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2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting:
Methodology Paper for Emission Factors

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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 Sarah Choudrie (AEA) and Keith James (WRAP) for the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (Defra)

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I. General Introduction

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, etc).

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 2012 Guidelines to Defra /DECC's Greenhouse Gas (GHG) Conversion Factors for Company Reporting (hereafter the 2012 GHG Conversion Factors) represent the current official set of government emissions factors. These factors are also used in a number of different policies. This paper outlines the methodology used to update and expand the emission factors for the 2012 GHG Conversion Factors. The new factors are presented at the end of each of the relevant following sections.

4. Values for the non-carbon dioxide (CO_2) greenhouse gases, methane (CH_4) and nitrous oxide (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. The factors for 2012 GHG Conversion Factors will be set for the next year, and will continue to be reviewed and updated on an annual basis.

6. The purpose of this report is to provide the methodological approach, the key data sources and the assumptions used to define the emission factors provided in the 2012 GHG Conversion Factors. The report aims to expand and compliment the information already provided in the data annexes themselves. However, it is not intended to be an exhaustively detailed explanation of every calculation performed (this is not practical/possible). Rather, the intention is to provide an overview with key information so that the basis of the emissions factors provided can be better understood and assessed.

7. Further information about the 2012 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/

Overview of changes since the previous update

8. Major changes and updates in terms of methodological approach from the 2011 version are summarised below. All other updates are essentially revisions of the previous year's data based on new/improved data using existing calculation methodologies (i.e. using a similar methodological approach as for the 2011 update)::
   a. All annexes: The indirect GHG emission factors (emissions from production and distribution of fuels to their point of use/combustion) have been updated reflecting the most recent analysis by JEC (2011)[1].
   b. New emission factors for Recycled Fuel Oil have been provided in Annex 1.
   c. In Annex 3 the emission factors for electricity for 1990 to 1995 have been recalculated based on changes to the NAEI time series and data from DECC's Digest of United Kingdom Energy Statistics (DUKES), 2011. In addition, GHG emissions from electricity produced in Crown Dependencies has been included across the time-series for better consistency with DUKES (2011) data on GWh electricity generation.
   d. New time-series emission factors for the supply of purchased heat or steam have been provided in Annex 3. These emission factors are based on average information from the UK CHPQA scheme.
   e. The methodology used to define the emission factors for road vehicles (except motorcycles and buses) in Annexes 6 and 7 has been updated to better account for the age/activity of the vehicle fleet in the UK.
   f. The source categories for emissions resulting from different refrigeration and air conditioning equipment have been updated in Annex 8 to reflect the updated characterisation in the UK NAEI.
   g. The emissions factors for waste in Annex 9 have been moved to Annex 14 and split out into Material Consumption and Material Waste Disposal components. The range of materials covered in the new Annex 14 tables has also been expanded, based on analysis provided by WRAP. Annex 9 has been renamed (to *Bioenergy and Water*), to avoid potential confusion and for better alignment with its reduced contents.
   h. Annex 13 has been updated to provide a time-series from 2004 to 2009 for supply chain emission factors for spending on products (emission factors were previously presented for a single year only). There have also been some revisions to the source categorisation.

   Further details on these changes are provided in the introduction to the 2012 GHG Conversion Factors annexes themselves.

9. Detailed guidance on how the emission factors provided should be used is contained in the introduction to the 2012 GHG Conversion Factors annexes themselves. This guidance must be referred to before using the emission factors and provides important context for the description of the methodologies presented in this report and in the annexes table footnotes.

[1] See http://iet.jrc.ec.europa.eu/about-jec/ for more information on these.

Structure of this methodology paper

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

Annex	**Area covered**	**Location in this document**
Annex 1	Fuel Conversion Factors	see Section I
Annex 2	CHP Imports and Export	N/A *
Annex 3	Electricity, Heat and Steam Factors	see Section III
Annex 4	Process Emissions	see Section IV
Annex 5	Process GWP Factors	see Section IV
Annex 6	Passenger Transport	see Sections V and VII
Annex 7	Freight Transport	see Sections VI and VII
Annex 8	Refrigeration and Aircon	see Section VIII
Annex 9	Bioenergy and Water	see Section IX
Annex 10	Overseas Electricity	see Section X
Annex 11	Fuel Properties	N/A *
Annex 12	Unit Conversions	N/A *
Annex 13	Supply Chain	see Section XI
Annex 14	Material Use and Disposal	see Section XII

* This report does not provide any methodological description for Annexes 2, 11 and 12 because these annexes only include simple supplementary information or guidance.

II. Fuel Conversion Factors (DCF Annex 1)

Summary of changes since the previous update

11. The main methodological change since the previous update is the inclusion of emission factors for recycled fuel oil. The indirect emission factors have also been updated with the most recent datasets from JEC (2011), which has resulted in some significant changes in the emission factors for certain fuels.

Direct Emissions

12. All the fuel conversion factors for direct emissions presented in the 2012 GHG Conversion Factors are based on the default emission factors used in the UK GHG Inventory (GHGI) for 2010 (managed by AEA)[2].

13. 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 2012 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.

14. 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 DECC's Digest of UK Energy Statistics (DUKES) 2011, available at: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

15. Emission factors for recycled fuel oil have been included for the first time in the 2012 GHG Conversion Factors, derived from the 2010 GHGI data. This fuel is produced from waste oil and is classified by the Environment Agency as waste and so is subject to the Waste Incineration Directive (WID). Therefore only those companies who are compliant with WID are able to use it as a fuel.

16. Four tables are presented in the 2012 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 below[3]).

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[2] UK Greenhouse Gas Inventory for 2010 (AEA), available at: http://naei.defra.gov.uk

[3] 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).

17. It is important to use the correct emission factor; otherwise emissions calculations will over- or under-estimate the results. When making calculations based on energy use, it is important to 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[4]. 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

18. These fuel lifecycle emissions (also sometimes referred to as 'Well-To-Tank' or simply WTT emissions in the context of transport fuels) 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.

19. In the absence of specific UK-based set of fuel lifecycle emissions factors information from JEC Well-To-Wheels (2011) were used as a basis for the factors in the 2012 GHG Conversion Factors[5]. This is the preeminent European study carried out in this area that covers a wide variety of fuels. This report is an update of the version used in the derivation of the 2011 GHG Conversion Factors, and the values for a number of fuels have changed in the new report version (e.g. petrol and diesel fuels). The coverage of the JEC WTW (2011) 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, naphtha, heating oil and (EU) electricity

20. For fuels covered by the 2012 Defra/DECC GHG Conversion Factors where no fuel lifecycle emission factor was available in JEC WTW (2011), these were estimated based on similar fuels, according to the assumptions in Table 1.

21. 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 2012 GHG Conversion Factors.

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4 See information available on Transco website: *http://www.transco.co.uk/services/cvalue/cvinfo.htm*

5 "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 3c, October 2011. Report EUR 24952 EN – 2011. *http://iet.jrc.ec.europa.eu/about-jec/*

22. Emission factors are also calculated for diesel supplied at public and commercial refuelling stations, factoring in the biodiesel supplied in the UK as a proportion of the total supply of diesel and biodiesel (3.5% by unit volume, 3.2% by unit energy – see Table 2). These estimates have been made based on DECC's Quarterly Energy Statistics for Renewables [6].

23. Emission factors are also calculated for petrol supplied at public and commercial refuelling stations, factoring in the bioethanol supplied in the UK as a proportion of the total supply of petrol and bioethanol (= 3.1% by unit volume, 2.0% by unit energy – see Table 2). These estimates have also been made based on DECC's Quarterly Energy Statistics for Renewables.

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

Fuel	Indirect EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect Emission Factor	Assumptions
Aviation Spirit	14.10	Estimate	Similar to petrol
Aviation Turbine Fuel [1]	14.95	Estimate	= Kerosene fuel, estimate based on average of petrol and diesel factors
Biofuels	Annex 9		
Burning Oil[1]	14.95	Estimate	= Kerosene, as above
CNG [2]	8.85	JEC WTW (2011)	
Coal (domestic)[3]	15.61	JEC WTW (2011)	Emission factor for coal
Coal (electricity generation)[4]	15.61	JEC WTW (2011)	Emission factor for coal
Coal (industrial)[5]	15.61	JEC WTW (2011)	Emission factor for coal
Coking Coal	15.61	Estimate	Assume same as factor for coal
Diesel	15.80	JEC WTW (2011)	
Electricity	Annex 3		
Fuel Oil [6]	14.95	Estimate	Assume same as factor for kerosene
Gas Oil [7]	15.80	Estimate	Assume same as factor for diesel
LPG	8.00	JEC WTW (2011)	
LNG [8]	20.00	JEC WTW (2011)	
Lubricants	9.49	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Naphtha	9.80	JEC WTW (2011)	
Natural Gas	5.90	JEC WTW (2011)	Natural gas EU mix
Other Petroleum Gas	6.96	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Petrol	14.10	JEC WTW (2011)	
Petroleum Coke	11.57	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Recycled fuel oil	9.49	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Refinery Miscellaneous	8.74	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Wood	Annex 9		

[6] DECC's Renewable Energy Statistics, 2011 – Energy Trends, Quarterly tables – data used here released 22 December 2011; *http://www.decc.gov.uk/assets/decc/11/stats/publications/energy-trends/3917-trends-dec-2011.pdf*

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: Liquid biofuels for transport consumption: 4th quarter 2010 – 3rd quarter 2011

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	*Conventional Fuel*	*per unit mass*	*per unit volume*	*per unit energy*
Diesel/Biodiesel	907.5	24,942.5	3.51%	3.51%	3.23%
Petrol/Bioethanol	617.7	19,191.9	3.36%	3.12%	2.04%

Source: DECC's Renewable Energy Statistics, 2011 – Energy Trends, Quarterly tables – data used here released 22 December 2011; http://www.decc.gov.uk/assets/decc/11/stats/publications/energy-trends/3917-trends-dec-2011.pdf

III. Electricity Conversion Factors (DCF Annex 3)

Summary of changes since the previous update

24. The main methodological changes and additions since the previous update include:
    a. Correction to include Crown Dependencies in electricity calculation (for consistency with DUKES electricity supply data);
    b. Amendment of 1990-1995 emissions factors to be more consistent with timeseries data from the UK GHG Inventory (2012) and DUKES (2011).
    c. The inclusion of emission factors for the supply of purchased heat or steam.

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

Direct Emissions from UK Grid Electricity

26. 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). The calculations also factor in net imports of electricity via the interconnectors 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.).

27. This factor changes from year to year as the fuel mix consumed in UK power stations changes, and as 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).

28. The electricity conversion factors provided in the 2012 GHG Conversion Factors Annex 3 are based on emissions from sector 1A1a (power stations) in the UK Greenhouse Gas Inventory (GHGI) for 2010 (AEA) according to the amount of CO_2, CH_4 and N_2O emitted per unit of electricity consumed (from DUKES 2011)[7].

29. In the 2012 update the 1990-1995 timeseries has also been updated to be more consistent with historic data from the UK GHGI and Table 5.1.2 from DUKES (2011) for this period, which has resulted in an increase in the factors for this time period.

30. The UK is a net importer of electricity from the interconnector with France, and a net exporter of electricity to Ireland according to DUKES (2011). For the 2012 GHG Conversion Factors net electricity imports were calculated from DUKES (2011) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2010).

31. The electricity emission factor for France (from Annex 10) – including losses – is used to account for the net import of electricity, as it will also have gone through the French distribution system. . Note that this method effectively reduces the UK's electricity emission factors as 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.

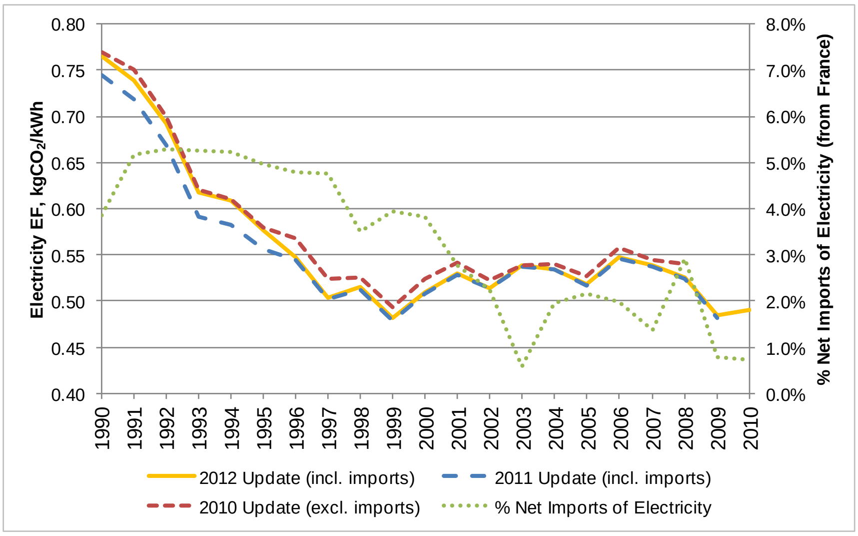
32. The source data and calculated emissions factors are summarised in Table 3, Table 4 and Table 5. The corresponding 5-year rolling average emission factors are presented in Table 6. The impact of the change in

[7] DUKES (2011): *http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx*

methodology in 2011 and 2012 is also summarised in Figure 1 for the electricity CO_2 emission factor time-series from the 2012, 2011 and 2010 updates. 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 2011 and 2010 in-year emission factor time-series. The change in the 1990-1995 emission factor timeseries is also evident when comparing the figures for the 2011 and 2012 updates to the GHG Conversion Factors.

Figure 1: Summary of the impact of the 2011 and 2012 methodology changes on actual in-year and 5-yr rolling average electricity emission factors

Actual in-year grid electricity emission factors:



5-year rolling average grid electricity emission factors:

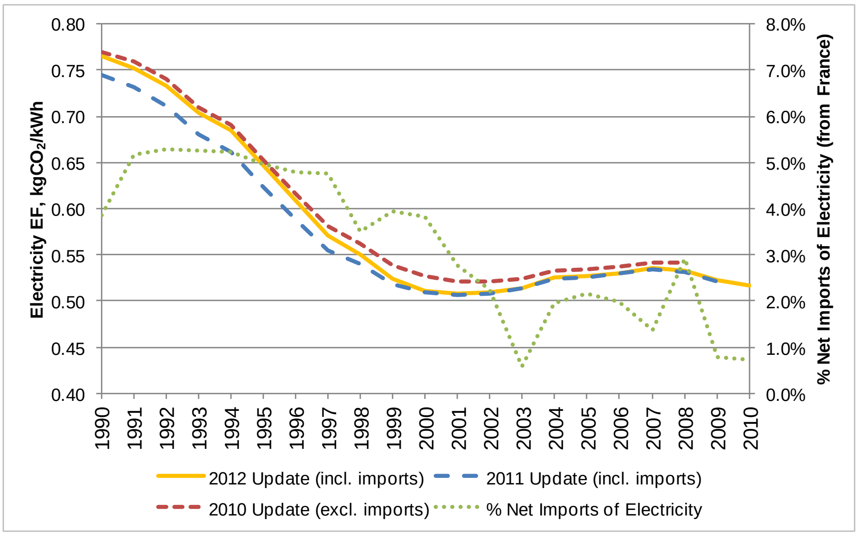


Table 3: Base electricity generation emissions data

Year	Electricity Generation (1)	Total Grid Losses (2)	UK electricity generation emissions (3), ktonne		
	GWh	%	CO_2	CH_4	N_2O
1990	279,661	8.1%	203,437	2.630	5.379
1991	282,622	8.3%	200,063	2.459	5.313
1992	280,648	7.5%	188,116	2.384	4.994
1993	283,769	7.2%	170,703	2.426	4.214
1994	288,535	9.6%	166,510	2.591	4.017
1995	298,584	9.1%	163,411	2.661	3.859
1996	312,430	8.4%	163,106	2.696	3.582
1997	310,660	7.8%	150,261	2.620	3.066
1998	320,317	8.4%	155,372	2.852	3.169
1999	323,213	8.3%	147,246	2.900	2.745
2000	329,345	8.4%	158,686	3.070	3.080
2001	340,525	8.6%	168,830	3.307	3.384
2002	342,299	8.3%	164,493	3.314	3.192
2003	350,385	8.5%	173,450	3.417	3.492
2004	349,092	8.7%	173,099	3.439	3.377
2005	353,481	7.2%	172,699	3.729	3.521
2006	352,066	7.2%	181,647	3.830	3.862
2007	351,045	7.1%	177,480	3.912	3.575
2008	345,949	7.3%	172,419	4.133	3.325
2009	335,306	7.6%	150,891	4.094	2.857
2010	341,868	7.4%	156,293	4.301	2.974

Notes:

(1) Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES (2011) 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 (2011) Table 5.1.2 (long term trends, only available online).

(3) Emissions from UK centralised power generation (including Crown Dependencies only) listed under UNFCC reporting category 1A1a from the UK Greenhouse Gas Inventory for 2010 (AEA, 2012)

Table 4: Base electricity generation emission 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	0.72744	0.00020	0.00596	0.73360	0.06392	0.00002	0.00052	0.06446	0.79136	0.00021	0.00649	0.79806	3.85%	0.11653
1991	0.70788	0.00018	0.00583	0.71389	0.06382	0.00002	0.00053	0.06436	0.77170	0.00020	0.00635	0.77825	5.18%	0.13119
1992	0.67029	0.00018	0.00552	0.67599	0.05471	0.00001	0.00045	0.05518	0.72501	0.00019	0.00597	0.73116	5.29%	0.10471
1993	0.60156	0.00018	0.00460	0.60634	0.04646	0.00001	0.00036	0.04683	0.64801	0.00019	0.00496	0.65316	5.25%	0.07255
1994	0.57709	0.00019	0.00432	0.58159	0.06109	0.00002	0.00046	0.06157	0.63818	0.00021	0.00477	0.64316	5.22%	0.07321
1995	0.54729	0.00019	0.00401	0.55148	0.05460	0.00002	0.00040	0.05502	0.60189	0.00021	0.00441	0.60650	4.97%	0.08075
1996	0.52206	0.00018	0.00355	0.52579	0.04789	0.00002	0.00033	0.04824	0.56995	0.00020	0.00388	0.57403	4.80%	0.08452
1997	0.48368	0.00018	0.00306	0.48692	0.04088	0.00001	0.00026	0.04116	0.52457	0.00019	0.00332	0.52808	4.76%	0.07778
1998	0.48506	0.00019	0.00307	0.48831	0.04445	0.00002	0.00028	0.04475	0.52951	0.00020	0.00335	0.53306	3.51%	0.10656
1999	0.45557	0.00019	0.00263	0.45839	0.04097	0.00002	0.00024	0.04122	0.49654	0.00021	0.00287	0.49961	3.94%	0.09232
2000	0.48182	0.00020	0.00290	0.48492	0.04410	0.00002	0.00027	0.04438	0.52592	0.00021	0.00316	0.52930	3.82%	0.08961
2001	0.49579	0.00020	0.00308	0.49908	0.04642	0.00002	0.00029	0.04673	0.54222	0.00022	0.00337	0.54581	2.78%	0.07667
2002	0.48055	0.00020	0.00289	0.48365	0.04324	0.00002	0.00026	0.04352	0.52379	0.00022	0.00315	0.52717	2.24%	0.08261
2003	0.49503	0.00020	0.00309	0.49832	0.04580	0.00002	0.00029	0.04611	0.54083	0.00022	0.00338	0.54443	0.57%	0.08636
2004	0.49586	0.00021	0.00300	0.49906	0.04731	0.00002	0.00029	0.04761	0.54316	0.00023	0.00329	0.54668	1.97%	0.08446
2005	0.48857	0.00022	0.00309	0.49187	0.03816	0.00002	0.00024	0.03842	0.52673	0.00024	0.00333	0.53030	2.16%	0.09941
2006	0.51595	0.00023	0.00340	0.51958	0.04012	0.00002	0.00026	0.04040	0.55607	0.00025	0.00366	0.55998	1.97%	0.09237
2007	0.50558	0.00023	0.00316	0.50897	0.03842	0.00002	0.00024	0.03868	0.54400	0.00025	0.00340	0.54764	1.38%	0.09597
2008	0.49839	0.00025	0.00298	0.50162	0.03930	0.00002	0.00023	0.03955	0.53769	0.00027	0.00321	0.54118	2.92%	0.09269
2009	0.45001	0.00026	0.00264	0.45291	0.03708	0.00002	0.00022	0.03731	0.48708	0.00028	0.00286	0.49022	0.80%	0.09613
2010	0.45717	0.00026	0.00270	0.46013	0.03640	0.00002	0.00021	0.03664	0.49358	0.00029	0.00291	0.49677	0.73%	0.09613

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

Table 5: Base electricity generation 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	0.70393	0.00019	0.00577	0.70989	0.06185	0.00002	0.00051	0.06237	0.76578	0.00021	0.00628	0.77226	3.85%	0.11653
1991	0.67804	0.00018	0.00558	0.68379	0.06113	0.00002	0.00050	0.06165	0.73916	0.00019	0.00609	0.74544	5.18%	0.13119
1992	0.64035	0.00017	0.00527	0.64579	0.05227	0.00001	0.00043	0.05271	0.69262	0.00018	0.00570	0.69850	5.29%	0.10471
1993	0.57379	0.00017	0.00439	0.57835	0.04431	0.00001	0.00034	0.04466	0.61810	0.00018	0.00473	0.62302	5.25%	0.07255
1994	0.55081	0.00018	0.00412	0.55511	0.05831	0.00002	0.00044	0.05877	0.60912	0.00020	0.00456	0.61387	5.22%	0.07321
1995	0.52410	0.00018	0.00384	0.52812	0.05229	0.00002	0.00038	0.05269	0.57639	0.00020	0.00422	0.58080	4.97%	0.08075
1996	0.50106	0.00017	0.00341	0.50464	0.04597	0.00002	0.00031	0.04630	0.54702	0.00019	0.00372	0.55094	4.80%	0.08452
1997	0.46436	0.00017	0.00294	0.46747	0.03925	0.00001	0.00025	0.03951	0.50361	0.00018	0.00319	0.50698	4.76%	0.07778
1998	0.47177	0.00018	0.00298	0.47493	0.04324	0.00002	0.00027	0.04353	0.51501	0.00020	0.00326	0.51846	3.51%	0.10656
1999	0.44127	0.00018	0.00255	0.44401	0.03968	0.00002	0.00023	0.03993	0.48096	0.00020	0.00278	0.48394	3.94%	0.09232
2000	0.46686	0.00019	0.00281	0.46986	0.04273	0.00002	0.00026	0.04300	0.50958	0.00021	0.00307	0.51286	3.82%	0.08961
2001	0.48416	0.00020	0.00301	0.48737	0.04533	0.00002	0.00028	0.04563	0.52949	0.00022	0.00329	0.53300	2.78%	0.07667
2002	0.47163	0.00020	0.00284	0.47466	0.04244	0.00002	0.00026	0.04271	0.51406	0.00022	0.00309	0.51737	2.24%	0.08261
2003	0.49269	0.00020	0.00308	0.49597	0.04559	0.00002	0.00028	0.04589	0.53828	0.00022	0.00336	0.54186	0.57%	0.08636
2004	0.48777	0.00020	0.00295	0.49092	0.04654	0.00002	0.00028	0.04684	0.53430	0.00022	0.00323	0.53776	1.97%	0.08446
2005	0.48016	0.00022	0.00303	0.48341	0.03751	0.00002	0.00024	0.03776	0.51766	0.00023	0.00327	0.52117	2.16%	0.09941
2006	0.50760	0.00022	0.00335	0.51117	0.03947	0.00002	0.00026	0.03975	0.54707	0.00024	0.00361	0.55092	1.97%	0.09237
2007	0.49994	0.00023	0.00312	0.50330	0.03799	0.00002	0.00024	0.03825	0.53794	0.00025	0.00336	0.54154	1.38%	0.09597
2008	0.48657	0.00024	0.00291	0.48972	0.03837	0.00002	0.00023	0.03861	0.52493	0.00026	0.00314	0.52833	2.92%	0.09269
2009	0.44718	0.00025	0.00262	0.45006	0.03684	0.00002	0.00022	0.03708	0.48403	0.00028	0.00284	0.48714	0.80%	0.09613
2010	0.45453	0.00026	0.00268	0.45747	0.03619	0.00002	0.00021	0.03643	0.49072	0.00028	0.00289	0.49390	0.73%	0.09613

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

Table 6: 5-Year Grid Rolling Average electricity emissions factors (including imported electricity)

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	0.70393	0.00019	0.00577	0.70989	0.06185	0.00002	0.00051	0.06237	0.76578	0.00021	0.00628	0.77226	3.85%	0.11653
1991	0.69098	0.00018	0.00568	0.69684	0.06149	0.00002	0.00051	0.06201	0.75247	0.00020	0.00618	0.75885	5.18%	0.13119
1992	0.67410	0.00018	0.00554	0.67982	0.05842	0.00002	0.00048	0.05891	0.73252	0.00019	0.00602	0.73873	5.29%	0.10471
1993	0.64903	0.00018	0.00525	0.65446	0.05489	0.00001	0.00044	0.05535	0.70391	0.00019	0.00570	0.70980	5.25%	0.07255
1994	0.62938	0.00018	0.00503	0.63459	0.05557	0.00002	0.00044	0.05603	0.68496	0.00019	0.00547	0.69062	5.22%	0.07321
1995	0.59342	0.00018	0.00464	0.59823	0.05366	0.00002	0.00042	0.05410	0.64708	0.00019	0.00506	0.65233	4.97%	0.08075
1996	0.55802	0.00017	0.00421	0.56240	0.05063	0.00002	0.00038	0.05103	0.60865	0.00019	0.00459	0.61343	4.80%	0.08452
1997	0.52282	0.00017	0.00374	0.52674	0.04803	0.00002	0.00034	0.04838	0.57085	0.00019	0.00408	0.57512	4.76%	0.07778
1998	0.50242	0.00018	0.00346	0.50605	0.04781	0.00002	0.00033	0.04816	0.55023	0.00019	0.00379	0.55421	3.51%	0.10656
1999	0.48051	0.00018	0.00314	0.48383	0.04408	0.00002	0.00029	0.04439	0.52460	0.00019	0.00343	0.52822	3.94%	0.09232
2000	0.46906	0.00018	0.00294	0.47218	0.04217	0.00002	0.00026	0.04245	0.51124	0.00020	0.00320	0.51463	3.82%	0.08961
2001	0.46568	0.00018	0.00286	0.46873	0.04205	0.00002	0.00026	0.04232	0.50773	0.00020	0.00312	0.51105	2.78%	0.07667
2002	0.46714	0.00019	0.00284	0.47016	0.04268	0.00002	0.00026	0.04296	0.50982	0.00021	0.00310	0.51313	2.24%	0.08261
2003	0.47132	0.00019	0.00286	0.47437	0.04315	0.00002	0.00026	0.04343	0.51448	0.00021	0.00312	0.51781	0.57%	0.08636
2004	0.48062	0.00020	0.00294	0.48376	0.04452	0.00002	0.00027	0.04481	0.52514	0.00022	0.00321	0.52857	1.97%	0.08446
2005	0.48328	0.00020	0.00298	0.48647	0.04348	0.00002	0.00027	0.04377	0.52676	0.00022	0.00325	0.53023	2.16%	0.09941
2006	0.48797	0.00021	0.00305	0.49123	0.04231	0.00002	0.00026	0.04259	0.53028	0.00023	0.00331	0.53382	1.97%	0.09237
2007	0.49363	0.00022	0.00311	0.49695	0.04142	0.00002	0.00026	0.04170	0.53505	0.00023	0.00337	0.53865	1.38%	0.09597
2008	0.49241	0.00022	0.00307	0.49570	0.03997	0.00002	0.00025	0.04024	0.53238	0.00024	0.00332	0.53594	2.92%	0.09269
2009	0.48429	0.00023	0.00301	0.48753	0.03804	0.00002	0.00024	0.03829	0.52233	0.00025	0.00324	0.52582	0.80%	0.09613
2010	0.47916	0.00024	0.00294	0.48234	0.03777	0.00002	0.00023	0.03802	0.51694	0.00026	0.00317	0.52037	0.73%	0.09613

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

Indirect Emissions from UK Grid Electricity

33. 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 lifecycle emissions as included in Annex 1). The average fuel lifecycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel / primary energy used in electricity generation.

34. 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, DUKES, 2011. 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	16,665	311,408	18,038	180,613	**944,741**
2007	382,857	13,509	355,878	14,613	143,547	**910,405**
2008	348,513	18,407	376,810	13,074	124,128	**880,933**
2009	286,820	17,606	359,303	11,551	172,969	**848,250**
2010	297,301	13,650	371,736	9,490	165,057	**857,233**

Source: Table 5.6, Digest of UK Energy Statistics 2011 (DECC, 2011), 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%	33.0%	1.9%	19.1%	**100.0%**
2007	42.1%	1.5%	39.1%	1.6%	15.8%	**100.0%**
2008	39.6%	2.1%	42.8%	1.5%	14.1%	**100.0%**
2009	33.8%	2.1%	42.4%	1.4%	20.4%	**100.0%**
2010	34.7%	1.6%	43.4%	1.1%	19.3%	**100.0%**

Notes: Calculated from figures in Table 7

Table 9: Indirect emissions share for 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%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.70393	0.10334	0.10334
1991	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.67804	0.09954	0.10144
1992	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.64035	0.09400	0.09896
1993	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.57379	0.08423	0.09528
1994	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.55081	0.08086	0.09239
1995	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.52410	0.07694	0.08711
1996	16.5%	18.9%	10.4%	12.5%	14.7%	**14.7%**	0.50106	0.07355	0.08192
1997	16.5%	18.9%	10.4%	12.5%	14.0%	**14.0%**	0.46436	0.06520	0.07616
1998	16.5%	18.9%	10.4%	12.5%	13.9%	**13.9%**	0.47177	0.06575	0.07246
1999	16.5%	18.9%	10.4%	12.5%	13.5%	**13.5%**	0.44127	0.05944	0.06818
2000	16.5%	18.9%	10.4%	12.5%	13.6%	**13.6%**	0.46686	0.06345	0.06548
2001	16.5%	18.9%	10.4%	12.5%	13.8%	**13.8%**	0.48416	0.06672	0.06411
2002	16.5%	18.9%	10.4%	12.5%	13.6%	**13.6%**	0.47163	0.06413	0.06390
2003	16.5%	18.9%	10.4%	12.5%	13.7%	**13.7%**	0.49269	0.06769	0.06429
2004	16.5%	18.9%	10.4%	12.5%	13.6%	**13.6%**	0.48777	0.06636	0.06567
2005	16.5%	18.9%	10.4%	12.5%	13.7%	**13.7%**	0.48016	0.06582	0.06615
2006	16.5%	18.9%	10.4%	12.5%	14.0%	**14.0%**	0.50760	0.07084	0.06697
2007	16.5%	18.9%	10.4%	12.5%	13.6%	**13.6%**	0.49994	0.06808	0.06776
2008	16.5%	18.9%	10.4%	12.5%	13.4%	**13.4%**	0.48657	0.06536	0.06729
2009	16.5%	18.9%	10.4%	12.5%	13.2%	**13.2%**	0.44718	0.05915	0.06585
2010	16.5%	18.9%	10.4%	12.5%	13.2%	**13.2%**	0.45453	0.05998	0.06468

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.

Emission Factors for the Supply of Purchased Heat or Steam

35. New time-series emission factors for the supply of purchased heat or steam have been provided in Annex 3 for the 2012 GHG Conversion Factors. These new conversion factors represent the average emission from the heat and steam supplied by the UK CHPQA (Combined Heat and Power Quality Assurance) scheme[8] operators for a given year. This factor changes from year to year, as the fuel mix consumed changes and is therefore to be updated annually. No statistics are available that would allow the calculation of UK national average emission factors for the supply of heat and steam from non-CHP operations.

36. CHP (Combined Heat and Power) simultaneously produces both heat and electricity, and there are a number of conventions used to allocate emissions between these products. At the extremes, emissions could be allocated wholly to heat or wholly to electricity, or in various proportions in-between. The following sections outline the methodology (including the basis, key sources and assumptions) utilised to develop the heat and steam emission factors for the 2012 GHG Conversion Factors.

Fuel allocation to electricity from CHP

37. To determine the amount of fuel attributed to CHP heat (qualifying heat output, or 'QHO'), it is necessary to apportion the total fuel to the CHP scheme to the separate heat and electricity outputs. This then enables the fuel, and therefore emissions, associated with the qualifying heat output to be determined. There are three possible methodologies for apportioning fuel to heat and power, which include:
    i. **Method 1:** 1/3 : 2/3 Method (DUKES)
    ii. **Method 2:** Boiler Displacement Method
    iii. **Method 3:** Power Station Displacement Method

    The basis of each method is described in the following sub-sections.

Method 1: 1/3 : 2/3 Method (DUKES)

38. Under the UK's Climate Change Agreements[9] (CCAs), this method which is used to apportion fuel use to heat and power assumes that twice as many units of fuel are required to generate each unit of electricity than are required to generate each unit of heat. This follows from the observation that the efficiency of the generation of electricity (at electricity only generating plant) varies from as little as 25% to 50%, while the efficiency of the generation of heat in fired boilers ranges from 50% to about 90%.

[8] See http://chpqa.decc.gov.uk/

[9] Climate Change Agreements (CCAs) are agreements between UK energy intensive industries and UK Government, whereby industry undertakes to make challenging, but achievable, improvements in energy efficiency in exchange for a reduction in the Climate Change Levy (CCL).

39. Mathematically, Method 1 can be represented as follows:

$$Heat\ Energy = \left(\frac{Total\ Fuel\ Input}{(2 \times Electricity\ Output) + Heat\ Output} \right) \times Heat\ Output$$

$$Electricity\ Energy = \left(\frac{2 \times Total\ Fuel\ Input}{(2 \times Electricity\ Output) + Heat\ Output} \right) \times Electricity\ Output$$

Where:

- *'Total Fuel Input'* is the total fuel to the prime mover.
- *'Heat Output'* is the useful heat generated by the prime mover.
- *'Electricity Output'* is the electricity (or the electrical equivalent of mechanical power) generated by the prime mover.
- *'Heat Energy'* is the fuel to the prime mover apportioned to the heat generated.
- *'Electricity Energy'* is the fuel to the prime mover apportioned to the electricity generated.

40. This method is used only in the UK for accounting for primary energy inputs to CHP where the CHP generated heat and electricity is used within a facility with a CCA.

Method 2: Boiler Displacement Method

41. Under this convention it is assumed that the heat generated by the CHP displaces heat raised by a boiler with an efficiency of 90% (NCV), but that the boiler uses the same fuel mix as the actual fuel mix to the CHP to determine the CO_2 emissions.

42. Mathematically, Method 2 can be represented as follows:

$$Heat\ Energy = \left(\frac{Heat\ Output}{0.9} \right)$$

Where: the *Heat Energy* and *Heat Output* are as defined for Method 1, above.

43. This method has wider understanding within the European Union and has the advantage that it would be compatible with other allocation methodologies for heat.

44. Carbon emission factors for Heat and Electricity are calculated according to this method as follows:

CO_2 emission from Fuel for Boiler

$$= \left(\frac{QHO}{0.9} \right) * FuelmixCO2Factor$$

CHP Heat EF = CO_2 emission from Fuel for Boiler / QHO

$$= \left(\frac{FuelMixCO2Factor}{0.9} \right)$$

CO_2 emission from Fuel for Electricity

$$= \{TFI - \left(\frac{QHO}{0.9}\right)\} * FuelMixCO2\,factor$$

3- CHP Electricity EF

$$= \{\{TFI - \left(\frac{QHO}{0.9}\right)\} * FuelMixCO2\,factor\} / TPO$$

Where: the QHO is the (Qualifying) Heat Output; EF = emission factor.

Method 3: Power Station Displacement Method

45. Under this convention it is assumed that the electricity generated by the CHP displaces electricity generated by conventional power only plant with an agreed efficiency (using the UK's fossil fuel fired power stations annual efficiencies, taken into consideration the transmission and distribution losses). This establishes the fuel for electricity and the balance of the fuel to the prime mover is then assumed to be for the generation of heat.

46. Mathematically, Method 3 can be represented by:

$$Heat\ Energy = Total\ Fuel\ Input - \left(\frac{Electricity\ Output}{Power.Stations.Efficiency}\right)$$

Where: Heat Energy, Total Fuel Input and Electricity Output are defined for Method 1, above.

47. This method raises the question of which power generation efficiency to use. For comparison in this analysis we have used the power generation efficiency of gas fired power stations.

48. Carbon emission factors for Heat and Electricity are calculated according to this method as follows::

CO_2 emission from Fuel for Boiler

$$= \{TFI - \left(\frac{ElectricityOutput}{PowerStationsEfficiency}\right)\} * FuelMixCO2\,factor$$

CHP Heat emission factor= CO_2 emission from Fuel for Boiler / QHO

CO_2 emission from Fuel for Electricity

$$= \left(\frac{TPO}{PowerStationsEfficiency}\right) * FuelMixCO2\,factor$$

CHP Electricity Emission factor

$$= \left(\frac{FuelMixCO2Factor}{PowerStationsEfficiency}\right)$$

Calculation of CO_2 Emissions Factor for CHP Fuel Input, $FuelMixCO_2factor$

49. The value *$FuelMixCO_2factor$* referred to above is the carbon emissions factor per unit fuel input to a CHP scheme. This factor is determined using fuel input data provided by CHP scheme operators to the CHP Quality Assurance (CHPQA) programme, which is held in confidence.

The value for *FuelMixCO_2factor* is determined using the following expression:

$$FuelMixCO2factor = \frac{\sum(Fuel\ Input \times Fuel\ CO2\ Emissions\ Factor)}{TFI}$$

Where:

- *FuelMixCO_2factor* is the composite emissions factor (in tCO_2/MWh thermal fuel input) for a scheme
- *Fuel Input* is the fuel input (in MWh thermal) for a single fuel supplied to the prime mover
- *Fuel CO_2 Emissions factor* is the CO_2 emissions factor (in tCO_2/MWh_{th}) for the fuel considered.
- *TFI* is total fuel input (in MWh thermal) for all fuels supplied to the prime mover

50. Fuel inputs and emissions factors are evaluated on a Gross Calorific Value (Higher Heating Value) basis. The following Table 10 provides the individual fuel types considered and their associated emissions factors, consistent with other reporting under the CHP QA scheme.

Table 10: Fuel types and associated emissions factors used in determination of FuelMixCO_2factor

Fuel	**CO_2 Emissions Factor ($kgCO_2/kWh_{th}$)**
Biomass (e.g. woodchips, chicken litter)	-
Blast furnace gas	1.061
Coal and lignite	0.333
Coke oven gas	0.338
Domestic refuse (raw)	0.008
Ethane	0.191
Fuel oil	0.267
Gas oil	0.279
Hydrogen	-
Methane	0.184
Mixed refinery gases	0.246
Natural gas	0.184
Other Biogas (e.g. gasified woodchips)	-
Other gaseous waste	0.214
Other liquid waste	0.262
Other solid waste	0.329
Refuse-derived Fuels (RDF)	0.008
Sewage gas	-
Unknown process gas	0.246
Waste exhaust heat from high temperature processes	-
Waste heat from exothermic chemical reactions	-
Wood Fuels (woodchips, logs, wood pellets etc.)	-

Sources: Defra/DECC GHG Conversion Factors for Company Reporting (2011 update) and National Atmospheric Emissions Inventory (NAEI).

51. The 1/3 : 2/3 method was utilised in deriving the new heat/steam emission factors provided in Annex 3 of the 2012 GHG Conversion Factors, for consistency with both DUKES and the approach recommended in Annex 2. However, results are provided for comparison according to all three methods in the following Table 11.

Table 11: Comparison of calculated Electricity and Heat/Steam CO_2 emission factors for the 3 different allocation methods

Year	$KgCO_2$/kWh supplied heat/steam			$KgCO_2$/kWh supplied power		
	Method 1 (DUKES: 2/3rd - 1/3rd)	Method 2 (Boiler displaced)	Method 3 (Power displaced)	Method 1 (DUKES: 2/3rd - 1/3rd)	Method 2 (Boiler displaced)	Method 3 (Power displaced)
2001	0.23770	0.26342	0.05903	0.22703	0.19519	0.44825
2002	0.22970	0.25361	0.07100	0.23765	0.20842	0.43157
2003	0.23393	0.26230	0.04925	0.23378	0.20112	0.44635
2004	0.22750	0.25638	0.05380	0.24085	0.20836	0.43627
2005	0.22105	0.24803	0.05115	0.23931	0.21029	0.42207
2006	0.23072	0.25544	0.06223	0.25681	0.23071	0.43468
2007	0.23118	0.25492	0.04048	0.24446	0.22089	0.43379
2008	0.22441	0.24731	0.04062	0.23564	0.21257	0.42084
2009	0.22196	0.24548	0.04567	0.24019	0.21650	0.41773
2010	0.21859	0.24163	0.05447	0.24125	0.21739	0.41118

Calculation of Non-CO_2 and Indirect Emissions Factor for Heat and Steam

52. CH_4 and N_2O emissions have been estimated relative to the CO_2 emissions, based upon activity weighted average values for each CHP fuel used (using relevant average fuel emission factors from the NAEI).

53. Indirect GHG emission factors have been estimated relative to the CO_2 emissions, based upon activity weighted average indirect GHG emission factor values for each CHP fuel used. Where fuels are not included in the set of indirect GHG emission factors provided in the 2012 GHG Conversion Factors, the value for the closest/most similar alternative fuel was utilised instead.

54. The complete final emission factors for supplied heat or steam utilised are presented in Annex 3 Table 3d of the 2012 GHG Conversion Factors.

55. For district heating systems, where the location of use of the heat is some distance from the point of production, there are distribution energy losses. These losses are typically around 5%, which need to be factored into the calculation of overall GHG emissions where relevant.

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

Summary of changes since the previous update

56. No changes have been made to DCF Annex 4 since the 2011 update.

57. Four additional refrigerants have been added to the list in DCF Annex 5.

Inventory of Likely Process Emissions (DCF Annex 4)

58. 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.

59. 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

60. 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) that is required to be used in inventory reporting.

61. *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.

62. Two additional blended gasses have been added to the list in the 2012 update, including R407A (20:40:40 blend of HFC-32, -125 and -134a) and

R407F (30:30:40 blend of HFC-32, -125 and -134a), based on information from http://www.fluorocarbons.org/applications/commercial-refrigeration.

Other Greenhouse Gases

63. 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).

64. *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.

65. Two additional gases have been added to the list for the 2012, including R1234yf (CH_2CFCF_3) and R1234ze ($CHFCHCF_3$), which are showing increasing use in mobile air conditioners. The GWP of R1234yf and R1234ze are tentative and still awaiting official confirmation. The figures presented here are based on data from producers and will be revisited in a future update.

V. Passenger Surface Transport Emission Factors (DCF Annex 6)

Summary of changes since the previous update

66. The main methodological changes and additions since the previous update include:
    a. The methodology used to define the emission factors for road vehicles (except motorcycles and buses) in Annexes 6 and 7 has been updated to utilise the factors used in the 2010 NAEI to account for the age/activity of the vehicle fleet in the UK, derived from DVLA licensing data and DfT's ANPR (Automatic Number Plate Recognition) data

67. All other factors have also been updated with more recent data for the latest 2012 GHG Conversion Factors.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

68. SMMT (Society for Motor Manufacturers and Traders)[10] provides numbers of registrations and averages of the NEDC[11] gCO_2/km figures for new vehicles registered from 1997 to 2011[12]. The dataset represents a good indication of the relative NEDC gCO_2/km by size category. Table 12 presents the 1997-2011 average CO_2 emission factors and number of vehicle registrations.

69. For the 2012 GHG Conversion Factors update, the SMMT data have been used in conjunction with DfT's ANPR (Automatic Number Plate Recognition) data to weight the emission factors to account for the age and activity distribution of the UK vehicle fleet in 2010.

70. The ANPR data have been collected annually (since 2007) over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for 2007, 2008, 2009 and 2010. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle, engine sizes, vehicle weight and road types.

71. Data for the UK car fleet were extracted from the 2010 ANPR dataset and categorised according to their engine size, fuel type and year of registration. The 2012 GHG Conversion Factors' emission factors for petrol and diesel passenger cars were subsequently calculated based upon the equation below:

$$\text{2012 update gCO}_2\text{/km} = \Sigma \left(gCO_2/km_{yr\ reg} \times \frac{ANPR_{yr\ reg}}{ANPR_{total\ 2010}} \right)$$

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[10] SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry. http://www.smmt.co.uk/

[11] NEDC = New European Driving Cycle, which is used in the type approval of new passenger cars.

[12] 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.

Table 12: Average CO_2 emission factors and total registrations by engine size for 1997 to 2011 (based on data sourced from SMMT)

Vehicle Type	Engine size	Size label	gCO_2 per km	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	147.8	10,974,228	46%
	1.4 - 2.0 l	Medium	185.0	10,917,250	46%
	> 2.0 l	Large	259.7	1,943,606	8%
Average petrol car			**179.4**	**23,835,084**	**100%**
Diesel car	<1.7 l	Small	123.7	2,354,017	23%
	1.7 - 2.0 l	Medium	155.5	5,733,641	55%
	> 2.0 l	Large	208.6	2,245,989	22%
Average diesel car			**164.1**	**10,333,647**	**100%**

72. 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.

73. 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 2012 GHG Conversion Factors for the UK car fleet as a whole. However, some recent studies have suggested that the differential may be widening for new cars (particularly for the most efficient models). The current assumptions for the UK fleet will be reconsidered in future updates.

74. The uplift of +15% was applied to the ANPR weighted SMMT gCO_2/km to give the *New 'Real-World'* 2012 GHG Conversion Factors, to take into account the 'real-world' impacts on fuel consumption not captured by drive cycles such as the NEDC in type-approval.

75. 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 62.0% petrol and 38.0% diesel, and can be compared to the respective total registrations of the different vehicle types for 1997-2011, which were 69.8% petrol and 30.2% diesel.

76. Emission factor for CH_4 and N_2O have been updated for all vehicle classes and are based on the emission factors from the UK GHG Inventory. Note that when compared with the 2011 update, changes in the CH_4 and N_2O

emission factors have arisen as a result of updates to the NAEI methodology. ANPR data and Regional Vehicle Licensing Statistics (DVLA) were used to define the petrol and diesel car mix by road type and by Devolved Administrations[13].

77. The final 2012 emission factors for petrol and diesel passenger cars by engine size are presented in Annex 6 Tables 6b, 6c and 6e of the 2012 GHG Conversions Factors.

Hybrid, LPG and CNG Passenger Cars

78. The methodology used in the 2012 update for medium and large hybrid petrol electric cars is similar to that in the 2011 update, having received numbers of registrations and averages of the NEDC[14] gCO_2/km figures from SMMT for new hybrid vehicles registered in 2011. DfT's ANPR data have also been included as described in the section above, following the approach used in calculating the emission factors for petrol/diesel cars by engine size.

79. 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. In the 2012 GHG Conversion Factors, CO_2 emission factors for CNG and LPG medium and large cars are derived by multiplying the equivalent petrol EF by the ratio of CNG (and LPG) to petrol EFs from Annex 1 on a unit energy basis. For example, for a Medium car run on CNG:

$$gCO_2/km_{CNG\ Medium\ car} = gCO_2/km_{Petrol\ Medium\ car} \times \frac{gCO_2/kWh_{CNG}}{gCO_2/kWh_{Petrol}}$$

80. For the 2012 GHG Conversion Factors, the emission factors for CH_4 and N_2O were updated, but the methodology remains unchanged. These are based on the emission factors from the UK GHG Inventory (managed by AEA) and are presented together with an overall total emission factors in Annex 6 Table 6d of the 2012 GHG Conversion Factors.

Emission Factors by Passenger Car Market Segments

81. For the 2012 GHG Conversion Factors, the market classification split (according to SMMT classifications) was derived using detailed SMMT data on new car registrations between 1997 and 2011 split by fuel[15], presented in Table 13, and again combining this with information extracted from the 2010 ANPR dataset. These data were then uplifted by 15% to take into account 'real-world' impacts, consistent with the methodology used to derive the car engine size emission factors. The supplementary

[13] For improvements in the 2010 inventory, see the report and annexes 'UK Greenhouse Gas Inventory, 1990 to 2010: Annual Report for submission under the Framework Convention on Climate Change', available from *http://naei.defra.gov.uk/reports.php*

[14] NEDC = New European Driving Cycle, which is used in the type approval of new passenger cars.

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

market segment based emission factors for passenger cars are presented in Annex 6 Tables 6f, 6g and 6h of the 2012 GHG Conversion Factors.

82. 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. The factors are presented together with the overall total emission factors in Annex 6 Tables 6f, 6g and 6h of the 2012 GHG Conversion Factors.

Table 13: Average car CO_2 emission factors and total registrations by market segment for 1999 to 2011 (based on data sourced from SMMT)

Fuel Type	Market Segment	Example Model	1999-2011		
			gCO2/km	# registrations	% Total
Diesel	Dual Purpose	Smart Fortwo	222.9	1,272,266	13.2%
	Executive	VW Polo	178.7	751,689	7.8%
	Lower Medium	Ford Focus	138.7	2,912,757	30.2%
	Luxury Saloon	Toyota Avensis	212.2	47,469	0.5%
	Mini	BMW 5-Series	89.4	8,035	0.1%
	Multi Purpose	Bentley Continental GT	174.1	782,627	8.1%
	Specialist Sports	Mercedes SLK	146.2	39,693	0.4%
	Super Mini	Land Rover Discovery	121.3	1,162,837	12.1%
	Upper Medium	Renault Espace	153.8	2,661,990	27.6%
	All	**Total**	**162.6**	**9,639,363**	**100%**
Petrol	Dual Purpose	Smart Fortwo	245.6	646,052	3.2%
	Executive	VW Polo	232.6	633,768	3.1%
	Lower Medium	Ford Focus	172.5	5,734,933	28.4%
	Luxury Saloon	Toyota Avensis	300.9	94,463	0.5%
	Mini	BMW 5-Series	133.6	509,317	2.5%
	Multi Purpose	Bentley Continental GT	195.4	600,065	3.0%
	Specialist Sports	Mercedes SLK	220.7	740,490	3.7%
	Super Mini	Land Rover Discovery	145.7	8,605,426	42.7%
	Upper Medium	Renault Espace	197.4	2,607,358	12.9%
	All	**Total**	**176.7**	**20,171,872**	**100%**
Unknown Fuel (Diesel + Petrol)	Dual Purpose	Smart Fortwo	230.5	1,918,318	6.4%
	Executive	VW Polo	203.3	1,385,457	4.6%
	Lower Medium	Ford Focus	161.1	8,647,690	29.0%
	Luxury Saloon	Toyota Avensis	271.2	141,932	0.5%
	Mini	BMW 5-Series	133.0	517,352	1.7%
	Multi Purpose	Bentley Continental GT	183.3	1,382,692	4.6%
	Specialist Sports	Mercedes SLK	216.9	780,183	2.6%
	Super Mini	Land Rover Discovery	142.8	9,768,263	32.8%
	Upper Medium	Renault Espace	175.4	5,269,348	17.7%
	All	**Total**	**172.2**	**29,811,235**	**100%**

Direct Emissions from Taxis

83. 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[16]). The

[16] 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*

emission factors for black cabs are based on the large car emission factor (which is consistent with the Vehicle Certification Agency (VCA)[17] dataset based on the NEDC for London Taxis International vehicles) and an average ***passenger*** occupancy of 1.5 (average 2.5 people per cab, including the driver, from LTI, 2007).

84. The 2012 update for emission factors per passenger km for taxis are presented in Annex 6 Table 6k of the 2012 GHG Conversion Factors. These have been updated to be consistent with the most recent data for cars. The base emission factors per vehicle km are also presented in Annex 6 Table 6k of the 2012 GHG Conversion Factors. 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. No other new data has been identified/made available to inform the 2012 update.

85. Emission factors for CH_4 and N_2O have been updated for all taxis for the 2012 update. These figures are, as before, based on the emission factors for diesel cars from the UK GHG Inventory and are presented together with overall total emission factors in Annex 6 Table 6k of the 2012 GHG Conversion Factors.

Direct Emissions from Vans

86. 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 14 (and Annex 6 Table 6i of the 2012 GHG Conversion Factors), have been updated for the 2011 GHG Conversion Factors. The data set used to allocate different vehicles to each class is based on reference weight (approximately equivalent to kerb weight plus 60kg) in the MVRIS data set. The assumed split of petrol van stock between size classes uses the split of registrations from this dataset

87. These test cycle based emission factors are uplifted by 15% to represent 'real-world' emissions, consistent with the approach used for cars, and agreed with DfT. Emission factors for petrol and diesel LGVs are based upon emission factors and vehicle km from the NAEI for 2010. In the 2012 GHG Conversion Factors, CO_2 emission factors for CNG and LPG vans are calculated using the same methodology as for passenger cars. The average van emission factor is calculated on the basis of the relative NAEI vehicle km for petrol and diesel LGVs for 2010, as presented in Table 14.

88. Emission factors for CH_4 and N_2O were also updated for all van classes, based on the emission factors from the UK GHG Inventory. N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for diesel vans.

[17] Vehicle Certification Agency (VCA) car fuel database is available at: http://www.vcacarfueldata.org.uk/

Table 14 New emission factors for vans for the 2012 GHG Conversion Factors

Van fuel	Van size	Direct gCO_2e per km					vkm	Capacity
		CO_2	CH_4	N_2O	Total		% split	tonnes
Petrol (Class I)	Up to 1.305 tonne	198.1	0.3	1.1	199.5		38.4%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	211.1	0.3	1.1	212.5		48.6%	0.72
Petrol (Class III)	Over 1.740 tonne	255.8	0.3	2.6	258.7		13.0%	1.29
Petrol (average)	**Up to 3.5 tonne**	**211.9**	**0.3**	**1.3**	**213.5**		**100.0%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	152.1	0.1	1.1	153.2		6.2%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	224.4	0.1	1.6	226.0		25.7%	0.98
Diesel (Class III)	Over 1.740 tonne	264.5	0.1	1.9	266.4		68.1%	1.29
Diesel (average)	**Up to 3.5 tonne**	**247.2**	**0.1**	**1.8**	**249.0**		**100.0%**	**1.17**
LPG	Up to 3.5 tonne	259.6	0.7	2.7	263.0			1.17
CNG	Up to 3.5 tonne	234.9	1.3	2.7	238.9			1.17
Average		**245.4**	**0.1**	**1.8**	**247.2**			**1.15**

Direct Emissions from Buses

89. The 2012 update uses data from DfT from the Bus Service Operators Grant (BSOG) in combination with DfT bus activity statistics (vehicle km, passenger km) to estimate emission factors for local buses. 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.

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

91. Emission factors for CH_4 and N_2O are based on the emission factors from the UK GHG Inventory. These factors are also presented together with an overall total factor in Table 15.

92. Table 15 gives a summary of the 2012 updated emission factors and average passenger occupancy. The increase in average passenger occupancy for local buses – and average local bus – is a result of significant increases in passenger-km statistics from DfT since the last statistics release in 2010[18]. This has resulted in a large decrease in the average CO_2 emission factor per pkm for local buses when compared with the 2011 update, which are presented in Table 16. It should also be noted that fuel consumption and emission factors for individual operators and services will vary significantly depending on the local conditions, the specific vehicles used and on the typical occupancy achieved.

[18] DfT have confirmed this difference was due to an error in their dataset in the 2010 statistical release (corrected in the 2011 dataset), which underestimated the non-London local bus passenger-km.

Table 15: Emission factors for buses for the 2012 GHG Conversion Factors

Bus type	Average passenger occupancy	gCO$_2$e per passenger km			
		CO_2	CH_4	N_2O	Total
Local bus	9.5	122.7	0.13	0.98	12$_3$.8
Local London bus	16.8	82.0	0.07	0.55	82.6
Average local bus	**10.8**	111.0	0.12	0.86	112.0
Coach	16.2*	28.1	0.07	0.57	28.7

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

Table 16: 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

93. 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.

94. For the practical purposes of the GHG Conversion Factors, 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)

95. For the 2009 update the emission factors were calculated based on a large dataset kindly provided by Clear (2008)[19]. 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 17, with the corresponding complete emission factors developed for motorcycles are presented in Annex 6 Table 6j of the 2012 GHG Conversion Factors. 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)[20]. In the

[19] 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.

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

absence of new information the methodology and dataset are unchanged for the 2012 GHG Conversion Factors.

96. These emission factors are based predominantly upon data derived from real-world riding conditions (rather than the test-cycle based data) and therefore likely to be more representative of typical in-use performance. The average difference between the factors based on real-world observed fuel consumption and figures based upon test-cycle data from ACEM[21] (+9%) is smaller than the corresponding differential used to uplift cars test cycle data to real-world equivalents (+15%).

97. Emission factors for CH_4 and N_2O were updated for the 2012 GHG Conversion Factors based on the emission factors from the 2010 UK GHG Inventory (AEA, 2012). These factors are also presented together with overall total emission factors in Annex 6 Table 6j of the 2012 GHG Conversion Factors.

Table 17: 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.

[21] The European Motorcycle Manufacturers Association

Direct Emissions from Passenger Rail

98. Emission factors for passenger rail services have been updated and provided in Annex 6 Table 6k of the 2012 GHG Conversion Factors. 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 2012 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

99. 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.

100. 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.

101. Eurostar's published figure (from 2010) is 7.71 gCO_2/pkm. This differs from the figure quoted in the 2010, 2011 and 2012 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 2012 update. For further information please visit: http://www.eurostar.com/UK/uk/leisure/about_eurostar/environment/greener_than_flying.jsp

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

National Rail

103. 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)[22]. 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 2012 update.

104. 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

105. 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 18.

106. Figures for the DLR, London Overground and Croydon Tramlink for 2009/10 based on figures from Transport for London's 2011 Health, Safety and Environment report[23] adjusted to the new 2010 grid electricity CO_2 emission factor.

107. 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'[24] and the new 2010 grid electricity CO_2 emission factor.

108. 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 2010 grid electricity CO_2 emission factor, for consistency.

109. The average emission factor was estimated based on the relative passenger km of the four different rail systems (see Table 18).

110. 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.

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

[23] TfL (2012); 2011 Health, Safety and Environment Report *http://www.tfl.gov.uk/assets/downloads/corporate/tfl-health-safety-and-environment-report-2011.pdf*

[24] DfT Light rail and tram statistics, *http://www.dft.gov.uk/statistics/series/light-rail-and-tram/*

Table 18: 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	0.130	67.5	0.033	0.498	76	414
Glasgow Underground	Light Rail	0.164	84.9	0.043	0.521	85.5	42
Midland Metro	Light Rail	0.135	69.9	0.035	0.429	70.4	50
Tyne & Wear Metro	Light Rail	0.198	102.1	0.051	0.626	102.8	315
London Overground	Light Rail	0.094	48.6	0.024	0.298	0.4	606
Croydon Tramlink	Tram	0.083	42.7	0.021	0.262	0.4	146
Manchester Metrolink	Tram	0.076	39.1	0.020	0.240	39.4	201
Nottingham Express Transit	Tram	No data	No data				No data
Supertram	Tram	0.186	96.0	0.048	0.589	96.6	97
Average*		**0.124**	**64.2**	**0.032**	**0.412**	**47.3**	**1871**

Notes: * Weighted by relative passenger km

London Underground

111. The London Underground rail factor is from Transport for London's 2011 Health, Safety and Environment report (TfL, 2012), corrected to the 2010 grid electricity CO_2 emission factor.

112. 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.

Direct Emissions from RoPax Ferries

113. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[25]. No new methodology or updated dataset has been identified for the 2012 GHG Conversion Factors.

114. 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.

115. 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 19.

[25] 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.

Table 19: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[26]
Average weight of passenger + luggage, total	0.100	MCA, 2007[26]
Average Freight Unit*, total	22.173	BFF, 2007[27]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[28]

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

116. 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 Annex 6 Table 6k of the 2012 GHG Conversion Factors. A further split has been provided between foot-only passengers and passengers with cars in the 2012 GHG Conversion Factors, again on a weight allocation basis.

117. 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).

118. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the 2010 UK GHG Inventory, proportional to the CO_2 emissions.

Indirect Emissions

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

119. Indirect emissions factors (EFs) for cars, vans, motorcycles, taxis, buses and ferries include only emissions resulting from the fuel lifecycle (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.

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

[27] 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.

[28] 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

Rail

120. 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.

121. 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 (no newer similar dataset is available).

VI. Freight Surface Transport Emission Factors (DCF Annex 7)

Summary of changes since the previous update

122. No changes have been made to the methodology to derive emission factors for road freight in the 2012 update of the GHG Conversion Factors.

123. All other factors have been updated with more recent data in the latest 2012 GHG Conversion Factors.

Direct Emissions from Heavy Goods Vehicles (HGVs)

124. 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 2008-11 GHG Conversion Factors. The new factors for the 2012 GHG Conversion Factors are presented in Annex 7 Table 7d.

125. The factors are based on road freight statistics from the Department for Transport (DfT, 2011)[29] for Great Britain (GB), from a survey on different sizes of rigid and articulated HGVs in the fleet in 2010. 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.

126. The miles per gallon (MPG) figures in Table RFS0141 of DfT (2011) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the 2011 GHG Conversion Factors tables. Table RFS0117 of DfT (2011) shows the percent loading factors are on average between 40-60% in the UK HGV fleet. Figures from the ARTEMIS project

[29] "Transport Statistics Bulletin: Road Freight Statistics 2011, (DfT, 2011). Available at: http://www.dft.gov.uk/statistics/releases/tsgb-2011-freight/

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 20 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.

Table 20: 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

127. Using these loading factors, the CO_2 factors derived from the DfT survey's MPG 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 Annex 7 Table 7d of the 2012 GHG Conversion Factors.

128. The loading factors in Table 20 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in Annex 7 Table 7d of the 2012 GHG Conversion Factors. 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.

129. 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 MPG 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 articulated 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 Annex 7 Table 7d of the 2012 GHG Conversion Factors. Thus the factors in Annex 7 Table 7d, linked to the DfT (2009) statistics on MPG (estimated by DfT from the survey data) reflect each HGV class's typical usage pattern on the GB road network.

130. 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 2010. 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 (2011).

131. UK average factors for all rigid and articulated HGVs are also provided in Annex 7 Table 7d of the 2012 GHG Conversion Factors 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 2010. These are derived directly from the mpg values for rigid and articulated HGVs in Table RFS0141of DfT (2011).

132. At a more aggregated level still are factors for all HGVs representing the average mpg for all rigid and articulated HGV classes in Table RFS0141 of DfT (2011). 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.

133. The conversion factors provided in Annex 7 Table 7d of the 2012 GHG Conversion Factors 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.

134. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO_2 factors in tonne km (tkm) units. Annex 7 Table 7e of the 2012 GHG Conversion Factors 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 Annex 7 Table 7d 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 RFS0119 and RFS0109, respectively (DfT, 2011). Dividing the tkm by the vkm figures gives the average tonnes freight lifted by each HGV class.

135. 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 Annex 7 Table 7e of the 2012 GHG Conversion Factors for the relevant HGV class.

136. Emission factors for CH_4 and N_2O have been updated for all HGV classes. These are based on the emission factors from the 2010 UK GHG Inventory. CH_4 and N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for HGVs. These factors are presented with an overall total factor in Annex 7 Table 7d and Annex 7 Table 7e of the 2012 GHG Conversion Factors.

Direct Emissions from Light Goods Vehicles (LGVs)

137. Emission factors for light good vehicles (vans up to 3.5 tonnes), presented in **Error! Reference source not found.**, were calculated based on the mission factors per vehicle-km in the earlier section on passenger transport.

138. 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 21. These are based on quantitative assessment of the van database used by AEA in a variety of policy assessments for DfT.

Table 21: Typical van freight capacities and estimated average payload

Van fuel	Van size	Vkm % split	Av. Capacity tonnes	Av. Payload 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**

139. The average load factors assumed for different vehicle types used to calculate the average payloads in Table 21 are summarised in Table 22, on the basis of DfT statistics from a survey of company owned vans.

Table 22: 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[30]

140. Emission factors for CH_4 and N_2O have been updated for all van classes in the 2012 GHG Conversion Factors. These are based on the emission factors from the UK GHG Inventory. N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for diesel vans.

141. Emission factors per tonne km (Annex 7 Table 7c of the 2012 GHG Conversion Factors) are calculated from the average load factors for the different weight classes in combination with the average freight capacities of the different vans in Table 21 and the earlier emission factors per vehicle-km in Annex 6 Table 6i and Annex 7 Table 7b of the 2012 GHG Conversion Factors.

Direct Emissions from Rail Freight

142. Data from Table 9.1 of the Office of the Rail Regulator's National Rail Trends Yearbook for 2010-11 (ORR, 2011)[31] has been used to update the rail freight emission factors for the 2012 GHG Conversion Factors. This factor is presented in Annex 7 Table 7f of the 2012 GHG Conversion Factors. There have been no further updates to the methodology in the 2012 update.

143. 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 93% of the total for 2010-11 (ORR, 2011).

144. 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).

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

146. 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.

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[30] 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*

[31] Available from the ORR's website at: *http://www.rail-reg.gov.uk/server/show/nav.2026*

Direct Emissions from RoPax Ferry Freight

147. 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 2012 GHG Conversion Factors.

148. 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.

149. 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 23.

Table 23: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[32]
Average weight of passenger + luggage, total	0.100	MCA, 2007[32]
Average Freight Unit*, total	22.173	BFF, 2007[33]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[34]

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

150. 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 Annex 7 Table 7g of the 2012 GHG Conversion Factors.

151. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2010, proportional to the CO_2 emissions.

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

[33] 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.

[34] 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

Direct Emissions from Other Marine Freight Transport

152. 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 2012 update.

153. 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)[35] report on GHG emissions from ships. The figures in Annex 7 Table 7g of the 2012 GHG Conversion Factors represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.

154. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2010, proportional to the CO_2 emissions.

Indirect Emissions

Vans, HGVs, Ferries and Ships

155. Indirect emission factors (EFs) for vans, HGVs, ferries and ships include only emissions resulting from the fuel lifecycle (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

156. 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 (2011)[36].

[35] "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*

[36] Available from the ORR's website at: *http://www.rail-reg.gov.uk/server/show/nav.2026*

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

Summary of changes since the previous update

157. There have been no methodological updates to the aviation emission factors methodology. Changes for the direct emission factors in the 2012 GHG Conversion Factors are therefore limited to updates to the core datasets.

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

158. There have been no changes in the methodology used to derive the passenger air transport emission factors for the 2012 GHG Conversion Factors.

159. The 2012 update of the 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)[37]. A full summary of the expanded representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 24. 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 Civil Aviation Authority (CAA, 2011)[38] statistics for UK registered airlines for the year 2010 (the most recent complete dataset available at the time of calculation);
    c. Average load factor for short-haul flights is the average for all European international flights calculated from CAA statistics for the selected aircraft;
    d. Average load factor for long-haul flights is the average for all non-European international flights calculated from CAA statistics for the selected aircraft;
    e. Freight transported on passenger services has also been taken into account (with the approach taken summarised in the following section). Accounting for freight makes a significant difference to long-haul factors;
    f. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

[37] EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (2006), available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf

[38] CAA, 2011; 2010 Annual Airline Statistics, available at: http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&sglid=1&fld=2010Annual

Table 24: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2012

	Average No. Seats	Average Load Factor	Proportion of passenger km
Domestic Flights			
Boeing 737-400	147	57.1%	11%
Boeing 737-700	146	78.1%	2%
Airbus A319/A320	158	71.6%	62%
BAE Jetstream 41	29	53.3%	5%
BAE 146	76	43.7%	0%
Dash 8 Q400	76	57.6%	20%
Total	***134***	***66.4%***	***100%***
Short-haul Flights			
Boeing 737-400	147	79.2%	9%
Boeing 737-800	189	86.1%	6%
Airbus A319/A320	158	82.4%	67%
Boeing 757	229	88.2%	18%
Total	***172***	***83.4%***	***100%***
Long-haul Flights			
Boeing 747-400	337	82.3%	42%
Boeing 767	243	84.4%	13%
Boeing 777	242	77.2%	23%
Airbus A330	318	90.7%	7%
Airbus A340	293	81.6%	15%
Total	***295***	***81.9%***	***100%***

Notes: Figures have been calculated from 2010 CAA statistics for UK registered airlines for the different aircraft types.

Taking Account of Freight

160. 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.

161. 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 25:

   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 25: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2012 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%	165.5	99.8%	165.1	99.8%	165.1
Short-haul flights	100.0%	94.9	99.4%	94.3	99.4%	94.3
Long-haul flights	100.0%	122.5	71.1%	87.1	88.1%	107.9

162. 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[39] 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 25.

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

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

services. It therefore seems preferable to treat freight on an equivalent basis by utilising freight weighting **Option 2**.

164. **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

165. 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)[40]. This information is combined with data from the Civil Aviation Authority (CAA, 2011) on average aircraft seating capacity, loading factors, and annual passenger-km and aircraft-km for 2010 (the most recent complete dataset available at the time of calculation). 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.

166. 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 an uplift of 10% is included in the emission factors in all of the presented tables, based on provisional evidence as no further evidence has since emerged.

167. 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.

168. 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.

169. The revised average emission factors for aviation are presented in Table 26. The figures in Table 26 include the uplift of 10% to correct underestimation of emissions by the CORINAIR methodology (discussed

[40] 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*

above) and DO NOT include the 9% uplift for Great Circle distance, which needs to be applied separately (and is discussed separately later).

Table 26: Average CO_2 emission factors for passenger flights for 2012 GHG Conversion Factors

Mode	Factors for 2012	
	Load Factor%	gCO_2/pkm
Domestic flights	66.4%	165.1
Short-haul flights	83.4%	94.3
Long-haul flights	81.9%	107.9

Seating Class Factors

170. The efficiency of aviation per passenger km is influenced not only by 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.

171. 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[41] 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 27. Information on the seating configurations including seating numbers, pitch, width and seating plans were obtained either directly from the airline websites or from specialist websites that had already collated such information for most of the major airlines (e.g. SeatGuru[42], UK-AIR.NET[43], FlightComparison[44] and SeatMaestro[45]).

[41] 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.

[42] See: http://www.seatguru.com/

[43] See: http://www.uk-air.net/seatplan.htm

[44] *See: http://www.flightcomparison.co.uk/flightcomparison/home/legroom.aspx*

[45] *See: http://www.seatmaestro.com/airlines.html*

172. 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[46] the space taken up by the basic economy seating. Table 27 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 27: Seating class based CO_2 emission factors for passenger flights for 2012 GHG Conversion Factors

Flight type	Size	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**66.4%**	**165.1**	**1.00**	**100%**	**100%**
Short-haul	**Average**	**83.4%**	**94.3**	**1.05**	**100%**	**100%**
	Economy class	83.4%	89.9	1.00	95%	90%
	First/Business class	83.4%	134.8	1.50	143%	10%
Long-haul	**Average**	**81.9%**	**107.9**	**1.37**	**100%**	**100%**
	Economy class	81.9%	78.8	1.00	73%	80%
	Economy+ class	81.9%	126.0	1.60	117%	5%
	Business class	81.9%	228.4	2.90	212%	10%
	First class	81.9%	315.0	4.00	292%	5%

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

173. 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.

174. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2011). These data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts approximately 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.

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

Emission Factors for Dedicated Air Cargo Services

176. 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

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

update and have been used for subsequent GHG Conversion Factors, including the 2012 update – presented in Table 28. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied to the CORINAIR based factors.

Table 28: Revised average CO_2 emission factors for dedicated cargo flights for 2012 GHG Conversion Factors

Mode	Revised factors for 2012	
	Load Factor%	$kgCO_2$ /tkm
Domestic flights	49.1%	2.03
Short-haul flights	65.4%	1.23
Long-haul flights	69.6%	0.70

177. 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)[47]. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 29. 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.

Table 29: Assumptions used in the calculation of average CO_2 emission factors for dedicated cargo flights for the 2012 GHG Conversion Factors

	Average Cargo Capacity, tonnes	Average Load Factor	Proportion of tonne km
Domestic Flights			
Boeing 737-300	16.0	50%	63.3%
Boeing 757-200	24.3	69%	6.4%
BAE ATP	8.0	45%	11.3%
Lockheed L188	12.0	36%	3.2%
BAE 748	6.3	20%	0.0%
BAE 146-200/QT	11.8	42%	15.9%
Total	***14.8***	***49%***	***100.0%***
Short-haul Flights			
Boeing 737-300	16.0	50%	0.0%
Boeing 757-200	24.3	68%	91.1%
BAE ATP	8.0	40%	1.5%
Lockheed L188	12.0	44%	0.5%
Boeing 747-200F	103.0	39%	6.9%
Total	***29.5***	***65%***	***100.0%***

[47] 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

	Average Cargo Capacity, tonnes	Average Load Factor	Proportion of tonne km
Long-haul Flights			
Boeing 747-400F	112.7	73%	64.2%
Boeing 757-200	25.8	63%	35.8%
Total	***81.6***	***70%***	***100.0%***

Notes: Figures have been calculated from 2010 CAA statistics for UK registered airlines for different aircraft.

Emission Factors for Freight on Passenger Services

178. 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 30 with the two different allocation options for long-haul services.

Table 30: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2012 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	4.1%	95.9%	0.2%	2.04	0.2%	2.04
Short-haul flights	20.9%	79.1%	0.6%	1.23	0.6%	1.23
Long-haul flights	71.4%	28.6%	28.9%	1.48	11.9%	0.63

179. It is useful to compare the emission factors calculated for freight carried on passenger services (in Table 30) with the equivalent factors for freight carried on dedicated cargo services (in Table 28). 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 30 is more than twice the comparable figure given in Table 28 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.

180. **Option 2** was selected as the preferred methodology for freight allocation for the 2008 update. The same methodology has been applied in

subsequent GHG Conversion Factors and is included in all of the presented emission factors.

Average Emission Factors for All Air Freight Services

181. The following Table 31 presents the final average air freight emission factors for all air freight for the 2012 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 31: Final average CO_2 emission factors for all air freight for 2012 GHG Conversion Factors

	% Total Air Freight tkm		All Air Freight
Mode	**Passenger Services**	**Cargo Services**	**kgCO_2/tkm**
Domestic flights	4.1%	95.9%	2.04
Short-haul flights	20.9%	79.1%	1.23
Long-haul flights	71.4%	28.6%	0.63

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

182. 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 2010 (see Table 32). The resulting air transport emission factors for the 2012 GHG Conversion Factors are presented in Table 33 for passengers and Table 34 for freight.

Table 32: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2010

2010	**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	1.77	98.96%	0.00	0.06%	0.02	0.97%
Aircraft - international	31.52	99.02%	0.00	0.01%	0.31	0.97%

Emissions of N_2O

183. Similar 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 2010 (see Table 32). The resulting air transport emission factors for the 2012 GHG Conversion Factors are presented in Table 33 for passengers and Table 34 for freight.

Table 33: Final average CO_2, CH_4 and N_2O emission factors for all air passenger transport for 2012 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**	165.1	0.10	1.61	166.9
Short-haul flights	**Average**	94.3	0.01	0.93	95.2
	Economy	89.9	0.01	0.88	90.7
	First/Business	134.8	0.01	1.33	136.1
Long-haul flights	**Average**	107.9	0.01	1.06	109.0
	Economy	78.8	0.00	0.78	79.5
	Economy+	126.0	0.01	1.24	127.3
	Business	228.4	0.01	2.25	230.7
	First	315.0	0.02	3.10	318.2

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

Table 34: Final average CO_2, CH_4 and N_2O emission factors for air freight transport for 2012 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	2.32	0.00	0.02	2.35
Short-haul flights	1.22	0.00	0.01	1.23
Long-haul flights	0.60	0.00	0.01	0.61
Dedicated Cargo				
Domestic flights	2.03	0.00	0.02	2.05
Short-haul flights	1.23	0.00	0.01	1.25
Long-haul flights	0.70	0.00	0.01	0.71
All Air Freight				
Domestic flights	2.04	0.00	0.02	2.06
Short-haul flights	1.23	0.00	0.01	1.24
Long-haul flights	0.63	0.00	0.01	0.64

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

Air Transport Indirect Emission Factors

184. Indirect emissions factors (EFs) for air passenger and air freight services include only emissions resulting from the fuel lifecycle (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 Flight Distances

185. 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.

186. A 9% uplift factor is used 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.

187. 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

188. The emission factors provided in the 2012 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.

189. 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.

190. 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.

191. 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 35 below[48]. If used, this factor would be applied to the emissions factors set out here.

Table 35: Impacts of radiative forcing according to R. Sausen et al. (2005)

		RF [mW/m^2]							
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 the previous update

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

193. In 2011, DECC funded a project to rebuild the model, to better make use of available data. The project, carried out by ICF, included extensive literature searches and stakeholder consultation to decide on the best parameters to use in the UK's model. Emissions are calculated based on
- The amount of HFC refrigerant filled into new units
- The amount of HFC which leaks during manufacture of new units
- The amount of HFC which leaks annually
- The lifetime of the units
- The amount of HFC which leaks at disposal

194. Each of these parameters can differ for specific types of unit (e.g. mobile air conditioning in cars, domestic refrigerators, industrial cold stores). The parameters are also not static in time – an older unit is likely to leak more, on an annual basis, than a newer unit. The term "HFCs" relates to a number of species, and refrigerants are usually a mixture, or blend, of various HFCs (and sometimes other substances too). To further complicate the calculations, the mix of refrigerant blends in use in a certain sector may also change in time.

195. As part of the project, new data were gathered to build a "bottom up" picture of the refrigeration sector in the UK, for example supermarket floor

[48] 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*

space to estimate the total refrigerant needs for that sector, or the total number of standalone air conditioning chillers in use in the UK. From these data, and an estimate of the typical amount of refrigerant used in each equipment type, it was possible to estimate the total "bank" of refrigerant in each sector, and using growth data it was possible to project and back cast data for new units for all years in the time series. This method replaced the old model, which was based on a "top down" estimate of total refrigerant in use, broken down by equipment type.

196. Leakage rates and typical equipment lifetimes were estimated through an initial literature search, and refined through consultation with stakeholders. The refrigerant blends used were estimated based on consultation with stakeholders, and sense checked against available sales data for the whole sector. For more information, the full report is available from: *http://www.decc.gov.uk/assets/decc/11/cutting-emissions/3844-greenhouse-gas-inventory-improvement-project-deve.pdf*

General Methodology

197. 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. A simple Screening Method has been provided in Annex 8 of 2012 GHG Conversion Factors. This should help organisations to estimate emissions from refrigeration and air conditioning based on the type of equipment used and emission factors. The methodology for this method is based upon that outlined in US EPA (2008)[49].

198. The Screening Method approach requires relatively little 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 2012 GHG Conversion Factors.

199. The emission factors used for the calculations (manufacturing, lifetime emissions, and recovery efficiency at disposal) are predominantly sourced from the 2010 UK GHG inventory. The emission factors are presented in Table 36 below.

[49] 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*)

Table 36: 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	-	0%	80%	65%
Small Hermetic Stand-Alone Refrigeration Units	-	2%	80%	60%
Condensing Units	2.0%	10%	80%	85%
Centralised Supermarket Refrigeration Systems	2.0%	18%	100%	92%
Industrial Systems	1.0%	8%	100%	85%
Small Stationary Air Conditioning	2.0%	3%	80%	70%
Medium Stationary Air Conditioning	1.0%	6%	80%	70%
Large Stationary Air Conditioning (Chillers)	0.5%	3%	80%	80%
Heat Pumps	2.0%	6%	80%	65%
Land Transport Refrigeration	-	15%	50%	80%
Marine Transport Refrigeration	0.5%	40%	50%	70%
Light-Duty Mobile Air Conditioning	-	10%	50%	70%
Other Mobile Air Conditioning	0.5%	10%	50%	70%

Source:
(1) UK Greenhouse Gas Inventory for year 2010 (AEA, 2012)
(2) US EPA (2008)
* Unweighted average of the figures for hermetically sealed units and for small distributed systems.

IX. Bioenergy and Water (DCF Annex 9)

Summary of changes since the previous update

200. There have been no methodological updates in Annex 9 of the GHG Conversion Factors, however the emission factors for waste previously presented in Annex 9 have been moved to Annex 14 – see Section XII for more details. Consequently Annex 9 has been renamed since the previous update (2011), to avoid potential confusion and for better alignment with its reduced contents.

201. All other factors have been updated with more recent data in the latest 2012 GHG Conversion Factors.

General Methodology

202. Annex 9 of the 2012 GHG Conversion Factors provides a number of additional tables with other UK emission factors, including those for water supply and treatment (Table 9a), biofuels (Table 9b), and for biomass and biogas (Table 9c).

203. 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.

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

Water

205. The emission factors for water supply and treatment in Annex 9 Table 9a of the 2012 GHG Conversion Factors have been sourced from Water UK (2008, 2009, 2010, 2011) and are based on submissions by UK water suppliers. Water UK represents all UK water and wastewater service suppliers at national and European level.

206. Water UK, 2011 gives total GHG emissions from water supply, waste water treatment, offices and transport. In the 2012 update of the GHG Conversion Factors, these emissions are split between Water supply and Water treatment using the same proportional split from previous years.

Biofuels

207. The emission factors for biofuels were based on UK average factors from the Quarterly Report (2011)[50] on the Renewable Transport Fuel Obligation (RTFO). These average factors are presented in Table 37.

208. The indirect/fuel lifecycle 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 37: Fuel lifecycle 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	33.654	0.025	0.503	34.182	75.300
Bioethanol	38.636	0.094	0.172	38.903	71.600
Biomethane	27.000	0.075	0.031	27.106	55.408

Notes:
(1) Based on UK averages from the RTFO Quarterly Report (2011) from DfT
(2) Based on corresponding emission factors for diesel, petrol or CNG.

[50] These cover the period from April 2010 - April 2011, published August 2011 and were the most recent figures available at the time of production of the 2012GHG Conversion Factors. The report is available from the DfT website at: *http://www.dft.gov.uk/topics/sustainable/biofuels/rtfo/*

(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 (2012)

209. 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. available from DfT's website at: *http://www2.dft.gov.uk/pgr/statistics/datatablespublications/biofuels/*

210. In addition to the direct and indirect emission factors provided in Table 37, emission factors for the out of scope CO_2 emissions have also been provided in the 2012 GHG Conversion Factors (see table and the table footnote), based on data sourced from the Biomass Energy Centre (BEC, 2012)[51].

Other biomass and biogas

211. 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 Annex 9 Table 9c of the 2012 GHG Conversion Factors.

212. The emission factors for wood pellets are based on the factor provided in SAP2009[52]. SAP is the Government's Standard Assessment Procedure for Energy Rating of Dwellings. Emission factors for wood logs and wood chips have also been based on this dataset.

213. 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, 2012).

214. 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 2012 GHG Conversion Factors (see Annex 9 Table 9c and the table footnote), also based on data from sourced from BEC (2012).

[51] BEC (2012). BEC is owned and managed by the UK Forestry Commission, via Forest Research, its research agency. Fuel property data on a range of other wood and other heating fuels is available at: *http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,20041&_dad=portal&_schema=PORTAL*, and *http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL*

[52] 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*

X. Overseas Electricity Emission Factors (DCF Annex 10)

Summary of changes since the previous update

215. Overseas electricity emission factors have been updated using 2009 data (the most recent data available at the time of calculation) from the IEA (2011).

Direct Emissions from Overseas Electricity Generation

216. 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.

217. The dataset on electricity and heat emission factors from the IEA provided mainly from the IEA website [53] 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.

218. The 2012 Conversion Factors have been updated using 2005 – 2009 country energy balances available at the IEA website[54].

219. Data on the proportion of electricity and heat[55] (for 2005 – 2009) is used to estimate the weighted net losses in the distribution of electricity and heat for different countries.

220. An example of the format for the Energy Balances data source from the IEA is provided in Table 38 for the UK (columns for other forms of energy have been removed). These data are for 2008. The percentage distribution losses for electricity and heat are calculated from the '*Distribution Losses*' and 'total Fuel Consumption' (*TFC*) figures from the Energy Balance tables.

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[53] Emission factor data is from the International Energy Agency (IEA) Data Services, 2011 for "CO_2 Emissions per kWh from electricity and heat generation" , from the IEA publication "*CO_2 Emissions from Fuel Combustion - 2011 Highlights*", within an Excel file at: *http://www.iea.org/CO2highlights/CO2highlights.xls*

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

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

Table 38: 2008 Energy Balances for Electricity and Heat for United Kingdom

SUPPLY and CONSUMPTION	**Electricity, ktoe**	**Heat, ktoe**
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[56]
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.

221. An example of the format for the Electricity and Heat data source from the IEA is provided in Table 39 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).

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

Table 39: 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 [57]

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

222. The emission factors for overseas electricity in Annex 10 of the 2012 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

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

CONSUMED) = Emission Factor (Electricity/Heat GENERATED) + Emission Factor (Electricity/Heat LOSSES).

223. 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[58], though it should be noted that the figures supplied there do not include losses from transmission and distribution of heat and electricity.

Indirect Emissions from Overseas Electricity Generation

224. 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 lifecycle emissions as included in Annex 1). The average fuel lifecycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel/primary energy used in electricity generation.

225. 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 are estimated as being roughly a similar ratio of the direct CO_2 emission factors as for the UK (which is 13.6%).

XI. Supply Chain (DCF Annex 13)

226. The emission factors for indirect emissions from the supply chain in Annex 13 of the 2012 GHG Conversion Factors are presented as emission factors per unit of spend on products, in kilogram of Carbon Dioxide equivalent per pound (kg CO_2e per £). Emission factors are provided for the years 2004 to 2009 (previously the factors were presented for one year of data only: 2006 in the 2010 update).

227. Since the first research was published in 2008, the model has been further refined by University of Leeds and Centre for Sustainable Accounting (CenSA). The data has been expanded, from solely covering CO_2 to covering all greenhouse gases. The factors for each of the six Kyoto gases (CO_2, CH_4, N_2O, HFC, PFC, SF_6) included in the overall calculation are available on request from Defra (*Enviro.Statistics@defra.gsi.gov.uk*). These factors have been calculated by CenSA as part of a research project funded by Defra.

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

228. The supply chain emission factors are expressed on a purchasers' price basis (i.e. the actual sales price including taxes on products and distribution margins). It may be advisable to take any price changes since 2009 into account when using the factors. It should also be noted that emissions in more recent years may have changed because of changes in the structure and emissions intensity of the supply chain.

229. A summary of the methodology used to calculate product indirect emission factors is provided in the following paragraphs. The Wiedmann and Barrett (2010)[59] report contains more detailed methodology.

230. Greenhouse gas (GHG) emissions can be allocated to a country in different ways: (1) territorial-based, (2) production-based, and (3) consumption-based emission reporting. Consumption-based emissions are currently not reported officially by any country.

231. Consumption-based emissions allocate emissions to the consumers in each country, usually based on final consumption as in the System of National Accounts (SNA). Consumption-based inventories can be thought of as:

Consumption emissions = production emissions - emissions from exports + emissions from imports + households direct emissions

232. Household direct emissions are from cars and heating, excluding electricity.

233. To derive the factors in this Annex 13 an input-output model of the world economy was used with two distinct regions: the UK and the Rest of World. By using the input-output model, the industrial emissions were attributed to final products bought by consumers. The result was an estimate of the total upstream emissions associated with the supply of a particular product group.

234. The data sources for the UK input-output table and national emission indicators remain consistent with the 2010 report.

235. ONS Input-Output Supply and Use Tables, 2011 Edition (www.ons.gov.uk/ons/taxonomy/index.html?nscl=Supply+and+Use+Tables)

236. The latest year of data available from National Accounts is 2009.

237. The monetary accounts are linked to information about the greenhouse gas emissions of different sectors of the economy.

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[59] Wiedmann, T. and Barrett, J. (2010) A Greenhouse Gas Footprint Analysis of UK Central Government, 1990-2008; Report to the UK Department for Environment, Food and Rural Affairs by the Centre for Sustainability Accounting. Defra, London, UK. *http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17486&FromSearch=Y&Publisher=1&SearchText=EV0464&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description*

238. ONS Environmental Accounts 2011 (www.ons.gov.uk/ons/rel/environmental/environmental-accounts/2011/index.html)

239. Emissions by economic sectors in the rest of the world trading region to calculate the impact of imported products are obtained from a combination of sources:
- Global Trade Analysis Project (GTAP) (www.gtap.agecon.purdue.edu)
- Climate Analysis Indicators Tool (CAIT) (cait.wri.org)
- The Carbon Dioxide Information Analysis Centre (CDIAC) (cdiac.ornl.gov)

240. A time series of environmentally-extended input–output tables for the UK were constructed for the period 1990 to 2009. Detailed trade data for the UK were compiled and reconciled with the UK input–output data; and economic and environmental accounts for an aggregated rest of world trade region was integrated in a UK-specific environmentally-extended multi-region input-output model. This was subsequently used to calculate a time series of national carbon and greenhouse gas footprints for the UK from 1990 to 2009 (see Table 40 for references). The basis for the time series of data is the input-output tables created by the University of York (SEI) and the University of Sydney in the course of a Defra-funded project on embedded emissions in 2008[60], as a result of which the tables were made publicly available. This covered consumer-based CO_2 emissions for 1992 to 2004 for the UK and three aggregated world trading regions.

241. Wiedmann and Barrett (2010) revised and extended the time series from 1990 to 2008 for the UK and a rest of world trade region to cover all greenhouse gases.

242. With the release of 2009 economic data in November 2011, 2009 was updated as part of the latest project.

Table 40: Model development stages

Years covered	Study
1990-2001	Wiedmann and Barrett (2010)
1992-2004	Wiedmann et al. (2008)
2005-2008	Wiedmann and Barrett (2010)
2009	2009 annual update

[60] Wiedmann, T., Wood, R., Lenzen, M., Minx, J., Guan, D. and Barrett, J. (2008) Development of an Embedded Carbon Emissions Indicator - Producing a Time Series of Input-Output Tables and Embedded Carbon Dioxide Emissions for the UK by Using a MRIO Data Optimisation System. Final Report to the Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney. EV02033, June 2008. Defra, London, UK. http://randd.defra.gov.uk.

http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=14606&FromSearch=Y&Publisher=1&SearchText=EV02033&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=16288#RelatedDocuments

243. The 2009 update uses the same method and data sources documented in Wiedmann and Barrett (2010), however, due to the change of classification in supply and use tables from SIC(03) with 123 sectors to SIC(07) with 110 sectors an additional step to re-allocate expenditure from 110 sectors to 123 was required.

244. The researchers decided to convert the new data from 110 sectors to the 123 sector classification previously used by ONS. This was because it allows for a comparison across the time series, and the latest published Analytical Input-Output Table for the year 2000 is in 123-sector format (SIC(03)). A conversion of recent time series data to SIC(07) (110 sectors) is planned once an Analytical Input-Output Table becomes available in this format.

245. The input-output table of 2008 was updated to 2009 using the RAS matrix balancing technique with 2009 sector totals as constraints. The method is outlined in Wiedmann and Barrett (2010) and was taken from Lenzen et al. (2009)[61] and Lenzen et al. (2010)[62].

246. The UK environmentally-extended input-output tables monitor monetary and physical (i.e. emission) flows between final consumers, industrial production sectors, non-industry inputs (e.g. wages and taxes), and capital between the UK and its trade with the rest of the world (ROW, represented as one aggregate region). In the form of supply and use tables as provided by ONS, they show the sales of UK and ROW industrial sectors to all other sectors (intermediate consumers) and to final consumers (households, government, exports and capital); both in the UK and ROW.

247. The environmental extension shows the distribution of emissions directly from industrial sectors to those embodied in a final product.

248. The output of the model is the supply chain emissions associated with each product consumed in the UK, in other words a consumer-based emissions account for the UK.

249. The estimated uncertainty in total net GHG emissions in the 2009 UK inventory was +/-17% as a 95% confidence interval (AEA and DECC, 2007). Estimates of greenhouse gas emissions will always have a degree of uncertainty associated with them. Inventory compilers can estimate emissions of CO_2 very accurately, but there is greater uncertainty associated with the emissions of the other five greenhouse gases. This feature is present in most greenhouse gas inventories and is not unique to the UK. Uncertainty is dominated by uncertainty in emissions from agricultural soils. See chapter 5 of AEA and DECC (2011)[63] for a more detailed summary.

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[61] Lenzen, M., Gallego, B. and Wood, R. (2009) Matrix balancing under conflicting information. Economic Systems Research, 21(1), 23-44. http://dx.doi.org/10.1080/09535310802688661.

[62] Lenzen, M., Kanemoto, K., Geschke, A., Moran, D., Muñoz, P., Ugon, J., Wood, R. and Yu, T. (2010) A global multi-region input-output time series at high country and sector detail. 18th International Input-Output Conference of the International Input-Output Association (IIOA), 20-25 June 2010. Sydney, Australia. http://www.isa.org.usyd.edu.au/io_2010/.

[63] AEA and DECC (2011) UK Greenhouse Gas Inventory: National Statistics User Guide, DECC Statistics, London.

XII. Material Consumption and Waste Disposal (DCF Annex 14)

250. This is a new Annex that contains information provided previously in Annex 9 Table 9d in the previous (2011) update.

251. Following publication of the 2011 update, separate guidance on accounting for indirect greenhouse gas emissions at a corporate level has been published. The GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard ('the Scope 3 Standard')[64] sets down rules on accounting for emissions associated with material consumption and waste management. The figures provided in the current updated have therefore changed significantly since the previous publication.

252. A key change is that whereas in previous iterations avoided emissions from energy recovery and sending materials for recycling have been shown, these avoided emissions are considered outside of the account of the company producing these wastes, and are instead exclusively within the scope of the company using these materials.

253. Whereas in previous editions negative carbon numbers have been presented to show savings from recycling and energy recovery, all figures presented in the current update are positive, showing only emissions from processing materials with no avoided impacts accounted for. This is line with the Scope 3 Standard.

254. The company sending waste for recycling may see a reduction in waste management emissions, but does not receive any benefit to its carbon account from recycling as the figures for waste disposal no longer include the potential benefits where primary resource extraction is replaced by recycled material. Under this accounting methodology, the organisation using recycled materials will see a reduction in their account where this use is in place of higher impact primary materials.

255. Whilst the factors are appropriate for accounting, they are therefore not appropriate for informing decision making on alternative waste management options (i.e. from a waste management perspective they do not indicate the lowest or highest impact option). DEFRA will provide separate figures appropriate for informing decision making on waste disposal.

256. In addition to these changes, emission factors for construction materials and wastes are also presented in Annex 14.

257. All figures expressed are kilograms of carbon dioxide equivalent (CO_2eq) per tonne of material. This includes the Kyoto protocol basket of

[64] http://www.ghgprotocol.org/standards/scope-3-standard

greenhouse gases. Please note that biogenic[65] CO_2 has also been excluded from these figures.

258. In Annex 14 the information for material consumption has been separated out from the emissions associated with waste disposal in order to allow separate reporting of these emission sources, in compliance with the Scope 3 Standard.

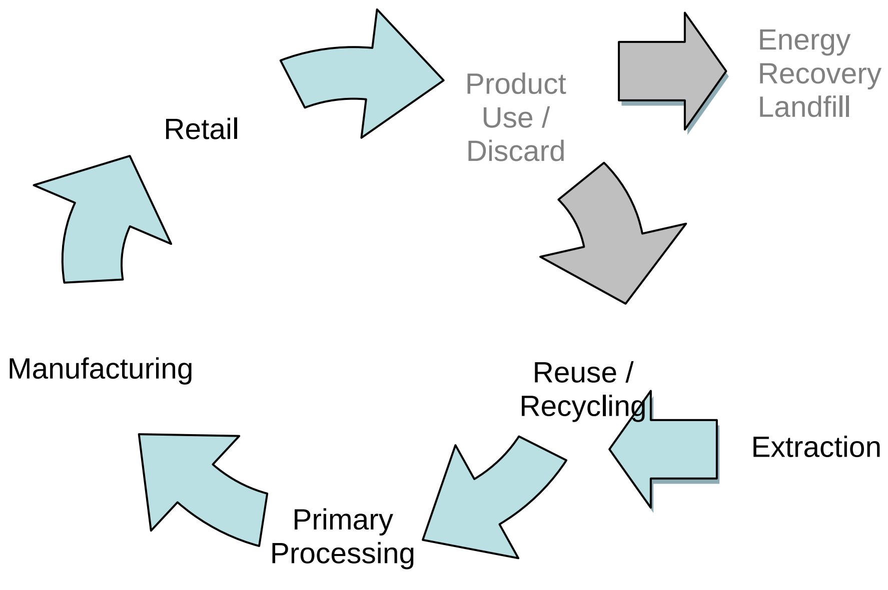
259. It is important that businesses quantify emissions associated with both material use and waste management in their Scope 3 accounting, to fully capture changes due to activities such as waste reduction.

260. The following subsections provide a summary of the methodology, key data sources and assumptions used to define the emission factors in Annex 14.

Material Consumption

261. Figure 2 shows the boundary of greenhouse gas emissions summarised in the material consumption table (Annex 14 Table 14a).

Figure 2: Boundary of material consumption data sets (Arrows represent transportation stages. Greyed items are excluded)



262. The factors presented for material consumption cover all greenhouse gas emissions from the point of raw material extraction through to the point at which a finished good is manufactured and provided for sale. Commercial enterprises may therefore use these figures to estimate the impact of goods they procure. Organisations involved in manufacture of goods using these materials should note that if they separately report emissions

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

associated with their energy use in forming products with these materials, there is potential for double counting. As many of the data sources used in preparing Annex 14 are confidential we are unable to publish a more detailed breakdown. However, the standard assumptions made are described below.

263. Emission factors are provided for both recycled and primary materials. To identify the appropriate carbon factor, an organisation should seek to identify the level of recycled content in materials and goods purchased. Under this accounting methodology, the organisation using recycled materials in place of primary materials receives the benefit of recycling in terms of reduced Scope 3 emissions.

264. These figures are estimates to be used in the absence of data specific to your goods and services. If you have more accurate information for your products, then please refer to the more accurate data for reporting your emissions

265. 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 the Appendix. 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.

266. Emission factors provided include emissions associated with product forming.

267. Table 42 identifies the transportation distances and vehicle types which have been assumed as part of the emission factors provided. 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 41: Distances and transportation types used in Annex 14 EF calculations

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Transport of raw materials to factory	112km	Average, all HGVs	Department for Transport (2009)[66] 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)[67] IGD (2008)[68]

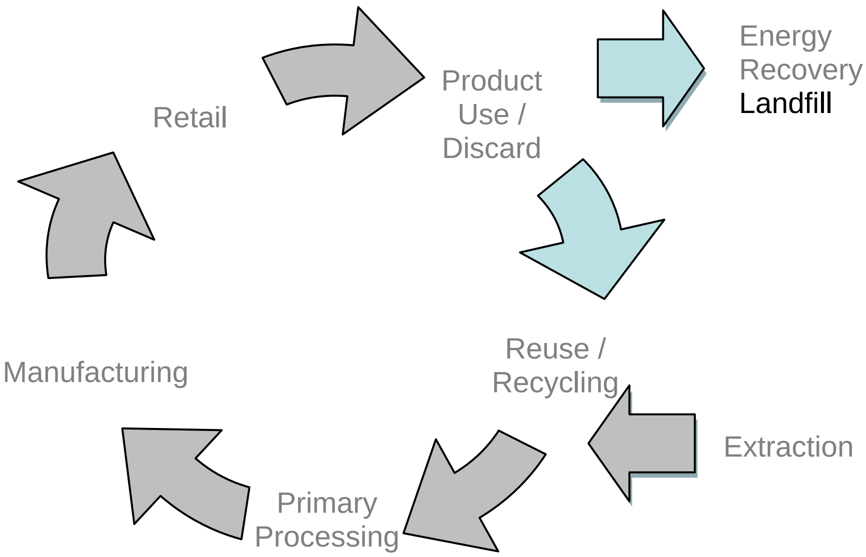
268. Transport of goods by consumers is excluded from the factors presented, as is use of the product. The transportation annexes and Greenhouse Gas Protocol[69] guidelines on vehicle emissions have been used for most vehicle emission factors.

269. The final material consumption GHG emission factors for the 2012 update is provided in Annex 14 Table 14a of the 2012 GHG Conversion Factors.

Waste Disposal

270. Figure 3 shows the boundary of greenhouse gas emissions summarised in the waste disposal table (Annex 14 Table 14b).

Figure 3: Boundary of waste disposal data sets (Arrows represent transportation stages. Greyed items are excluded)



[66] 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

[67] 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

[68] 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

[69] The Greenhouse Gas Protocol (2010). Available at: www.ghgprotocol.org/downloads/calcs/CO_2-mobile.pdf

271. Whereas the 2011 factors covered the whole life cycle of products and materials, the factors presented in the 2012 guidelines have taken account of the changes in published accounting guidelines. A key change is that, as defined under the Scope 3 standard, emissions associated with recycling and energy recovery are attributed to the organisation which uses the recycled material or which uses the waste to generate energy. The emissions attributed to the company which generates the waste cover only the collection of waste from their site. This does not mean that these emissions are zero, or are not important; it simply means that, in accounting terms, these emissions are for another organisation to report.

272. The final waste disposal GHG emission factors for the 2012 update are provided in Annex 14 Table 14b of the 2012 GHG Conversion Factors.

273. The final emissions factor data summarised in Annex 14 has been revised to be in line with company reporting requirements in the Scope 3 Standard. Under this standard, in order to avoid double-counting, the emissions associated with recycling are attributed to the user of the recycled materials, and the same attribution approach has also been applied to the emissions from energy generation from waste. Only transportation and minimal preparation emissions are attributed to the entity disposing of the waste. DEFRA will separately provide information on the full GHG impact of different waste disposal options.

274. Landfill emissions remain within the accounting scope of the organisation producing waste materials. Factors for landfill are shown. As noted above, these factors now exclude avoided emissions achieved through use of landfill gas to generate energy.

275. Figures for Refuse Collection Vehicles have been taken from the Environment Agency's Waste and Resource Assessment Tool for the Environment (WRATE)[70].

276. 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 in Table 42.

Table 42: Distances used in calculation of Annex 14

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		
Recyclate	50km by Road	Average, all HGVs	WRATE (2005)
Inert recycling	10km by Road		WRATE (2005)

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

277. Road vehicles are volume limited rather than weight limited. For all HGVs, an average loading factor (including return journeys) of 56% is used based on DEFRA (2009)[71]. Waste vehicles leave a depot empty and return fully laden. A 50% loading assumption reflects the change in load over a collection round which could be expected.

278. 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[72]. 10% of uncaptured methane is assumed to be oxidised at the cap. Key data sources for waste disposal emissions are identified in the Appendix.

279. Emissions from the landfill of different materials are calculated using WRATE and the LandGem model[73]. Methane generation rate constants have been taken from IPCC[74].

[71] DEFRA (2009). Greenhouse Gas Conversion Factors. Available at: *http://www.defra.gov.uk/environment/business/reporting/conversion-factors.htm*

[72] 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*

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

[74] 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/

APPENDIX:
Additional Methodological Information on the Material Consumption and Waste Disposal Factors in Annex 14

1.0 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 Conversion Factors in Annex 14. 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.

1.1 Data Quality Requirements

Data used in this methodology should meet the data quality indicators described in Table 1.1 below.

Table 1.1: 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	
Representative-ness	The data should represent UK conditions	This is determined by reference to the above data quality indicators

Data Quality Indicator	Requirement	Comments
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.

1.2 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 XII. Data on waste management options has been modelled using SimaPro[75] and WRATE.

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

1.3 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 1.1 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

[75] SimaPro (2010). Life Cycle Assessment Software. Available at: http://www.pre.nl/simapro/

each dataset is explained. The most common data quality issues encountered concerned data age and availability.

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[76]. Data used in this report for material consumption 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[77] 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 material consumption 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.

Steel data

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

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 material consumption 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.

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[76] 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*

[77] WRAP (2009) Wood Waste Market in the UK WRAP; Banbury. Available at: *http://www.wrap.org.uk/recycling_industry/publications/wood_waste_market.html*

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 UK impacts, and so the results should be viewed with caution.

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 industrial waste streams, furniture and paint.

2.0 Data Sources

Material	Reference	
	Material Consumption	**Waste Disposal**
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	PE International (2009) *Life Cycle Assessment of Container Glass in Europe* FEVE; Brussels	
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 for Life Cycle Inventories	*Ecoinvent v2.0* (2007) Swiss Centre for Life Cycle Inventories
Books	Estimate based on paper	

Material	Reference	
	Material Consumption	**Waste Disposal**
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*[78]) 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. WRAP (2011) The Water and Carbon Footprint of UK Household Food Waste	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 impacts) Kranert, M. & Gottschall (2007) *Grünabfälle – besser kompostieren oder energetisch verwerten?* Eddie (information on peat)
Garden Waste	-	

[78] http://www.recyclemetals.org/about_metal_recycling

Material	Reference	
	Material Consumption	**Waste Disposal**
		DEFRA (unpublished) (information on composting impacts)
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
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)	Farrant (2008) *Environmental Benefit from Reusing Clothes*, WRATE (2005)

Material	**Reference**	
	Material Consumption	**Waste Disposal**
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 WEEE – Mixed WEEE – Small	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	
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	
Aggregates	WRAP (2008) Life Cycle Assessment of Aggregates	
Concrete	Hammond, G.P. and Jones (2008) Embodied Energy and Carbon in Construction Materials Prc Instn Civil Eng, WRAP (2008) Life Cycle Assessment of Aggregates	
Bricks	Environment Agency (2011) Carbon Calculator USEPA (2003) Background Document for Life-Cycle Greenhouse Gas Emission Factors for Clay Brick Reuse and Concrete Recycling Christopher Koroneos, Aris Dompros, Environmental assessment of brick production in Greece, Building and Environment, Volume 42, Issue 5, May 2007, Pages 2114-2123	
Asphalt	Aggregain (2010) *CO_2 calculator*	
Asbestos	Swiss Centre for Life Cycle Inventories (2007) *Ecoinvent*	
Insulation	Hammond, G.P. and Jones (2008) *Embodied Energy and Carbon in Construction Materials* Prc Instn Civil Eng WRAP (2008) *Recycling of Mineral Wool Composite Panels Into New Raw Materials*	

3.0 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