger km for taxis for 2010 GHG Conversion Factors

	Average passenger occupancy	gCO$_2$e per passenger km			
		CO_2	CH_4	N_2O	Total
Taxi	1.4	152.3	0.04	1.19	153.5
Black Cab	1.5	199.6	0.12	0.64	200.3

Table 18: Emission factors per vehicle km for taxis for 2010 GHG Conversion Factors

	gCO$_2$e per passenger km			
	CO_2	CH_4	N_2O	Total
Taxi	213.2	0.05	1.66	214.9
Black Cab	245.5	0.05	1.66	247.2

Direct Emissions from Vans

58. Average emission factors by fuel for light good vehicles (N1 vehicles, vans up to 3.5 tonnes) by size class (I, II or III), presented in Table 19, were calculated for the 2010 update based on revisions to the diesel emission factors used in the National Atmospheric Emissions Inventory (NAEI) and UK GHG Inventory for 2008. These test cycle based emission factors were then uplifted by 15% to represent 'real-world' emissions, consistent with the approach used for cars agreed with DfT. Emission factors for petrol vehicles were calculated from the relative emissions and vehicle km of petrol and diesel LGVs in the NAEI. Emission factors for LPG and CNG vans were estimated to be similar to diesel vehicles, as indicated by EST for cars (see earlier section for updated assumptions). The average van emission factor was calculated on the basis of the relative NAEI vehicle km for petrol and diesel LGVs for 2008.

59. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O have also been updated for all van classes. These are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. N_2O emissions are assumed to scale relative to vehicle

class/CO_2 emissions for diesel vans. These factors are also presented together with an overall total factor in Table 19.

Table 19: New emission factors for vans for the 2010 GHG Conversion Factors

Van fuel	Van size	gCO_2e per km			
		CO_2	CH_4	N_2O	Total
Petrol (Class I)	Up to 1.305 tonne	194.1	0.2	0.8	195.1
Petrol (Class II)	1.305 to 1.740 tonne	211.1	0.2	0.8	212.2
Petrol (Class III)	Over 1.740 tonne	255.8	0.3	1.8	257.8
Petrol (average)	**Up to 3.5 tonne**	**240.5**	**0.3**	**1.5**	**242.2**
Diesel (Class I)	Up to 1.305 tonne	157.0	0.1	1.1	158.2
Diesel (Class II)	1.305 to 1.740 tonne	224.8	0.1	1.5	226.4
Diesel (Class III)	Over 1.740 tonne	269.1	0.1	1.8	271.0
Diesel (average)	**Up to 3.5 tonne**	**250.8**	**0.1**	**1.7**	**252.6**
LPG	Up to 3.5 tonne	263.3	0.5	1.9	265.8
CNG	Up to 3.5 tonne	238.3	1.3	1.9	241.5
Average		**250.2**	**0.1**	**1.7**	**251.9**

Direct Emissions from Buses

60. Previous emission factors were based on information provided on major bus operator websites/environmental reports (e.g. fuel consumption/emission factors, fuel consumption and passenger km). For the 2010 update the approach has been revised to instead base the emission factors for local buses on data from DfT from the Bus Service Operators Grant (BSOG) in combination with DfT bus activity statistics (vehicle km, passenger km). DfT holds very accurate data on the total amount of money provided to bus service operators under the scheme, which provides a fixed amount of financial support per unit of fuel consumed. Therefore the total amount of fuel consumed (and hence CO_2 emissions) can be calculated from this, which when combined with DfT statistics on total vehicle km and passenger km allows the calculation of emission factors.

61. Emission factors for coach services were based on figures from National Express, who provide the majority of scheduled coach services in the UK.

62. The overall bus and coach emission factor has been removed due to concerns over its robustness following detailed discussion with DfT and the lack of suitable data in order to recalculate it.

63. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O have also been updated for all bus classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 20.

64. The new (2010 GHG Conversion Factors) average emission factors for different bus service types are summarised in Table 20, together with

indicative figures from DfT statistics on average bus occupancy levels. As a result of the change in methodology the local bus emission factors have increased very significantly – by over 40% for non-London services and by 29% for all local buses. However, it is believed this is a much more accurate method of calculation than that used in previous years. It should be noted that fuel consumption and emission factors for individual operators and services will vary very significantly depending on the local conditions, the specific vehicles used and on the typical occupancy achieved.

Table 20: New emission factors for buses for the 2010 GHG Conversion Factors

Bus type	Average passenger occupancy	gCO_2e per passenger km			
		CO_2	CH_4	N_2O	Total
Local bus	7.2	157.3	0.20	1.28	158.7
Local London bus	16.6	88.5	0.09	0.56	89.1
Average local bus	**9.0**	**133.9**	**0.16**	**1.04**	**135.1**
Coach	16.2*	30.0	0.08	0.57	30.7

Notes: Average load factors/passenger occupancy provided by DfT Statistics Division.
* Combined figure from DfT for non-local buses and coaches combined. Actual occupancy for coaches alone is likely to be significantly higher.

Direct Emissions from Motorcycles

65. Data from type approval is not currently readily available for motorbikes and CO_2 emission measurements were only mandatory in motorcycle type approval from 2005.

66. For the practical purposes of the reporting guidelines and the government 'Act on CO_2 calculator' for personal transport, emission factors for motorcycles are split into 3 categories:
    a. Small motorbikes (mopeds/scooters up to 125cc),
    b. Medium motorbikes (125-500cc), and
    c. Large motorbikes (over 500cc)

67. For the 2009 update the emission factors were calculated based on a large dataset kindly provided by Clear (2008)[22]. This dataset was more comprehensive compared to the one previously used, containing almost 1200 data points (over 300 different bikes from 50-1500cc and from 25 manufacturers) from a mix of magazine road test reports and user reported data compared to only 42 data points in the previous dataset. A summary is presented in Table 21 and the corresponding new emission factors developed in 2009 for motorcycles are presented in Table 22. The total average has been calculated weighted by the relative number of registrations of each category in 2008 according to DfT statistics from CMS

[22] Dataset of motorcycle fuel consumption compiled by Clear (http://www.clear-offset.com/) for the development of its motorcycle CO_2 model used in its carbon offsetting products.

(2008)[23]. In the absence of new information the dataset and calculations remain essentially unchanged for the 2010 GHG Conversion Factors.

68. The 2009 emission factors presented in Table 22 are significantly higher than the previous figures. Since the 2009 dataset is also based predominantly upon real-world riding conditions (rather than the test-cycle based data from ACEM[24] used previously) the new emission factors are anticipated to be more representative of typical in-use performance. The average difference between the new factors based on real-world observed fuel consumption and the previous figures based upon test-cycle data (+9%) is smaller than the corresponding differential used to uplift cars test cycle data to real-world equivalents (+15%).

69. For the 2009 GHG Conversion Factors emission factor for CH_4 and N_2O have also been added for all motorcycle classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. These factors are also presented together with an overall total factor in Table 22.

Table 21: Summary dataset on CO_2 emissions from motorcycles based on detailed data provided by Clear (2008)

CC Range	Model Count	Number	Av. gCO_2/km	Av. MPG
Up to 125cc	24	58	85.0	77.0
125cc to 200cc	3	13	77.8	84.0
200cc to 300cc	16	57	93.1	70.2
300cc to 400cc	8	22	112.5	58.1
400cc to 500cc	9	37	122.0	53.6
500cc to 600cc	24	105	139.2	47.0
600cc to 700cc	19	72	125.9	51.9
700cc to 800cc	21	86	133.4	49.0
800cc to 900cc	21	83	127.1	51.4
900cc to 1000cc	35	138	154.1	42.4
1000cc to 1100cc	14	57	135.6	48.2
1100cc to 1200cc	23	96	136.9	47.8
1200cc to 1300cc	9	32	136.6	47.9
1300cc to 1400cc	3	13	128.7	50.8
1400cc to 1500cc	61	256	132.2	49.5
1500cc to 1600cc	4	13	170.7	38.3
1600cc to 1700cc	5	21	145.7	44.9
1700cc to 1800cc	3	15	161.0	40.6
1800cc to 1900cc	0	0		
1900cc to 2000cc	0	0		
2000cc to 2100cc	1	5	140.9	46.4
<125cc	24	58	85.0	77.0
126-500cc	36	129	103.2	63.4
>500cc	243	992	137.2	47.7
Total	**303**	**1179**	**116.1**	**56.4**

[23] "Compendium of Motorcycling Statistics: 2008", available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/vehicles/motorcycling/
[24] The European Motorcycle Manufacturers Association

Note: Summary data based data provided by Clear (*http://www.clear-offset.com/*) from a mix of magazine road test reports and user reported data.

Table 22: Updated emission factors for motorcycles for the 2010 GHG Conversion Factors

Vehicle Type	Engine size	Size label	MPG	gCO_2 per km			
				CO_2	CH_4	N_2O	Total
Petrol motorcycle	Up to 125cc	Small (mopeds/scooters)	77.0	85.0	2.56	0.35	87.9
	125cc to 500cc	Medium	63.4	103.2	2.89	0.62	106.7
	Over 500cc	Large	47.7	137.2	2.24	0.62	140.1
	Average	**-**	**56.4**	**116.1**	**2.64**	**0.60**	**119.3**

Notes: MPG = miles per gallon. The average is a weighted average based on number of registrations of different size categories.

Direct Emissions from Passenger Rail

70. Emission factors for passenger rail services have been updated and provided in Table 24. These include updates to the national rail, international rail (Eurostar), light rail schemes and the London Underground. Emission factors for CH_4 and N_2O emissions have also been updated in the 2010 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

71. The international rail factor is based on a passenger-km weighted average of the emission factors for the Eurostar London-Brussels and London-Paris routes. The emission factors were provided by Eurostar, together with information on the basis of the electricity figures used in their calculation.

72. The methodology applied in calculating the Eurostar emission factors currently uses 3 key pieces of information:
    a. Total electricity use by Eurostar trains on the UK and France/Belgium track sections;
    b. Total passenger numbers (and therefore calculated passenger km) on Eurostar London-Paris and London-Brussels services;
    c. Emission factors for electricity (in $kgCO_2$ per kWh) for the UK and France/Belgium journey sections. These are based on the UK grid average electricity from the Defra/DECC GHG Conversion Factors and the France/Belgium grid averages.

73. Eurostar's published figure is 7.71 gCO_2/pkm. This differs from the figure quoted in the 2010 GHG Conversion Factors as it is calculated using the individual conversion factors as specified by each electricity supplier across each network section upon which they operate, rather than the grid average. For further information please visit: *http://www.eurostar.com/UK/uk/leisure/about_eurostar/environment/greener_than_flying.jsp*

74. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation, proportional to the CO_2 emission factors.

National Rail

75. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2007-08. The factor is sourced from information from the Office of the Rail Regulator's National rail trends for 2007-8 (ORR, 2009)[25]. This has been calculated based on total electricity and diesel consumed by the railways for the year (sourced from ATOC), and the total number of passenger kilometres (from National Rail Trends). The factor for conversion of kWh electricity into CO_2 is based on the 2006 grid mix (the most recent figure available at the time).

76. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation and diesel rail (from the UK GHG Inventory), proportional to the CO_2 emission factors. The emission factors were calculated based on the relative passenger km proportions of diesel and electric rail provided by DfT for 2006-7.

Light Rail

77. The light rail factors were based on an average of factors for a range of UK tram and light rail systems, as detailed in Table 23.

78. Figures for the DLR, London Overground and Croydon Tramlink for 2008/09 based on figures from Transport for London's 2009 environmental report[26] adjusted to the new 2008 grid electricity CO_2 emission factor.

79. The factors for the Glasgow Underground, Midland Metro, Tyne and Wear Metro, the Manchester Metrolink and Supertram were based on annual electricity consumption and passenger km data provided by the network operators for 2005/6 and the new 2008 grid electricity CO_2 emission factor (for consistency with the DLR and Croydon Tramlink figures).

80. The average emission factor was estimated based on the relative passenger km of the four different rail systems (see Table 23).

81. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation, proportional to the CO_2 emission factors.

[25] Available from the ORR's website at: *http://www.rail-reg.gov.uk/upload/pdf/rolling-c9-environ.pdf*
[26] TfL, 2010. TfL's 2009 environmental report is available at: *http://www.tfl.gov.uk/corporate/about-tfl/publications/1478.aspx*

Table 23: CO_2 emission factors, electricity consumption and passenger km for different tram and light rail services

	Type	Electricity use, kWh/pkm	gCO_2e per passenger km				Million pkm
			CO_2	CH_4	N_2O	Total	
DLR (Docklands Light Rail)	Light Rail	0.146	79.2	0.033	0.498	76	316
Glasgow Underground	Light Rail	0.164	89.0	0.039	0.554	89.6	42
Midland Metro	Light Rail	0.135	73.3	0.032	0.456	73.8	51
Tyne & Wear Metro	Light Rail	0.233	126.1	0.056	0.785	127.0	313
London Overground	Light Rail	0.098	53.1	0.024	0.330	53.5	426
Croydon Tramlink	Tram	0.087	47.1	0.021	0.293	47.4	140
Manchester Metrolink	Tram	0.078	42.5	0.019	0.264	42.8	204
Nottingham Express Transit	Tram	No data	No data				No data
Supertram	Tram	0.350	189.6	0.084	1.180	190.8	42
Average*		**0.142**	**76.8**	**0.034**	**0.479**	**76.6**	**1535**

Notes: * Weighted by relative passenger km

London Underground

82. The London Underground rail factor is from Transport for London's 2009 environmental report (TfL, 2010)[27], corrected to the 2008 grid electricity CO_2 emission factor.

83. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation, proportional to the CO_2 emission factors.

Table 24: Updated 2010 GHG emission factors for passenger rail travel

Rail	gCO_2e per passenger km				Source*
	CO_2	CH_4	N_2O	Total	
International rail	15.0	0.010	0.090	15.1	Average figures from Eurostar for London to Brussels and Paris routes
National rail	53.4	0.060	3.050	56.5	Emission factor based on ORR (2009)
Light rail (and tram)	76.8	0.040	0.460	77.3	Average of UK light rail and tram systems
London underground	74.1	0.040	0.440	74.6	Transport for London's 2008 environmental report

Notes: * Source is for CO_2 data only; CH_4 and N_2O emissions have been estimated by other means.

[27] TfL, 2010. TfL's 2009 environmental report is available at: *http://www.tfl.gov.uk/corporate/about-tfl/publications/1478.aspx*

Direct Emissions from RoPax Ferries

84. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[28]. No new methodology or updated dataset has been identified for the 2010 GHG Conversion Factors.

85. The BFF study analysed data for mixed passenger and vehicle ferries (RoPax ferries) on UK routes supplied by PSA members. Data provided by the PSA operators included information by operating route on: the route/total distance, total passenger numbers, total car numbers, total freight units, total fuel consumptions.

86. From the information provided by the operators, figures for passenger km, tonne km and carbon dioxide emissions were calculated. Carbon dioxide emissions from ferry fuels were allocated between passengers and freight on the basis of tonnages transported, taking into account freight, vehicles and passengers. Some of the assumptions included in the analysis are presented in the following Table 25.

Table 25: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[29]
Average weight of passenger + luggage, total	0.100	MCA, 2007[29]
Average Freight Unit*, total	22.173	BFF, 2007[30]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[31]

Notes: Freight Unit includes the weight of the vehicle/container as well as the weight of the actual freight load

87. CO_2 emissions are allocated to passengers based on the weight of passengers + luggage + cars relative to the total weight of freight including freight vehicles/containers. For the data supplied by the 11 (out of 17) PSA operators this equated to just under 12% of the total emissions of the ferry operations. The emission factor for passengers was calculated from this figure and the total number of passenger km, and is presented in Table 26. A further split has been provided between foot-only passengers and passengers with cars in the 2009 GHG Conversion Factors, again on a weight allocation basis.

88. It is important to note that this emission factor is relevant only for ferries carrying passengers and freight and that emissions factors for passenger

[28] BFF, 2007. "Carbon emissions of mixed passenger and vehicle ferries on UK and domestic routes", Prepared by Best Foot Forward for the Passenger Shipping Association (PSA), November 2007.
[29] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=82A572A99504695B
[30] This is based on a survey of actual freight weights at 6 ferry ports. Where operator-specific freight weights were available these were used instead of the average figure.
[31] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006. Available at: http://www.dft.gov.uk/162259/162469/221412/221522/222944/coll_roadfreightstatistics2005in/rfs05comp.pdf

only ferries are likely to be significantly higher. No suitable dataset has yet been identified to enable the production of a ferry emission factor for passenger-only services (these services were excluded from the BFF, 2007 work for PSA).

89. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2008, proportional to the CO_2 emissions.

Table 26: 2010 GHG Conversion Factors for passengers on RoPax ferries

Large RoPax ferry	**gCO_2 per passenger km**			
	CO_2	CH_4	N_2O	Total
Foot Passengers	19.1	0.00	0.15	**19.3**
Car Passengers	132.2	0.00	1.02	**133.2**
Average	**115.2**	**0.00**	**0.88**	**116.1**

Indirect Emissions

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

90. Indirect emissions factors (EFs) for cars, vans, motorcycles, taxis, buses and ferries include only emissions resulting from the fuel cycle (i.e. production and distribution of the relevant transport fuel). These indirect emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect EFs for the relevant fuels from Annex 1 and the corresponding direct CO_2 EFs for vehicle types using these fuels in Annex 6.

Rail

91. Indirect EFs for international rail (Eurostar), light rail and the London Underground were derived using a simple ratio of the direct CO_2 EFs and the indirect EFs for grid electricity from Annex 3 and the corresponding direct CO_2 EFs for vehicle types using these fuels in Annex 6.

92. The EFs for national rail services are based on a mixture of emissions from diesel and electric rail. Indirect EFs were therefore calculated from corresponding estimates for diesel and electric rail combined using relative passenger km proportions of diesel and electric rail provided by DfT for 2006-7.

VI. Freight Surface Transport Emission Factors (Annex 7)

Summary of changes since previous update

93. Besides the addition of indirect emission factors (for emissions from the fuel production cycle), the main methodological changes and additions since the previous update include:

a. Emission factors for LPG and CNG vans have been split out and revised assumptions used to derive them;
b. Petrol and diesel van emission factor calculations now utilise updated speed-emission curve data;
c. Revised payload capacity assumptions have been used to derive figures per tonne-km for vans;
d. Petrol vans have been disaggregated into Class I, II and III vans.
e. Marine shipping emission factors have been updated with figures based on those from a recent report on GHG emissions from shipping by the International Maritime Organisation (IMO).

94. All other factors have also been updated with more recent data in the latest 2010 GHG Conversion Factors.

Direct Emissions from Heavy Goods Vehicles (HGVs)

95. A revised set of CO_2 conversion factors for road freight has been derived for different sizes of rigid and articulated HGVs with different load factors, using the same methodology as used in the 2008 and 2009 GHG Conversion Factors. The new factors for the 2010 GHG Conversion Factors are presented in Table 28 at the end of this section.

96. The factors are based on road freight statistics from the Department for Transport (DfT, 2009)[32] for Great Britain (GB), from a survey on different sizes of rigid and artic HGVs in the fleet in 2008. The statistics on fuel consumption figures (in miles per gallon) have been estimated by DfT from the survey data. For the GHG Conversion Factors these are combined with test data from the European ARTEMIS project showing how fuel efficiency, and hence CO_2 emissions, varies with vehicle load.

97. The miles per gallon (MPG) figures in Table 5.1 of DfT (2009) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the 2010 GHG Conversion Factors tables. Table 1.15 of DfT (2009) shows the percent loading factors are on average mostly between 40-60% in the UK HGV fleet. Figures from the ARTEMIS project show that the effect of load becomes proportionately greater for heavier classes of HGVs. In other words, the relative difference in fuel consumption between running an HGV completely empty or fully laden is greater for a large >33t HGV than it is for a small <7.5t HGV. From analysis of the ARTEMIS data, it was possible to derive the figures in Table 27 showing the change in CO_2 emissions for a vehicle completely empty (0% load) or fully laden (100% load) on a weight basis compared with the emissions at half-load (50% load). The data show the effect of load is symmetrical and largely independent of the HGVs Euro emission classification and type of drive cycle. So, for example, a >17t rigid HGV emits 18% more CO_2 per kilometre when fully laden and 18% less CO_2 per kilometre when empty relative to emissions at half-load.

[32] "Transport Statistics Bulletin: Road Freight Statistics 2009", October 2009, SB (09) 21. Available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/freight/goodsbyroad/roadfreightstatistics2009

Table 27: Change in CO_2 emissions caused by +/- 50% change in load from average loading factor of 50%

	Gross Vehicle Weight (GVW)	% change in CO_2 emissions
Rigid	<7.5t	± 8%
	7.5-17t	± 12.5%
	>17 t	± 18%
Articulated	<33t	± 20%
	>33t	± 25%

Source: EU-ARTEMIS project

98. Using these loading factors, the CO_2 factors derived from the DfT survey's miles per gallon data, each corresponding to different average states of HGV loading, were corrected to derive the 50% laden CO_2 factor shown for each class of HGV for the final factors presented in Table 28.

99. The loading factors in Table 27 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in Table 28. Because the effect of vehicle loading on CO_2 emissions is linear with load (according to the ARTEMIS data), then these factors can be linearly interpolated if a more precise figure on vehicle load is known. For example, an HGV running at 75% load would have a CO_2 factor halfway between the values for 50% and 100% laden factors.

100. It might be surprising to see that the CO_2 factor for a >17t rigid HGV is greater than for a >33t articulated HGV. However, these factors merely reflect the estimated miles per gallon figures from DfT statistics that consistently show worse mpg fuel efficiency, on average, for large rigid HGVs than large articulated HGVs once the relative degree of loading is taken into account. This might reflect the usage pattern for different types of HGVs where large rigid HGVs may spend more time travelling at lower, more congested urban speeds, operating at lower fuel efficiency than artic HGVs which spend more time travelling under higher speed, free-flowing traffic conditions on motorways where fuel efficiency is closer to optimum. Under the drive cycle conditions more typically experienced by large articulated HGVs, the CO_2 factors for large rigid HGVs may be lower than indicated in Table 28. Thus the factors in Table 28, linked to the DfT (2009) statistics on miles per gallon (estimated by DfT from the survey data) reflect each HGV class's typical usage pattern on the GB road network.

101. As well as CO_2 factors for 0%, 50% and 100% loading, CO_2 factors are shown for the average loading of each weight class of HGV in the GB fleet in 2008. These should be used as default values if the user does not know the loading factor to use and are based on the actual laden factors and mpg figures from the tables in DfT (2009).

102. UK average factors for all rigid and articulated HGVs are also provided in Table 28 if the user requires aggregate factors for these main classes of

HGVs, perhaps because the weight class of the HGV is not known. Again, these factors represent averages for the GB HGV fleet in 2008. These are derived directly from the mpg values for rigid and articulated HGVs in Table 5.1 of DfT (2009).

103. At a more aggregated level still are factors for all HGVs representing the average mpg for all rigid and articulated HGV classes in Table 5.1 of DfT (2009). This factor should be used if the user has no knowledge of or requirement for different classes of HGV and may be suitable for analysis of HGV CO_2 emissions in, for example, inter-modal freight transport comparisons.

104. The conversion factors in Table 28 are in distance units, that is to say, they enable CO_2 emissions to be calculated just from the distance travelled by the HGV in km multiplied by the appropriate conversion factor for the type of HGV and, if known, the extent of loading.

105. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO_2 factors in tonne km (tkm) units. Table 29 provides such factors for each weight class of rigid and articulated HGV, for all rigids and all artics and aggregated for all HGVs. These are derived from the 2008 fleet average gCO_2 per vehicle km factors in Table 28 and the average tonne freight per vehicle lifted by each HGV weight class. The average tonne freight lifted figures are derived from the tkm and vehicle km (vkm) figures given for each class of HGV in Tables 1.11 and 1.12, respectively, in DfT (2009). Dividing the tkm by the vkm figures gives the average tonnes freight lifted by each HGV class.

106. A tonne km (tkm) is the distance travelled multiplied by the weight of freight carried by the HGV. So, for example, an HGV carrying 5 tonnes freight over 100 km has a tkm value of 500 tkm. The CO_2 emissions are calculated from these factors by multiplying the number of tkm the user has for the distance and weight of the goods being moved by the CO_2 conversion factor in Table 29 for the relevant HGV class.

107. For the 2010 GHG Conversion Factors emission factors for CH_4 and N_2O have also been added for all HGV classes. These are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. CH_4 and N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for HGVs. These factors are also presented together with an overall total factor in Table 28 and Table 29.

Table 28: Emission factors per vehicle km for HGV road freight for 2010 GHG Conversion Factors

Body Type	Gross Vehicle Weight	% weight laden	gCO2e per vehicle km			
			CO_2	CH_4	N_2O	Total
Rigid	<7.5t	0%	527.6	0.30	5.87	533.8
		50%	573.5	0.30	5.87	579.7
		100%	619.4	0.30	5.87	625.6
		41% (UK average)	565.3	0.30	5.87	571.4
Rigid	7.5-17t	0%	671.3	0.40	7.79	679.4
		50%	767.1	0.40	7.79	775.3
		100%	863.0	0.40	7.79	871.2
		41% (UK average)	749.9	0.40	7.79	758.1
Rigid	>17t	0%	798.1	0.52	10.22	808.9
		50%	973.3	0.52	10.22	984.1
		100%	1148.5	0.52	10.22	1159.3
		53% (UK average)	983.8	0.52	10.22	994.5
All Rigid	**UK Average**	**52% (UK average)**	**829.0**	**0.44**	**8.61**	**838.1**
Articulated	<33t	0%	692.1	0.95	8.81	701.9
		50%	865.2	0.95	8.81	874.9
		100%	1038.2	0.95	8.81	1048.0
		45% (UK average)	847.9	0.95	8.81	857.6
Articulated	>33t	0%	697.9	1.09	10.20	709.2
		50%	930.6	1.09	10.20	941.9
		100%	1163.2	1.09	10.20	1174.5
		61% (UK average)	981.8	1.09	10.20	993.0
All Articulated	**UK Average**	**60% (UK average)**	**969.0**	**1.08**	**10.07**	**980.2**
All HGVs	**UK Average**	**58% (UK average)**	**895.2**	**0.77**	**9.30**	**905.3**

Notes: The % weight laden refers to the extent to which the vehicle is loaded to its maximum carrying capacity. So a 0% weight laden means the vehicle is empty. 100% weight laden means the vehicle is travelling with loads bringing the vehicle to its maximum weight carrying capacity.

Table 29: Emission factors per tonne km for HGV road freight (based on UK average vehicle loads in 2008) for 2010 GHG Conversion Factors

Body Type	Gross Vehicle Weight	% weight laden	UK av. goods carried per vehicle, tonnes	gCO2e per tonne km			
				CO_2	CH_4	N_2O	Total
Rigid	>3.5-7.5t	**41%**	**0.86**	659.5	0.35	6.85	666.7
Rigid	>7.5-17t	**41%**	**1.82**	412.4	0.22	4.28	416.9
Rigid	>17t	**53%**	**4.91**	200.3	0.11	2.08	202.5
All rigid	**UK average**	***52%***	***3.30***	**251.2**	**0.13**	**2.61**	**253.9**
Articulated	>3.5-33t	45%	**5.56**	152.6	0.17	1.59	154.4
Articulated	>33t	61%	**11.31**	86.8	0.10	0.90	87.8
All articulated	**UK average**	***60%***	***10.93***	**88.7**	**0.10**	**0.92**	**89.7**
ALL HGVs	**UK average**	***58%***	***7.20***	**124.3**	**0.13**	**1.91**	**126.3**

Direct Emissions from Light Goods Vehicles (LGVs)

108. Emission factors for light good vehicles (vans up to 3.5 tonnes), presented in Table 32, were calculated based on the emission factors per vehicle-km in the earlier section on passenger transport.

109. The typical / average load factors agreed with DfT that are used in the calculation of van emission factors per tonne km are presented in Table 30. These are based on a general survey of information available on typical van payload capacities, supplemented with quantitative assessment of the van database used by AEA in variety of policy assessment for DfT. The resulting typical payload capacities are significantly lower than the previous estimates, resulting in almost 60% higher emission factors per tonne-km in the 2010 GHG Conversion Factors than for the 2009 update.

Table 30: Typical van freight capacities

High		**GVW**			
N1 Class	**Payload Capacity**	**Low**	**High**	**Average**	**%Payload**
I	0.50	0.90	1.10	1.00	50%
II	0.90	1.40	1.75	1.58	57%
III	1.50	1.80	3.50	2.65	57%
Low		**GVW**			
N1Class	**Payload Capacity**	**Low**	**High**	**Average**	**%Payload**
I	0.40	0.90	1.10	1.00	40%
II	0.50	1.40	1.75	1.58	32%
III	1.00	1.80	3.50	2.65	38%
Average		**GVW**			
N1Class	**Payload Capacity**	**Low**	**High**	**Average**	**%Payload**
I	0.45	0.90	1.10	1.00	45%
II	0.70	1.40	1.75	1.58	44%
III	1.25	1.80	3.50	2.65	47%

110. The average load factors assumed for different vehicle types are summarised in Table 31, on the basis of DfT statistics from a survey of company owned vans.

Table 31: Utilisation of vehicle capacity by company-owned LGVs: annual average 2003 – 2005 (proportion of total vehicle kilometres travelled)

	Utilisation of vehicle volume capacity				
Average van loading	**0-25%**	**26-50%**	**51-75%**	**76-100%**	**Total**
Mid point for van loading ranges	*12.5%*	*37.5%*	*62.5%*	*87.5%*	
Proportion of vehicles in the loading range					
Up to 1.8 tonnes	45%	25%	18%	12%	**100%**
1.8 – 3.5 tonnes	36%	28%	21%	15%	**100%**
All LGVs	38%	27%	21%	14%	**100%**
Estimated weighted average % loading					
Up to 1.8 tonnes					**36.8%**
1.8 – 3.5 tonnes					**41.3%**
All LGVs					**40.3%**

Notes: Based on information from Table 24, TSG/UW, 2008[33]

111. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O have also been updated for all van classes. These are based on the emission factors from the UK GHG Inventory (managed by AEA), which have been updated in 2010 following the development of revised speed-emission curves. N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for diesel vans.

112. Emission factors per tonne km (Table 32) were calculated from the average load factors for the different weight classes in combination with the average freight capacities of the different vans in Table 30 and the earlier emission factors per vehicle-km in earlier Table 19.

Table 32: Emission factors freight carried on vans for 2010 GHG Conversion Factors

Van fuel	**Van size**	**gCO_2e per tonne km**			
		CO_2	**CH_4**	**N_2O**	**Total**
Petrol (Class I)	Up to 1.305 tonne	1173.5	1.45	5.05	1180.0
Petrol (Class II)	1.305 to 1.740 tonne	820.6	0.93	3.25	824.8
Petrol (Class III)	Over 1.740 tonne	496.0	0.50	3.55	500.1
Petrol (average)	**Up to 3.5 tonne**	**563.7**	**0.59**	**3.55**	**567.9**
Diesel (Class I)	Up to 1.305 tonne	949.5	0.38	6.46	956.4
Diesel (Class II)	1.305 to 1.740 tonne	873.9	0.24	5.94	880.0
Diesel (Class III)	Over 1.740 tonne	522.0	0.12	3.55	525.6
Diesel (average)	**Up to 3.5 tonne**	**588.0**	**0.15**	**4.00**	**592.2**
LPG (average)	Up to 3.5 tonne	617.4	1.21	4.54	623.2
CNG (average)	Up to 3.5 tonne	558.6	2.95	4.54	566.1
Average		**586.5**	**0.17**	**3.97**	**590.7**

Direct Emissions from Rail Freight

113. For the 2009 GHG Conversion Factors, the previous rail freight emission factor of 21 gCO_2 per tonne km has been updated using information from Table 9.1 of the Office of the Rail Regulator's National rail trends for 2007-8 (ORR, 2009)[34]. This factor is presented in Table 33. In the absence of an update to this figure when the 2010 GHG Conversion Factors were being developed this figure remains unchanged.

114. The factor can be expected to vary with rail traffic route, speed and train weight. Freight trains are hauled by electric and diesel locomotives, but the vast majority of freight is carried by diesel rail and correspondingly CO_2 emissions from diesel rail freight are over 90% of the total (ORR, 2009).

[33] TSG/UW, 2008. "Using official data sources to analyse the light goods vehicle fleet and operations in Britain" a report by Transport Studies Group, University of Westminster, London, November 2008 , . Available at: *http://www.greenlogistics.org/SiteResources/61debf21-2b93-4082-ab15-84787ab75d26_LGV%20activity%20report%20(final)%20November%202008.pdf*
[34] Available from the ORR's website at: *http://www.rail-reg.gov.uk/upload/pdf/rolling-c9-environ.pdf*

115. Traffic-, route- and freight-specific factors are not currently available, but would present a more appropriate means of comparing modes (e.g. for bulk aggregates, intermodal, other types of freight).

116. The rail freight CO_2 factor will be reviewed and updated if data become available relevant to rail freight movement in the UK.

117. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for diesel rail from the UK GHG Inventory, proportional to the CO_2 emissions. The emission factors were calculated based on the relative passenger km proportions of diesel and electric rail provided by DfT for 2006-7 in the absence of more suitable tonne km data for freight.

Table 33: Emission factors for rail freight for 2009 GHG Conversion Factors

	gCO_2e per tonne km			
	CO_2	**CH_4**	**N_2O**	**Total**
Rail Freight	28.5	0.030	3.060	31.6

Direct Emissions from RoPax Ferry Freight

118. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA). No new methodology or updated dataset has been identified for the 2010 GHG Conversion Factors.

119. The BFF study analysed data for mixed passenger and vehicle ferries (RoPax ferries) on UK routes supplied by PSA members. Data provided by the PSA operators included information by operating route on: the route/total distance, total passenger numbers, total car numbers, total freight units, total fuel consumptions.

120. From the information provided by the operators, figures for passenger km, tonne km and carbon dioxide emissions were calculated. Carbon dioxide emissions from ferry fuels were allocated between passengers and freight on the basis of tonnages transported, taking into account freight, vehicles and passengers. Some of the assumptions included in the analysis are presented in the following Table 34.

Table 34: Assumptions used in the calculation of ferry emission factors

Assumption	**Weight, tonnes**	**Source**
Average passenger car weight	1.250	MCA, 2007[35]
Average weight of passenger + luggage, total	0.100	MCA, 2007[35]
Average Freight Unit*, total	22.173	BFF, 2007[36]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[37]

[35] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=82A572A99504695B
[36] This is based on a survey of actual freight weights at 6 ferry ports. Where operator-specific freight weights were available these were used instead of the average figure.
[37] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006. Available at: http://www.dft.gov.uk/162259/162469/221412/221522/222944/coll_roadfreightstatistics2005in/rfs05comp.pdf

Notes: Freight Unit includes the weight of the vehicle/container as well as the weight of the actual freight load

121. CO_2 emissions are allocated to freight based on the weight of freight (including freight vehicles/containers) relative to the total weight passengers + luggage + cars. For the data supplied by the 11 (out of 17) PSA operators this equated to just over 88% of the total emissions of the ferry operations. The emission factor for freight was calculated from this figure and the total number of tonne km (excluding the weight of the freight vehicle/container), and is presented in Table 35.

122. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2007, proportional to the CO_2 emissions.

Table 35: 2010 GHG Conversion Factors for freight on RoPax ferries

	gCO_2e per tonne km			
	CO_2	CH_4	N_2O	Total
Large RoPax ferry	384.3	0.12	2.95	387.4

Direct Emissions from Other Marine Freight Transport

123. The methodology/source of the emissions factors for other marine freight transport has been entirely updated for the 2010 GHG Conversion Factors, with the exception of RoPax ferries.

124. CO_2 emission factors for the other representative ships (apart from RoPax ferries discussed above) are now based on information from Table 9-1 of the IMO (2009)[38] report on GHG emissions from ships.

125. Previously figures on the typical loading factors for different vessels were not available in the public domain. The emission factors gCO_2/tonne km freight from earlier updates to the Defra/DECC GHG Conversion Factors were therefore based on the assumption of 100% loading and so were underestimates of the actual situation. The new 2010 factors presented in Table 36 therefore represent a significant improvement and are the best available figures. These figures represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.

126. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2008, proportional to the CO_2 emissions.

[38] "PREVENTION OF AIR POLLUTION FROM SHIPS, Second IMO GHG Study 2009. Update of the 2000 IMO GHG Study, Final report covering Phase 1 and Phase 2", Table 9-1 – Estimates of CO_2 efficiency for cargo ships, International Maritime Organisation, 2009. Available at: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D26046/4-7.pdf

Table 36: Emission factors for marine freight transport for 2010 GHG Conversion Factors

Shipping Vessel Category	Size Class	Average Loading %	gCO_2e per tonne km			
			CO_2	CH_4	N_2O	Total
Crude tanker (oil)	200,000+ dwt	48%	2.9	0.00	0.02	2.9
Crude tanker (oil)	120,000–199,999 dwt	48%	4.4	0.00	0.03	4.4
Crude tanker (oil)	80,000–119,999 dwt	48%	5.9	0.00	0.05	6.0
Crude tanker (oil)	60,000–79,999 dwt	48%	7.5	0.00	0.06	7.6
Crude tanker (oil)	10,000–59,999 dwt	48%	9.1	0.00	0.07	9.2
Crude tanker (oil)	0–9999 dwt	48%	33.3	0.01	0.26	33.6
Crude tanker (oil)	**Average**	**48%**	**4.5**	**0.00**	**0.03**	**4.5**
Products tanker	60,000+ dwt	55%	5.7	0.00	0.04	5.7
Products tanker	20,000–59,999 dwt	55%	10.3	0.00	0.08	10.4
Products tanker	10,000–19,999 dwt	50%	18.7	0.01	0.14	18.9
Products tanker	5000–9999 dwt	45%	29.2	0.01	0.22	29.4
Products tanker	0–4999 dwt	45%	45.0	0.01	0.35	45.4
Products tanker	**Average**	**54%**	**8.9**	**0.00**	**0.07**	**9.0**
Chemical tanker	20,000+ dwt	64%	8.4	0.00	0.06	8.5
Chemical tanker	10,000–19,999 dwt	64%	10.8	0.00	0.08	10.9
Chemical tanker	5000–9999 dwt	64%	15.1	0.00	0.12	15.2
Chemical tanker	0–4999 dwt	64%	22.2	0.01	0.17	22.4
Chemical tanker	**Average**	**64%**	**10.2**	**0.00**	**0.08**	**10.3**
LPG tanker	50,000+ m3	48%	9.0	0.00	0.07	9.1
LPG tanker	0–49,999 m3	48%	43.5	0.01	0.33	43.8
LNG tanker	200,000+ m3	48%	9.3	0.00	0.07	9.4
LNG tanker	0–199,999 m3	48%	14.5	0.00	0.11	14.6
LNG tanker	**Average**	**48%**	**11.4**	**0.00**	**0.09**	**11.5**
Bulk carrier	200,000+ dwt	50%	2.5	0.00	0.02	2.5
Bulk carrier	100,000–199,999 dwt	50%	3.0	0.00	0.02	3.0
Bulk carrier	60,000–99,999 dwt	55%	4.1	0.00	0.03	4.1
Bulk carrier	35,000–59,999 dwt	55%	5.7	0.00	0.04	5.7
Bulk carrier	10,000–34,999 dwt	55%	7.9	0.00	0.06	8.0
Bulk carrier	0–9999 dwt	60%	29.2	0.01	0.22	29.4
Bulk carrier	**Average**	**51%**	**3.5**	**0.00**	**0.03**	**3.5**
General cargo	10,000+ dwt	60%	11.9	0.00	0.09	12.0
General cargo	5000–9999 dwt	60%	15.8	0.01	0.12	15.9
General cargo	0–4999 dwt	60%	13.9	0.00	0.11	14.0
General cargo	10,000+ dwt 100+ TEU	60%	11.0	0.00	0.08	11.1
General cargo	5000–9999 dwt 100+ TEU	60%	17.5	0.01	0.13	17.6
General cargo	0–4999 dwt 100+ TEU	60%	19.8	0.01	0.15	20.0
General cargo	**Average**	**60%**	**13.1**	**0.00**	**0.10**	**13.2**
Refrigerated cargo	**All dwt**	**50%**	**12.9**	**0.00**	**0.10**	**13.0**
Container	8000+ TEU	70%	12.5	0.00	0.10	12.6
Container	5000–7999 TEU	70%	16.6	0.01	0.13	16.7
Container	3000–4999 TEU	70%	16.6	0.01	0.13	16.7
Container	2000–2999 TEU	70%	20.0	0.01	0.15	20.2
Container	1000–1999 TEU	70%	32.1	0.01	0.25	32.4
Container	0–999 TEU	70%	36.3	0.01	0.28	36.6
Container	**Average**	**70%**	**15.9**	**0.01**	**0.12**	**16.1**
Vehicle transport	4000+ CEU	70%	32.0	0.01	0.25	32.3
Vehicle transport	0–3999 CEU	70%	57.6	0.02	0.44	58.1
Vehicle transport	**Average**	**70%**	**38.1**	**0.01**	**0.29**	**38.4**
Ro–Ro ferry	2000+ LM	70%	49.5	0.02	0.38	49.9
Ro–Ro ferry	0–1999 LM	70%	60.3	0.02	0.46	60.8
Ro–Ro ferry	**Average**	**70%**	**51.0**	**0.02**	**0.39**	**51.4**

Source: Based on data from Table 9-1, IMO (2009). Average emission factors for shipping vessel categories have been estimated from the IMO (2009) dataset by AEA by weighting individual size classes by the corresponding total transport work done by that ship class (also provided in the same table)..

Notes:
TEU = Twenty-Foot Equivalent Units (intermodal shipping container)
CEU = Car Equivalent Units
LM = Lane Meters
m3 = volume in cubic meters

Indirect Emissions

Vans, HGVs, Ferries and Ships

127. Indirect emissions factors (EFs) for vans, HGVs, ferries and ships include only emissions resulting from the fuel cycle (i.e. production and distribution of the relevant transport fuel). These indirect emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect EFs for the relevant fuels from Annex 1 and the corresponding direct CO_2 EFs for vehicle types using these fuels in Annex 7.

Rail

128. The EFs for freight rail services are based on a mixture of emissions from diesel and electric rail. Indirect EFs were therefore calculated in a similar way to the other freight transport modes, except from combining indirect EFs for diesel and electricity into a weighted average for freight rail using relative CO_2 emissions from traction energy for diesel and electric freight rail provided in Table 9.1 of ORR (2009)[39].

[39] Available from the ORR's website at: http://www.rail-reg.gov.uk/upload/pdf/rolling-c9-environ.pdf

VII. Aviation Emission Factors (Annex 6 and Annex 7)

Summary of changes since previous update

129. With the exception of the addition of indirect emission factors, there have been no methodological updates to the aviation emission factors methodology. Changes for the direct emission factors in the 2010 GHG Conversion Factors are therefore limited to updates to the core datasets.

Passenger Air Transport Direct CO_2 Emission Factors (Annex 6)

130. Following feedback received on the emission factors currently used in the 2007 Act on CO_2 calculator and 2007 GHG Conversion Factors[40] datasets and discussions with DfT and the aviation industry the assumptions used in calculating average emission factors for flights were re-evaluated for the 2008 update. The same methodological approach has been followed for the 2009 and 2010 GHG Conversion Factors.

131. The updated average factors (presented at the end of this section) have been calculated in the same basic methodology as previously, using the aircraft specific fuel consumption/emission factors from AEIG (2006)[41]. A full summary of the expanded representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 37. Key features of the calculation methodology, data and assumptions include:
    a. A wide variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights.
    b. Average seating capacities, load factors and proportions of passenger km by the different aircraft types have all been calculated from the UK CAA (Civil Aviation Authority) statistics for UK registered airlines for the year 2008 (the latest available complete dataset);
    c. Average load factor for short-haul flights is the average for all European international flights calculated from CAA statistics for the selected aircraft.
    d. Average load factor for long-haul flights is the average for all non-European international flights calculated from CAA statistics for the selected aircraft;
    e. Freight transported on passenger services has also been taken into account (with the approach taken summarised in the following section). Accounting for freight makes a significant difference to long-haul factors.
    f. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

[40] Defra GHG conversion factors for the Company Reporting Guidelines, 2007. Also used in the government's 'Act on CO_2' calculator.
[41] EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (2006), available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf

Table 37: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2010

	Average No. Seats	Average Load Factor	Proportion of passenger km
Domestic Flights			
Boeing 737-400	142	59%	14%
Boeing 737-700	154	69%	10%
Airbus A319/A320	158	67%	55%
BAE Jetstream 41	29	50%	4%
BAE 146	102	50%	1%
Dash 8 Q400	75	63%	16%
Total	***136***	***64%***	***100%***
Short-haul Flights			
Boeing 737-400	142	77%	12%
Boeing 737-800	189	86%	14%
Airbus A319/A320	158	81%	50%
Boeing 757	224	86%	23%
Total	***176***	***82%***	***100%***
Long-haul Flights			
Boeing 747-400	339	79%	47%
Boeing 767	238	82%	14%
Boeing 777	236	74%	19%
Airbus A330	311	84%	7%
Airbus A340	294	73%	14%
Total	***298***	***78%***	***100%***

Notes: Figures have been calculated from 2008 CAA statistics for UK registered airlines for the different aircraft types.

Taking Account of Freight

132. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers and their luggage, as well as freight. The CAA data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights. In fact, the quantity of freight carried on scheduled long-haul passenger flights is nearly 5 times higher than the quantity of freight carried on scheduled long-haul cargo services. The apparent importance of freight movements by passenger services creates a complicating factor in calculating emission factors. Given the significance of air freight transport on passenger services there were good arguments for developing a method to divide the CO_2 between passengers and freight, which was developed for the 2008 update, which has also been applied in subsequent updates.

133. The CAA data provides a split of tonne km for freight and passengers (plus luggage) by airline for both passenger and cargo services. This data may be used as a basis for an allocation methodology. There are essentially three options, with the resulting emission factors presented in Table 38:
    a. ***No Freight Weighting*****:** Assume all the CO_2 is allocated to passengers on these services. ;
    b. ***Freight Weighting Option 1*****:** Use the CAA tonne km (tkm) data directly to apportion the CO_2 ***between passengers and freight***. However, in this case the derived emission factors for freight are significantly higher than those derived for dedicated cargo services using similar aircraft.
    c. ***Freight Weighting Option 2:*** Use the CAA tonne km data modified to treat freight on a more equivalent /consistent basis to dedicated cargo services. This takes into account the additional weight of equipment

specific to passenger services (e.g. seats, galleys, etc) in the calculations.

Table 38: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2010 GHG Conversion Factors

Freight Weighting:	None		Option 1: Direct		Option 2: Equivalent	
Mode	Passenger tkm % of total	gCO_2 /pkm	Passenger tkm % of total	gCO_2 /pkm	Passenger tkm % of total	gCO_2 /pkm
Domestic flights	100.0%	171.9	99.7%	171.5	99.7%	171.5
Short-haul flights	100.0%	97.6	99.4%	97.0	99.4%	97.0
Long-haul flights	100.0%	128.4	71.7%	92.0	88.1%	113.2

134. The basis of the freight weighting **Option 2** is to take into account of the supplementary equipment (such as seating, galley) and other weight for passenger aircraft compared to dedicated cargo aircraft in the allocation. The Boeing 747 cargo configurations account for the vast majority of long-haul freight services (and over 90% of all tkm for dedicated freight services). In comparing the freight capacities from BA World Cargo's website[42] of the cargo configuration (125 tonnes) compared to passenger configurations (20 tonnes) we may assume that the difference represents the tonne capacity for passenger transport. This 105 tonnes will include the weight of passengers and their luggage (around 100 kg per passenger according to IATA), plus the additional weight of seating, the galley, and other airframe adjustments necessary for passenger service operations. For an average seating capacity of around 350 passengers, this means that the average weight per passenger seat is just over 300 kg. This is around 3 times the weight per passenger and their luggage alone. In the **Option 2** methodology this factor of 3 is used to upscale the CAA passenger tonne km data, increasing this as a percentage of the total tonne km – as shown in Table 38.

135. It does not appear that there is a distinction made (other than in purely practical size/bulk terms) in the provision of air freight transport services in terms of whether something is transported by dedicated cargo service or on a passenger service. The related calculation of freight emission factors (discussed in a later section) leads to very similar emission factors for both passenger service freight and dedicated cargo services for domestic and short-haul flights. This is also the case for long-haul flights under freight weighting **Option 2**, whereas under **Option 1** the passenger service factors are substantially higher than those calculated for dedicated cargo services. It therefore seems preferable to treat freight on an equivalent basis by utilising freight weighting **Option 2**.

136. **Option 2** was selected as the preferred methodology to allocate emissions between passengers and freight for the 2008, 2009 and 2010 GHG Conversion Factors.

'Real-World' Uplift

---

42 British Airways World Cargo provides information on both passenger and dedicated freight services at: http://www.baworldcargo.com/configs/

137. As discussed, the developed emissions factors are based on typical aircraft fuel burn over illustrative trip distances listed in the EMEP/CORINAIR Emissions Inventory Guidebook (EIG 2007)[43]. This information is combined with data from the Civil Aviation Authority (CAA) on average aircraft seating capacity, loading factors, and annual passenger-km and aircraft-km for 2006 (most recent full-year data available). However, the provisional evidence to date suggests an uplift in the region of 10-12% to climb/cruise/descent factors derived by the CORINAIR approach is appropriate in order to ensure consistency with estimated UK aviation emissions as reported in line with the UN Framework on Climate Change (UNFCCC), covering UK domestic flights and departing international flights.

138. The emissions reported under UNFCCC are based on bunker fuel consumption and are closely related to fuel on departing flights. The 10% uplift is therefore based on comparisons of national aviation fuel consumption from this reported inventory, with detailed bottom up calculations in DfT modelling along with the similar NAEI approach, which both use detailed UK activity data (by aircraft and route) from CAA, and the CORINAIR fuel consumption approach. Therefore for the 2008 GHG Conversion Factors an uplift of 10% is included in the emission factors in all the presented tables, based on provisional evidence. No further evidence has since emerged, so the same uplift was applied in the 2009 and 2010 GHG Conversion Factors.

139. The CORINAIR uplift is separate to the assumption that Great Circle Distances (GCD) used in the calculation of emissions should be increased by 9% to allow for sub-optimal routeing and stacking at airports during periods of heavy congestion. This GCD uplift factor is **NOT** included in the presented emission factors, and must be applied to the Great Circle Distances when calculating emissions.

140. It should be noted that work will continue to determine a more robust reconciliation and this will be accounted for in future versions of these factors.

141. The revised average emission factors for aviation are presented in Table 39. The figures in Table 39 include the uplift of 10% to correct underestimation of emissions by the CORINAIR methodology (discussed above) and DO NOT include the 9% uplift for Great Circle distance, which needs to be applied separately (and is discussed separately later).

[43] Available at the EEA website at: *http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851vs2.4.pdf* and *http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851_annex.zip*

Table 39: Revised average CO_2 emission factors for passenger flights for 2010

Mode	2007 update		2008 update		2009 update		Revised factors for 2010	
	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm
Domestic flights	65.0%	158.0	66.3%	175.3	65.2%	171.0	64.5%	171.5
Short-haul flights	65.0%	130.4	81.2%	98.3	80.9%	98.3	82.4%	97.0
Long-haul flights	79.7%	105.6	78.1%	110.6	77.8%	112.2	78.2%	113.2

Seating Class Factors

142. The efficiency of aviation per passenger km is influenced by not only the technical performance of the aircraft fleet, but also by the occupancy/load factor of the flight. Different airlines provide different seating configurations that change the total number of seats available on similar aircraft. Premium priced seating, such as in First and Business class, takes up considerably more room in the aircraft than economy seating and therefore reduces the total number of passengers that can be carried. This in turn raises the average CO_2 emissions per passenger km.

143. At the moment there is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, for the 2008 update a review was carried out of the seating configurations from a selection of 16 major airlines[44] and average seating configuration information from Boeing and Airbus websites. 24 different aircraft variants were considered including those from the Boeing 737, 747, 757, 767 and 777 families, and the Airbus A319/320, A330 and A340 families. These represent a mix of the major representative short-, medium- and long- haul aircraft types. The different seating classes were assessed on the basis of the space occupied relative to an economy class seat for each of the airline and aircraft configurations. This evaluation was used to form a basis for the seating class based emission factors provided in Table 40. Information on the seating configurations including seating numbers, pitch, width and seating plans were obtained either directly from the airline websites or from specialist websites that had already collated such information for most of the major airlines (e.g. SeatGuru[45], UK-AIR.NET[46], FlightComparison[47] and SeatMaestro[48]).

144. For long-haul flights, the relative space taken up by premium seats can vary by a significant degree between airlines and aircraft types. The variation is at its most extreme for First class seats, which can account for from 3 to over

[44] The list of airline seating configurations was selected on the basis of total number of passenger km from CAA statistics, supplemented by additional non-UK national carriers from some of the most frequently visited countries according to the UK's International Passenger Survey. The list of airlines used in the analysis included: BA, Virgin Atlantic, Continental Airlines, Air France, Cathay Pacific, Gulf Air, Singapore Airlines, Emirates, Lufthansa, Iberia, Thai Airways, Air New Zealand, Air India, American Airlines, Air Canada, and United Airlines.
[45] See: http://www.seatguru.com/
[46] See: http://www.uk-air.net/seatplan.htm
[47] *See: http://www.flightcomparison.co.uk/flightcomparison/home/legroom.aspx*
[48] *See: http://www.seatmaestro.com/airlines.html*

6 times[49] the space taken up by the basic economy seating. Table 40 shows the seating class based emission factors, together with the assumptions made in their calculation. An indication is also provided of the typical proportion of the total seats that the different classes represent in short- and long-haul flights. The effect of the scaling is to lower the economy seating emission factor in relation to the average, and increase the business and first class factors.

Table 40: Seating class based CO_2 emission factors for passenger flights for 2010

Flight type	Size	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**64.5%**	**171.5**	**1.00**	**100%**	**100%**
Short-haul	**Average**	**82.4%**	**97.0**	**1.05**	**100%**	**100%**
	Economy class	82.4%	92.4	1.00	95%	90%
	First/Business class	82.4%	138.7	1.50	143%	10%
Long-haul	**Average**	**78.2%**	**113.2**	**1.37**	**100%**	**100%**
	Economy class	78.2%	82.6	1.00	73%	80%
	Economy+ class	78.2%	132.2	1.60	117%	5%
	Business class	78.2%	239.6	2.90	212%	10%
	First class	78.2%	330.5	4.00	292%	5%

Freight Air Transport Direct CO_2 Emission Factors (Annex 7)

145. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers and their luggage, as well as freight.

146. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2009). This data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts for 69% of all long-haul air freight transport. How this freight carried on long-haul passenger services is treated has a significant effect on the average emission factor for all freight services.

147. The next section describes the calculation of emission factors for freight carried by cargo aircraft **only** and then the following sections examine the impact of freight carried by passenger services and the overall average for all air freight services.

Emission Factors for Dedicated Air Cargo Services

148. Following the further development of emission factors for passenger flights and discussions with DfT and the aviation industry, revised average emission factors for dedicated air cargo were developed for the 2008 update and have been updated using the same methodology for the 2009 and for the 2010 GHG Conversion Factors - presented in Table 41. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied to the CORINAIR based factors.

[49] For the first class sleeper seats/beds frequently used in long-haul flights.

Table 41: Revised average CO_2 emission factors for dedicated cargo flights for 2010

Mode	2008 update		2009 update		Revised factors for 2010	
	Load Factor%	$kgCO_2$ /tkm	Load Factor%	$kgCO_2$ /tkm	Load Factor%	$kgCO_2$ /tkm
Domestic flights	56.4%	1.85	55.5%	1.88	51.3%	1.93
Short-haul flights	59.2%	1.32	56.0%	1.42	54.8%	1.53
Long-haul flights	65.4%	0.60	67.3%	0.58	65.3%	0.61

149. The updated factors have been calculated in the same basic methodology as for the passenger flights, using the aircraft specific fuel consumption /emission factors from EIG (2007)[50]. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 42. The key features of the calculation methodology, data and assumptions for the 2008, 2009 and 2010 GHG Conversion Factors include:
    a. A wide variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights;
    b. Average freight capacities, load factors and proportions of tonne km by the different airlines/aircraft types have been calculated from CAA (Civil Aviation Authority) statistics for UK registered airlines for the year 2008 (the latest available complete dataset).
    c. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

Table 42: Assumptions used in the calculation of revised average CO_2 emission factors for dedicated cargo flights for the 2010 GHG Conversion Factors

	Average Cargo Capacity, tonnes	Average Load Factor	Proportion of tonne km
Domestic Flights			
Boeing 737-300	16.0	54%	61.5%
Boeing 757-200	24.1	56%	8.1%
BAE ATP	8.2	45%	8.2%
Lockheed L188	14.0	41%	6.3%
BAE 748	6.3	20%	0.1%
BAE 146-200/QT	11.8	47%	15.8%
Total	***15.2***	***51%***	***100.0%***
Short-haul Flights			
Boeing 737-300	16.0	54%	0.3%
Boeing 757-200	24.1	57%	89.3%
BAE ATP	8.2	36%	1.7%
Lockheed L188	14.0	45%	4.7%
Boeing 747-200F	94.5	27%	4.0%
Total	***26.1***	***55%***	***100.0%***
Long-haul Flights			
Boeing 747-400F	112.6	71%	52.6%
Boeing 747-200F	111.6	59%	33.4%
Boeing 757-200	25.8	59%	14.1%
Total	***100.1***	***65%***	***100.0%***

Notes: Figures have been calculated from 2008 CAA statistics for UK registered airlines for different aircraft.

[50] Available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851vs2.4.pdf and http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851_annex.zip

Emission Factors for Freight on Passenger Services

150. The CAA data provides a similar breakdown for freight on passenger services as it does for cargo services. As already discussed earlier, the statistics give tonne-km data for passengers and for freight. This information has been used in combination with the assumptions for the earlier calculation of passenger emission factors to calculate the respective total emission factor for freight carried on passenger services. These emission factors are presented in the following Table 43 with the two different allocation options for long-haul services.

Table 43: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2010 GHG Conversion Factors

Freight Weighting:	% Total Freight tkm		Option 1: Direct		Option 2: Equivalent	
Mode	Passenger Services (PS)	Cargo Services	PS Freight tkm, % total	Overall $kgCO_2$ /tkm	PS Freight tkm, % total	Overall $kgCO_2$ /tkm
Domestic flights	5.5%	94.5%	0.3%	1.96	0.3%	1.96
Short-haul flights	22.2%	77.8%	0.6%	1.47	0.6%	1.47
Long-haul flights	69.1%	30.9%	28.3%	1.46	11.9%	0.61

151. It is useful to compare the emission factors calculated for freight carried on passenger services (in Table 43) with the equivalent factors for freight carried on dedicated cargo services (in Table 41). The comparison shows that in the case of domestic and European services, the CO_2 emitted per tonne-km of either cargo or combined cargo and passengers are very similar. In other words, freight transported on a passenger aircraft could be said to result in similar carbon dioxide emissions as if the same freight was carried on a cargo aircraft. In the case of other international flights, the factor in Table 43 is more than twice the comparable figure given in Table 41 for **Option 1**, but is the same as the figure for **Option 2**. This would mean that under **Option 1**, freight transported on a passenger aircraft could be said to result in over two times as much CO_2 being emitted than if the same freight was carried on a cargo aircraft. This is counter-intuitive since freight carriage on long-haul services is used to help maximise the overall efficiency of the service. Furthermore, CAA statistics do include excess passenger baggage in the 'freight' category, which would under **Option 1** also result in a degree of under-allocation to passengers. **Option 2** therefore appears to provide the more reasonable means of allocation.

152. **Option 2** was selected as the preferred methodology for freight allocation for the 2008 update. The same methodology has been applied in the 2009 and 2010 GHG Conversion Factors and is included in all the presented emission factors.

Average Emission Factors for All Air Freight Services

153. The following Table 44 presents the final average air freight emission factors for all air freight for the 2010 GHG Conversion Factors. The emission factors have been calculated from the individual factors for freight carried on passenger and dedicated freight services, weighted according to their

respective proportion of the total air freight tonne km. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied to the CORINAIR based factors. The figures DO NOT include the 9% uplift for Great Circle distances, which needs to be applied separately (and is discussed separately later).

Table 44: Final average CO_2 emission factors for all air freight for 2010 GHG Conversion Factors

	% Total Air Freight tkm		All Air Freight
Mode	**Passenger Services**	**Cargo Services**	**$kgCO_2/tkm$**
Domestic flights	5.5%	94.5%	1.96
Short-haul flights	22.2%	77.8%	1.47
Long-haul flights	69.1%	30.9%	0.61

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

154. Emission factors for CH_4 (methane) were calculated from the CO_2 emission factors on the basis of the relative proportions of total CO_2 and CH_4 emissions from the UK GHG inventory for 2008 (see Table 45). The resulting air transport emission factors for the 2010 GHG Conversion Factors are presented in Table 46 for passengers and Table 47 for freight.

Table 45: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2008

2008	**CO_2**		**CH_4**		**N_2O**	
	Mt CO_2e	**% Total CO_2e**	**Mt CO_2e**	**% Total CO_2e**	**Mt CO_2e**	**% Total CO_2e**
Aircraft - domestic	2.18	98.95%	0.00	0.07%	0.02	0.97%
Aircraft - international	34.10	99.02%	0.00	0.01%	0.34	0.97%

Emissions of N_2O

155. Similarly to CH_4, emission factors for N_2O (nitrous oxide) were calculated from the CO_2 emission factors on the basis of the relative proportions of total CO_2 and N_2O emissions from the UK GHG inventory for 2008 (see Table 45). The resulting air transport emission factors for the 2010 GHG Conversion Factors are presented in Table 46 for passengers and Table 47 for freight.

Table 46: Final average CO_2, CH_4 and N_2O emission factors for all air passenger transport for 2010 GHG Conversion Factors

Air Passenger		CO_2	CH_4	N_2O	Total GHG
Mode	**Seating Class**	**gCO_2/pkm**	**gCO_2e/pkm**	**gCO_2e/pkm**	**gCO_2e/pkm**
Domestic flights	**Average**	**64.5%**	**171.5**	**0.13**	**1.69**
Short-haul flights	**Average**	**82.4%**	**97.0**	**0.01**	**0.95**
	Economy	82.4%	92.4	0.01	0.91
	First/Business	82.4%	138.7	0.01	1.36
Long-haul flights	**Average**	**78.2%**	**113.2**	**0.01**	**1.11**
	Economy	78.2%	82.6	0.00	0.81
	Economy+	78.2%	132.2	0.01	1.30
	Business	78.2%	239.6	0.01	2.36
	First	78.2%	330.5	0.02	3.25

Notes: Totals may vary from the sums of the components due to rounding in the more detailed dataset.

Table 47: Final average CO_2, CH_4 and N_2O emission factors for air freight transport for 2010 GHG Conversion Factors

Air Freight	CO_2	CH_4	N_2O	Total GHG
Mode	**$kgCO_2/tkm$**	**$kgCO_2e/tkm$**	**$kgCO_2e/tkm$**	**$kgCO_2e/tkm$**
Passenger Freight				
Domestic flights	2.41	0.00	0.02	**2.43**
Short-haul flights	1.26	0.00	0.01	**1.27**
Long-haul flights	0.62	0.00	0.01	**0.62**
Dedicated Cargo				
Domestic flights	1.93	0.00	0.02	**1.96**
Short-haul flights	1.53	0.00	0.02	**1.55**
Long-haul flights	0.61	0.00	0.01	**0.61**
All Air Freight				
Domestic flights	1.96	0.00	0.02	**1.98**
Short-haul flights	1.47	0.00	0.01	**1.49**
Long-haul flights	0.61	0.00	0.01	**0.62**

Notes: Totals may vary from the sums of the components due to rounding in the more detailed dataset.

Air Transport Indirect Emission Factors

156. Indirect emissions factors (EFs) for air passenger and air freight services include only emissions resulting from the fuel cycle (i.e. production and distribution of the relevant transport fuel). These indirect emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect EFs for aviation turbine fuel (kerosene) from Annex 1 and the corresponding direct CO_2 EFs for air passenger and air freight transport in Annex 6 and Annex 7.

Other Factors for the Calculation of GHG Emissions

Great Circle Fight Distances

157. We wish to see standardisation in the way that emissions from flights are calculated in terms of the distance travelled and any uplift factors applied to account for circling and delay. However, we acknowledge that a number of methods are currently used.

158. A 9% uplift factor is used in the Act on CO_2 calculator and in the UK Greenhouse Gas Inventory to scale up Great Circle distances (GCD) for flights between airports to take into account indirect flight paths and delays, etc. This factor (also provided previously with previous GHG Conversion Factors) comes from the IPCC Aviation and the global Atmosphere 8.2.2.3, which states that 9-10% should be added to take into account non-direct routes (i.e. not along the straight line great circle distances between destinations) and delays/circling.

159. The first version of the Act on CO_2 calculator only captured the number of flights taken and assumes average distance factors (plus the 9% uplift) for domestic, short-haul or long-haul flights. In the version 2 of the Act on CO_2 calculator due to be released late spring 2009, the option to perform a calculation based on airport origin and destinations for passenger flights will be included. This will allow a more precise calculation of CO_2 emissions using the Great Circle distances and the above uplift factor specific to the flight details entered.

160. It is not practical to provide a database of origin and destination airports to calculate flight distances. However, the principal of adding a factor of 9% to distances calculated on a Great Circle is recommended (for consistency with the existing Defra/DfT approach) to take into account of indirect flight paths and delays/congestion/circling.

Radiative Forcing

161. The emission factors provided in the 2010 GHG Conversion Factors Annex 6 and Annex 7 refer to aviation's direct carbon dioxide, methane and nitrous oxide emissions only. There is currently uncertainty over the other non-CO_2 climate change effects of aviation (including water vapour, contrails, NOx etc) which have been indicatively been accounted for by applying a multiplier in some cases.

162. Currently there is no suitable climate metric to express the relationship between emissions and climate warming effects from aviation but this is an active area of research. Nonetheless, it is clear that aviation imposes other effects on the climate which are greater than that implied from simply considering its CO_2 emissions alone.

163. The application of a 'multiplier' to take account of non-CO_2 effects is a possible way of illustratively taking account of the full climate impact of aviation. A multiplier is not a straight forward instrument. In particular it

implies that other emissions and effects are directly linked to production of CO_2, which is not the case. Nor does it reflect accurately the different relative contribution of emissions to climate change over time, or reflect the potential trade-offs between the warming and cooling effects of different emissions.

164. On the other hand, consideration of the non-CO_2 climate change effects of aviation can be important in some cases, and there is currently no better way of taking these effects into account. A multiplier of 1.9 is recommended as a central estimate, based on the best available scientific evidence[51]. If used, this factor would be applied to the emissions factors set out here.

VIII. Direct GHG Emissions from Use of Refrigeration and Air Conditioning Equipment (Annex 8)

Summary of changes since previous update

165. No changes have been made since the 2009 update.

General Methodology

166. Very powerful greenhouse gases are often used in refrigeration and air conditioning equipment. However, estimating GHG emissions from this equipment over its lifetime can be difficult. As for the 2009 update, a simple Screening Method has been provided in Annex 8 of 2010 GHG Conversion Factors. This should help organisations to estimate emissions from refrigeration and air conditioning based on the type of equipment used and emissions factors. The methodology for this method is based upon that outlined in US EPA (2008)[52].

167. The Screening Method approach requires relatively little actual data collection however there is a high degree of uncertainty with these emission factors. Therefore if emissions from this equipment are determined to be significant when compared to your organisation's other emissions sources, then you should apply a better estimation method (e.g. a Material Balance Method, also outlined in US EPA, 2008). A simplified Material Balance calculation has also been provided, based on GWP factors from Annex 5 of the 2010 GHG Conversion Factors.

168. The emission factors used for the calculations (manufacturing, lifetime emissions, and recovery efficiency at disposal) are predominantly sourced from the UK GHG inventory. These UK factors have been updated recently following a workshop with industry representatives. The emission factors are presented in Table 48 below. These factors are used in combination with

[51] Aviation radiative forcing in 2000: An update on IPCC (1999) Meteorologische Zeitschrift 14: 555-561
[52] US EPA Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance - Direct HFC and PFC Emissions from use of Refrigeration and Air Conditioning Equipment (see: http://www.epa.gov/stateply/documents/resources/mfgrfg.pdf)

the relevant GWP values for the particular refrigerant being used, according to the tables provided in Annex 5 of the 2010 GHG Conversion Factors (discussed in earlier Section IV).

Table 48: Emission factors for the simple Screening Method for estimating direct GHG emissions from use of refrigeration and air conditioning equipment

Type of Equipment	Installation Emission Factor (1)	Annual Leak Rate (1)	Capacity Left at Disposal (2)	Refrigerant Recovered (1)
Domestic Refrigeration	1.0%	0.3%	80%	99.0%
Stand-alone Commercial Applications	1.5% *	2.0% *	80%	94.5% *
Medium & Large Commercial Applications	2.0%	11.0%	100%	95.0%
Transport Refrigeration	1.0%	8.0%	50%	94.0%
Industrial Refrigeration (inc. food processing and cold storage)	1.0%	8.0%	100%	95.0%
Chillers	1.0%	3.0%	100%	95.0%
Residential and Commercial A/C including Heat Pumps	1.0%	8.5%	80%	95.0%
Mobile Air Conditioning	1.0%	7.5%	50%	88.0%

Source:
(1) UK Greenhouse Gas Inventory for year 2007 (AEA, 2009)
(2) US EPA (2008)
* Unweighted average of the figures for hermetically sealed units and for small distributed systems.

IX. Other UK Conversion Factors (Annex 9)

Summary of changes since previous update

169. The main methodological changes and additions since the previous update include:
    a. Lifecycle emissions factors for pure biofuels are now based on UK averages from the Renewable Fuels Agency for 2009 (plus direct emissions of CH_4 and N_2O from combustion of biofuels that are not already included in these).
    b. Emissions factors for out of scope CO_2 emissions from direct combustion of biofuels, biomass and biogas have been added.
    c. Waste factors for kitchen and food waste have been revised by WRAP.
    d. The calculation methodology for net CO_2e emissions from waste has been revised according to advice by WRAP.

170. All other factors have also been updated with more recent data in the latest 2010 GHG Conversion Factors.

General Methodology

171. Annex 9 of the 2010 GHG Conversion Factors provides a number of additional tables with other UK emission factors, including those for water supply and treatment (presented in Table 49), biofuels (presented in Table

50), biomass and biogas (presented in Table 51) and for waste disposal (presented in Table 52).

172. The emission factors presented in the tables incorporate emissions from the full life-cycle and include net CO_2, CH_4 and N_2O emissions. The addition of indirect emissions factors to other annexes means the emission factors in this annex are now directly comparable with the total lifecycle (direct + indirect) emission factors in other Annexes.

173. The basis of the different emission factors is discussed in the following sub-sections.

Water

174. The emission factors for water supply and treatment in Table 49 have been sourced from Water UK (2008, 2009) and are based on submissions by UK water suppliers. Water UK represents all UK water and wastewater service suppliers at national and European level.

Table 49: Life-cycle GHG conversion factors for water

Fuel used	Units	kg CO_2e per unit	
		2007/08	2008/09
Water supply	million litres	276	300
Water treatment	million litres	693	750

Source:
Water UK (2008) and Water UK (2009). Water UK Sustainability Indicators, available at:
http://www.water.org.uk/home/policy/reports/sustainability/sustainability-indicators-2007-08 (for 2007/08), and
http://www.water.org.uk/home/policy/reports/sustainability/2008-09-sustainability-indicators (for 2008/09)

Biofuels

175. Previously the emission factors for biofuels were based on the Renewable Fuels Agency (RFA) defaults (in gCO_2e per MJ) where the source/production pathway of the biofuel is unknown. However, for the 2010 GHG Conversion Factors these have been replaced by UK average factors from the RFA Quarterly Report 7 (2010)[53] on the Renewable Transport Fuel Obligation (RTFO). These average factors are presented in Table 50.

176. The RFA indirect/fuel cycle emission factors do not include the direct emissions of CH_4 and N_2O that are produced by the use of biofuels in vehicles. Unlike the directly emitted CO_2 emissions, these are not offset by adsorption of CO_2 in the growth of the feedstock used to produce the biofuel. In the absence of other information these emissions factors have been assumed to be equivalent to those produced by combusting the corresponding fossil fuels (i.e. diesel, petrol or CNG) from Annex 1.

[53] These cover the period from 15 April 2009 - 14 January 2010 and were the most recent figures available at the time of production of the 2010 GHG Conversion Factors. The report is available from the RFA's website at: *http://www.renewablefuelsagency.gov.uk/carbon-and-sustainability/rtfo-reports*

Table 50: Life-Cycle GHG Conversion Factors for biofuels

Biofuel	**Emissions Factor, gCO_2e/MJ**				
	RFA Lifecycle (1)	**Direct CH_4 (2)**	**Direct N_2O (2)**	**Total Lifecycle**	**Direct CO_2 Emissions (Out of Scope (3))**
Biodiesel	47.077	0.039	0.769	47.886	75.300
Bioethanol	30.729	0.133	0.453	31.315	71.600
Biomethane	27.000	0.075	0.031	27.106	55.408

Notes:
(1) Based on UK averages from the RFA Quarterly Report 7 (2010)
(2) Based on corresponding emission factors for diesel, petrol or CNG.
(3) The Total GHG emissions outside of the GHG Protocol Scope 1, 2 and 3 is the actual amount of CO_2 emitted by the biofuel when combusted. This will be counter-balanced by /equivalent to the CO_2 absorbed in the growth of the biomass feedstock used to produce the biofuel. These factors are based on data from BEC (2010)

177. The net GHG emissions for biofuels vary significantly depending on the feedstock source and production pathway. Therefore for accuracy it is recommended that more detailed/specific figures are used where available. For example, detailed indirect emission factors by source/supplier are provided and updated regularly in the RFA Quarterly Reports, available on the RFA's website at: *http://www.renewablefuelsagency.gov.uk/carbon-and-sustainability/rtfo-reports*

178. In addition to the direct and indirect emission factors provided in Table 50, emission factors for the out of scope CO_2 emissions have also been provided in the 2010 GHG Conversion Factors (see table and the table footnote), based on data from sourced from the Biomass Energy Centre (BEC, 2010)[54].

Other biomass and biogas

179. A number of different bioenergy types can be used in dedicated biomass heating systems, including wood logs, chips and pellets, as well as grasses/straw or biogas. Emission factors produced for these bioenergy sources are presented in Table 51.

180. The previous emission factors for wood pellets were based on the factor of 0.025 kgCO2/kWh provided in SAP200555. SAP is the Government's Standard Assessment Procedure for Energy Rating of Dwellings. This factor includes only a limited number of upstream emissions and has therefore been updated using the draft emission factors for the 2009 update to SAP56 which include additional upstream components. New emission factors for wood logs and wood chips have also been based on this dataset.

[54] BEC (2010). BEC is owned and managed by the UK Forestry Commission, via Forest Research, its research agency. Fuel property data on a range of other wood and other heating fuels is available at: http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,20041&_dad=portal&_schema=PORTAL, and http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL
[55] Standard Assessment Procedure 2005 update, Table 12, available at: *http://www.bre.co.uk/sap2005*
[56] Details on the consultation and draft documentation/tables are available at: *http://www.bre.co.uk/sap2009/* and with specific data obtained from SAP 2009 STP 09/$CO_2$01 31/03/2009, available at: *http://www.bre.co.uk/filelibrary/SAP/2009/STP09-CO201_Revised_emission_factors.pdf*

181. Additional emission factors for grasses/straw and for biogas (= 60% CH4, 40% CO_2, e.g. essentially unpurified landfill gas or gas from sewage treatment) have also been sourced from the Biomass Energy Centre (BEC, 2010).

182. In addition to the direct and indirect emission factors provided in, emission factors for the out of scope CO_2 emissions have also been provided in the 2010 GHG Conversion Factors (see Table 51 and the table footnote), also based on data from sourced from BEC (2010).

Table 51: Life-Cycle GHG Conversion Factors for biomass and biogas

Bioenergy type	Emissions Factor, gCO_2e/kWh fuel	
	Total Net Emissions (GHG Protocol Scope 3)	**Direct CO_2 Emissions (Out of Scope (3))**
Wood logs (1)	0.01895	0.35150
Wood chips (1)	0.01579	0.35400
Wood pellets (1)	0.03895	0.34900
Grasses/straw (2)	0.01020	0.34800
Biogas (2)	-	0.24600

Notes:
(1) Based on data from draft SAP 2009
(2) Based on data from BEC (2010)
(3) The Total GHG emissions outside of the GHG Protocol Scope 1, 2 and 3 is the actual amount of CO_2 emitted by the biomass when combusted. This will be counter-balanced by /equivalent to the CO_2 absorbed in the growth of the biomass.

Waste

183. The life-cycle emission factors presented in Table 52 were sourced primarily from the Defra Waste Strategy (2007)[57], with additional updated factors (in **bold**) provided by WRAP (**2009** and **2010**)[58]. A brief summary of the basis of WRAP calculations is provided in the following paragraphs for different materials, with additional information and background provided in a guidance note from WRAP included as Annex 1 to this document.

184. The figures on waste prevention are estimates based on the range of products supplied into the UK, and do not reflect any one supply chain. For example, paper and card covers newsprint and cardboard. Therefore they may not represent the savings from preventing waste in specific products, and should be used only where primary supply chain data is unavailable.

185. The figures on waste prevention exclude the impacts associated with forming of products, as these will also be specific to the use of the material (e.g. plastic car parts, packaging). In assessing waste prevention, this should also be considered in respect of where in the supply chain the waste prevention activity has taken place.

---

[57] Defra Waste Strategy (2007), Table A.28: Emission factors for waste treatment processes (kg carbon dioxide equivalents/tonne of waste processed).
http://www.defra.gov.uk/environment/waste/strategy/strategy07/pdf/waste07-annex-a.pdf
[58] More information on WRAP can be found at: *http://www.wrap.org.uk/*

Table 52: Life-Cycle GHG Conversion Factors for Waste Disposal

Waste fraction	Net kg CO_2e emitted per tonne of waste treated [4]						kg CO_2e emitted per tonne waste PRODUCED [5]
	Recycling		Energy from waste		Composting	Landfill	
	Open Loop	Closed Loop	Power only moving grate	Anaerobic Digestion			
Paper and Card	**-713**		**-500**	-121	57	**550**	**950**
Kitchen/food waste			-89	**-100**	**30**	**365**	**4000**
Garden/plant waste			-121	**-100**	57	**210**	89
Other organic	44		-271	-330	34	230	0
Wood	**-6**		**-700**		**250**	**930**	256
Textiles		**-3,800**	**600**			**300**	19,294
Plastic (dense)		**-1,500**	**1,800**			**40**	**3,100**
Plastic (film)		**-1,000**	**1,800**			**35**	**2,500**
Ferrous metal		**-1,300**	-786			10	**3,100**
Non-ferrous metal		**-9,000**	23			10	**11,000**
Silt/soil	16		35			10	4
Aggregate materials		**-4**	35			10	**8**
Misc combustibles	58		242			305	102
Glass	**2**	**-315**	**5**			10	**840**
Tyres	**-20**	**-2,900**	**-1,500**			**not permitted**	**3,410**
Estimated impact of other materials (municipal and C&I)	-259		97	-13	7	81	2,860

Sources: Defra Waste Strategy (2007) [57]; with updated figures in **BOLD** provided by WRAP, **2009** and **2010** [58].

Notes: The data summarised in the table covers the life cycle stages highlighted below. It excludes use of the product as this will be variable. For example, plastic may be used as automotive parts or as drinks packaging amongst other things. If it is used as drinks packaging it will require filling. As it is not known what the final use of the material is, this section of the life cycle is excluded for all materials. For some products forming is also excluded. Metals may be made into various products by different methods, excluded from these figures.

[4] Impact of other treatments as in pRIA – http://www.defra.gov.uk/corporate/consult/wastestratreview/partialRIA.pdf – p.58.

[5] The waste prevention figure for textiles currently does not account for the split of material types on the UK market. Improvements will be made to this figure in future updates.

Saving from embodied fossil energy resulting from avoiding waste are the negative of these figures.

186. *Paper and Card:* The data for the production, primary processing and manufacture of paper and board is taken from three main sources, with supplementary information from paperprofiles developed in accordance with the paperprofile methodology (*http://www.paperprofile.com/*). Procarton[59] and FEFCO[60] provide EU average data for the production of cartonboard and corrugated cardboard respectively. Data for the manufacture of paper is taken from Hischier (2007)[61]. An average figure for the mix of products used was calculated using this information plus Paper and Board Consumption in CEPI Countries 2007 (from CEPI 2007)[62]. The figures assume that paper and board procured is derived from sustainably managed sources and do not incur any changes in land use. Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it. Waste management impacts are informed by Doka (2009)[63].

[59] Procarton (2006) Carbon Footprint for Cartons
[60] FEFCO (2006) European Database for Corrugated Board Life Cycle Studies
[61] Hischier R. (2007) *Life Cycle Inventories of Packaging and Graphical Paper*. Final report ecoinvent data v2.0 No. 11. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.
[62] CEPI (2008) Key Statistics 2007 European Pulp and Paper Industry
[63] Doka G. (2009) *Life Cycle Inventories of Waste Treatment Services.* Final report ecoinvent v2.1 No. 13. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: *www.ecoinvent.ch*.

187. *Organic wastes:* Data on organic wastes is based on information held by DEFRA and developed for the Environment Agency tool WRATE[64]*.* Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it.

188. *Wood:* Data on wood is based on information held by DEFRA[65] and developed for the Environment Agency tool WRATE[66]. It assumes that wood is chipped for use in composting, although a range of alternative reuse and recycling routes exist. The figures assume that wood procured is derived from sustainably managed sources and do not incur any changes in land use. Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it.

189. *Textiles:* Data on textiles is based on information held by DEFRA[67] and developed for the Environment Agency tool WRATE[68]. It assumes 70% of textiles collected separately are reused and the remaining 30% recycled. The figure for waste prevention should be viewed with caution as the range of impacts associated with the production of textiles varies enormously across natural and synthetic fibres. The figures assume that natural fibres procured are derived from sustainably managed sources and do not incur any changes in land use. Much source information cannot be published as it remains the intellectual property of the respective parties supplying it.

190. *Plastics:* Data on Plastics is based upon Ecoprofiles published by Plastics Europe, information on the market share of different polymers and uses. Information on the impacts of alternative waste management options is derived from WRAP reports[69]. Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it.

191. *Steel (Ferrous metal):* There are a variety of grades of steel, such as unalloyed, low alloyed and stainless. Each has a different impact associated with it. Data on the production and recycling of steel is informed by *IISI (2000) and Classen et al (2009)*[70]. Data on product manufacture uses *Steiner et al (2007)*[71]. Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it.

192. *Aluminium (Non-ferrous metal):* Following primary processing, aluminium may be classified into three product groups: Casting alloys, rolled aluminium

[64] *http://www.environment-agency.gov.uk/research/commercial/102922.aspx*
[65] ERM (2006) *Carbon Balances and Energy Impacts of the Management of UK Wastes* Defra R&D Project WRT 237. DEFRA, London
[66] *http://www.environment-agency.gov.uk/research/commercial/102922.aspx*
[67] ERM (2006) *Carbon Balances and Energy Impacts of the Management of UK Wastes* Defra R&D Project WRT 237. DEFRA, London
[68] *http://www.environment-agency.gov.uk/research/commercial/102922.aspx*
[69] http://www.wrap.org.uk/go.rm?id=27462
[70] Classen M., Althaus H.-J., Blaser S., Doka G., Jungbluth N. and Tuchschmid M. (2009) *Life Cycle Inventories of Metals. Final report* ecoinvent data v2.1 No.10. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.
[71] Steiner R. and Frischknecht R. (2007) *Life Cycle Inventories of Metal Processing and Compressed Air Supply. Final report* ecoinvent data v2.0, No. 23. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.

and extruded aluminium. Rolled and extruded aluminium are also referred to as wrought aluminium. The main uses for Aluminium are in transport, building, packaging, and engineering, and each tye of aluminium will be preferred for different uses. Data on aluminium manufacture and recycling is informed by work undertaken by the European Aluminium Association (2008)[72], *Classen et al (2009)*[73] *and Steiner et al (2007)*[74]. Much of the source information cannot be published as it remains the intellectual property of the respective parties supplying it.

193. *Aggregates:* Data is taken from the WRAP CO_2 Emissions Estimator Tool and updates which account for other greenhouse gases, as well as the Environment Agency Construction Carbon Calculator. The Carbon Dioxide (CO_2) Emissions Estimator Tool is an Excel based calculation tool which estimates the carbon dioxide saved in selecting different construction techniques and supply alternatives, including the use of primary or recycled and secondary aggregates. The tool assesses the carbon dioxide output resulting from four types of construction applications:
    a. bitumen bound
    b. concrete
    c. hydraulically bound
    d. unbound

The output is an estimate of the savings in CO_2 realised by selecting sustainable construction techniques and recycled/secondary materials.

194. *Glass:* Information on glass is based upon *Enviros (2003* [75]*.*

[72] European Aluminium Association (2008) *Environmental Profile Report for the European Aluminium Industry*, EEA, Belgium

[73] Classen M., Althaus H.-J., Blaser S., Doka G., Jungbluth N. and Tuchschmid M. (2009) *Life Cycle Inventories of Metals. Final report* ecoinvent data v2.1 No.10. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.

[74] Steiner R. and Frischknecht R. (2007) *Life Cycle Inventories of Metal Processing and Compressed Air Supply. Final report* ecoinvent data v2.0, No. 23. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.

[75]Enviros (2003) Glass Recycling – Life Cycle Carbon Dioxide Emissions, British Glass http://www.britglass.org.uk/Files/Enviros_LCA.pdf

X. Overseas Electricity Emission Factors (Annex 10)

Summary of changes since previous update

195. Indirect emission factors have been added to provide an estimate of the emissions due to the production and distribution of primary fuels used in power generation, as for Annex 3. No other changes have been made since the 2009 update.

Direct Emissions from Overseas Electricity Generation

196. UK companies reporting on their emissions may need to include emissions resulting from overseas activities. Whilst many of the standard fuel emissions factors are likely to be similar for fuels used in other countries, grid electricity emission factors vary very considerably. It was therefore deemed useful to provide a set of overseas electricity emission factors to aid in reporting where such information is hard to source locally.

197. The dataset on electricity and heat emission factors from the IEA provided mainly on the GHG Protocol website [76] was identified as the best available consistent dataset for electricity emissions factors. However, these factors are a time series of combined electricity and heat CO_2 emission factors per kWh GENERATED. Therefore they exclude losses from the transmission and distribution grid and are not directly comparable with the point-of-use grid electricity emission factors provided in Annex 3 for the UK.

198. Data on losses in distribution of electricity and heat is calculated from 2006 country energy balances available at the IEA website[77]. Data on the proportion of electricity and heat (for 2006) is also provided for context, sourced from the IEA website[78], and was used to estimate the weighted net losses in the distribution of electricity and heat for different countries.

199. An example of the format for the Energy Balances data source from the IEA is provided in Table 53 for the UK (columns for other forms of energy have been removed). The percentage distribution losses for electricity and heat were calculated from the '*Distribution Losses*' and '*TFC*' total figures from the Energy Balance tables.

[76] Emission factor data is from International Energy Agency Data Services, 2006 and 2008 for "CO_2 Emissions per kWh Electricity and Heat Generated" and mainly sourced from the GHG Protocol website *http://www.ghgprotocol.org/calculation-tools*
[77] Information on energy balances is available from the IEA website at: *http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Balances*
[78] Information from the IEA website is available at: *http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Electricity/Heat*

Table 53: 2005 Energy Balances for Electricity and Heat for United Kingdom

SUPPLY and CONSUMPTION	**Electricity**	**Heat**
Production	0	0
Imports	960	0
Exports	-244	0
International Marine Bunkers**	0	0
Stock Changes	0	0
TPES	**716**	**0**
Transfers	0	0
Statistical Differences	0	0
Electricity Plants	31903	0
CHP Plants	2290	0
Heat Plants	0	1354
Gas Works	0	0
Petroleum Refineries	0	0
Coal Transformation	0	0
Liquefaction Plants	0	0
Other Transformation	0	0
Own Use	-2447	-38
Distribution Losses	-2771	0
TFC	**29691**	**1317**
Industry sector	**10220**	**860**
Transport sector	**740**	**0**
Other sectors	**18731**	**457**
Residential	10046	52
Commercial and Public Services	8328	405
Agriculture / Forestry	357	0
Fishing	0	0
Non-Specified	0	0
Non-Energy Use	**0**	**0**
- of which		
Petrochemical Feedstocks	*0*	*0*

Source: Subset of data from the IEA Data Services [77]

Notes: Figures are in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis.
* Totals may not add up due to rounding.
** International marine bunkers are not subtracted out of the total primary energy supply for world totals.

200. An example of the format for the Electricity and Heat data source from the IEA is provided in Table 54 for the UK (an additional column with Heat presented in units of GWh has been added). The percentage electricity comprises of the total for electricity and heat is calculated both for the Total Production (corresponding to electricity GENERATED) and the Total Final Consumption (corresponding to electricity CONSUMED).

Table 54: Electricity / Heat for United Kingdom in 2005

	Electricity *Unit: GWh*	**Heat** *Unit: TJ*	**Heat** *Unit: GWh*
Production from:			
- coal	136564	8602	2389
- oil	5417	1728	480
- gas	153229	46379	12883
- biomass	8078	0	0
- waste	4811	0	0
- nuclear	81618	0	0
- hydro	7891		0
- geothermal	0	0	0
- solar PV	8		0
- solar thermal	0	0	0
- wind	2908	0	0
- tide	0	0	0
- other sources	0	0	0
Total Production	**400524**	**56709**	15753
Imports	11160	0	0
Exports	-2839	0	0
Domestic Supply	**408845**	**56709**	15753
Statistical Differences	0	0	0
Total Transformation*	**0**	**0**	0
Electricity Plants	0	0	0
Heat Plants	0		0
Energy Sector**	**31383**	**1579**	439
Distribution Losses	32219	0	0
Total Final Consumption	**345243**	**55130**	15314
Industry	118832	35999	10000
Transport	8609	0	0
Residential	116811	2175	604
Commercial and Public Services	96839	16956	4710
Agriculture / Forestry	4152	0	0
Fishing	0	0	0
Other Non-Specified	0	0	0

Source: Subset of data from the IEA Data Services [78]

Notes: Figures are in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis.
* Transformation sector includes electricity used by heat pumps and electricity used by electric boilers.
** Energy Sector also includes own use by plant and electricity used for pumped storage.
% Electricity (of total electricity + heat) = 96.2% Total Production
95.8% Total Final Consumption

201. The emission factors for overseas electricity in Annex 10 of the 2009 GHG Conversion Factors are presented in three tables as a time series of combined electricity and heat CO_2 emission factors per kWh GENERATED (Table 10a, i.e. before losses in transmission/distribution), CO_2 emission factors per kWh due to LOSSES in transmission/distribution (Table 10b) and per kWh CONSUMED (Table 10c, i.e. for the final consumer, including transmission/distribution losses). Additional data are also presented on the relative proportions of generated or consumed electricity and heat for different countries and the corresponding losses between generation and consumption. Emission Factor (Electricity/Heat CONSUMED) = Emission Factor (Electricity/Heat GENERATED) + Emission Factor (Electricity/Heat LOSSES).

202. Emission factors have been provided for all EU Member States and major UK trading partners. Additional emission factors for other countries not included in this list can be found at the GHG Protocol website[79], though it should be noted the figures supplied there do not include losses from transmission and distribution of heat and electricity.

Indirect Emissions from Overseas Electricity Generation

203. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect / fuel cycle emissions as included in Annex 1). The average fuel cycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel/primary energy used in electricity generation.

204. Average indirect emission factors for UK electricity were calculated and included in Annex 3 by using Annex 1 indirect emission factors and data on the total fuel consumption by type of generation for the UK. This information was not available for the overseas emission factors included in Annex 10. As an approximation therefore, the indirect (Scope 3) emission factors for different countries were estimated as being roughly a similar ratio of the direct CO_2 emission factors as for the UK (which is 13.4%).

[79] GHG Protocol website: *http://www.ghgprotocol.org/calculation-tools*

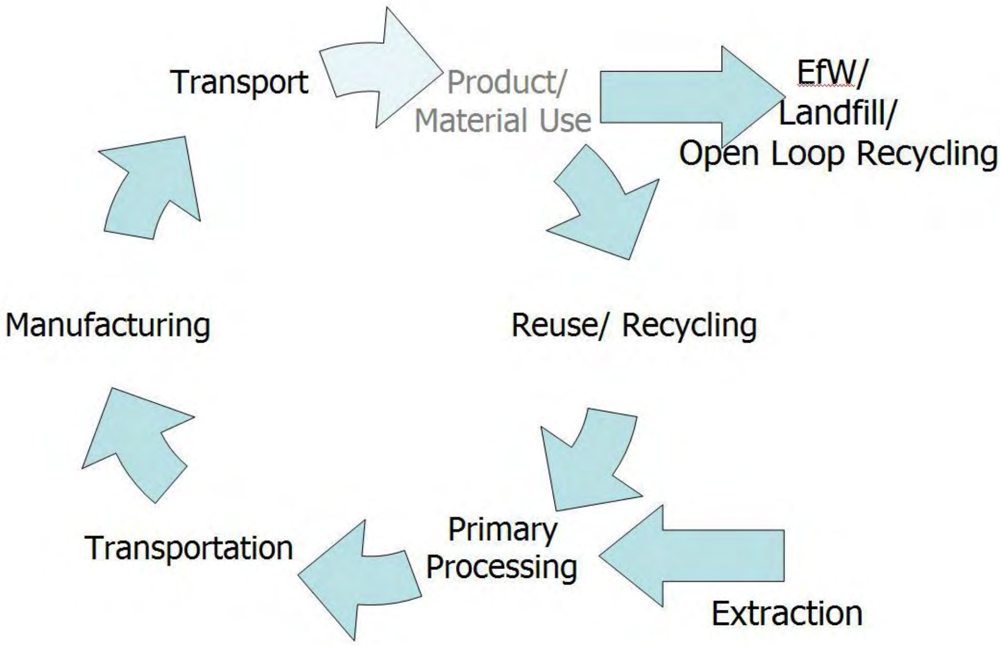
ANNEX: WRAP Guidance note on Annex 9: Life Cycle Conversion Factors for Waste Disposal

Background

205. The materials we use create emissions at every stage of their life, from extraction through manufacture of goods containing these materials, and in the way we dispose of these at the end of life. The emissions may arise directly from the processes they go through, or indirectly through the use of electricity.

206. A high level overview of the life cycle of materials and products is shown in Figure 1.

Figure 1: Overview schematic of the materials lifecycle



207. The figures provided in Annex 9 Table 9d cover those stages highlighted in the diagram. The use phase is excluded. The use phase could cover, for example, energy used in cooking food or in using an electrical appliance, or the use of one material in a range of different applications (e.g. plastics in packaging, furniture and automotive applications). Please note that biogenic[80] CO_2 has also been excluded from these figures.

[80] Biogenic CO_2 is the CO_2 absorbed and released by living organisms during and at the end of their life. By convention, this is assumed to be in balance in sustainably managed systems.

Use of the figures

208. The figures may be used in the absence of data specific to your goods and services (e.g. a PAS 2050 compliant assessment) as an approximation for the environmental impact of the goods which your organisation procure, and the waste which they dispose of. If you have more accurate information for your products, then please refer to the more accurate data for reporting your emissions.

209. The data provided for recycling, energy recovery and landfill are based on absolute emissions for these options. Therefore, to identify the benefit of one option versus another (e.g. recycling versus landfill), the benefit is the difference between the two columns.

210. On average in the UK in 2009, 88% of non-recycled municipal solid waste is sent to landfill and 12% goes to energy from waste (power only moving grate).

Material Use and Waste Management

211. It is essential that, where possible, data is used to cover both the materials used by an organisation, and the waste generated by an organisation. These figures maybe strongly or weakly related. For example, an office based organisation may buy large quantities of paper for mailing, whilst a manufacturer will inevitably have large quantities of material coming on site and moving off site.

212. By quantifying both material use and emissions from waste management, the benefits of waste prevention and more effective management may be estimated. If only waste management emissions are calculated, the benefit of waste prevention will not be adequately covered.

213. These figures should be used for site based reporting only. They should not be added together along a supply chain, as material use would be counted several times along a supply chain.

Data Sources and Quality

214. Table 55 provides an overview of the data quality indicators used to identify the factors to be used in Annex 9 Table 9d. The data provided for each of the materials are based on critically reviewed sources, most of which are in the public domain. However, although the data is of high quality, it's application to specific products and processes should be treated with caution.

215. For example, data on paper and card is based on average manufacturing across Europe, with average levels of recycled content. Data for 100% recycled and 100% virgin is not available. In addition, even if they become available, the emissions from the production of paper and card are strongly

influenced by the energy sources used in the country of origin, and figures can therefore vary significantly. In addition, approximately 50% of paper and card collected for recycling in the UK is exported to the India and the Far East. Whilst there is a benefit to this, it does not affect the recycled content of paper and card manufactured in Europe.

216. Certain materials should be viewed with particular caution and will be the focus of review. These are textiles (for which the figures vary between fibre types) and paper and card (for which greater understanding of the relationship between recycling and use of primary pulp is required)

Table 55: Data Quality Indicators used to develop the GHG reporting factors

Data Quality Indicator	Requirement	Comments
Time-related coverage	Data less than 5 years old	Ideally data should represent the year of assessment. However, the secondary data in material eco-profiles is only periodically updated.
Geographical coverage	Data should be representative of the materials placed on the market in the UK	Many datasets reflect European average production. This is in line with the majority of materials used in the UK.
Technology coverage	Average technology	A range of information is available, covering best in class, average and pending technology. Average is considered the most appropriate but may not reflect individual supply chain organisations.
Precision / variance	No requirement	Many datasets used provide average data with no information on the range. It is therefore not possible to identify the variance.
Completeness	All datasets must be reviewed to ensure they cover inputs and outputs pertaining to the life cycle stage	
Representativeness	The data should represent UK conditions	This is determined by reference to the above data quality indicators
Consistency	The methodology has been applied consistently.	
Reproducibility	An independent practitioner should be able to follow the method and arrive at the same results.	
Sources of data	Data will be derived from credible sources and databases	Where possible data in public domain will be used. All data sources referenced.
Uncertainty of the information	The level of certainty of the data should be clearly communicated.	Many data sources come from single sources. Uncertainty will arise from assumptions made and the setting of the system boundaries. Before making decisions on the basis of data, users will need to make their own assessment and be satisfied there are no unintended consequences.
Transparency	The process for deriving factors should be readily understood.	Independent practitioners should be able to derive the same results by following the steps described.

Calculation of the greenhouse gas impacts of material use and waste management

217. The approach to recycling and recycled content is in line with the WRAP Courtauld Carbon Methodology. It varies from to highlight the difference in impact between different waste management routes.

218. Several allocation procedures exist for dealing with reuse and recycling. The methodology is in line with the spirit of ISO 14044 (2006), which proposes that allocation procedures for recycling can be addressed as follows:

219. "a) A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where *no changes* occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. However, the first use of virgin materials in applicable open-loop product systems may follow an open-loop allocation procedure outlined in b).

220. b) An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties."

221. Under example (a), aluminium packaging may be recycled into aluminium packaging or other applications. In either case, where it substitutes for primary aluminium, the environmental benefit is the same. Where plastic is used in place of wood, an open-loop allocation procedure is more appropriate.

222. For card products, it is not true to say that all products in one category are recycled back into that category. For example, carton board may be recycled and made into corrugate. Although the fibres may be shortened through the recycling process, the net environmental impact is the same regardless of whether the material goes to corrugate or cartonboard manufacture, and it is therefore inappropriate to only recognise the benefit of one alternative as closed loop in nature.

223. Where the life cycle of a product includes a material input with recycled content originating from the same product or material system, the emissions arising from that material shall reflect the product specific recycle content and/or recycling rate based on the calculation given below.

    Emissions / unit = $(1 - R1) \times EV + (R1 \times ER1) + (R3 \times ER2) + (1 - R2) \times ED$

    For metals the following formula would be applied:

    Emissions / unit = $(1 - R2) \times EV + (R2 \times ER2) + (1 - R2) \times ED$

224. The recycled content is taken as being equivalent to the proportion of material which is sent for closed loop recycling at end of life. This is in line with Frees (2008) and the 2007 the metals industry "Declaration by the Metals Industry on Recycling Principles" (Atherton 2007). It varies slightly from PAS 2050 owing to the focus of the guidelines on end of life management, rather than recycled content.

Where:

***R*1 =** proportion of recycled material input (i.e. closed loop recycling),
***R*2 =** proportion of material in the product that is recycled at end-of-life,
R3 = proportion of material which enters alternative recycling system at end-of-life.
***ER1* =** emissions arising from recycled material input, per unit of material,
***ER2* =** emissions arising from open loop recycling process, per unit of material,
***EV* =** emissions arising from virgin material input, per unit of material,
***ED* =** emissions arising from disposal of waste material, per unit of material

References

- Defra (2007) *Waste Strategy for England*, Table A.28: Emission factors for waste treatment processes (kg carbon dioxide equivalents/tonne of waste processed) *http://www.defra.gov.uk/environment/waste/strategy/strategy07/pdf/waste07-annex-a.pdf*

Updated figures in BOLD provided by WRAP, 2010 using the following data sources:

- Atherton (2007) Declaration by the Metals Industry on Recycling Principles *International Journal of Life Cycle Assessment* 12 (1) 59 – 60 (2007)
- Frees, N (2008) Crediting Aluminium Recycling in LCA by Demand or by Disposal *International Journal of Life Cycle Assessment* 13 (3) 212 – 218

Aggregates

- WRAP (unpublished) *LCA of Aggregates*. TO be published as part of revised AggRegain Tools.

Aluminium

- European Aluminium Association (2008) *Environmental Profile Report for the European Aluminium Industry* - EAA intellectual property

Glass

- Enviros (2003) Glass Recycling - *Life Cycle Carbon Dioxide Emissions*; Sheffield, British Glass
- An update from FEVE has been published in May 2010.

Organic Waste

- Internal WRAP calculation and unpublished DEFRA report

Plastic

- WRAP (2006) *UK Plastics Waste – A review of supplies for recycling, global market demand, future trends and associated risks*. Banbury: WRAP http://www.wrap.org.uk/downloads/UK_Plastics_Waste.345a82f2.5543.pdf
- WRAP (2008) *LCA of Mixed Waste Plastic Recovery Options* http://www.wrap.org.uk/document.rm?id=5448
- WRAP (2010) *LCA of Example Milk Packaging Systems* http://www.wrap.org.uk/retail/case_studies_research/example_systems.html
- Plastics Europe Library of Ecoprofiles http://lca.plasticseurope.org/index.htm

Paper and Card

- CEPI (2008) *Key Statistics 2007 European Pulp and Paper Industry* http://www.cepi.org/Content/Default.asp?
- Procarton (2010) *Carbon Footprint for Cartons* http://www.procarton.com/
- FEFCO (2010) *European Database for Corrugated Board Life Cycle Studies* http://www.fefco.org/
- National *Life Cycle Inventory Database "Ecoinvent 2000" - Part III - Paper and Board*. December 2003. http://www.ecoinvent.ch

Steel

- Data on primary and recycled steel is based upon data from the World Steel Association, last updated in 2000.

Textiles

- Golder (2004) ID48119_Textile_recycling.html, published as part of WRATE

Manufacturing Background Information

- http://www.e4s.org.uk/textilesonline/content/6library/report2/textile_fibre_usage.htm

Wood

- Environment Agency (April 2010) *WRATE version 2*. Assumes wood is chipped for composting. A range of other uses exist
- Kellenberger D. (2007) *Life Cycle Inventories of Building Products* Ecoinvent, EMPA