www.defra.gov.uk

2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting:
Methodology Paper for Emission Factors

August 2011

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, Helen Walker and Jamie Beevor (AEA) and Keith James (WRAP) 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
PB13625

2011 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 2011 Guidelines to Defra /DECC's Greenhouse Gas (GHG) Conversion Factors for Company Reporting (hereafter the 2011 GHG Conversion Factors) represent the current official set of government emissions factors. These factors are also used in a number of different policies, such as the Act on CO_2 Calculator[1]. This paper outlines the methodology used to update and expand the emission factors for the 2011 GHG Conversion Factors. The new factors are presented at the end of each of the relevant following sections.

4. In the 2009 update, emissions factors for the non-carbon dioxide (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 annually updated. Values for CH_4 and N_2O are presented as CO_2 equivalents (CO_2e) using Global Warming Potential (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.

5. In 2010, indirect emissions from the fuel cycle were included for the first time and have been updated in 2011. 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. These emissions are classed as Scope 3 according to the GHG Protocol.

[1] The Act on CO_2 Calculator is available at http://carboncalculator.direct.gov.uk. At the time of publication of this paper the Calculator was still utilising emission factors from the 2009 GHG Conversion Factors.

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. Therefore the indirect emission factors provided do not cover such situations.

6. The factors for 2011 GHG Conversion Factors will be set for the next financial year, 2011/2012. It is the intention to continue to review and update them once a year.

7. Further information about the 2011 GHG Conversion Factors together with previous methodology papers is available from Defra's website at: http://www.defra.gov.uk/environment/economy/business-efficiency/reporting/,

8. Further information on the factors used in the Act on CO_2 Calculator can be found on DECC's website[2].

Overview of changes since previous update

9. Major changes and updates in terms of methodological approach from the October 2010 version are as follows:
   a. In previous years, the UK electricity emission factors in Annex 3 have been calculated based solely on UK electricity generation - i.e. excluding imported electricity via the electricity grid interconnects with Ireland and France. Following a review of this methodology it has been decided to revise it to factor in electricity imports in order to provide a more accurate estimation of emissions produced from usage of the UK electricity grid. This has been applied in this 2011 update across the full time-series.
   In general the UK is a net electricity exporter to Ireland and a net electricity importer from France. Therefore, because France has significantly lower emission factors for electricity generation (being predominantly nuclear power), this has resulted in a reduction in the UK grid average emission factors across the time-series. The degree to which the emission factors have changed varies by year according to the relative proportion of electricity imported.
   b. New emission factors have been provided in Annex 1, Annex 6 and Annex 7 for fuels supplied at public refuelling stations with the national average proportion of biofuel blended into them. These emission factors are intended to supplement the existing emission factors for 100% conventional petrol and diesel (i.e. refined from crude oil).
   c. The lifecycle emissions factors and calculations for waste in Annex 9 have been expanded (as well as updated /amended) to include a wider range of materials and also products, based on information on new analysis provided by WRAP.

[2] Available at: http://www.decc.gov.uk/assets/decc/what%20we%20do/global%20climate%20change%20and%20energy/tackling%20climate%20change/ind_com_action/calculator/1_20091120174357_e_@@_actonCO$_2$calculatormethodology.pdf

10. More minor methodological changes have been applied to the following areas, which are summarised in greater detail in the relevant later sections:
    a. *Hybrid car emission factors (Annex 6):* these emission factors are now based on new vehicle registrations data from SMMT[3], rather than estimates based on a limited range of models used in previous updates;
    b. *Van emission factors (Annex 7):* a correction has been made to the data set used to calculate van emissions which has reallocated some vans between the different weight categories for the payload capacity calculation. This has resulted in some significant changes to emission factors per tonne-km;
    c. *Overseas electricity (Annex 10):* the dataset used to calculate distribution losses has been expanded based on data from the IEA (2010) to improve on estimates for the most recent 5 years.
    d. *Supply Chain Emissions (Annex 13):* this has been updated with the more recent data provided in a separate update to Annex 13 by Defra.

Structure of this methodology paper

11. The following Sections I to X provide methodological summary for the data Annexes numbered 1-10 contained in the Defra/DECC GHG Conversion Factors for Company Reporting (DCF), including:

DCF Annex 1:	Fuel Conversion Factors (see Section I);
DCF Annex 2:	CHP Imports and Export (no relevant section, since this Annex only includes methodological guidance);
DCF Annex 3:	Electricity Factors (see Section III);
DCF Annex 4:	Process Emissions (see Section IV);
DCF Annex 5:	Process GWP Factors (see Section IV);
DCF Annex 6:	Passenger Transport (see Section V and Section VII);
DCF Annex 7:	Freight Transport (see Section VI and Section VII);
DCF Annex 8:	Refrigeration and Aircon (see Section VIII);
DCF Annex 9:	Other UK Factors (see Section IX);
DCF Annex 10:	Overseas Electricity (see Section X);

For easier identification/navigation of this document, the major Section headings contain references to the relevant 'DCF Annex'.

[3] SMMT = the UK Society for Motor Manufacturers and Traders

II. Fuel Conversion Factors (DCF 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) from 2009.

13. The factors are also used in the Government's Act on CO_2 Calculator released most recently updated in 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 biofuel blends of diesel and petrol commonly supplied at public refuelling stations, factoring in the biodiesel supplied in the UK as a proportion of the total supply.

New Fuel Emission Factors

Direct Emissions

16. All the fuel conversion factors for direct emissions presented in the 2011 GHG Conversion Factors are based on the default emission factors used in the UK GHG Inventory (GHGI) for 2009 (managed by AEA)[4].

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 2011 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 2010 (DECC), available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

[4] UK Greenhouse Gas Inventory for 2009 (AEA), available at: http://naei.defra.gov.uk

19. Four tables are presented in the 2011 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[5] 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[6]. 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. Indirect emission factors for fuels were included in the Annexes for the first time in 2010, and have been updated in 2011.. 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. They are classed as Scope 3 according to the GHG Protocol.

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 2011 GHG Conversion Factors[7]. This is the preeminent 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.

[5] 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).
[6] See information available on Transco website: http://www.transco.co.uk/services/cvalue/cvinfo.htm
[7] 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

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 2011 Defra/DECC Conversion Factors.

25. In 2011 emission factors were also calculated for diesel supplied at public refuelling stations, factoring in the biodiesel supplied in the UK as a proportion of the total supply of diesel and biodiesel (3.6% by unit volume, 3.3% by unit energy – see Table 2). These estimates have been made based on the most recently available reports on the Renewable Transport Fuel Obligation (RTFO)[8].

26. Emission factors were also calculated for petrol supplied at public refuelling stations, factoring in the bioethanol supplied in the UK as a proportion of the total supply of petrol and bioethanol (= 2.9% by unit volume, 1.9% by unit energy – see Table 2). These estimates have also been made based on the most recently available reports on the RTFO[9].

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

[8] For more information see: http://www.dft.gov.uk/pgr/statistics/datatablespublications/biofuels
[9] RTFO Quarterly Report 11: 15 April 2010 - 14 January 2011, available from DfT's website at: http://www2.dft.gov.uk/pgr/statistics/datatablespublications/biofuels/

Fuel	Indirect EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect Emission Factor	Assumptions
			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.

Table 2: UK Sales of conventional and biofuels 15 April 2010-14 January 2011[10]

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	*Conventional Fuel*	*per unit mass*	*per unit volume*	*per unit energy*
Diesel/Biodiesel	740.4	19,904.6	3.81%	3.59%	3.32%
Petrol/Bioethanol	464.4	15,576.4	3.12%	2.90%	1.89%

III. Electricity Conversion Factors (DCF Annex 3)

Summary of changes since previous update

27. The main methodological changes and additions since the previous update include:
    a. The inclusion of imported electricity in calculations.

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

[10] Based on the most recently available data from RTFO monitoring at the time of production of the 2011 GHG Conversion Factors. The dataset (Quarterly report 11) is available from the DfT website at: http://www2.dft.gov.uk/pgr/statistics/datatablespublications/biofuels/

Direct Emissions from UK Grid Electricity

29. The electricity conversion factors given represent the average CO_2 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). In the 2011 update, for the first time the calculations also factor in net imports of electricity via the interconnects with Ireland and France. These factors include only direct CO_2, CH_4 and N_2O emissions at UK power stations, plus those from the proportion of imported electricity. They do not include emissions resulting from production and delivery of fuel to these power stations (i.e. from gas rigs, refineries and collieries, etc.).

30. This factor changes from year to year, as the fuel mix consumed in UK power stations changes, and the proportion of net imported electricity also changes. These annual changes can be large as the factor depends very heavily on the relative prices of coal and natural gas as well as fluctuations in peak demand and renewables. Therefore 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. In the majority of cases (i.e. for company reporting), the 'Grid Rolling Average' factor should be used. The actual in-year (i.e. non-rolling average) emission factors may be more appropriate for more specific purposes (e.g. policy impact analysis).

31. The electricity conversion factors provided in the 2011 GHG Conversion Factors Annex 3 are based on UK Greenhouse Gas Inventory for 2009 (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) 2010[11].

32. In previous updates the electricity emission factors only accounted for UK generated electricity by major power producers and renewables supplied to the national grid. As indicated, for the first time the impact of net imports of electricity via the interconnects the UK has with other countries have been factored into the calculations in the 2011 GHG Conversion Factors. It is believed this should provide a closer representation of the average quality of the electricity obtained from the UK's national grid.

33. The UK is a net importer of electricity from the interconnect with France, and a net exporter of electricity to Ireland according to DUKES (2010). For the 2011 GHG Conversion Factors net electricity imports were calculated from DUKES (2010) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2009).

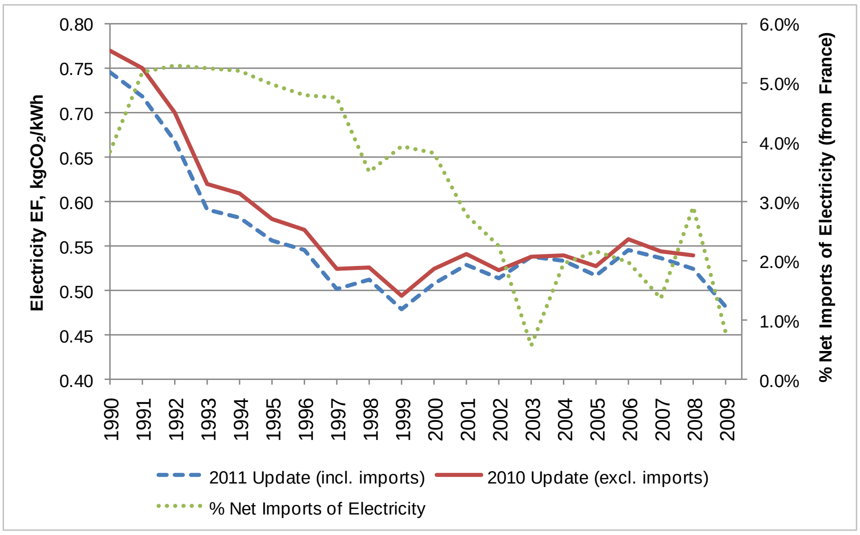
[11] DUKES (2010): *http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx*

34. The electricity emission factor for France (from Annex 10) – including losses – was used to account for the net import of electricity, as it will also have gone through the French distribution system. The UK's electricity emissions factors are subsequently smaller than those reported in Annex 3 of the 2010 GHG Conversion Factors because the electricity emission factor for France is lower than that for the UK. This is largely due to the fact that France's electricity generation is much less carbon-intensive than that of the UK.

35. The source data and corresponding calculated emissions factors are summarised in the following Table 3, Table 4 and Table 5. The corresponding 5-year rolling average emission factors are presented in Table 6. The impact of the change in methodology is also summarised in Figure 1 for the electricity CO_2 emission factor time-series from the 2011 update and 2010 update. The time-series of the percentage of net imports of electricity from France is also provided in the same chart and the impact of this can be seen in comparing the two in-year emission factor time-series.

Figure 1: Summary of the impact of the 2011 methodology change on actual in-year and 5-year rolling average grid electricity emission factors

Actual in-year grid electricity emission factors:



5-year rolling average grid electricity emission factors:

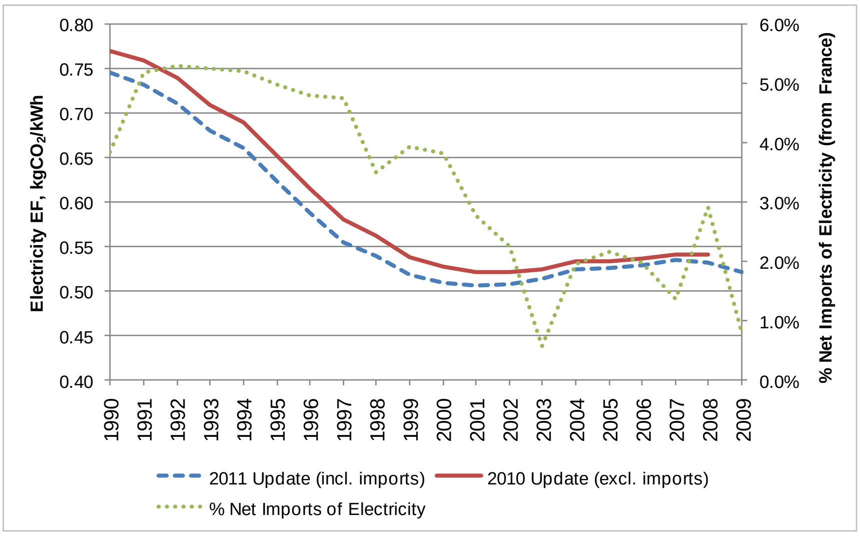


Table 3: Base electricity generation emissions data

Year	Electricity Generation (1)	Total Grid Losses (2)	UK electricity generation emissions (3), ktonnes		
	GWh	%	CO_2	CH_4	N_2O
1990	286,681	8.1%	202,916	2.592	5.361
1991	289,991	8.3%	199,507	2.419	5.295
1992	289,670	7.5%	187,467	2.339	4.975
1993	295,543	7.2%	170,100	2.382	4.197
1994	300,741	9.6%	165,890	2.544	4.000
1995	308,625	9.1%	162,765	2.613	3.842
1996	312,430	8.4%	162,459	2.647	3.567
1997	310,660	7.8%	149,664	2.573	3.051
1998	320,317	8.4%	154,730	2.802	3.154
1999	323,213	8.3%	146,593	2.850	2.731
2000	329,345	8.4%	158,199	3.022	3.066
2001	340,525	8.6%	168,618	3.271	3.372
2002	342,299	8.3%	164,285	3.279	3.180
2003	350,385	8.5%	173,310	3.384	3.480
2004	349,092	8.7%	172,876	3.390	3.364
2005	353,481	7.2%	172,436	3.682	3.507
2006	352,075	7.2%	181,345	3.779	3.847
2007	351,094	7.1%	177,139	3.861	3.560
2008	345,926	7.4%	172,066	4.081	3.311
2009	334,351	7.5%	149,919	4.034	2.838

Notes:

(1) Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES (2010) 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) Based upon calculated net grid losses from data in DUKES (2010) Table 5.1.2 (long term trends, only available online).

(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 2009 (AEA, 2011)

Table 4: Base electricity generation emissions electricity emissions factors (excluding imported electricity

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)				% Net Electricity Imports	Imported Electricity EF
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
1990	0.70781	0.00019	0.00580	0.71380	0.06219	0.00002	0.00051	0.06272	0.77000	0.00021	0.00631	0.77651	3.85%	0.11653
1991	0.68798	0.00018	0.00566	0.69381	0.06202	0.00002	0.00051	0.06255	0.75000	0.00019	0.00617	0.75636	5.18%	0.13119
1992	0.64717	0.00017	0.00532	0.65267	0.05283	0.00001	0.00043	0.05327	0.70000	0.00018	0.00576	0.70594	5.29%	0.10471
1993	0.57555	0.00017	0.00440	0.58012	0.04445	0.00001	0.00034	0.04480	0.62000	0.00018	0.00474	0.62492	5.25%	0.07255
1994	0.55161	0.00018	0.00412	0.55591	0.05839	0.00002	0.00044	0.05885	0.61000	0.00020	0.00456	0.61476	5.22%	0.07321
1995	0.52739	0.00018	0.00386	0.53142	0.05261	0.00002	0.00039	0.05302	0.58000	0.00020	0.00424	0.58444	4.97%	0.08075
1996	0.51999	0.00018	0.00354	0.52370	0.04770	0.00002	0.00032	0.04804	0.56769	0.00019	0.00386	0.57175	4.80%	0.08452
1997	0.48176	0.00017	0.00304	0.48498	0.04072	0.00001	0.00026	0.04099	0.52248	0.00019	0.00330	0.52597	4.76%	0.07778
1998	0.48305	0.00018	0.00305	0.48629	0.04427	0.00002	0.00028	0.04457	0.52732	0.00020	0.00333	0.53086	3.51%	0.10656
1999	0.45355	0.00019	0.00262	0.45636	0.04079	0.00002	0.00024	0.04104	0.49434	0.00020	0.00286	0.49740	3.94%	0.09232
2000	0.48034	0.00019	0.00289	0.48342	0.04396	0.00002	0.00026	0.04424	0.52430	0.00021	0.00315	0.52766	3.82%	0.08961
2001	0.49517	0.00020	0.00307	0.49844	0.04636	0.00002	0.00029	0.04667	0.54153	0.00022	0.00336	0.54511	2.78%	0.07667
2002	0.47994	0.00020	0.00288	0.48303	0.04319	0.00002	0.00026	0.04346	0.52313	0.00022	0.00314	0.52649	2.24%	0.08261
2003	0.49463	0.00020	0.00308	0.49791	0.04576	0.00002	0.00028	0.04607	0.54039	0.00022	0.00336	0.54398	0.57%	0.08636
2004	0.49522	0.00020	0.00299	0.49841	0.04725	0.00002	0.00029	0.04755	0.54247	0.00022	0.00327	0.54596	1.97%	0.08446
2005	0.48782	0.00022	0.00308	0.49112	0.03810	0.00002	0.00024	0.03836	0.52593	0.00024	0.00332	0.52948	2.16%	0.09941
2006	0.51508	0.00023	0.00339	0.51869	0.04006	0.00002	0.00026	0.04034	0.55514	0.00024	0.00365	0.55903	1.97%	0.09238
2007	0.50454	0.00023	0.00314	0.50791	0.03843	0.00002	0.00024	0.03869	0.54297	0.00025	0.00338	0.54660	1.37%	0.09597
2008	0.49741	0.00025	0.00297	0.50062	0.03967	0.00002	0.00024	0.03992	0.53708	0.00027	0.00320	0.54055	2.92%	0.08838
2009	0.44839	0.00025	0.00263	0.45127	0.03625	0.00002	0.00021	0.03649	0.48464	0.00027	0.00284	0.48776	0.80%	0.08838

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

Table 5: Base electricity generation emissions electricity emissions factors (including imported electricity)

Year	Emission Factor, $kgCO_2e$ / kWh													
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				% Net Electricity Imports	Imported Electricity EF
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
1990	0.68505	0.00018	0.00561	0.69084	0.06019	0.00002	0.00049	0.06070	0.74524	0.00020	0.00610	0.75154	3.85%	0.11653
1991	0.65916	0.00017	0.00542	0.66475	0.05942	0.00002	0.00049	0.05993	0.71858	0.00018	0.00591	0.72468	5.18%	0.13119
1992	0.61845	0.00016	0.00509	0.62370	0.05048	0.00001	0.00042	0.05091	0.66894	0.00018	0.00550	0.67461	5.29%	0.10471
1993	0.54915	0.00016	0.00420	0.55352	0.04241	0.00001	0.00032	0.04275	0.59156	0.00017	0.00453	0.59626	5.25%	0.07255
1994	0.52665	0.00017	0.00394	0.53076	0.05575	0.00002	0.00042	0.05619	0.58241	0.00019	0.00435	0.58695	5.22%	0.07321
1995	0.50519	0.00017	0.00370	0.50906	0.05040	0.00002	0.00037	0.05079	0.55559	0.00019	0.00407	0.55984	4.97%	0.08075
1996	0.49909	0.00017	0.00340	0.50265	0.04579	0.00002	0.00031	0.04611	0.54487	0.00019	0.00371	0.54877	4.80%	0.08452
1997	0.46253	0.00017	0.00292	0.46562	0.03910	0.00001	0.00025	0.03936	0.50163	0.00018	0.00317	0.50498	4.76%	0.07778
1998	0.46984	0.00018	0.00297	0.47298	0.04306	0.00002	0.00027	0.04335	0.51290	0.00020	0.00324	0.51633	3.51%	0.10656
1999	0.43933	0.00018	0.00254	0.44205	0.03951	0.00002	0.00023	0.03975	0.47884	0.00020	0.00277	0.48180	3.94%	0.09232
2000	0.46543	0.00019	0.00280	0.46842	0.04260	0.00002	0.00026	0.04287	0.50803	0.00020	0.00305	0.51129	3.82%	0.08961
2001	0.48355	0.00020	0.00300	0.48675	0.04528	0.00002	0.00028	0.04557	0.52883	0.00022	0.00328	0.53232	2.78%	0.07667
2002	0.47103	0.00020	0.00283	0.47406	0.04238	0.00002	0.00025	0.04266	0.51341	0.00022	0.00308	0.51671	2.24%	0.08261
2003	0.49230	0.00020	0.00306	0.49557	0.04555	0.00002	0.00028	0.04585	0.53785	0.00022	0.00335	0.54142	0.57%	0.08636
2004	0.48714	0.00020	0.00294	0.49028	0.04648	0.00002	0.00028	0.04678	0.53362	0.00022	0.00322	0.53706	1.97%	0.08446
2005	0.47943	0.00021	0.00302	0.48267	0.03745	0.00002	0.00024	0.03770	0.51688	0.00023	0.00326	0.52037	2.16%	0.09941
2006	0.50674	0.00022	0.00333	0.51030	0.03942	0.00002	0.00026	0.03969	0.54616	0.00024	0.00359	0.54999	1.97%	0.09238
2007	0.49892	0.00023	0.00311	0.50225	0.03801	0.00002	0.00024	0.03826	0.53692	0.00025	0.00335	0.54051	1.37%	0.09597
2008	0.48548	0.00024	0.00290	0.48862	0.03872	0.00002	0.00023	0.03897	0.52420	0.00026	0.00313	0.52759	2.92%	0.08838
2009	0.44550	0.00025	0.00261	0.44837	0.03602	0.00002	0.00021	0.03625	0.48152	0.00027	0.00283	0.48462	0.80%	0.08838

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

Table 6: 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, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				% Net Electricity Imports	Imported Electricity EF
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
1990	0.68505	0.00018	0.00561	0.69084	0.06019	0.00002	0.00049	0.06070	0.74524	0.00020	0.00610	0.75154	3.85%	0.11653
1991	0.67210	0.00018	0.00552	0.67780	0.05981	0.00002	0.00049	0.06031	0.73191	0.00019	0.00601	0.73811	5.18%	0.13119
1992	0.65422	0.00017	0.00537	0.65977	0.05670	0.00001	0.00047	0.05718	0.71092	0.00019	0.00584	0.71695	5.29%	0.10471
1993	0.62795	0.00017	0.00508	0.63320	0.05313	0.00001	0.00043	0.05357	0.68108	0.00018	0.00551	0.68677	5.25%	0.07255
1994	0.60769	0.00017	0.00485	0.61271	0.05365	0.00001	0.00043	0.05409	0.66135	0.00018	0.00528	0.66681	5.22%	0.07321
1995	0.57172	0.00017	0.00447	0.57636	0.05169	0.00002	0.00040	0.05211	0.62342	0.00018	0.00487	0.62847	4.97%	0.08075
1996	0.53971	0.00017	0.00406	0.54394	0.04897	0.00002	0.00037	0.04935	0.58867	0.00018	0.00443	0.59329	4.80%	0.08452
1997	0.50852	0.00017	0.00363	0.51232	0.04669	0.00002	0.00033	0.04704	0.55521	0.00018	0.00396	0.55936	4.76%	0.07778
1998	0.49266	0.00017	0.00338	0.49622	0.04682	0.00002	0.00032	0.04716	0.53948	0.00019	0.00371	0.54337	3.51%	0.10656
1999	0.47520	0.00017	0.00310	0.47847	0.04357	0.00002	0.00029	0.04387	0.51877	0.00019	0.00339	0.52235	3.94%	0.09232
2000	0.46724	0.00018	0.00292	0.47035	0.04201	0.00002	0.00026	0.04229	0.50925	0.00019	0.00319	0.51263	3.82%	0.08961
2001	0.46414	0.00018	0.00284	0.46716	0.04191	0.00002	0.00026	0.04218	0.50605	0.00020	0.00310	0.50934	2.78%	0.07667
2002	0.46584	0.00019	0.00283	0.46885	0.04257	0.00002	0.00026	0.04284	0.50840	0.00020	0.00308	0.51169	2.24%	0.08261
2003	0.47033	0.00019	0.00284	0.47337	0.04306	0.00002	0.00026	0.04334	0.51339	0.00021	0.00311	0.51671	0.57%	0.08636
2004	0.47989	0.00020	0.00292	0.48301	0.04446	0.00002	0.00027	0.04475	0.52435	0.00021	0.00320	0.52776	1.97%	0.08446
2005	0.48269	0.00020	0.00297	0.48586	0.04343	0.00002	0.00027	0.04371	0.52612	0.00022	0.00324	0.52958	2.16%	0.09941
2006	0.48733	0.00021	0.00304	0.49057	0.04226	0.00002	0.00026	0.04254	0.52958	0.00023	0.00330	0.53311	1.97%	0.09238
2007	0.49291	0.00021	0.00309	0.49621	0.04138	0.00002	0.00026	0.04166	0.53429	0.00023	0.00335	0.53787	1.37%	0.09597
2008	0.49154	0.00022	0.00306	0.49482	0.04001	0.00002	0.00025	0.04028	0.53156	0.00024	0.00331	0.53510	2.92%	0.08838
2009	0.48322	0.00023	0.00299	0.48644	0.03792	0.00002	0.00023	0.03817	0.52114	0.00025	0.00323	0.52462	0.80%	0.08838

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

Indirect Emissions from UK Grid Electricity

36. 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.

37. 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 2010 (DECC, 2010). The data used in these calculations are presented in Table 7, Table 8 and Table 9, together with the final indirect emission factors for electricity.

Table 7: 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	15,171	331,658	21,877	186,978	**934,531**
2006	418,018	17,272	311,408	18,038	180,608	**945,343**
2007	382,857	14,099	355,878	14,613	143,706	**911,154**
2008	348,513	19,048	376,810	13,074	124,147	**881,592**
2009	287,187	18,058	356,186	9,875	175,430	**846,736**

Source: Table 5.6, Digest of UK Energy Statistics 2010 (DECC, 2010), available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Table 8: 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%	1.6%	35.5%	2.3%	20.0%	**100.0%**
2006	44.2%	1.8%	32.9%	1.9%	19.1%	**100.0%**
2007	42.0%	1.5%	39.1%	1.6%	15.8%	**100.0%**
2008	39.5%	2.2%	42.7%	1.5%	14.1%	**100.0%**
2009	33.9%	2.1%	42.1%	1.2%	20.7%	**100.0%**

Notes: Calculated from figures in Table 7

Table 9: 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%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.68505	0.09843	0.09843
1991	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.65916	0.09471	0.09657
1992	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.61845	0.08886	0.09400
1993	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.54915	0.07891	0.09023
1994	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.52665	0.07567	0.08732
1995	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.50519	0.07259	0.08215
1996	16.5%	17.0%	9.8%	12.6%	14.4%	**14.4%**	0.49909	0.07171	0.07755
1997	16.5%	17.0%	9.8%	12.6%	13.7%	**13.7%**	0.46253	0.06354	0.07248
1998	16.5%	17.0%	9.8%	12.6%	13.7%	**13.7%**	0.46984	0.06413	0.06953
1999	16.5%	17.0%	9.8%	12.6%	13.1%	**13.1%**	0.43933	0.05773	0.06594
2000	16.5%	17.0%	9.8%	12.6%	13.3%	**13.3%**	0.46543	0.06179	0.06378
2001	16.5%	17.0%	9.8%	12.6%	13.5%	**13.5%**	0.48355	0.06522	0.06248
2002	16.5%	17.0%	9.8%	12.6%	13.3%	**13.3%**	0.47103	0.06260	0.06230
2003	16.5%	17.0%	9.8%	12.6%	13.5%	**13.5%**	0.49230	0.06624	0.06272
2004	16.5%	17.0%	9.8%	12.6%	13.3%	**13.3%**	0.48714	0.06484	0.06414
2005	16.5%	17.0%	9.8%	12.6%	13.4%	**13.4%**	0.47943	0.06434	0.06465
2006	16.5%	17.0%	9.8%	12.6%	13.7%	**13.7%**	0.50674	0.06936	0.06547
2007	16.5%	17.0%	9.8%	12.6%	13.3%	**13.3%**	0.49892	0.06648	0.06625
2008	16.5%	17.0%	9.8%	12.6%	13.1%	**13.1%**	0.48548	0.06364	0.06573
2009	16.5%	17.0%	9.8%	12.6%	12.9%	**12.9%**	0.44550	0.05746	0.06425

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 8 and Table 9.

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

Summary of changes since previous update

38. No changes have been made since the 2010 update.

Inventory of Likely Process Emissions (DCF Annex 4)

39. 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.

40. Global Warming Potential (GWP) is used to compare the impact of the emission of equivalent masses of different GHGs relative to CO_2. For example, it is estimated that the emission of 1 kilogram of CH_4 will have the same warming impact 1 as 21 kilograms of CO_2. Therefore the GWP of CH_4 is 21. The GWP of CO_2 is, by definition, 1.

Global Warming Potentials of Greenhouse Gases (DCF Annex 5)

Greenhouse Gases Listed in the Kyoto Protocol

41. 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).

42. *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

43. 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).

44. *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 (DCF Annex 6)

Summary of Changes Since the Previous Update

45. The main methodological changes and additions since the previous update include:
    a. Hybrid passenger car emission factors are now entirely based upon time-series new car CO_2 emission data from SMMT (Society for Motor Manufacturers and Traders) [12].
    b. A correction has been made to the data set used to calculate van emissions which has reallocated some vans between the different weight categories.

46. All other factors have also been updated with more recent data in the latest 2011 GHG Conversion Factors.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

47. 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 10, provides numbers of registrations and averages of the NEDC[13] gCO_2/km figures for new vehicles registered from 1997[14]. 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

[12] SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry. http://www.smmt.co.uk/
[13] NEDC = New European Driving Cycle, which is used in the type approval of new passenger cars.
[14] 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.

derived from the speed-emission curves used in UK GHG Inventory. However, for the 2010 update the emission factors by car engine size were based entirely on the SMMT dataset to bring these in better alignment with the corresponding emission factors by car market segment. This methodology is also applied to the 2011 update.

Table 10: Average CO_2 emission factors and total registrations from SMMT data for 1998 to 2010 (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	147.9	44.0	9,396,212	45%
	1.4 - 2.0 l	Medium	183.6	35.4	9,938,585	47%
	> 2.0 l	Large	259.2	25.1	1,746,271	8%
Average petrol car			**180.6**	**36.0**	**21,081,068**	**100%**
Diesel car	<1.7 l	Small	124.6	60.0	1,878,534	21%
	1.7 - 2.0 l	Medium	155.8	48.0	5,135,362	57%
	> 2.0 l	Large	210.1	35.6	1,987,245	22%
Average diesel car			**166.8**	**44.8**	**9,001,141**	**100%**

48. 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.

49. 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[15] 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 fuel card provider) on observations from the real performance of 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

[15] 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.

cases due to the nature of fleet vehicle usage compared to more typical driving styles of the general public.

50. 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[16]).

51. 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[17], with nearly all medium and large cars having air conditioning as standard equipment[18]. SMMT (Society for Motor Manufacturers and Traders)[19] 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[20].

52. 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 2011 GHG Conversion Factors.

53. The updated SMMT data was used to update the factors for the 2011 GHG Conversion Factors. The resulting *New 'Real-World'* 2010 GHG Conversion Factors, presented in Table 11, 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 62.7% petrol and 37.3% diesel, and can be compared to the respective total registrations of the different vehicle types for 1998-2010, which was 70.1% petrol and 29.9% diesel.

54. For the 2011 GHG Conversion Factors emission factor for CH_4 and N_2O were also been updated for all vehicle classes. These figures are based on the emission factors from the UK GHG Inventory (managed

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

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 11.

55. Individuals may wish to calculate their carbon emissions for a particular door-to-door journey using Transport Direct[21] - *www.transportdirect.info*.

Table 11: Revised CO_2 emission factors for cars by engine size for 2011 update

Vehicle Type	Engine size	Size label	Final New 'real-world' 2011 GHG Conversion Factors(1)				
			gCO_2 per km				MPG
			CO_2	CH_4	N_2O	Total	
Petrol car	< 1.4 l	Small	170.1	0.16	0.84	171.1	37.6
	1.4 - 2.0 l	Medium	211.1	0.16	0.84	212.1	30.3
	> 2.0 l	Large	298.1	0.16	0.84	299.1	21.7
		Ave	**207.6**	**0.16**	**0.84**	**208.6**	**30.9**
Diesel car	<1.7 l	Small	143.3	0.05	1.67	145.0	52.2
	1.7 - 2.0 l	Medium	179.2	0.05	1.67	181.0	41.7
	> 2.0 l	Large	241.6	0.05	1.67	243.3	31.0
		Ave	**191.8**	**0.05**	**1.67**	**193.5**	**39.0**
Car (unknown fuel)	(2)	Small	165.7	0.14	1.03	166.8	40.5
	(2)	Medium	200.2	0.12	1.16	201.5	34.5
	(2)	Large	268.0	0.10	1.31	269.4	26.7
	(2)	**Ave**	**203.3**	**0.12**	**1.15**	**204.6**	**33.6**

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

56. A new methodology for calculating CO_2 emission factors generated by medium and large hybrid petrol-electric cars has been used for the 2011 update. This follows the same approach used in calculating the petrol and diesel emission factors and has been facilitated thanks to the provision of new time series data for new hybrid vehicle registrations from the SMMT. Previously a simplified methodology was adopted which looked at the types of vehicle available on the market over the preceding five years.

57. The impact of the change in methodology is to reduce the medium hybrid emission factor from 119.1g CO_2/km to 117.3g CO_2/km and to reduce the large hybrid emission factor reduce from 217.3g CO_2/km to 209.5g CO_2/km. It has also brought the average hybrid emission factor down from 164.7g CO_2/km to 138.1g CO_2/km.

58. For the 2010 GHG Conversion Factors the assumptions of the emission factors for LPG and CNG vehicles were split out (whereas previously

[21] 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.

they were combined) using updated information from the Energy Saving Trust (EST[22]). Previous information from EST indicated that LPG and CNG cars result in a 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 12. New factors for LPG and CNG cars, presented in Table 13, 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. This methodology is also applied to the 2011 update.

59. For the 2010 GHG Conversion Factors emission factor for CH_4 and N_2O were also added for all vehicle classes, and updated in 2011. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA). These factors are also presented together with an overall total factor in Table 13.

Table 12: Assumptions based 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 13: New emission factors for Hybrid, LPG and CNG passenger cars for 2011 GHG Conversion Factors

		gCO_2e per km			
Car fuel	**Car size**	**CO_2**	**CH_4**	**N_2O**	**Total**
Petrol Hybrid	Medium	117.2	0.09	0.84	118.2
	Large	209.5	0.11	0.84	210.5
	Average	**138.1**	**0.11**	**0.84**	**139.0**
LPG	Medium	190.0	0.34	1.15	191.5
	Large	268.3	0.34	1.15	269.8
	Average	**211.6**	**0.34**	**1.15**	**213.1**
CNG	Medium	168.9	0.80	1.15	170.8
	Large	238.5	0.80	1.15	240.4
	Average	**188.1**	**0.80**	**1.15**	**190.0**

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

Emission Factors by Passenger Car Market Segments

60. 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 2011 GHG Conversion Factors, the market classification split was derived using detailed SMMT data on new car registrations between 1998 and 2010 split by fuel[23]. 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 13. The supplementary market segment based emission factors for passenger cars are presented in Table 14.

61. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O were also updated for all car classes. These figures are based on the emission factors from the UK GHG Inventory (managed by AEA). The factors are also presented together with an overall total factor in Table 14 to Table 17.

Table 14: Passenger car market class based CO_2 emission factors for 2011 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	156.8	103.3	156.0
B. Supermini	VW Polo	170.0	142.0	166.9
C. Lower Medium	Ford Focus	200.5	162.8	188.9
D. Upper Medium	Toyota Avensis	228.7	179.4	205.9
E. Executive	BMW 5-Series	270.7	211.2	242.0
F. Luxury	Bentley Continental GT	345.4	249.0	319.0
G. Sports	Mercedes SLK	254.5	173.6	251.5
H. Duel Purpose 4x4	Land Rover Discovery	285.9	263.9	272.0
I. MPV	Renault Espace	230.5	204.6	216.4
All	**Total**	**210.71**	**191.8**	**203.3**

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

Table 15: Passenger car market class based CH_4 emission factors for 2011 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	0.16	0.05	0.15
B. Supermini	VW Polo	0.16	0.05	0.14
C. Lower Medium	Ford Focus	0.16	0.05	0.13
D. Upper Medium	Toyota Avensis	0.16	0.05	0.12
E. Executive	BMW 5-Series	0.16	0.05	0.10
F. Luxury	Bentley Continental GT	0.16	0.05	0.10
G. Sports	Mercedes SLK	0.16	0.05	0.10
H. Duel Purpose 4x4	Land Rover Discovery	0.16	0.05	0.10
I. MPV	Renault Espace	0.16	0.05	0.11
All	**Total**	**0.16**	**0.05**	**0.12**

Table 16: Passenger car market class based N_2O emission factors for 2011 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	0.84	1.67	0.9
B. Supermini	VW Polo	0.84	1.67	1.03
C. Lower Medium	Ford Focus	0.84	1.67	1.09
D. Upper Medium	Toyota Avensis	0.84	1.67	1.16
E. Executive	BMW 5-Series	0.84	1.67	1.31
F. Luxury	Bentley Continental GT	0.84	1.67	1.31
G. Sports	Mercedes SLK	0.84	1.67	1.31
H. Duel Purpose 4x4	Land Rover Discovery	0.84	1.67	1.31
I. MPV	Renault Espace	0.84	1.67	1.23
All	**Total**	**0.84**	**1.67**	**1.15**

Table 17: Passenger car market class based total GHG emission factors for 2011 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	157.8	105.0	157.1
B. Supermini	VW Polo	171.0	143.7	168.1
C. Lower Medium	Ford Focus	201.5	164.6	190.1
D. Upper Medium	Toyota Avensis	229.7	181.1	207.2
E. Executive	BMW 5-Series	271.7	212.9	243.4
F. Luxury	Bentley Continental GT	346.4	250.7	320.4
G. Sports	Mercedes SLK	255.5	175.3	252.9
H. Duel Purpose 4x4	Land Rover Discovery	286.9	265.6	273.5
I. MPV	Renault Espace	231.5	206.4	217.8
All	**Total**	**208.6**	**193.5**	**204.6**

Direct Emissions from Taxis

62. 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[24]). The emission factors for black cabs are based on the large car emission factor (which is consistent with the VCA[25] 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[26]).

63. The emission factors per passenger km for taxis presented in Table 18 have been updated to be consistent with the most recent data for the 2011 update. The base emission factors per vehicle km are also presented in Table 19. It should be noted that many black cabs will probably have a significantly different operational cycle to the NEDC, which would be likely to increase the emission factor. At the moment there is insufficient information available to take this into account in the current factors. It is anticipated that for the 2012 update new data may be available to allow for better estimates to be developed.

64. For the 2011 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 18 and Table 19.

Table 18: Emission factors per passenger km for taxis for 2011 GHG Conversion Factors

	Average passenger occupancy	gCO_2e per passenger km			
		CO_2	CH_4	N_2O	Total
Taxi	1.4	150.3	0.04	1.19	151.5
Black Cab	1.5	198.7	0.11	0.56	199.4

Table 19: Emission factors per vehicle km for taxis for 2011 GHG Conversion Factors

	gCO_2e per passenger km			
	CO_2	CH_4	N_2O	Total
Taxi	210.4	0.05	1.67	212.1
Black Cab	241.6	0.05	1.67	243.3

[24] 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
[25] Vehicle Certification Agency (VCA) car fuel database is available at: http://www.vcacarfueldata.org.uk/
[26] *See:* http://www.lti.co.uk/news/index.php?p=98

Direct Emissions from Vans

65. Average emission factors by fuel for light good vehicles (N1 vehicles, vans up to 3.5 tonnes gross vehicle weight) by size class (I, II or III), presented in Table 20, have been updated for the 2011 GHG Conversion Factors. The data set used to allocate different vehicles to each class was based on gross vehicle weight (maximum permissible weight) rather than reference weight (approximately equivalent to kerb weight plus 60kg). A correction has been made to the MVRIS data set used to calculate van emissions in 2010, which has reallocated some vans between the different weight categories for the payload capacity calculation. In addition the assumed split of petrol van stock between size classes has been adjusted using the split of registrations from this dataset. This has resulted in some changes to emission factors, particularly since the proportion of smaller petrol vans is much higher. The 2010 emission factors are given in Table 21 for comparison.

66. 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 and diesel vehicles were calculated emission factors and vehicle km of petrol and diesel LGVs from the NAEI for 2009. 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 2009.

67. For the 2010 GHG Conversion Factors, emission factors for CH_4 and N_2O were also updated for all van classes. These are based on the emission factors from the UK GHG Inventory (managed by AEA). N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for diesel vans.

Table 20 New emission factors for vans for the 2011 GHG Conversion Factors

Van fuel	Van size	gCO_2e per km				vkm	Capacity
		CO_2	CH_4	N_2O	Total	% split	tonnes
Petrol (Class I)	Up to 1.305 tonne	200.7	0.3	1.3	202.2	38.4%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	211.1	0.3	1.3	212.7	48.6%	0.72
Petrol (Class III)	Over 1.740 tonne	256.8	0.4	2.8	260.0	13.0%	1.29
Petrol (average)	**Up to 3.5 tonne**	**213.1**	**0.3**	**1.5**	**214.9**	**100.0%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	155.6	0.1	1.1	156.8	6.2%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	224.9	0.1	1.6	226.6	25.7%	0.98
Diesel (Class III)	Over 1.740 tonne	268.2	0.1	1.9	270.1	68.1%	1.29
Diesel (average)	**Up to 3.5 tonne**	**250.1**	**0.1**	**1.7**	**251.9**	**100.0%**	**1.17**
LPG	Up to 3.5 tonne	262.6	0.7	2.0	265.3		1.17
CNG	Up to 3.5 tonne	237.6	1.6	2.0	241.3		1.17
Average		**247.8**	**0.1**	**1.7**	**249.6**		**1.15**

Table 21: Emission factors for vans from the 2010 GHG Conversion Factors

Van fuel	Van size	gCO_2e per km					vkm	Capacity
		CO_2	CH_4	N_2O	t		% split	tonnes
Petrol (Class I)	Up to 1.305 tonne	194.1	0.2	0.8	195.1		6.2%	0.45
Petrol (Class II)	1.305 to 1.740 tonne	211.1	0.2	0.8	212.2		25.7%	0.70
Petrol (Class III)	Over 1.740 tonne	255.8	0.3	1.8	257.8		68.1%	1.25
Petrol (average)	**Up to 3.5 tonne**	**240.5**	**0.3**	**1.5**	**242.2**		**100.0%**	**1.06**
Diesel (Class I)	Up to 1.305 tonne	157.0	0.1	1.1	158.2		6.2%	0.45
Diesel (Class II)	1.305 to 1.740 tonne	224.8	0.1	1.5	226.4		25.7%	0.70
Diesel (Class III)	Over 1.740 tonne	269.1	0.1	1.8	271.0		68.1%	1.25
Diesel (average)	**Up to 3.5 tonne**	**250.8**	**0.1**	**1.7**	**252.6**		**100.0%**	**1.06**
LPG	Up to 3.5 tonne	263.3	0.5	1.9	265.8			1.06
CNG	Up to 3.5 tonne	238.3	1.3	1.9	241.5			1.06
Average		**250.2**	**0.1**	**1.7**	**251.9**			**1.06**

Direct Emissions from Buses

68. 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 was 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. This methodology is also applied to the 2011 update.

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

70. The overall bus and coach emission factor was removed in the 2010 update due to concerns over its robustness following detailed discussion with DfT and the lack of suitable data in order to recalculate it.

71. For the 2011 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). These factors are also presented together with an overall total factor in Table 22: Emission factors for buses for the 2011 GHG Conversion Factors.

72. The new (2011 GHG Conversion Factors) average emission factors for different bus service types are summarised in Table 22, together with

indicative figures from DfT statistics on average bus occupancy levels. As a result of the change in methodology in 2010, the local bus emission factors 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. The change between 2010 and 2011 updates is much smaller. 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 22: Emission factors for buses for the 2011 GHG Conversion Factors

Bus type	Average passenger occupancy	gCO$_2$e per passenger km			
		CO_2	**CH_4**	**N_2O**	**Total**
Local bus	6.3	184.3	0.2	1.4	185.9
Local London bus	16.7	85.7	0.1	0.6	86.3
Average local bus	**8.2**	**147.5**	**0.2**	**1.1**	**148.8**
Coach	16.2*	30.0	0.1	0.6	30.6

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

73. 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.

74. 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)

75. For the 2009 update the emission factors were calculated based on a large dataset kindly provided by Clear (2008)[27]. 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 23 and the corresponding emission factors developed in 2009 for motorcycles are presented in Table 24. The total average has been calculated weighted by the relative number of registrations of each category in 2008 according to DfT statistics from CMS (2008)[28]. In the absence of new information the dataset and

[27] 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.
[28] "Compendium of Motorcycling Statistics: 2008", available at: *http://www.dft.gov.uk/pgr/statistics/datatablespublications/vehicles/motorcycling/*

calculations remain essentially unchanged for the 2011 GHG Conversion Factors.

76. The 2009 emission factors presented in Table 24 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[29] 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%).

77. For the 2010 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). These factors are also presented together with an overall total factor in Table 24.

Table 23: 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**

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.

[29] The European Motorcycle Manufacturers Association

Table 24: Updated emission factors for motorcycles for the 2011 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	2.44	0.36	87.8
	125cc to 500cc	Medium	63.4	103.2	2.71	0.62	106.5
	Over 500cc	Large	47.7	137.2	2.06	0.62	139.9
	Average	**-**	**56.4**	**116.1**	**2.46**	**0.60**	**119.1**

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

78. Emission factors for passenger rail services have been updated and provided in Table 26. 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 were also updated in the 2010 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

79. 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 for the 2010 update, together with information on the basis of the electricity figures used in their calculation.

80. 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.

81. 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. More recent data was not available for the 2011 update. For further information please visit: http://www.eurostar.com/UK/uk/leisure/about_eurostar/environment/greener_than_flying.jsp

82. 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

83. 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)[30]. 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). No newer dataset was available for the 2011 update.

84. 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

85. 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 25.

86. Figures for the DLR, London Overground and Croydon Tramlink for 2009/10 based on figures from Transport for London's 2010 environmental report[31] adjusted to the new 2009 grid electricity CO_2 emission factor.

87. The factors for Midland Metro, Tyne and Wear Metro, the Manchester Metrolink and Supertram were based on annual passenger km data from DfT's Light rail and tram statistics'[32] and the new 2009 grid electricity CO_2 emission factor.

88. The factor for the Glasgow Underground was provided by the network based on annual electricity consumption and passenger km data provided by the network operators for 2005/6 and the new 2009 grid electricity CO_2 emission factor, for consistency.

89. The average emission factor was estimated based on the relative passenger km of the four different rail systems (see Table 25).

---

[30] Available from the ORR's website at: *http://www.rail-reg.gov.uk/upload/pdf/rolling-c9-environ.pdf*
[31] TfL, 2011. TfL's 2010 environmental report is available at: *http://www.tfl.gov.uk/corporate/about-tfl/publications/1478.aspx*
[32] DfT Light rail and tram statistics, *http://www2.dft.gov.uk/pgr/statistics/datatablespublications/public/lightrail/*

90. 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 25: GHG emission factors, electricity consumption and passenger km for different tram and light rail services

	Type	Electricity use kWh/pkm	gCO$_2$e per passenger km				Million pkm
			CO_2	CH_4	N_2O	Total	
DLR (Docklands Light Rail)	Light Rail	0.131	68.3	0.033	0.498	76	365
Glasgow Underground	Light Rail	0.164	85.6	0.041	0.531	86.2	42
Midland Metro	Light Rail	0.135	70.5	0.034	0.437	71.0	50
Tyne & Wear Metro	Light Rail	0.198	103.0	0.049	0.638	103.6	327
London Overground	Light Rail	0.098	51.0	0.024	0.316	51.3	437
Croydon Tramlink	Tram	0.085	44.3	0.021	0.274	44.6	134
Manchester Metrolink	Tram	0.076	39.5	0.019	0.245	39.7	206
Nottingham Express Transit	Tram	No data	No data				No data
Supertram	Tram	0.186	96.8	0.046	0.600	97.4	103
Average*		**0.129**	**67.3**	**0.032**	**0.434**	**69.4**	**1664**

Notes: * Weighted by relative passenger km

London Underground

91. The London Underground rail factor is from Transport for London's 2010 environmental report (TfL, 2011), corrected to the 2009 grid electricity CO_2 emission factor.

92. 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 26: Updated 2010 GHG emission factors for passenger rail travel

Rail	gCO$_2$e 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	3.030	56.5	Emission factor based on ORR (2009)
Light rail (and tram)	71.0	0.030	0.440	71.5	Average of UK light rail and tram systems
London underground	73.1	0.030	0.450	73.6	Transport for London's 2010 environmental report

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

Direct Emissions from RoPax Ferries

93. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[33]. No new methodology or updated dataset has been identified for the 2011 GHG Conversion Factors.

[33] 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.

94. 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.

95. From the information provided by the operators, figures for passenger km, tonne km and CO_2 emissions were calculated. CO_2 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 27.

Table 27: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[34]
Average weight of passenger + luggage, total	0.100	MCA, 2007[34]
Average Freight Unit*, total	22.173	BFF, 2007[35]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[36]

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

96. 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 28. A further split has been provided between foot-only passengers and passengers with cars in the 2011 GHG Conversion Factors, again on a weight allocation basis.

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

98. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2009, proportional to the CO_2 emissions.

[34] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=82A572A99504695B

[35] 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.

[36] 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

Table 28: 2011 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

99. 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

100. 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.

101. 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 (DCF Annex 7)

Summary of changes since previous update

102. 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. A correction has been made to the data set used to calculate van emissions which has reallocated some vans between the different weight categories for the payload capacity calculation. In addition the assumed split of petrol van stock between size classes has been adjusted. This has resulted in some changes to emission factors.

103. All other factors have also been updated with more recent data in the latest 2011 GHG Conversion Factors.

Direct Emissions from Heavy Goods Vehicles (HGVs)

104. 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 2008-10 GHG Conversion Factors. The new factors for the 2011 GHG Conversion Factors are presented in Table 30 at the end of this section.

105. The factors are based on road freight statistics from the Department for Transport (DfT, 2010)[37] for Great Britain (GB), from a survey on different sizes of rigid and artic HGVs in the fleet in 2009. 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.

106. The miles per gallon (MPG) figures in Table 5.1 of DfT (2010) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the 2011 GHG Conversion Factors tables. Table 1.15 of DfT (2010) 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 29 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.

[37] "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 29: 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

107. 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 30.

108. The loading factors in Table 29 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in Table 30. 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.

109. 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 30. Thus the factors in Table 30, 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.

110. 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 2009. 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 (2010).

111. UK average factors for all rigid and articulated HGVs are also provided in Table 30 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 2009. These are derived directly from the mpg values for rigid and articulated HGVs in Table 5.1 of DfT (2010).

112. 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 (2010). 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.

113. The conversion factors in Table 30 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.

114. 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 31 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 2009 fleet average gCO_2 per vehicle km factors in Table 30 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 (2010). Dividing the tkm by the vkm figures gives the average tonnes freight lifted by each HGV class.

115. 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 31 for the relevant HGV class.

116. For the 2011 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 were updated in 2010 following the development of revised speed-emission curves, and subsequently revised for the 2011 update. 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 30 and Table 31.

Table 30: Emission factors per vehicle km for HGV road freight for 2011 GHG Conversion Factors

Body Type	Gross Vehicle Weight	% weight laden	gCO$_2$e per vehicle km			
			CO_2	CH_4	N_2O	Total
Rigid	<7.5t	0%	543.7	0.28	6.11	550.1
		50%	591.0	0.28	6.11	597.4
		100%	638.3	0.28	6.11	644.7
		43% (UK average)	584.4	0.28	6.11	590.8
Rigid	7.5-17t	0%	671.5	0.36	7.75	679.6
		50%	767.5	0.36	7.75	775.6
		100%	863.4	0.36	7.75	871.5
		36% (UK average)	740.6	0.36	7.75	748.7
Rigid	>17t	0%	782.0	0.47	10.06	792.5
		50%	953.6	0.47	10.06	964.2
		100%	1125.3	0.47	10.06	1135.8
		52% (UK average)	961.4	0.47	10.06	971.9
All Rigid	**UK Average**	**50% (UK average)**	**822.0**	**0.40**	**8.60**	**831.0**
Articulated	<33t	0%	693.9	0.81	8.89	703.6
		50%	867.4	0.81	8.89	877.1
		100%	1040.8	0.81	8.89	1050.5
		45% (UK average)	850.0	0.81	8.89	859.7
Articulated	>33t	0%	699.7	0.94	10.30	710.9
		50%	932.9	0.94	10.30	944.1
		100%	1166.1	0.94	10.30	1177.4
		61% (UK average)	984.2	0.94	10.30	995.4
All Articulated	**UK Average**	**60% (UK average)**	**971.4**	**0.93**	**10.16**	**982.5**
All HGVs	**UK Average**	**55% (UK average)**	**888.9**	**0.66**	**9.30**	**898.8**

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 31: Emission factors per tonne km for HGV road freight (based on UK average vehicle loads in 2009) for 2011 GHG Conversion Factors

Body Type	Gross Vehicle Weight	% weight laden	UK av. goods carried per vehicle, tonnes	gCO_2e per tonne km			
				CO_2	CH_4	N_2O	Total
Rigid	>3.5-7.5t	43%	0.86	599.4	0.29	6.27	605.9
Rigid	>7.5-17t	36%	1.82	388.0	0.19	4.06	392.3
Rigid	>17t	52%	4.91	196.2	0.10	2.05	198.4
All rigid	**UK average**	***50%***	***3.30***	***259.0***	***0.13***	***2.71***	***261.8***
Articulated	>3.5-33t	45%	5.56	146.6	0.14	1.53	148.3
Articulated	>33t	61%	11.31	85.7	0.08	0.90	86.7
All articulated	**UK average**	***60%***	***10.93***	***88.5***	***0.08***	***0.93***	***89.5***
ALL HGVs	**UK average**	***55%***	***7.20***	***127.2***	***0.11***	***1.91***	***129.2***

Direct Emissions from Light Goods Vehicles (LGVs)

117. Emission factors for light good vehicles (vans up to 3.5 tonnes), presented in Table 34, were calculated based on the emission factors per vehicle-km in the earlier section on passenger transport.

118. The typical / average capacities and average payloads agreed with DfT that are used in the calculation of van emission factors per tonne km are presented in Table 32. These are based on quantitative assessment of the van database used by AEA in variety of policy assessment for DfT. For the 2011 update, a correction has been made to the dataset used to calculate van emissions in 2010, where it was discovered some van models had been included in the incorrect weight classes. The correction reallocated some vans between the different weight categories for the payload capacity calculation. In addition the assumed split of petrol van stock between size classes has been adjusted using the split of registrations from this dataset. This has resulted in some changes to emission factors, particularly since the proportion of smaller petrol vans is much higher..

Table 32: Typical van freight capacities and estimated average payload

Van fuel	**Van size**	**vkm**	**Av. Capacity**	**Av. Payload**
		% split	**tonnes**	**tonnes**
Petrol (Class I)	Up to 1.305 tonne	38.4%	0.64	0.24
Petrol (Class II)	1.305 to 1.740 tonne	48.6%	0.72	0.26
Petrol (Class III)	Over 1.740 tonne	13.0%	1.29	0.53
Petrol (average)	**Up to 3.5 tonne**	**100.0%**	**0.76**	**0.31**
Diesel (Class I)	Up to 1.305 tonne	6.2%	0.64	0.24
Diesel (Class II)	1.305 to 1.740 tonne	25.7%	0.98	0.36
Diesel (Class III)	Over 1.740 tonne	68.1%	1.29	0.53
Diesel (average)	**Up to 3.5 tonne**	**100.0%**	**1.17**	**0.47**
LPG (average)	Up to 3.5 tonne		1.17	0.47
CNG (average)	Up to 3.5 tonne		1.17	0.47
Average			**1.15**	**0.46**

119. The average load factors assumed for different vehicle types used to calculate the average payloads in Table 32 are summarised in Table 33, on the basis of DfT statistics from a survey of company owned vans.

Table 33: 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[38]

120. For the 2011 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 were 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.

121. Emission factors per tonne km (Table 34) 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 32 and the earlier emission factors per vehicle-km in earlier Table 20.

Table 34: Emission factors freight carried on vans for 2011 GHG Conversion Factors

Van fuel	**Van size**	**gCO_2e per tonne km**					**vkm**	**Capacity**
		CO_2	**CH_4**	**N_2O**	**Total**	**1**	**% split**	**tonnes**
Petrol (Class I)	Up to 1.305 tonne	852.5	1.37	5.40	859.2		38.4%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	801.3	1.22	4.82	807.4		48.6%	0.72
Petrol (Class III)	Over 1.740 tonne	481.8	0.66	5.34	487.8		13.0%	1.29
Petrol (average)	**Up to 3.5 tonne**	**693.9**	**1.06**	**4.80**	**699.7**		**100.0%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	659.5	0.24	4.56	664.3		6.2%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	624.0	0.16	4.31	628.5		25.7%	0.98
Diesel (Class III)	Over 1.740 tonne	503.6	0.11	3.48	507.2		68.1%	1.29
Diesel (average)	**Up to 3.5 tonne**	**530.2**	**0.12**	**3.66**	**534.0**		**100.0%**	**1.17**
LPG (average)	Up to 3.5 tonne	556.7	1.47	4.28	562.5			1.17
CNG (average)	Up to 3.5 tonne	503.7	3.45	4.28	511.5			1.17
Average		**537.0**	**0.16**	**3.71**	**540.9**			**1.15**

[38] 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

Direct Emissions from Rail Freight

122. 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)[39]. This factor is presented in Table 35. In the absence of an update to this figure when the 2011 GHG Conversion Factors were being developed, this figure remains unchanged.

123. 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).

124. 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).

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

126. 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 35: 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	0.050	3.060	31.6

Direct Emissions from RoPax Ferry Freight

127. 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 2011 GHG Conversion Factors.

128. 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.

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

129. From the information provided by the operators, figures for passenger km, tonne km and CO_2 emissions were calculated. CO_2 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 36.

Table 36: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[40]
Average weight of passenger + luggage, total	0.100	MCA, 2007[40]
Average Freight Unit*, total	22.173	BFF, 2007[41]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[42]

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

130. 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 37.

131. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2009, proportional to the CO_2 emissions.

Table 37: 2011 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

132. The methodology/source of the emissions factors for other marine freight transport was entirely updated for the 2010 GHG Conversion Factors, with the exception of RoPax ferries, with this methodology unchanged for the 2011 update.

133. 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)[43] report on GHG emissions from ships.

[40] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.dft.gov.uk/mca/347.pdf

[41] 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.

[42] 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://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/statistics/datatablespublications/freight/goodsbyroad/roadfreightstatistics2005int511

134. 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 2011 factors presented in Table 38 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.

135. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2009, proportional to the CO_2 emissions.

Table 38: Emission factors for marine freight transport for 2011 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

[43] "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

Shipping Vessel Category	Size Class	Average Loading %	gCO_2e per tonne km			
			CO_2	CH_4	N_2O	Total
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

136. 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

137. 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)[44].

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

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

Summary of changes since previous update

138. There have been no methodological updates to the aviation emission factors methodology. Changes for the direct emission factors in the 2011 GHG Conversion Factors are therefore limited to updates to the core datasets.

Passenger Air Transport Direct CO_2 Emission Factors (DCF Annex 6)

139. Following feedback received on the emission factors currently used in the 2007 Act on CO_2 calculator and 2007 GHG Conversion Factors[45] 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, 2010 and 2011 GHG Conversion Factors.

140. 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)[46]. A full summary of the expanded representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 39. 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 2009 (the latest 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.

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

f. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

Table 39: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2011

	Average No. Seats	Average Load Factor	Proportion of passenger km
Domestic Flights			
Boeing 737-400	147	60.7%	12%
Boeing 737-700	144	74.0%	7%
Airbus A319/A320	158	70.9%	56%
BAE Jetstream 41	29	49.9%	5%
BAE 146	80	57.7%	0%
Dash 8 Q400	76	60.6%	19%
Total	***134***	***66.9%***	***100%***
Short-haul Flights			
Boeing 737-400	147	78.1%	9%
Boeing 737-800	189	85.4%	11%
Airbus A319/A320	158	81.3%	61%
Boeing 757	223	86.6%	19%
Total	***173***	***82.5%***	***100%***
Long-haul Flights			
Boeing 747-400	338	82.4%	46%
Boeing 767	240	82.0%	12%
Boeing 777	238	77.9%	21%
Airbus A330	306	87.1%	7%
Airbus A340	294	75.9%	14%
Total	***297***	***80.9%***	***100%***

Notes: Figures have been calculated from 2009 CAA statistics for UK registered airlines for the different aircraft types.

Taking Account of Freight

141. 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, and has also been applied in subsequent updates.

142. 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 40:

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 40: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2011 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%	163.6	99.7%	163.1	99.7%	163.1
Short-haul flights	100.0%	96.5	99.4%	95.9	99.4%	95.9
Long-haul flights	100.0%	124.5	72.2%	89.9	88.6%	110.4

143. The basis of the freight weighting **Option 2** is to take 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[47] 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 40.

144. 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

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

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**.

145. **Option 2** was selected as the preferred methodology to allocate emissions between passengers and freight for the 2008 and subsequent GHG Conversion Factors.

'Real-World' Uplift

146. 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)[48]. 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 2009 (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.

147. 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% was 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 subsequent GHG Conversion Factors, including the 2011 update.

148. 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.

149. 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.

---

[48] 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*

150. The revised average emission factors for aviation are presented in Table 41. The figures in Table 41 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).

Table 41: Revised average CO_2 emission factors for passenger flights for 2011

Mode	2008 update		2009 update		2010 update		Revised factors for 2011	
	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm	Load Factor%	gCO_2 /pkm
Domestic flights	66.3%	175.3	65.2%	171.0	64.5%	171.5	66.9%	163.1
Short-haul flights	81.2%	98.3	80.9%	98.3	82.4%	97.0	82.5%	95.9
Long-haul flights	78.1%	110.6	77.8%	112.2	78.2%	113.2	80.9%	110.4

Seating Class Factors

151. 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.

152. 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[49] 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 42. 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

[49] 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.

major airlines (e.g. SeatGuru[50], UK-AIR.NET[51], FlightComparison[52] and SeatMaestro[53]).

153. 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 6 times[54] the space taken up by the basic economy seating. Table 42 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 42: Seating class based CO_2 emission factors for passenger flights for 2011

Flight type	Size	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**66.9%**	**163.1**	**1.00**	**100%**	**100%**
Short-haul	**Average**	**82.5%**	**95.9**	**1.05**	**100%**	**100%**
	Economy class	82.5%	91.4	1.00	95%	90%
	First/Business class	82.5%	137.1	1.50	143%	10%
Long-haul	**Average**	**80.9%**	**110.4**	**1.37**	**100%**	**100%**
	Economy class	80.9%	80.6	1.00	73%	80%
	Economy+ class	80.9%	128.9	1.60	117%	5%
	Business class	80.9%	233.6	2.90	212%	10%
	First class	80.9%	322.3	4.00	292%	5%

Freight Air Transport Direct CO_2 Emission Factors (DCF Annex 7)

154. 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.

155. 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 71% 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.

156. 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.

[50] See: http://www.seatguru.com/
[51] See: http://www.uk-air.net/seatplan.htm
[52] *See: http://www.flightcomparison.co.uk/flightcomparison/home/legroom.aspx*
[53] *See: http://www.seatmaestro.com/airlines.html*
[54] For the first class sleeper seats/beds frequently used in long-haul flights.

Emission Factors for Dedicated Air Cargo Services

157. 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 subsequent GHG Conversion Factors, including the 2011 update – presented in Table 43. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied to the CORINAIR based factors.

Table 43: Revised average CO_2 emission factors for dedicated cargo flights for 2011

Mode	2008 update		2009 update		2010 update		Revised factors for 2011	
	Load Factor%	gCO_2 /tkm	Load Factor%	gCO_2 /tkm	Load Factor%	gCO_2 /tkm	Load Factor%	gCO_2 /tkm
Domestic flights	56.4%	1.85	55.5%	1.88	51.3%	1.93	59.1%	1.71
Short-haul flights	59.2%	1.32	56.0%	1.42	54.8%	1.53	60.4%	1.36
Long-haul flights	65.4%	0.60	67.3%	0.58	65.3%	0.61	65.9%	0.61

158. 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)[55]. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 44. The key features of the calculation methodology, data and assumptions for the 2008 and subsequent 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 2009 (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.

[55] 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 44: Assumptions used in the calculation of revised average CO_2 emission factors for dedicated cargo flights for the 2011 GHG Conversion Factors

	Average Cargo Capacity, tonnes	Average Load Factor	Proportion of tonne km
Domestic Flights			
Boeing 737-300	16.0	66%	62.7%
Boeing 757-200	24.1	62%	6.9%
BAE ATP	8.2	46%	9.5%
Lockheed L188	14.0	38%	4.9%
BAE 748	6.3	20%	0.1%
BAE 146-200/QT	11.7	45%	15.9%
Total	***15.0***	***59%***	***99.9%***
Short-haul Flights			
Boeing 737-300	16.0	52%	0.0%
Boeing 757-200	24.1	63%	91.9%
BAE ATP	8.2	32%	2.3%
Lockheed L188	14.0	42%	1.2%
Boeing 747-200F	111.2	36%	4.6%
Total	***27.6***	***60%***	***100.0%***
Long-haul Flights			
Boeing 747-400F	113.4	67%	58.4%
Boeing 747-200F	103.5	65%	25.0%
Boeing 757-200	25.8	65%	16.6%
Total	***96.4***	***66%***	***100.0%***

Notes: Figures have been calculated from 2009 CAA statistics for UK registered airlines for different aircraft.

Emission Factors for Freight on Passenger Services

159. 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 45 with the two different allocation options for long-haul services.

Table 45: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2011 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	4.8%	95.2%	0.3%	1.74	0.3%	1.74
Short-haul flights	22.7%	77.3%	0.6%	1.33	0.6%	1.33
Long-haul flights	70.6%	29.4%	27.8%	1.47	11.4%	0.61

160. It is useful to compare the emission factors calculated for freight carried on passenger services (in Table 45) with the equivalent factors for freight carried on dedicated cargo services (in Table 43). 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 CO_2 emissions as if the same freight was carried on a cargo aircraft. In the case of other international flights, the factor in Table 45 is more than twice the comparable figure given in Table 43 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.

161. **Option 2** was selected as the preferred methodology for freight allocation for the 2008 update. The same methodology has been applied in the 2009, 2010 and 2011 GHG Conversion Factors and is included in all the presented emission factors.

Average Emission Factors for All Air Freight Services

162. The following Table 46 presents the final average air freight emission factors for all air freight for the 2011 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 46: Final average CO_2 emission factors for all air freight for 2011 GHG Conversion Factors

	% Total Air Freight tkm		All Air Freight
Mode	**Passenger Services**	**Cargo Services**	**$kgCO_2$/tkm**
Domestic flights	4.8%	95.2%	1.74
Short-haul flights	22.7%	77.3%	1.33
Long-haul flights	70.6%	29.4%	0.61

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

163. Emission factors for CH_4 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 2009 (see Table 47). The resulting air transport emission factors for the 2011 GHG Conversion Factors are presented in Table 48 for passengers and Table 49 for freight.

Table 47: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2009

2009	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	1.94	98.96%	0.00	0.06%	0.02	0.97%
Aircraft - international	32.62	99.02%	0.00	0.01%	0.32	0.97%

Emissions of N_2O

164. Similarly to CH_4, emission factors for N_2O 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 2009 (see Table 47). The resulting air transport emission factors for the 2011 GHG Conversion Factors are presented in Table 48 for passengers and Table 49 for freight.

Table 48: Final average CO_2, CH_4 and N_2O emission factors for all air passenger transport for 2011 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**	163.1	0.10	1.61	164.8
Short-haul flights	**Average**	95.9	0.01	0.94	96.8
	Economy	91.4	0.01	0.90	92.3
	First/Business	137.1	0.01	1.35	138.4
Long-haul flights	**Average**	110.4	0.01	1.09	111.5
	Economy	80.6	0.00	0.79	81.4
	Economy+	128.9	0.01	1.27	130.2
	Business	233.7	0.01	2.30	236.0
	First	322.3	0.02	3.17	325.5

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

Table 49: Final average CO_2, CH_4 and N_2O emission factors for air freight transport for 2011 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	2.29	0.00	0.02	**2.31**
Short-haul flights	1.24	0.00	0.01	**1.25**
Long-haul flights	0.61	0.00	0.01	**0.61**
Dedicated Cargo				
Domestic flights	1.71	0.00	0.02	**1.73**
Short-haul flights	1.36	0.00	0.01	**1.38**
Long-haul flights	0.61	0.00	0.01	**0.62**
All Air Freight				
Domestic flights	1.74	0.00	0.02	**1.76**
Short-haul flights	1.33	0.00	0.01	**1.35**
Long-haul flights	0.61	0.00	0.01	**0.61**

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

Air Transport Indirect Emission Factors

165. 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

166. 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.

167. 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.

168. It is not practical to provide a database of origin and destination airports to calculate flight distances in the GHG Conversion Factors. 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. This is the methodology recommended to be used with the Defra/DECC GHG Conversion Factors and is applied in the automatic calculations performed in the Excel spreadsheet version of the Annexes.

Radiative Forcing

169. The emission factors provided in the 2011 GHG Conversion Factors Annex 6 and Annex 7 refer to aviation's direct CO_2, CH_4 and N_2O emissions only. There is currently uncertainty over the other non-CO_2 climate change effects of aviation (including water vapour, contrails, NO_X etc) which have been indicatively been accounted for by applying a multiplier in some cases.

170. 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.

171. 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.

172. 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, as summarised in Table 50 below[56]. If used, this factor would be applied to the emissions factors set out here.

Table 50: Impacts of radiative forcing according to R. Sausen et al. (2005)

		RF [mW/m²]							
Year	Study	CO_2	O_3	CH_4	H_2O	Direct Sulphate	Direct Soot	Contrails	Total (w/o) Cirrus
1992	IPCC (1999)	18.0	23.0	−14.0	1.5	−3.0	3.0	20.0	48.5
2000	IPCC (1999) scaled to 2000	25.0	28.9	−18.5	2.0	−4.0	4.0	33.9	71.3
2000	TRADEOFF	25.3	21.9	−10.4	2.0	−3.5	2.5	10.0	47.8

Notes: Estimates for scaling CO_2 emissions to account for Radiative Forcing impacts are not quoted directly in the table, but are derived as follows: IPCC (1999) = 48.5/18.0 = 2.69 ≈ 2.7; TRADEOFF = 47.8/25.3 = 1.89 ≈ 1.9

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

Summary of changes since previous update

173. Information in this annex was reviewed for the 2011 GHG Conversion Factors. Only minor updates to refrigerant leakage rates were made based upon information used in the most recent UK GHG inventory.

General Methodology

174. 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 2010 update, a simple Screening Method has been provided in Annex 8 of 2011 GHG

[56] R. Sausen et al. (2005). Aviation radiative forcing in 2000: An update on IPCC (1999) Meteorologische Zeitschrift 14: 555-561, available at: http://elib.dlr.de/19906/1/s13.pdf

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)[57].

175. 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 2011 GHG Conversion Factors.

176. The emission factors used for the calculations (manufacturing, lifetime emissions, and recovery efficiency at disposal) are predominantly sourced from the 2009 UK GHG inventory. The emission factors are presented in Table 51 below. Note that emission factors for Residential and Commercial A/C and Heat Pumps are provided separately in the 2011 update. These factors are used in combination with the relevant GWP values for the particular refrigerant being used, according to the tables provided in Annex 5 of the 2011 GHG Conversion Factors (discussed in earlier Section IV).

Table 51: 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% *	1.5% *	80%	94.5% *
Medium & Large Commercial Applications	2.0%	11.0%	100%	95.0%
Transport Refrigeration (3)	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	1.0%	8.5%	80%	95.0%
Residential and Commercial Heat Pumps	1.0%	0.3%	80%	99.0%
Mobile Air Conditioning	1.0%	7.5%	50%	88.0%

Source:
(1) UK Greenhouse Gas Inventory for year 2009 (AEA, 2011)
(2) US EPA (2008)
(3) Transport Refrigeration annual leakage rate is taken from UK Greenhouse Gas Inventory for 2008 (AEA, 2010). Note that this figure is subject to review and may subsequently increase in the future.
* Unweighted average of the figures for hermetically sealed units and for small distributed systems.

[57] 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)

IX. Other UK Conversion Factors (DCF Annex 9)

Summary of changes since previous update

177. The main methodological changes and additions since the previous update include:
    a. Significant methodological update and expansion of waste dataset by WRAP.

178. All other factors have also been updated with more recent data in the latest 2011 GHG Conversion Factors.

General Methodology

179. Annex 9 of the 2011 GHG Conversion Factors provides a number of additional tables with other UK emission factors, including those for water supply and treatment (presented in Table 52), biofuels (presented in Table 53), biomass and biogas (presented in Table 54) and for waste disposal (presented in Table 55).

180. 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.

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

Water

182. The emission factors for water supply and treatment in Table 52 have been sourced from Water UK (2008, 2009, 2010) 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 52: Life-cycle GHG conversion factors for water

Fuel used	**Units**	**kg CO_2e per unit**		
		2007/08	**2008/09**	**2009/10**
Water supply	million litres	276	300	340
Water treatment	million litres	693	750	700

Source:
Water UK (2008), Water UK (2009) and Water UK (2010). Water UK Sustainability Indicators, available at: *http://www.water.org.uk/home/policy/reports/sustainability/sustainability-indicators-2007-08* (for 2007/08), *http://www.water.org.uk/home/policy/reports/sustainability/2008-09-sustainability-indicators* (for 2008/09) and *http://www.water.org.uk/home/news/press-releases/sustainability-indicators-09-10* (for 2009/10)

Biofuels

183. The emission factors for biofuels were based on UK average factors from the Quarterly Report 11 (2011)[58] on the Renewable Transport Fuel Obligation (RTFO). These average factors are presented in Table 53.

184. The indirect/fuel cycle emission factors from the RTFO reporting do not include the direct emissions of CH_4 and N_2O that are produced by the use of biofuels in vehicles. Unlike the direct emissions of CO_2, 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.

Table 53: Life-Cycle GHG Conversion Factors for biofuels

Biofuel	Emissions Factor, gCO_2e/MJ				
	RTFO Lifecycle [(1)]	Direct CH_4 [(2)]	Direct N_2O [(2)]	Total Lifecycle	Direct CO_2 Emissions (Out of Scope [(3)])
Biodiesel	37.478	0.033	0.481	37.992	75.300
Bioethanol	37.224	0.097	0.189	37.510	71.600
Biomethane	27.000	0.075	0.031	27.106	55.408

Notes:
(1) Based on UK averages from the RTFO Quarterly Report 11 (2011) from DfT
(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)

185. 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 Quarterly Reports on the RTFO. Reports are available up to the end of March 2011 (when the Renewable Fuels Agency closed), on the RFA's website[59], with subsequent reports available from DfT's website at: *http://www2.dft.gov.uk/pgr/statistics/datatablespublications/biofuels/*

186. In addition to the direct and indirect emission factors provided in Table 53, emission factors for the out of scope CO_2 emissions have also been provided in the 2011 GHG Conversion Factors (see table and the table footnote), based on data sourced from the Biomass Energy Centre (BEC, 2010)[60].

[58] These cover the period from 15 April 2010 - 14 January 2011 and were the most recent figures available at the time of production of the 2011 GHG Conversion Factors. The report is available from the DfT website at: *http://www2.dft.gov.uk/pgr/statistics/datatablespublications/biofuels/*
[59] RFA reports on the RTFO: http://www.renewablefuelsagency.gov.uk/carbon-and-sustainability/rtfo-reports
[60] 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*

Other biomass and biogas

187. 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 54.

188. The previous emission factors for wood pellets were based on the factor of 0.025 kgCO_2/kWh provided in SAP2005[61]. 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 SAP[62] which include additional upstream components. New emission factors for wood logs and wood chips have also been based on this dataset.

189. Additional emission factors for grasses/straw and for biogas (= 60% CH_4, 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).

190. In addition to the direct and indirect emission factors provided in, emission factors for the out of scope CO_2 emissions are also provided in the 2011 GHG Conversion Factors (see Table 54 and the table footnote), also based on data from sourced from BEC (2010).

Table 54: 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.

, and http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL

[61] Standard Assessment Procedure 2005 update, Table 12, available at: http://www.bre.co.uk/sap2005

[62] 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

Waste

191. The life-cycle conversion factors for waste disposal presented in Table 55 were collated and developed by WRAP (2011)63

192. The data summarised in the table covers the life cycle stages highlighted below. There are essentially zero Scope 1 emissions for waste. 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.

193. There have been significant changes to the methodologies and assumptions used by WRAP in deriving the emission factors between the previous (2010) and the current (2011) update. As a result, some of the factors have changed significantly. Further more detailed information is presented in the Appendix to this document.

[63] More information on WRAP can be found at: http://www.wrap.org.uk/

Table 55: Life-Cycle GHG Conversion Factors for Waste Disposal

Waste fraction	Production Emissions (avoidance excl disposal), kg CO_2e [2]	Net kgCO_2e emitted per tonne of waste treated/disposed of (incl. avoided impacts) by method[1]:						
		(Preparation for) Re-use, kg CO_2e	Recycling		Energy Recovery		Composting	Landfill
			Open Loop[3, 6]	Closed Loop[3]	Combustion	Anaerobic Digestion (AD)		
Aggregates (Rubble)	8		No Data	-4				0
Batteries (Post Consumer Non Automotive)	No Data		No Data		No Data			75
Books	955		No Data	-157	-529		57	580
Glass	895	No Data	-197	-366	26			26
Metal: Aluminium cans and foil (excl forming)	9,844			-9,245	31			21
Metal: Mixed Cans	4,778			-3,889	31			21
Metal: Scrap Metal	3,169			-2,241	29			20
Metal: Steel Cans	2,708			-1,702	31			21
Mineral Oil	1,401			-725	-1,195			0
Mixed commercial and industrial waste	1,613			-1,082	-347	-50	-30	199
Mixed municipal waste	2,053		257	-1,679	-37	-50	-15	290
Organic Waste: Food and Drink Waste	3,590				-89	-162	-39	450
Organic Waste: Garden Waste					-63	-119	-42	213
Organic Waste: Mixed Food and Garden Waste					-67	-126	-42	254
Paper and board: Board (Av. board: 78% corrugate, 22% cartonboard)	1,038		No Data	-240	-529		57	580
Paper and board: Mixed (assumed 25% paper, 75% board)	1,017		No Data	-219	-529		57	580
Paper and board: Paper	955		No Data	-157	-529		57	580
Plasterboard	120			-67				72
Plastics: Average plastics	3,179		-282	-1,171	1,197			34
Plastics: Average plastic film (incl bags)	2,591		-447	-1,042	1,057			34
Plastics: Average plastic rigid (incl bottles)	3,281		-230	-1,170	1,057			34
Plastics: HDPE (incl forming)	2,789		-433	-1,127	1,057			34
Plastics: LDPE and LLDPE (incl forming)	2,612		-458	-1,064	1,057			34
Plastics: PET (incl forming)	4,368		-187	-1,671	1,833			34
Plastics: PP (incl forming)	3,254		12	-914	1,357			34
Plastics: PS (incl forming)	4,548		368	-1,205	1,067			34

Waste fraction	Production Emissions (avoidance excl disposal), kg CO_2e [2]	Net $kgCO_2e$ emitted per tonne of waste treated/disposed of (incl. avoided impacts) by method[1]:						
		(Preparation for) Re-use, kg CO_2e	Recycling		Energy Recovery		Composting	Landfill
			Open Loop[3, 6]	Closed Loop[3]	Combustion	Anaerobic Digestion (AD)		
Plastics: PVC (incl forming)	3,136		14	-854	1,833			34
Silt / Soil	4		16		35			20
Textiles [5]	22,310	-13,769		-13,769	600			300
Tyres	3,410	-2,900	23	0				
WEEE - Fridges and Freezers	3,814	No Data	-656					17
WEEE - Large	537	No Data	-1,249		No Data			17
WEEE - Mixed	1,149	No Data	-1,357		No Data			17
WEEE - Small	1,761	No Data	-1,465		No Data			17
Wood	666	-599	No Data	-523	-817		285	792

Notes: [1] *Impact of other treatments can be found in: http://www.defra.gov.uk/publications/files/pb13548-economic-principles-wr110613.pdf*

[2] *Savings from embodied fossil energy resulting from avoiding waste are the negative of these figures.*

[3] *Open loop recycling is the process of recycling material into other products. Closed loop recycling is the process of recycling material back into the same product.*

[4] *On average in the UK 88% of non-recycled waste goes to landfill and 12% goes to energy recovery (combustion).*

[5] *The waste production 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. Benefit of recycling and reuse is based on 60% reused, 30% recycled (replacing paper towels), 10% landfill. Of the items reused, 80% are assumed to avoid new items.*

[6] *"For Open Loop Recycling, any calculation of impact should include the avoided raw material (e.g. if glass is used in aggregate, the impact is the open loop recycling emissions, minus the production of aggregates and any avoided waste management emissions). The figures presented in the main table include estimates resulting from avoided raw material based on the typical/average expected situation for different waste fractions.*

X. Overseas Electricity Emission Factors (DCF Annex 10)

Summary of changes since previous update

194. Overseas electricity emission factors have been revised based upon an extended and consistent dataset from the IEA (2010).

Direct Emissions from Overseas Electricity Generation

195. 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.

196. The dataset on electricity and heat emission factors from the IEA provided mainly from the IEA website [64] 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.

197. Whereas data on losses in distribution of electricity and heat was calculated from 2006 country energy balances, the 2011 Conversion Factors have been updated using 2004 – 2008 data available at the IEA website[65]. Data on the proportion of electricity and heat (for 2004 – 2008) is also provided for context, sourced from the IEA website[66], and was used to estimate the weighted net losses in the distribution of electricity and heat for different countries.

198. An example of the format for the Energy Balances data source from the IEA is provided in Table 56 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.

---

[64] Emission factor data is from International Energy Agency Data Services, for 'CO_2 Emissions per kWh Electricity and Heat Generated', from the IEA publication "*CO_2 Emissions from Fuel Combustion 2010 – Highlights"*, within an Excel file at: *http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2143*

[65] Information on energy balances is available from the IEA website at: *http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Balances*

[66] Information from the IEA website is available at: *http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Electricity/Heat*

Table 56: 2008 Energy Balances for Electricity and Heat for United Kingdom

SUPPLY and CONSUMPTION	**Electricity**	**Heat**
Production	0	0
Imports	1057	0
Exports	-109	0
International Marine Bunkers**	0	0
Stock Changes	0	0
TPES	**948**	**0**
Transfers	0	0
Statistical Differences	0	0
Electricity Plants	30859	0
CHP Plants	2274	0
Heat Plants	0	1281
Gas Works	0	0
Petroleum Refineries	0	0
Coal Transformation	0	0
Liquefaction Plants	0	0
Other Transformation	0	0
Own Use	-2283	-72
Distribution Losses	-2425	0
TFC	**29374**	**1209**
Industry sector	**9766**	**773**
Transport sector	**725**	**0**
Other sectors	**18883**	**437**
Residential	10134	52
Commercial and Public Services	8399	385
Agriculture / Forestry	350	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 [65]

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.

199. An example of the format for the Electricity and Heat data source from the IEA is provided in Table 57 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 57: Electricity / Heat for United Kingdom in 2008

	Electricity *Unit: GWh*	**Heat** *Unit: TJ*	**Heat** *Unit: GWh*
Production from:			
- coal	126699	7483	2079
- oil	6101	1388	386
- gas	176748	44763	12434
- biomass	8090	0	0
- waste	2871	0	0
- nuclear	52486	0	0
- hydro	9257		0
- geothermal	0	0	0
- solar PV	17		0
- solar thermal	0	0	0
- wind	7097	0	0
- tide	0	0	0
- other sources	0	0	0
Total Production	**389366**	**53634**	14898
Imports	12294	0	0
Exports	-1272	0	0
Domestic Supply	**400388**	**53634**	14898
Statistical Differences	1	0	0
Total Transformation*	**0**	**0**	0
Electricity Plants	0	0	0
Heat Plants	0		0
Energy Sector**	**30632**	**2997**	833
Distribution Losses	28195	0	0
Total Final Consumption	**341562**	**50638**	14066
Industry	113558	32357	8988
Transport	8434	0	0
Residential	117841	2175	604
Commercial and Public Services	97662	16106	4474
Agriculture / Forestry	4067	0	0
Fishing	0	0	0
Other Non-Specified	0	0	0

Source: Subset of data from the IEA Data Services [66]

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) = 96.3% Total Production
96.0% Total Final Consumption

200. The emission factors for overseas electricity in Annex 10 of the 2011 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).

201. 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[67], 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

202. 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.

203. 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%).

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

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

This document lays out the methodology and evidence that has been used to develop the waste management GHG factors for the 2011 GHG Conversion Factors.

The assessment methodology is underpinned by the following standards:

- ISO 14040:2006: Environmental management — Life cycle assessment — Principles and framework
- ISO 14044:2006: Environmental management — Life cycle assessment — Requirements and guidelines
- PAS 2050 (2008): Specification for the assessment of the life cycle greenhouse gas emissions of goods and services
- The World Resource Institute and the World Business Council for Sustainable Development Greenhouse Gas Protocol Initiative[68]

It also draws on the work undertaken by Sevenster et al. (2007)[69] in the Netherlands.

1.0 Life Cycle Impacts

1.1 Life Cycle Assessment and Life Cycle Thinking

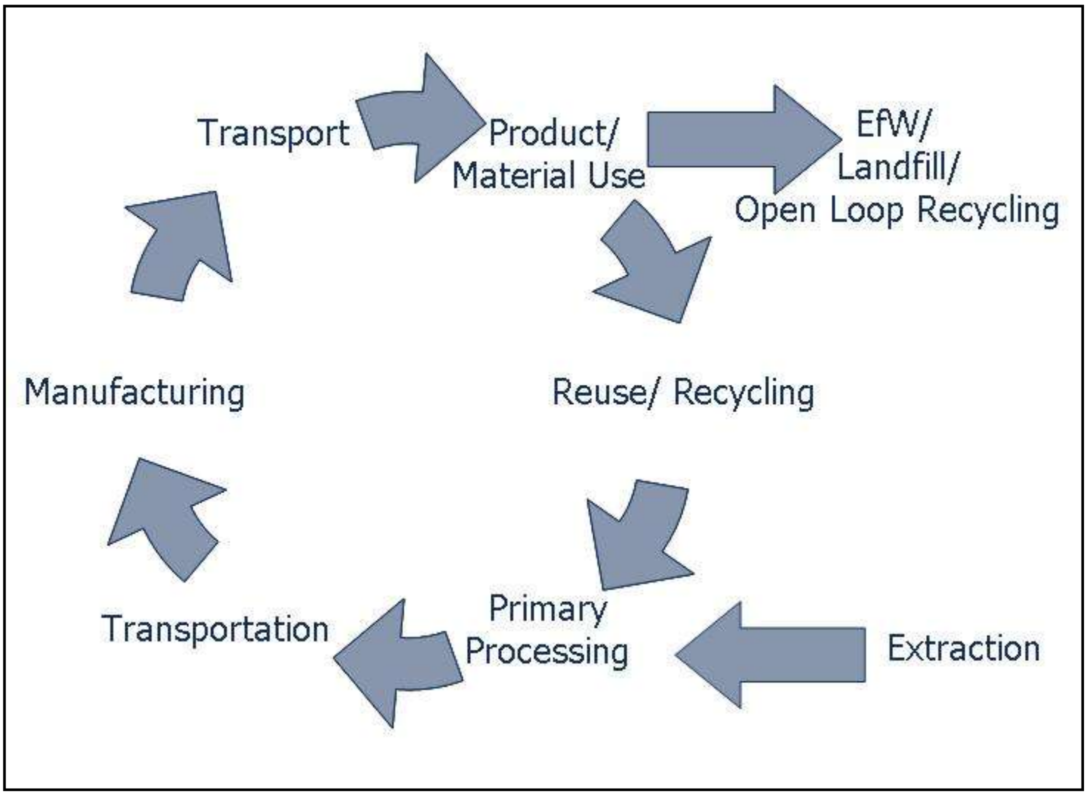
Life Cycle Assessment (LCA) is used to quantify the environmental impacts associated with a specific product, supply chain and waste management option. This allows comparisons to be made between materials, products and life cycle options depending on the different environmental impacts of each option.

The approach proposed in this report builds on Life Cycle Thinking, rather than strict LCA. Life Cycle Thinking incorporates the basic approach of LCA without requiring a detailed assessment of each product or process. Whilst it is informed by standards on life cycle assessment, it does not use an approach which is compliant with such standards for the purposes of making environmental claims about specific products or packaging. Nonetheless, the methodology is considered appropriate for the purposes of taking measures which will lead to reductions in the environmental impact of waste management, and for estimating the magnitude of such changes. The waste management GHG factors are therefore based on a number of assumptions about what happens, which are considered representative for the UK.

[68] WRI (2005), Greenhouse gas Protocol Initative. Available at: *www.ghgprotocol.org*
[69] Sevenster, M., Wielders, L., Bergsma, G., Vroonhof, J., (2007) Environmental indices for the Dutch packaging tax Delft, The Netherlands, CE Delft

Life Cycle Thinking is essential when considering environmental impacts associated with goods and services. By considering all stages in the life of a product, illustrated in Figure 1.1, from extraction of raw materials through to the end of its life, we can ensure that measures taken at one stage do not lead to unintended consequences in another, and highlight the actions with the greatest potential for improvement.

Figure 1.1: Simplified Life Cycle of a Product



Using a life cycle approach can also help to ensure that an improvement in one environmental indicator does not lead to an adverse impact in another category. This is dependent on the categories being considered.

Life Cycle Thinking can support a range of policy needs. Recent European research[70] has found that although our use of materials has been decoupling from economic growth in relative terms, in absolute terms they have remained constant for a decade. In absolute terms, this level of resource use is still unsustainably high, and many of the burdens associated with using these resources have been shifted abroad as the balance of trade itself has shifted. The consumption of these resources has a negative impact on the environment, be it via air emissions, emissions to water, solid waste, the extraction of raw materials and / or through the use of energy.

[70] Moll, S., Bringezu, S., and Schutz, H. (2005) Resource Use In European Countries, Copenhagen: European Topic Centre on Waste and Material Flows

Examples of Life Cycle Thinking in European Union policies include the Integrated Product Policy Communication (COM (2003) 302)[71], as well as the two Thematic Strategies on the Sustainable Use of Natural Resources (COM (2005) 670)[72], and on the Prevention and Recycling of Waste (COM (2005) 666)[73]. The Sustainable Consumption and Production Action Plan (SCP)[74] integrates these and other related policies, aiming to reduce the overall environmental impact and consumption of resources associated with the complete life cycles of goods and services (products).

The use of weight-based and carbon-based targets in a complementary fashion can facilitate the delivery of a range of policy, strategy and operational outcomes, and can lead to more informed decision-making. Through the use of methodologies for Life Cycle Assessment and Carbon Footprinting, the relationship between materials and emissions may be reviewed in tandem by Local Authorities to optimise their waste prevention and management operations.

2.0 The Scope of the waste management GHG factors

Currently the most developed waste data is available for local authority-collected municipal waste reported through WasteDataFlow, therefore in the first instance the methodology and range of materials investigated in this document cover the materials that are most relevant to this waste stream. The principles of the waste management GHG factors apply equally to commercial and industrial and construction and demolition waste. It is anticipated that additional factors relevant to these waste streams will be added in future editions.

Section 2.1 details the system boundaries applied to the data sources. Section 2.2 explains how biogenic carbon, an issue which can be covered in more than one way in LCA, is considered in the waste management GHG factors methodology. Section 2.3 – 2.6 explore how specific stages of the Life Cycle of materials and products are considered in the waste management GHG factors methodology.

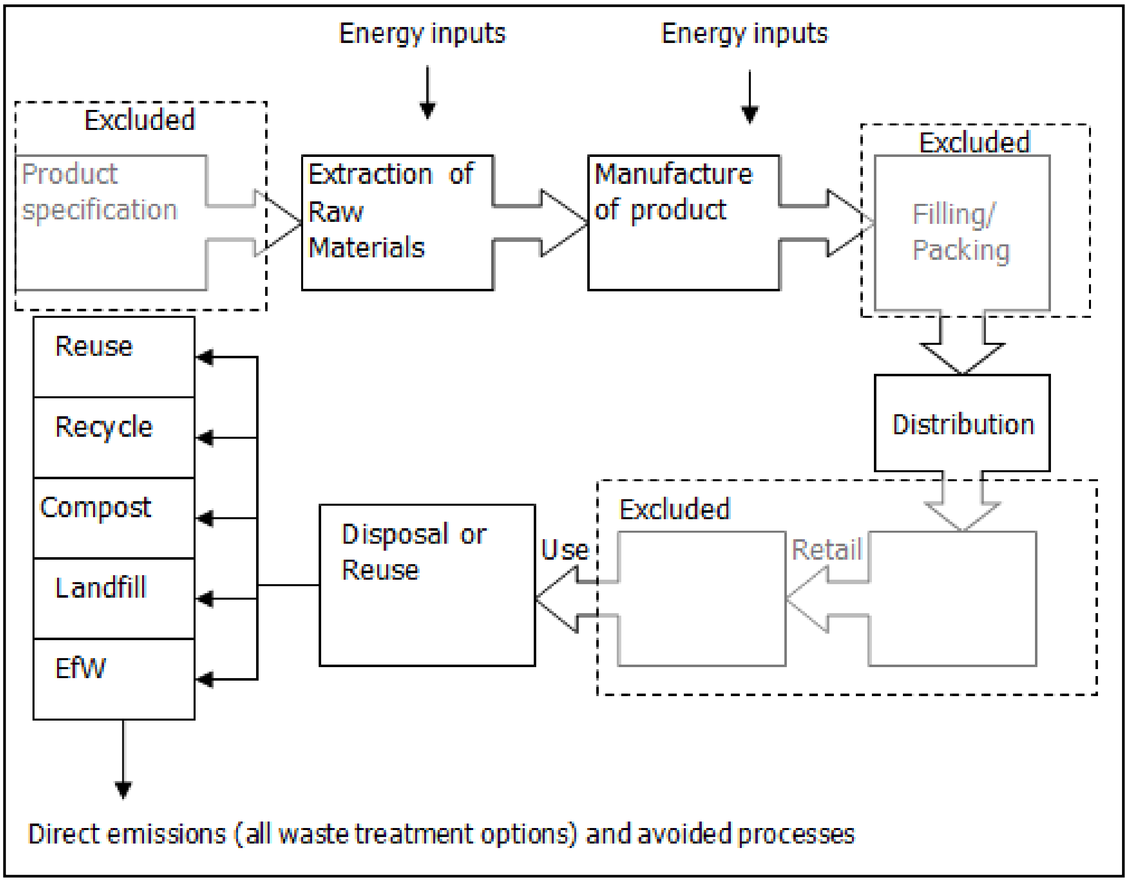
2.1 System boundaries

The flow chart below shows the steps that would typically be included in a full product LCA. It is proposed that the following steps are included / excluded from the carbon calculation for the purposes of the company reporting guidelines.

[71] European Commission (2010), Integrated Product Policy. Available at: http://ec.europa.eu/environment/ipp/home.htm
[72] European Commission (2010), Thematic Strategies on the Sustainable Use of Natural Resources. Available at: http://ec.europa.eu/environment/natres/index.htm
[73] European Commission (2010), Prevention and Recycling of Waste. Available at: http://ec.europa.eu/environment/waste/strategy.htm
[74] European Commission (2010), Sustainable Consumption and Production Action Plan. Available at: http://ec.europa.eu/environment/eussd/escp_en.htm

The reasons for excluding each section highlighted in the flow chart in Figure 2.1 are explained below.

Figure 2.1: Life Cycle Stages included and excluded from the Waste management GHG



Product specification is the most influential stage in the life cycle of the goods we buy, since it determines many of the carbon intensive features of the product (e.g. material, weight, and cost). However, this stage is not assumed to contribute significant direct emissions. Therefore, it has been excluded from the waste management GHG factors methodology.

The stages associated with filling and packing a product, have been also been excluded. This is because the impact of this stage is specific to the product. Although this may be an important source of emissions with regard to waste prevention activity, it does not materially affect the difference between other stages of the waste hierarchy (recycling, energy recovery, and landfill) because forming, filling and packing will be the same whatever the disposal method. Since these factors will be utilised at a national level, it is recommended that this stage is excluded from the factors.

2.2 Treatment of Biogenic Carbon

When considering the impacts of extraction and disposal of materials in carbon-based terms, there is a need to distinguish between the carbon dioxide which arises from fossil fuels (so-called "long cycle" carbon or "fossil CO_2") and that which is taken up by plants and released when the plant degrades ("short cycle" carbon or biogenic CO_2).

By extracting and burning fossil fuels, fossil carbon is being moved from one store (underground) to another (the atmosphere). This creates an imbalance and leads to an increase in atmospheric carbon. In contrast, the biogenic carbon can be said to be in a short cycle, as carbon is taken up from the atmosphere, whilst flora and fauna are alive, and released at the end of their life (i.e. inputs equal outputs). This has the effect that, in a sustainable production system, over the whole life of the material the carbon account can be considered neutral. The burning of fossil fuels releases stored carbon into the atmosphere and cannot be considered neutral.

Where a production system is unsustainable (e.g. clear-felling of forests), biogenic CO_2 uptake and emissions may not be balanced, and use of renewable materials may cause CO_2 to be emitted to the atmosphere.

In this methodology, it is proposed that biogenic CO_2 is excluded from the calculations, and that it is assumed that biomass is derived from sustainable sources. Other biogenic greenhouse gases (CH_4 and N_2O) will be accounted for. As an illustration, this would mean that CO_2 absorbed by trees as they grow is not counted, but when paper is disposed of by landfill or energy recovery, CO_2 emissions are not counted either. The alternative would be to give paper and card products a carbon credit during production, and then showing this emission at end of life. Emissions from energy recovery would appear counterintuitive to many, as more CO_2 would be released per kWh electricity generated from paper than energy generated from fossil fuels.

2.3 Extraction of Raw Materials and Manufacture of Products

Information on the extraction of raw materials and manufacturing impacts are commonly sourced from the same reports, typically life cycle inventories published by trade associations. The sources utilised in this study are listed in Annex 4. The stages covered include mining activities for non-renewable resources, agriculture and forestry for renewable materials, production of materials used to make the primary material (e.g. soda ash used in glass production) and primary production activities such as casting metals and producing board. Intermediate transport stages are also included. Full details are available in the referenced reports.

Waste management GHG factors have been provided for a combination of materials (e.g. paper) and products (e.g. shoes). Where information is provided on a product, the carbon factor provided accounts for secondary manufacturing activity (e.g. the manufacture of a shoe from raw materials). Where data is provided for a material, this typically excludes the forming of a product from this raw material. The reason for excluding this stage is that the impacts can be very different depending upon the product being made. Without a compositional analysis of what the products are, it is considered inappropriate to include forming emissions. The consequence of this decision is that the figures presented for waste prevention are an underestimate of the true impact of waste prevention activities. The exclusion does not affect the relative difference between other waste management options.

2.4 Transport

The waste management factors incorporate transport of materials and waste, based on average loading factors. These factors are taken from the other annexes of the DEFRA / DECC guidelines. Figures for Refuse Collection Vehicles have been taken from the Environment Agency's Waste and Resource Assessment Tool for the Environment (WRATE)[75].

Once materials have been manufactured, they are transported to factories where they are used to make a variety of goods. The following transportation distances and vehicle types have been assumed for this methodology. The impact of transporting the raw material (e.g. forestry products, granules, glass raw materials) is already included in the manufacturing profile for all products:

Table 2.1: Distances and transportation types used in the calculation of the waste management GHG factors

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Transport of raw materials to factory	112km	Average, all HGVs	Department for Transport (2009)[76] Based on average haulage distance for all commodities, not specific to the materials in the first column.
Distribution to Retail Distribution Centre & to retailer	95km		McKinnon (2007)[77] IGD (2008)[78]

Transport emissions from distribution from the manufacturer to the retailer could be excluded from the analysis for the same reasons given above for excluding forming. However, these emissions have been included in preparation for further development of the waste management GHG factors to include other waste management options. These distribution emissions do not make a significant difference to the carbon factors.

Transport of goods by consumers is excluded from the scope of the waste management GHG factors. Again, although this may be an important source of emissions with regard to waste prevention activity, but it does not materially affect the difference between other stages of the waste hierarchy (recycling,

---

[75] Environment Agency (2010), Waste and Resource Assessment Tool for the Environment. Available at: www.environment-agency.gov.uk/research/commercial/102922.aspx

[76] Department for Transport (2009) Transport Statistics Bulletin: Road Freight Statistics 2008 National Statistics Table 1.14d. Available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/freight/goodsbyroad/roadfreightstatistics2008

[77] McKinnon, A.C. (2007) Synchronised Auditing of Truck Utilisation and Energy Efficiency: A Review of the British Government's Transport KPI Programme. Available at: http://www.sml.hw.ac.uk/logistics/downloads/efficiency/Review%20of%20Transport%20KPI%20programme%20(WCTR%202007).pdf

[78] IGD (2008) UK Food & Grocery Retail Logistics Overview Date Published: 15/01/2008. Available at: http://www.igd.com/index.asp?id=1&fid=1&sid=17&tid=0&folid=0&cid=223

energy recovery and landfill). Since these factors will be utilised at a national level, it is recommended that this stage is excluded from the life cycle calculations.

Transport distances for waste were estimated using a range of sources, principally data supplied by the Environment Agency for use in the WRATE tool (2005). The distances adopted are shown below.

Table 4.2: Distances used in calculation of the waste management GHG factors

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Household, commercial and industrial landfill	25km by Road	26 Tonne Refuse Collection Vehicle, maximum capacity 12 tonnes	WRATE (2005)
Inert landfill	10km by Road		WRATE (2005)
Transfer station / CA site	10km by Road		
MRF	25km by Road		
MSW incinerator	50km by Road		
Cement kiln	50km by Road		
Paper and Card	41% 250km by Road, 59% 250km by Road, 18000km by Boat to Guangdong, 50km by road	Average, all HGVs	WRAP (2008)[79]
Glass (Container – Clear and Amber)	50km by Road		WRATE (2005)
Glass (Container Green) 24% total	50km by road and 390km by Boat		WRAP
Glass – construction aggregate	50km by Road		WRATE (2005)
Aluminium	50% 250km by Road, 50% 50km by Road and 390km by Boat	Average, all HGVs,	WRAP estimate based on Hull – Rotterdam
Steel/Iron	34% 250km by Road, 66% 50km by Road and 390km by Boat	5000-10,000 TEU capacity vessel.	

[79] The Waste and Resource Action Programme (WRAP) (2008) CO_2 impacts of transporting the UK's recovered paper and plastic bottles to China; Banbury. Available at: http://www.wrap.org.uk/downloads/CO2_Impact_of_Export_Report_v8_1Aug08.67624114.5760.pdf

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Plastics	33% 250km by Road, 67% 250km by Road, mixed plastics 17600km by Boat to Hong Kong, PET 19000km by Boat to Shanghai, HDPE 18000km by Boat to Tianjin, then 150km by road (80km for mixed plastic)	For China, the vehicle is assumed to be 32 tonne vehicle meeting Euro II emissions criteria	WRAP (2008)
Wood	50km by Road	Average, all HGVs	WRATE (2005)
Inert recycling	10km by Road		WRATE (2005)

For international sea freight, there is a trade imbalance between Europe and the Far East. This means that vessels may return empty (but with ballast), or partially empty, unless they were carrying materials for recycling. In these circumstances, it would be appropriate to consider only the marginal emissions, i.e. those incurred by moving the additional weight of the freight, but not of the vessel itself.

2.5 End of Life

In landfill, it is assumed that as biogenic materials degrade, they will release greenhouse gases, including methane. A proportion of this is captured for flaring or electricity generation. In this methodology, we assume that 75% of methane is captured, of which 46% is used for electricity generation, at a generation efficiency of 35%[80]. 10% of uncaptured methane is assumed to be oxidised at the cap. These figures are also liable to change over time.

Emissions from the landfill of different materials are calculated using WRATE and the LandGem model[81]. Methane generation rate constants have been taken from IPCC[82].

For energy recovery, a typical efficiency for energy production of 23% has been assumed. Detail on this assumption is provided on Annex 1.

[80] Jackson J, Choudrie S, Thistlethwaite G, Passant N, Murrells T, Watterson J, Mobbs D, Cardenas L, Thomson A, Leech A (2009) UK Greenhouse Gas Inventory, 1990 to 2007: Annual Report for submission under the Framework Convention on Climate Change Annex 3. Available at: http://www.naei.org.uk/reports.php?list=GHG

[81] US EPA (2005) Landfill Gas Emissions Model (LandGEM) V3.02. Available at: http://www.epa.gov/ttncatc1/products.html

[82] IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan 2006. Available at: http://www.ipcc-nggip.iges.or.jp/

When considering recycling, for some materials there are limited options, whereas for others there is significant choice in how to use materials. For example, recycled metal invariably replaces primary metal, whereas recycled glass may be used in place of glass or aggregates, and plastic may be used in place of wood or textiles. Recycling may take place in the UK or abroad, and the proportion recycled domestically varies widely between materials. In this document, only two options have been considered: closed and open loop recycling.

The definition of closed and open loop recycling used is discussed in Annex 2, but closed loop occurs when the recycled material substitutes the same primary material in a similar quality application.

Where an item enters open loop recycling, the impact of processing the recyclate has been included in the waste management GHG factors, but the avoided impact has been excluded. The reason for excluding the avoided impacts is consistency. For some materials, the avoided materials from open loop recycling are known and predictable. For others, the material is not known. In general the closed loop, rather than open loop, recycling figure is used with the methodology and this does not have a material effect on the results. However, it is an area for future improvement and is discussed in Section 5.2.

When an item is sent for recycling, it is rare for 1 tonne of collected material to displace 1 tonne of primary material due to losses in the recycling process. The quantity of material displaced by 1 tonne of recyclate is contained in Annex 5. These loss rates have been factored in when considering the benefit of collecting a tonne of material for recycling.

The data for local-authority collected municipal waste does not currently distinguish between recyclate that goes to open or closed loop recycling. For many materials closed loop recycling is the only option and for most materials it is closed loop recycling that is assumed in the weightings. The only materials that differ from this are:

- Glass, where sorted, glass is assumed to go to closed loop recycling but where the glass is collected as mixed colours, a proportion is assumed to be sent for remelt and a proportion is sent for use as aggregate replacement, based on data from Valpak;
- Food and garden waste, where closed loop recycling is not possible. Two different weightings are given for each, depending on whether the material is sent for composting or anaerobic digestion.

The carbon-emissions associated with open loop recycling for additional figures are quantified in the methodology to allow for future extension of the waste management GHG factors to take account of different recycling methods should sufficient waste data become available.

2.6 Reuse

At present, information on the impact of reuse is limited. Data is available on textiles and wooden pallets, but not for many common items (e.g. furniture). The current waste management GHG factors incorporates reuse for clothing and shoes as this is the primary destination for the material that is currently recorded as recycled, and some data is available on the impacts associated with this. Future improvements in reuse data available may allow reuse to be accounted for differently in the waste management GHG factors in the future as part of the review process.

3.0 Data Quality

This section explains the methodology for the choice of data used in the calculation of carbon emissions used in the waste management GHG factors equations explained in Section 2. Section 3.1 details the indicators used to assess whether data met the data quality standards required for this project. Section 3.2 states the sources used to collect data. Finally, Section 3.3 explains and justifies the use of data which did not meet the data quality requirements.

3.1 Data Quality Standard

Data used in this methodology should meet the data quality indicators described in Table 3.1 below.

Table 3.1: Data Quality Indications for the waste management GHG factors

Data Quality Indicator	**Requirement**	**Comments**
Time-related coverage	Data less than 5 years old	Ideally data should represent the year of study. However, the secondary data in material eco-profiles is only periodically updated.
Geographical coverage	Data should be representative of the products placed on the market in the UK	Many datasets reflect European average production.
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	

Data Quality Indicator	Requirement	Comments
Representative-ness	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		Many data sources come from single sources. Uncertainty will arise from assumptions made and the setting of the system boundaries.

3.2 Data Sources

The methodology is based on published greenhouse gas emission data rather than data collected from onsite measurements directly.

Data has been taken from a combination of trade associations, who provide average information at a UK or European level, data from the Ecoinvent database and reports / data from third parties (e.g. academic journals, Intergovernmental Panel on Climate Change). Data on wood and many products are taken from published life cycle assessments as no trade association eco-profile is available. Data sources for transport are referenced in Section 2.4. Data on waste management options has been modelled using SimaPro[83] and WRATE. Assumptions are identified in Annexes 1, 2 and 5, and Section 3.3.

The emissions data and weightings will be updated on a five year basis to take into account any new or improved information available, such as updates from the Scottish Environmental Protection Agency's (SEPA) Waste Data Strategy[84].

Some data sources used do not meet the quality criteria. The implications of this are discussed in the following section.

[83] SimaPro (2010). Life Cycle Assessment Software. Available at: http://www.pre.nl/simapro/
[84] SEPA 2010 Waste Data Flow Reports. Available at: http://www.wastedataflow.org/

3.3 Use of data below the set quality standard

Every effort has been made to obtain relevant and complete data for this project. For the majority of materials and products data which fits the quality standards defined in Section 3.1 above are met. However, it has not always been possible to find data which meets these standards in a field which is still striving to meet the increasing data demands set by science and government. This section details data which do not meet the expected quality standard set out in the methodology of this project but were never-the-less included because they represent the best current figures available. The justification for inclusion of each dataset is explained. The most common data quality issues encountered concerned data age and availability.

Glass data

The most relevant data on glass is older than desired, being sourced from Enviros (2003)[85]. However, as the data is sourced from the UK, it is applicable to this project. The European Container Glass Federation (FEVE) has published a Life Cycle Inventory for glass at a European level[86]. It is anticipated that future editions will use the FEVE data.

Wood and Paper data

Published data on wood products is sparse, an issue highlighted by the Waste and Resources Action Programme (WRAP) in 2006 and 2010[87]. Data used in this report for waste prevention is based on studies from the USA, where production processes may not be representative of activity in the UK (e.g. different fuel mix to generate electricity). This data should therefore be viewed with caution. Data on different types of wood has been used in combination with information on the composition of wood waste in the UK[88] to provide a figure which represents a best estimate of the impact of a typical tonne of wood waste.

Many trade associations publish data on the impact of manufacturing 100% primary and 100% recycled materials. However, for various reasons, the bodies representing paper and steel only produce industry average profile data, based on a particular recycling rate.

Furthermore, paper recycling in particular is dependent on Asian export markets, for which information on environmental impacts of recycling or primary production is rare. This means that the relative impact of producing paper from virgin and recycled materials is difficult to identify. The figure for waste prevention for paper represents average production, rather than 100% primary material, so already accounts for the impact of recycling. Caution should therefore be taken in using these numbers. There is a commitment by the

[85] Enviros (2003) Glass Recycling - Life Cycle Carbon dioxide Emissions; British Glass, Sheffield
[86] PE International (2009) Life Cycle Assessment of Container Glass in Europe FEVE; Brussels
[87] WRAP (2006) Environmental Benefits of Recycling and WRAP (2010) Environmental Benefits of Recycling – 2010 update. WRAP; Banbury. Available at: *http://www.wrap.org.uk/downloads/Executive_summary_Environmental_benefits_of_recycling_-_2010_update.081ff1a9.8671.pdf*
[88] WRAP (2009) Wood Waste Market in the UK WRAP; Banbury. Available at: *http://www.wrap.org.uk/recycling_industry/publications/wood_waste_market.html*

Chinese Life Cycle Assessment community to place more information in the public domain[89], but there is no timetable for this. As more information becomes available the waste management GHG factors can be updated.

Steel data

The figures on steel production are an estimate only and should be treated as such.

Waste Electrical and Electronic Equipment

Information on Waste Electrical and Electronic Equipment (WEEE) is sourced from Huisman (2008)[90], a study for the United Nations University, which presents data on the benefit of recycling WEEE, but not total impacts. Although the figures contained are of good quality, they do not match the format of the other figures used in this report. As a consequence the carbon factors for WEEE include the benefit from avoided emissions which could not be disaggregated from the data source.

Plastics data

Whilst not an issue from a data quality perspective, Plastics Europe are in the process of updating the Life Cycle Inventories for plastic polymers. Again, as the publications are updated the factors for waste prevention for plastics can be updated.

Data on polystyrene recycling does not meet the age criteria, as it originates from one 2002 study. This will be updated as new sources are identified.

Textiles and footwear

The BIO IS study is the most relevant data source to calculate the carbon factors for textiles even though the report is not yet published. This is because the factor proposed is based upon the market share of all textile products in Europe, categorised by product types and fibre types. The factor is considered to be representative of household textiles in general rather than specific fibres. It is understood that this will be published by the EU.

Information for footwear comes from one study from the USA. As with wood, this may not reflect Scottish impacts, and so the results should be viewed with caution.

Non-automotive batteries data

Published information on non-automotive batteries addresses the relative impact of alternative waste management options, but not the impact of battery manufacture. Therefore, whilst recycling, energy recovery and landfill factors are available; there is no figure for waste prevention at present.

[89] Second Chinese Conference on Life Cycle Management (CLCM2009), Nov.15-16, 2009 in Beijing. Available at: http://www.iscp.org.cn/conference/clcm2009en/program.html

[90] Huisman, J., et al (2008) 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment – Study No. 07010401/2006/442493/ETU/G4, United Nations University, Bonn Germany

Oil Data

Vegetable oil factors are based on studies of rapeseed oil. There is discussion in scientific journals on which is the appropriate oil to use when assessing environmental impacts, since growth is strongest in palm oil manufacture and use. However, palm oil has particular properties (e.g. high ignition point) which mean its use as a standalone product, rather than as an ingredient in other products, is limited.

Mineral oil will be included in the waste management GHG factors. Although there is no available data on waste arising for mineral oil, this waste stream is banned from landfill. Therefore, it is assumed that all collected mineral oil is recycled or combusted and the data on recycled mineral oil is used both for the arising and the recycled figure.

Excluded Materials and Products

For some materials and products, such as automotive batteries and fluorescent tubes, no suitable figures have been identified to date. WRAP are in the process of identifying factors for furniture and paint, but at present there are no plans to carry out primary research to obtain figures for the other waste streams.

4.0 Calculating the waste management GHG factors

This section of the report brings together the Life Cycle Thinking theory and the data on emissions of materials and products to explain how the waste management GHG factors has been calculated, through a multi-step process.

Variations from the standard calculation

For most materials, the impact of recycling is the difference between avoided production of average primary materials and emissions from the recycling process. However, there are exceptions to this. The following assumptions have been made about the segregation for key materials into different end of life options:

- For colour separated glass, the benefit of recycling shown is based on this being sent to remelt for closed loop recycling. For glass which is mixed colour, data from Valpak suggests 44% is used in place of aggregate and 56% is used in remelt applications in the UK and abroad. The impact of recycling mixed glass is based on this split.
- For food, both anaerobic digestion and composting are identified as separate options. For garden waste, the same options have also been shown. However, due to its composition, garden waste is not suited to the same anaerobic digestion process as food waste. It requires a 'dry' AD system. At the time of writing no such systems have been identified. However, data is presented for this eventuality. Mixed food and garden waste is modelled as being sent to a 'wet' AD system. More details are given

in Annex 3. In both cases, the recycling route selected is not closed loop (i.e. it does not avoid food or garden plants). The calculation therefore excludes the impacts associated with earlier life cycle stages.

- Information on the reuse and recycling of textiles was obtained from the Zero Waste Scotland report on the Composition of municipal solid waste in Scotland (2010)[91]. The report suggests that 46% of textiles arising in Scotland MSW in 2009 was reusable, 32% was non-reusable textiles and 22% was shoes, belts and bags.
- For wood, the typical recycling route is conversion to particleboard[92]. Therefore, rather than compare to average recycling, the calculation assumes that recyclate is sent to this market.
- For plastics the impact of forming is excluded from the calculation of the benefits of recycling. Although prevention of plastic waste would prevent emissions from this stage, products made from recycled materials require forming, and so the calculation follows a non-standard format to allow for this. The average plastics factor is based on the split of polymers used in UK packaging identified by AMA research (2009)[93].
- For electrical items, the calculation is based upon data sourced from Huisman (2008)34 which presents data on the benefit of recycling WEEE, but not total impacts. Although the figures contained are of good quality, they do not match the format of the other figures used in this report.
- For post-consumer batteries the same issue as WEEE exists, that the benefit of recycling, but not the total impact, can be identified from the literature.

5.0 Conclusion

5.1 Summary

This report has given technical background information on the creation of the waste management GHG factors. The report has introduced the concept of Life Cycle Assessment and Life Cycle thinking and explained how these concepts have contributed to the methodology of the waste management GHG factors. The scope and methodology have been discussed in detail and data sources, quality issues and anomalies explained. Finally, the construction of the waste management GHG factors itself, through the assembly of Carbon Factors and weightings has been discussed.

Further information on how to use the waste management GHG factors is given in the Guidance Report and the waste management GHG factors Calculator.

5.2 Recommendations for future WRAP development of the waste management GHG factors

[91] ZWS (2010) The Composition of Municipal Solid Waste in Scotland. Available from: http://www.wrap.org.uk/downloads/Scotland_MSW_report_final.67a78687.8938.pdf
[92] WRAP (2009) Wood Waste Market In The UK WRAP; Banbury
[93] AMA Research (2009) Plastics Recycling Market UK 2009-2013, AMA Research; Cheltenham

Although this methodology currently relies on secondary data mainly from a European level, the use of primary UK data would be preferred. WRAP is aware of plans to update the following factors, which should be incorporated into the waste management GHG factors:

- Information on the impacts of reusing furniture and electrical items from a WRAP project;
- Data on the environmental impact of the manufacture of glass and plastics.

Further information on commercial and industrial waste would also be valuable.

Annex 1 Energy from Waste

A range of energy recovery technologies exist which could convert materials to energy at end of life. These include combustion (electricity only or combined heat and power), gasification, pyrolysis and anaerobic digestion.

Despite the potential for the different technologies, combustion with electricity generation is the most prevalent technology, and will continue to be in the short term.

The efficiency with which the incinerator converts energy in the waste into electricity is an important factor affecting the results of this study, as it determines to what degree the impacts of the incineration process are offset by avoiding the need to produce electricity from primary fuels. Published studies give a wide range of values for the efficiency of power generation from municipal waste incinerators.

This variation arises due to a number of factors including:

- Type and nature of the waste feedstock;
- Output options – potential to use electricity, water, steam produced;
- Technology applied;
- Whether internal energy consumption of the process is accounted for;
- Whether gross calorific values (GCV) or net calorific values (NCV) are used in the calculations (in some reports it is not clear which is used).

Examples of values quoted in recent studies are given below:

- A 2006 study by the United States Environmental Protection Agency (USEPA)[94] gives an efficiency of 17.8% for electricity generated from mass burn incineration (not clear whether these figures are based on NCV or GCV).
- A 2001 report for the European Commission[95] indicates that efficiencies for power generation range from 15–22% in thermal treatment plants based on NCV.
- The 2006 BAT standard for incineration[96] quotes efficiencies ranging from 15-30% for thermal plants producing electricity only (not clear whether these figures are based on NCV or GCV).
- A 2003 Biffaward study carried out by C-Tech Innovation[97] reports a figure of 25.4% based on NCV.
- Fichtner, in a 2004 report[98] for ESTET, state that "For a modern plant based combustion technology, the net electrical efficiency is in the range 19 to 27%" based on NCV.

---

94 USEPA (2006) Solid Waste Management and Greenhouse Gases – A Life-cycle Assessment of Emissions and Sinks, 3rd Edition

95 Smith, A. et al. (2001) Waste Management Options and Climate Change, Final Report to the European Commission

96 European Integrated Pollution Prevention and Control Bureau (2006) Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration

97 C-Tech Innovation for Biffaward (2003) Thermal Methods of Municipal Waste Treatment

- A 2003 good-practice guide produced by CIWM[99] reports efficiency of generation of 22%-25% (not clear whether these figures are based on NCV or GCV).

The default assumption for this work is that a conversion efficiency (NCV) of 23%, which is midway between the extremes reported in the literature, is typical for modern incinerators.

98 Fichtner Consulting Engineers Limited (2004) The Viability Of Advanced Thermal Treatment Of MSW In The UK, ESTET

99 CIWM (2003) Energy from Waste: A Good Practice Guide, Northampton: IWM Business Services Group

Annex 2 Approach to Recycling

In Life Cycle Assessment, ISO 14044 (2006), sets out definitions for closed and open loop recycling as follows:

"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).

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."

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

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.

For card and paper, the recycling rate reflects the information provided by the industry on actual performance for different grades of packaging.

Annex 3 Anaerobic Digestion

The calculation of the greenhouse gas impacts of anaerobic digestion is based upon the following information.

Food and drink waste to anaerobic digestion is assumed to go to a wet system, whilst the garden waste to anaerobic digestion is assumed to go to a dry system. The mixed food, drink and garden waste stream is also assumed to go to a dry anaerobic digestion system, which is based on 17.5% food and drink and 82.5% garden waste.

Food is assumed to be 70% water and 30% dry matter[100] generating 98m^3 of methane per tonne of food waste[101]. Garden waste is assumed to be 47% moisture and 53% dry matter, generating 85m^3 of methane per tonne of garden waste[102]. 3% of methane is assumed to escape as fugitive emissions.

For both the food and drink anaerobic digestion system and the garden waste anaerobic digestion system the methane, at a calorific value of 35.8 MJ/m^3[103], has then been assumed to be converted to electricity at a conversion efficiency of 37%. Of the electricity produced, 15% is assumed to have been fed back into the process.

The net electricity output has then been contrasted to the grid rolling average for 2008[104] to identify avoided greenhouse gas emissions associated with electricity production.

Avoided landfill emissions are as described in Section 4.5.

The digestate is assumed to be used in agricultural applications replacing fertiliser. Using factors identified in Williams et al (2006)[105].

In 2007/08, the UK consumed 1.6 million tonnes of fertilizer, of which two thirds was nitrogen fertilizer[106]. The main market for this is use in agriculture.

[100] Bingemer, H.G. and P.J. Crutzen, (1987) The production of methane from solid wastes. J. Geophys. Res., 92 (D2), 2181-2187
[101] WRAP calculation
[102] Mitaftsi, O and Smith, S R (2006) Quantifying Household Waste Diversion from Landfill Disposal by Home Composting and Kerbside Collection, Imperial College, London
[103] Zaher, U., Khachatryan, H.; Ewing, T.; Johnson, R.; Chen, S.; Stockle, C.O. (2010) Biomass assessment for potential bio-fuels production: Simple methodology and case study, The Journal of solid waste technology and management vol:36 iss:3 pg:182 -192
[104] DEFRA/DECC (October 2010) Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting. Available at: *http://www.defra.gov.uk/environment/economy/business-efficiency/reporting*
[105] Williams AG, Audsley E and Sandars DL (2006). Determining the Environmental Burdens and Resource Uses in the Production of Agricultural and Horticultural Commodities. Main Report. DEFRA Research Project IS0205. Bedford: Cranfield University and DEFRA

[106] Agricultural Industries Confederation (2009) Fertiliser Statistics 2009 Report, AIC, Peterborough. Available at:
www.agindustries.org.uk/document.aspx?fn=load&media_id=3625&publicationId=350

Williams et al (2006)[99] identify the following emissions from the manufacture of nitrogen, phosphorous and potassium.

Table A3.1: Emissions from the Manufacture of Fertilisers

Fertiliser	kg CO_2 e per kg fertiliser
Nitrogen (N)	6.8
Phosphorous (P)	1.2
Potassium (K)	0.5

When used in place of fertilizer, compost is used based upon its available nutrient content.

When identifying the quantity of nitrogen within biowaste products, it is important to note that the total nitrogen in compost and other biowaste products is not an indication of how much nitrogen will become available with time[107] . Unlike fertiliser, compost and digestate release nitrogen over a number of years, reducing N_2O emissions relative to fertiliser application. Some discussions and recommendations with regard to nutrient availability are set out in a recent WRAP literature review. In 2006, the following formula was proposed for predicting nitrogen availability from composted materials:

'The nitrogen available to crops equals the percentage of total N as water extractable N (e.g. 1%), plus the mineralisable N based on C/N ratio. Half of the potential available nitrogen may be expected to be released in year one, with the remainder in years two and three'[108].

The 'fertiliser equivalent' for compost nitrogen varies with feedstock, but can be up to 25% over 3 years[109]. Potassium is readily available in compost in water extractable and exchangeable forms, and can be taken to be 80 % available. Phosphate is 85% available in inorganic fertiliser.

Using the factors from Williams et al (2006)[99] for fertiliser production, the following estimates are made of the benefit of sending 1 tonne of food or food and garden waste to anaerobic digestion.

[107] WRAP (2006) Production of Guidelines for Using Compost in Crop Production – A Brief Literature Review. Enviros Consulting Ltd report for WRAP, Banbury

[108] WRAP (2006) Production of Guidelines for Using Compost in Crop Production – A Brief Literature Review. Enviros Consulting Ltd report for WRAP, Banbury

[109] Prasad, M (2009) EPA STRIVE Programme 2007-2013 A Literature Review on the Availability of Nitrogen from Compost in Relation to the Nitrate Regulations SI 378 of 2006 Small Scale Study Report Environmental Protection Agency, Ireland

Table A3.2: Greenhouse Gas emissions avoided per tonne of food or food and garden waste sent to Anaerobic Digestion

	kg CO_2e avoided per tonne of input material, fertiliser displacement	kg CO_2e avoided via energy generation	Total kg CO_2e avoided per tonne of input material
1 tonne green & food waste digestate (not stabilised)	6.8	140	147 (150 including liquor)
1 tonne of food waste to digestate (not stabilised)	3.3	154	157 (160 including liquor)
Liquor from AD process (1 tonne of food or green waste input)	3	Within digestate figures	Within digestate figures

Annex 4 Data Sources

Material	Reference	
	Raw material extraction, processing and transport	**Waste Management Impacts**
Aluminium cans and foil	European Aluminium Association (2008) *Environmental Profile Report for the European Aluminium Industry*, European Aluminium Association	WRATE (2005)
Steel Cans	Estimate based on data from World Steel Life Cycle Inventory (2009), BOF route, 1kg , weighted average, EU, World Steel Association, Brussels	WRATE (2005)
Mixed Cans	Estimate based on aluminium and steel data.	WRATE (2005)
Glass	Enviros (2003) *Glass Recycling - Life Cycle Carbon dioxide Emissions*; British Glass, Sheffield	
Wood	Corrim (2005 & 2010) *Life Cycle Environmental Performance of Renewable Building Materials in the Context of Residential Construction*; Corrim, Seattle WRAP (2009) *Life Cycle Assessment of Closed Loop MDF Recycling*; WRAP, Banbury	WRAP (2009) *Life Cycle Assessment of Closed Loop MDF Recycling*; WRAP, Banbury Gasol C., Farreny, R., Gabarrell, X., and Rieradevall, J., (2008) Life cycle assessment comparison among different reuse intensities for industrial wooden containers *The International Journal of LCA* Volume 13, Number 5, 421-431 Merrild, H., and Christensen, T.H. (2009) Recycling of wood for particle board production: accounting of greenhouse gases and global warming contributions *Waste Management and Research* (27) 781-788 WRATE (2005)
Aggregates (Rubble)	WRAP CO_2 Emissions Estimator Tool Environment Agency (2007) Construction Carbon Calculator	
Paper	Ecoinvent v2.0 (2007) Swiss Centre	*Ecoinvent v2.0* (2007)

Material	**Reference**	
	Raw material extraction, processing and transport	**Waste Management Impacts**
	for Life Cycle Inventories	Swiss Centre for Life Cycle Inventories
Books	Estimate based on paper	
Board	FEFCO (2009) *European Database for Corrugated Board Life Cycle Studies*, FEFCO Procarton (2009) *Carbon Footprint for Cartons,* Zurich, Switzerland	*Ecoinvent v2.0* (2007) Swiss Centre for Life Cycle Inventories
Mixed paper and board	Estimate based on above	
Scrap Metal	British Metals Recycling Association (*website*) Ecoinvent v2.0 (2007) Swiss Centre for Life Cycle Inventories	Ecoinvent v2.0 (2007) Swiss Centre for Life Cycle Inventories WRATE (2005)
Incinerator Residues (Non Metal)	To be identified	To be identified
Automotive Batteries	To be identified	To be identified
WEEE - Fluorescent Tubes	To be identified	To be identified
WEEE - Fridges and Freezers	ISIS (2008) Preparatory Studies for Eco-design Requirements of EuPs (Tender TREN/D1/40-2005) LOT 13: Domestic Refrigerators & Freezers	ISIS (2008) Preparatory Studies for Eco-design Requirements of EuPs (Tender TREN/D1/40-2005) LOT 13: Domestic Refrigerators & Freezers WRATE (2005)
Food and Drink Waste	Several data sources used to estimate food production impacts. Agriculture UNFCC *website* Fertiliser production: Wood., S and Cowie, A., (2004) *A Review of Greenhouse Gas Emission Factors for Fertiliser Production* Research and Development Division, State Forests of New South Wales. Cooperative Research Centre for Greenhouse Accounting Food Manufacture, Transport, Catering and Home Related	AFOR (2009) *Market survey of the UK organics recycling industry - 2007/08*; WRAP, Banbury (Substitution rates for compost) Williams AG, Audsley E and Sandars DL (2006) *Determining the Environmental Burdens and Resource Uses in the Production of Agricultural and Horticultural Commodities. Main Report. IS0205*, DEFRA (avoided fertiliser

Material	**Reference**	
	Raw material extraction, processing and transport	**Waste Management Impacts**
	Impacts: Brook Lyndhurst (2009) *London's Food Sector Greenhouse Gas Emissions*, GLA Retail: Tassou (2008) FO0405 *Greenhouse Gas Impacts of Food Retailing*, DEFRA	impacts) Kranert, M. & Gottschall (2007) *Grünabfälle – besser kompostieren oder energetisch verwerten?* Eddie (information on peat) DEFRA (unpublished) (information on composting impacts)
Garden Waste	-	
Plastics:		
LDPE and LLDPE (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry Low Density Polyethylene* (LDPE). Plastics Europe, Brussels	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
HDPE (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry High Density Polyethylene* (HDPE). Plastics Europe, Brussels	WRAP (2010) LCA of Example Milk Packaging Systems; WRAP, Banbury
PP (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry Polypropylene* (PP). Plastics Europe, Brussels	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
PVC (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry Polyvinyl Chloride* (PVC) (Suspension). Plastics Europe, Brussels	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
PS (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry Polystyrene (High Impact)* (HIPS). Plastics Europe, Brussels	PWC (2002) *Life Cycle Assessment of Expanded Polystyrene Packaging*, Umps
PET (excel forming)	Boustead (2005) *Eco-profiles of the European Plastics Industry Polyethylene Terephthalate* (PET). Plastics Europe, Brussels	WRAP (2010*) LCA of Example Milk Packaging Systems*; WRAP, Banbury

Material	**Reference**	
	Raw material extraction, processing and transport	**Waste Management Impacts**
Average plastic film (inch bags)	Based on split in AMA Research (2009) *Plastics Recycling Market UK 2009-2013*, UK; Cheltenham	WRAP (2008) *LCA of Mixed Waste Plastic Management Options*; WRAP, Banbury
Average plastic rigid (inch bottles)		
Clothing	BIO IS (unpublished data)	Arrant (2008) *Environmental Benefit from Reusing Clothes*, WRATE (2005)
Footwear	Albers, K., Canapé, P., Miller, J. (2008) *Analysing the Environmental Impacts of Simple Shoes*, University of Santa Barbara, California	
Furniture	To be updated following pending WRAP research	
WEEE – Large	Huisman, J., et al (2008) *2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment* – Study No. 07010401/2006/442493/ETU/G4, United Nations University, Bonn Germany	
WEEE – Mixed		
WEEE – Small		
Batteries (Post Consumer Non-Automotive)	-	DEFRA (2006) *Battery Waste Management Life Cycle Assessment*, prepared by ERM; WRAP, Banbury
Paint	Althaus et al (2007) *Life Cycle Inventories of Chemicals, Final report Ecoinvent data v2.2*; ESU Services, Switzerland CBI (2009) Market Survey The paints and other coatings market in the United Kingdom; CBI, The Netherlands	-
Vegetable Oil	Schmidt, J (2010) Comparative life cycle assessment of rapeseed oil and palm oil *International Journal of LCA*, 15, 183-197 Schmidt, Jannick and Weidema, B., (2008) Shift in the marginal supply of vegetable oil *International Journal of LCA*, 13, 235-239	
Mineral Oil	IFEU (2005) *Ecological and energetic assessment of re-refining used oils to base oils: Substitution of primarily produced base oils including semi-synthetic and synthetic compounds*; GEIR	
Plasterboard	WRAP (2008) *Life Cycle Assessment of Plasterboard,* prepared by ERM; WRAP; Banbury	

Annex 5 Material Substitution Rates for Recycling

Finished primary material	Amount of primary materials saved per tonne recycled (tonnes)*	References
Aluminium (cans and foil)	0.943	EAA (2008) Aluminium use in Europe - Country profiles - 2005-2008
Steel cans	0.917	World Steel Life Cycle Inventory (2009) EAF steel slab
Mixed cans	0.925	EAA (2008) Aluminium use in Europe - Country profiles - 2005-2008 and World Steel Life Cycle Inventory (2009) EAF steel slab
Glass (containers and aggregates production)	1.000	Cook, R.F. (1978) The collection and recycling of waste glass (cullet) in glass container manufacture, Conservation & Recycling Volume 2, Issue 1, 1978, Pages 59-69
Wood (general)	1.000	Lack of data so conversion factor assumed to be 1
Aggregates	1.000	Lack of data so conversion factor assumed to be 1
Plastics (general)	0.628	WRAP (2008) LCA of Mixed Waste Plastic Management Options
Recycled plastics replacing virgin plastic granules	0.666	WRAP (2008) LCA of Mixed Waste Plastic Management Options
Recycled plastics replacing virgin sawn timber	0.420	WRAP (2008) LCA of Mixed Waste Plastic Management Options
Paper (all types)	0.800	WRAP (2006) The environmental benefits of recycling
Scrap metals	Not identified	
Incinerator residue	Not identified	
Automotive batteries	Not identified	
Plastics: HDPE replacing virgin HDPE	0.833	WRATE, Waste and Resources Assessment Tool for the Environment (http://www.environment-agency.gov.uk/research/commercial/102922.aspx)

Finished primary material	**Amount of primary materials saved per tonne recycled (tonnes)***	**References**
Plastics: Polypropylene replacing polypropylene	0.666	WRAP (2008) LCA of Mixed Waste Plastic Management Options
Fluorescent tubes	Not identified	
Fridges and freezers	Not identified	
Green waste compost replacing peat	0.350	WRAP (2003) Compost and Growing Media Manufacturing in the UK, Opportunities for the Use of Composted Materials. WRAP Research Report, Banbury
Digestate replacing peat	0.380	Fuchs, J.G., (2008) Pres.Nr. 19 Effects of digestate on the environment and on plant production - results of a research project ECN/ORBIT e.V. Workshop 2008 "The future for Anaerobic Digestion of Organic Waste in Europe"
Green waste compost replacing fertiliser (per tonne of green waste in)	0.007 Nitrogen 0.0005 Phosphorous	Williams AG, Audsley E and Sandars DL (2006) *Determining the Environmental Burdens and Resource Uses in the Production of Agricultural and Horticultural Commodities. Main Report. IS0205*, DEFRA (avoided fertiliser impacts)
Digestate replacing fertiliser (per tonne of food in)	0.010 Nitrogen 0.0013 Phosphorous	
Textiles	0.952	DEFRA (2009) Maximising Reuse and Recycling of UK Clothing and Textiles EV0421 - Appendix I - Technical Report
Footwear	0.901	SMART (2007) Recycling of Footwear Products – A Position Paper Prepared by Centre for Sustainable Manufacturing and Reuse/recycling Technologies (SMART) – Loughborough University
Furniture	Not identified	
WEEE - Large domestic appliances	Not identified	
WEEE - Mixed domestic appliances	Not identified	

Finished primary material	**Amount of primary materials saved per tonne recycled (tonnes)***	**References**
WEEE - Small domestic appliances	Not identified	
Post-consumer, non-automotive batteries	1.000	Not identified
Paint	0.877	Community RePaint Annual Survey (http://www.communityrepaint.org.uk/)
Vegetable oil	0.787	BIO IS (2010) BIO IS for ADEME ; Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer ; Ministère de l'Alimentation, de l'Agriculture et de la Pêche, and France Agrimer – Analyses de Cycle de Vie appliquées aux biocarburants de première génération consommés en France
Mineral oil	1.000	Not identified
Plasterboard	1.000	ERM (2008) Technical Report for WRAP – Life Cycle Assessment of Plasterboard – Quantifying the environmental impacts throughout the product life cycle, building the evidence base in sustainable construction

* The system boundary for the virgin material is one tonne of finished virgin material – overburden from upstream processes are excluded

Annex 6 Greenhouse Gas Conversion Factors

Industrial Designation or Common Name	**Chemical Formula**	**Lifetime (years)**	**Radiative Efficiency (Wm^{-2} ppb^{-1})**	**Global Warming Potential with 100 year time horizon (previous estimates for 1st IPCC assessment report)**	**Possible source of emissions**
Carbon dioxide	CO_2	Variable	1.4×10^{-5}	1	Combustion of fossil fuels
Methane	CH_4	12	3.7×10^{-4}	25 (23)	Decomposition of biodegradable material, enteric emissions.
Nitrous Oxide	N_2O	114	3.03×10^{-3}	298 (296)	N_2O arises from Stationary Sources, mobile sources, manure, soil management and agricultural residue burning, sewage, combustion and bunker fuels
Sulphur hexafluoride	SF_6	3200	0.52	22,800 (22,200)	Leakage from electricity substations, magnesium smelters, some consumer goods
HFC 134a (R134a refrigerant)	CH_2FCF_3	14	0.16	1,430 (1,300)	Substitution of ozone depleting substances, refrigerant manufacture / leaks, aerosols, transmission and distribution of electricity.
Dichlorodifluoro-methane CFC 12 (R12 refrigerant)	CCl_2F_2	100	0.32	10900	
Difluoromono-chloromethane HCFC 22 (R22 refrigerant)	$CHClF_2$	12	0.2	1810	

No single lifetime can be determined for carbon dioxide because of the difference in timescales associated with long and short cycle biogenic carbon. For a calculation of lifetimes and a full list of greenhouse gases and their global warming potentials please see:

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (eds.) (2007) *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, United Kingdom Table 2.14. *Lifetimes, radiative efficiencies and direct (except for CH_4) global warming potentials (GWP) relative to* CO_2. Available at: http://www.ipcc.ch/ipccreports/assessments-reports.htm