Department of Energy & Climate Change

2015 Government GHG Conversion Factors for Company Reporting:

Methodology Paper for Emission Factors

Final Report

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1. General Introduction

1.1. 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.).

1.2. 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.

1.3. The 2015 Government Greenhouse Gas (GHG) Conversion Factors for Company Reporting[1] (hereafter the 2015 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 2015 GHG Conversion Factors. The new factors are presented at the end of each of the relevant following sections.

1.4. 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 fourth assessment report (GWP for CH_4 = 25, GWP for N_2O = 298), consistent with reporting under the Kyoto Protocol. It should be noted here that the fourth assessment report by the IPCC (AR4) is used for the GHG Conversion Factors as this is now the report which is accepted for use in national GHG reporting under the Kyoto Protocol. Although the IPCC have prepared newer versions since, the methods have not yet been officially accepted for use under the Kyoto Protocol. This is therefore also the basis upon which all emissions are calculated under the UK GHG inventory (GHGI), which is the basis of many of the conversion factors and with which this work should be consistent with. Please note that *previous updates (prior to 2015) have referred to GWPs from the Second Annual Assessment report. This is discussed in more detail later*

1.5. Note that publication of the GHGI for 2013, on which these conversion factors are based, has been delayed. However, published emissions statistics based on the GHGI for 2013 are available[2].

1.6. The 2015 GHG Conversion Factors for one year from the end of May 2015, and will continue to be reviewed and updated on an annual basis.

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[1] Previously known as the 'Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting'

[2] Available at: https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

1.7. In order to further improve the usefulness of the GHG Conversion Factors and the guidance and other information provided alongside them, Defra commissioned a piece of work to consult on the format and content of the GHG Conversion Factors in September 2012. This work has culminated in a revised set of reporting tables and guidance, which will be provided via an online tool[3]. In this new format a number of the previous 'Annexes' for the GHG Conversion Factors were moved instead to Defra's new guidance on company reporting[4], including former Annex 2, Annex 4, Annex 8 and Annex 13. In addition, in the new structure the remaining information previously provided (prior to its first application for the 2013 update) is distributed across a number of similar tables grouped for better consistency with the GHG Protocol Reporting categories.

1.8. 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 2015 GHG Conversion Factors. The report aims to expand and compliment the information already provided in the data tables themselves. However, it is not intended to be an exhaustively detailed explanation of every calculation performed (this is not practical/possible). Nor is it intended to provide guidance on the practicalities of reporting for organisations. 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.

1.9. Further information about the 2015 GHG Conversion Factors together with previous methodology papers is available from Defra's website at: https://www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-businesses and also from the main Conversion Factors website at http://www.ukconversionfactorscarbonsmart.co.uk/.

1.10. Before the 2016 factors are published, the conversion factors website will be moving to a gov.uk domain. The current http://www.ukconversionfactorscarbonsmart.co.uk/ website will redirect to the new gov.uk site. All of the information which is on the current site will still be accessible after this change.

Overview of changes since the previous update

1.11. Major changes and updates in terms of methodological approach from the 2014 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 2014 update):

a. *Revision to UK GHG Inventory methodology for methane (CH_4) and nitrous oxide (N_2O) factors:* All the fuel conversion factors for direct emissions presented in the 2015 update are based on the default emission factors used in the UK GHG Inventory (GHGI) for 2013 (managed by Ricardo-AEA). 2015 was the first year that UK GHG Inventory reported using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. This has resulted in the emission factors for methane (CH_4) and nitrous oxide (N_2O) being updated. This has caused large variance to the CH_4 and N_2O emission factors for fuels reported this year when compared to previous years. Despite very large variances in the emissions of CH_4 and N_2O when compared to previous years the overall carbon dioxide equivalents (CO_2e) have not changed significantly and therefore, the implications of this change are quite small. Exceptions

[3] Available at: http://www.ukconversionfactorscarbonsmart.co.uk

[4] Available at: https://www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-businesses

to this are the refrigerant factors (please see below) and many waste to landfill factors where more significant changes are found due to this methodology change.

b. *Update to the global warming potential (GWP) factors:* Values for the non-carbon dioxide (CO_2) greenhouse gases, CH_4 and N_2O, are presented as CO_2 equivalents (CO_2e) using Global Warming Potential (GWP) factors. In previous years these have been from the Intergovernmental Panel on Climate Change (IPCC)'s Second Assessment Report (AR2) (GWP for CH_4 = 21, GWP for N_2O = 310). However, they have now been taken from the IPCC Fourth Assessment Report (AR4) (GWP for CH_4 = 25, GWP for N_2O = 298) to remain consistent with UK GHG Inventory reporting under the Kyoto Protocol. Additionally, in past years the IPCC's AR2 was used for the Kyoto Protocol listed refrigerant gases. This year, however, these have also been updated to use the IPCC AR4 which is in line with how the emissions are calculated for UK GHG Inventory reporting under the Kyoto Protocol. The change in GWP factors will mean that CO_2 equivalents for CH_4 and N_2O emissions will be affected. However, in general, given the small change in the GWP factors, and the small impact of CH_4 and N_2O on total CO_2e, the overall implications of this are small. Exceptions to this are the refrigerant factors and many waste to landfill factors where more significant changes are found.

c. *Addition of conversion factor for shipping gas oil and fuel oil:* There are two new conversion factors for to cover the main two different types of shipping fuel with greater clarity – these are called 'Marine gas oil' and 'Marine fuel oil'. No additional shipping fuels have been added in to the 'Fuel Properties' section to allow for conversions of these new factors, as their fuel properties are essentially the same as the pre-existing 'Gas oil' and 'Fuel oil' values respectively.

d. *Revision to bioenergy conversion factors:* There have been two changes made to bioenergy conversion factors in the 2015 update to improve the accuracy of reporting (and in response to requests). First, the addition of two well to tank (WTT)-bioenergy conversion factors (Scope 3) for biodiesel sourced from used cooking oil (UCO) and tallow. Second, the addition of two corresponding 'outside of scopes' conversion factors for these fuels is the second amendment.

e. *Revision to the basis and coverage of refrigerant factors published:* There have been two changes made to refrigeration conversion factors in the 2015 update. First, there have been some additional refrigerants added to those previously listed. Also there have been changes to GWP factors, which are now all based on values from the IPCC's AR4 as explained in point b).

f. *Revision to methodology for flight conversion factors:* There have been two changes made to the conversion factors for flights to/from the UK in the 2015 update. First, the data sources and assumptions are now better aligned with those used in the current Department for Transport (DfT) aviation model. Second, DfT data on passenger cabin class split (%) by haul type (Domestic, Short-Haul and Long-Haul) has been used to improve/update our assumptions in this area.

g. *Addition of conversion factors for flights starting/ending entirely outside of the UK:* A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations. This is a relatively high level analysis and allows users to choose a different factor for air travel if flying between countries outside of the UK. All factors presented are for direct (non-stop) flights only. This analysis was only possible for passenger air travel however in the interests of consistency with the air freight travel, international freight factors have been included this year. These factors have been set equal to the current UK, long haul freight factors[5].

h. *Revision to structure of material use factors:* Two changes have been made to the 2015 material use factors to assist users in interpreting and understanding how to use these factors. It was decided to remove the values in ‘compost source’ (now set as 'N/A') for all factors. In 2014 and earlier these were given values, however it is now thought this was misleading as it is not possible for any of these materials to come from a compost source. Secondly, the sources “Organic: mixed food and garden waste” and "Organic: garden waste” have been changed to “Compost derived from garden and food waste” and “Compost derived from garden waste” respectively, for clarity. The source name of "Organic: food and drink waste" has also been changed to simply "Food and Drink". In doing this (as mentioned above) the "Compost source" column has been removed from the "Refuse" table as the change in material source means these factors can now be listed as emissions from "Primary material production" only.

1.12. Additional information is also provided in Appendix 3 of this report on major changes to the values of specific emission factors (i.e. +-10% since the 2014 GHG Conversion Factors). Some of these changes are due to the methodological adjustments outlined above and in the later sections of this methodology paper, whist others are due to changes in the underlying source datasets.

1.13. Detailed guidance on how the emission factors provided should be used is contained in the introduction to the 2015 GHG Conversion Factors 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 table footnotes.

Structure of this methodology paper

1.14. The following Sections 1 to 12 provide methodological summary for the data tables contained in the Government GHG Conversion Factors for Company Reporting (GCF). For easier identification/navigation of this document, the major Section headings contain references grouped in a consistent way to the new GHG Conversion Factors format.

Area covered	Location in this document
Fuel Emission Factors	see Section 2
UK Electricity, Heat and Steam Factors	see Section 3
Refrigerant and Process Factors	see Section 4
Passenger Land Transport Factors	see Sections 5
Freight Land Transport Factors	see Sections 6
Sea Transport Factors	see Section 7

[5] Please note - The international factors included are an average of short and long-haul flights which explains the difference between the UK factors and the international ones.

Area covered	Location in this document
Air Transport Factors	see Section 8
Bioenergy and Water Factors	see Section 9
Overseas Electricity Factors	see Section 10
Material Use and Waste Disposal	see Section 11
Fuel Properties	see Section 12
Unit Conversions	N/A *

*This report does not provide any methodological description for unit conversions, since these are for standard units, provided as simple supplementary information or guidance.

Table 1: Summary Structure of this Methodology Paper

2. Fuel Emission Factors

Summary of changes since the previous update

2.1. The only methodological change since the previous update is that additional emission factors are now provided for two different types of shipping fuel – these are called 'Marine gas oil' and 'Marine fuel oil'. Hover over each fuel within the "Fuels" tab to see their uses. No additional shipping fuels have been added in to the 'Fuel Properties' section to allow for conversions of these new factors, as their fuel properties are essentially the same as the pre-existing 'Gas oil' and 'Fuel oil' values respectively.

Direct Emissions

2.2. All the fuel conversion factors for direct emissions presented in the 2015 GHG Conversion Factors are based on the default emission factors used in the UK GHG Inventory (GHGI) for 2013 (managed by Ricardo-AEA). This has not been published yet, but previous year's versions are available.[6].

2.3. The CO_2 emissions factors are based on 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 for Fuels the 2015 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.

2.4. 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) 2014[7].

2.5. Four tables are presented in the 2015 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[8]).

2.6. 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

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[6] UK Greenhouse Gas Inventory for 2013 (Ricardo-AEA), available at: http://naei.defra.gov.uk

[7] Available at: https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes

[8] 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).

figures quoted in kWh by suppliers in the UK are generally calculated (from the volume of gas used) on a Gross CV basis[9]. Therefore the emission factor for energy consumption on a 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/WTT Emissions from Fuels

2.7. These fuel lifecycle emissions (also sometimes referred to as 'Well-To-Tank' or simply WTT emissions usually 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.

2.8. In the absence of specific UK-based set of fuel lifecycle emissions factors information from JEC Well-To-Wheels (2013) were used as a basis for the factors in the 2015 GHG Conversion Factors[10]. 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 2013 GHG Conversion Factors, and the values for a number of fuels changed in the new report version (e.g. petrol and diesel fuels), which was used first in the 2013 update and has been used again as the basis for the 2015 GHG Conversion Factors. The coverage of the JEC WTW (2013) 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

2.9. For fuels covered by the 2015 GHG Conversion Factors where no fuel lifecycle emission factor was available in JEC WTW (2013), these were estimated based on similar fuels, according to the assumptions in Table 3.

2.10. The final combined emission factors (in $kgCO_2e/GJ$, Net CV basis) are presented in Table 3. These include indirect/WTT 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 also provided in the 2015 GHG Conversion Factors alongside the emission factor data tables.

2.11. The methodology for calculating the indirect/WTT emission factors for natural gas and CNG was updated for the 2014 update to account for the increasing share of UK gas supplied via imports of LNG (which have a higher WTT emission factor than conventionally sourced natural gas) in recent years. Table 2 provides a summary of the information on UK imports of LNG and their significance compared to other sources of natural gas used in the UK grid, updated to include the most recent data used in the 2015 update. These figures have been used to calculate the revised figures for Natural Gas and CNG WTT emission factors provided in Table 3 below.

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

[10] "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4, July 2013. Report EUR 26028 EN – 2013. http://iet.jrc.ec.europa.eu/about-jec/

2.12. Emission factors are also calculated for diesel supplied at public and commercial refuelling stations, factoring in the WTT component due to biodiesel supplied in the UK as a proportion of the total supply of diesel and biodiesel (3.47% by unit volume, 2.88% by unit energy – see Table 4). These estimates have been made based on DECC's Quarterly Energy Statistics for Renewables[11].

2.13. 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 (=4.59% by unit volume, 3.03% by unit energy – see Table 4). These estimates have also been made based on DECC's Quarterly Energy Statistics for Renewables.

	LNG % of total natural gas imports (2)	**Net Imports as % total UK supply of natural gas (1)**	**LNG Imports as % total UK supply of natural gas**
2007	4.6%	20.8%	**1.41%**
2008	2.3%	25.8%	**0.82%**
2009	24.7%	31.1%	**10.97%**
2010	35.1%	39.2%	**18.64%**
2011	46.8%	41.8%	**29.92%**
2012	27.6%	47.1%	**17.28%**
2013	19.5%	50.1%	**12.07%**

Source: DUKES 2014, (1) Table 4.1 - Commodity balances and (2) Table 4.5 - Natural gas imports and exports.

Table 2: Imports of LNG into the UK as a share of imports and net total natural gas supply

Fuel	**Indirect/WTT EF ($kgCO_2e/GJ$, Net CV basis)**	**Source of Indirect/WTT Emission Factor**	**Assumptions**
Aviation Spirit	13.76	Estimate	Similar to petrol
Aviation Turbine Fuel [1]	14.93	Estimate	= Kerosene fuel, estimate based on average of petrol and diesel factors
Burning Oil[1]	14.93	Estimate	= Kerosene, as above
CNG (excl. LNG imports) [2]	8.70	JEC WTW (2011)[12]	CNG from natural gas EU mix
CNG	11.78	JEC WTW (2013)	Factors in UK % share LNG imports
Coal (domestic)[3]	14.72	JEC WTW (2013)	Emission factor for coal
Coal (electricity generation)[4]	14.72	JEC WTW (2013)	Emission factor for coal

[11] DECC's Renewable Energy Statistics, 2015 – Energy Trends, Quarterly tables – data used here released March 2015; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/415778/qep_mar_15.pdf

[12] The 2013 updated data included significant imports from Russia as well as LNG (at similar level to UK). Therefore previous (2011) value is more representative of UK situation when excluding LNG imports (and including no Russian imports).

Fuel	Indirect/WTT EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Coal (industrial)[5]	14.72	JEC WTW (2013)	Emission factor for coal
Coal (electricity generation – home imports)[6]	14.72	JEC WTW (2013)	Emission factor for coal
Coking Coal	14.72	Estimate	Assume same as factor for coal
Diesel	16.10	JEC WTW (2013)	
Fuel Oil [7]	14.93	Estimate	Assume same as factor for kerosene
Gas Oil [8]	16.10	Estimate	Assume same as factor for diesel
LPG	8.04	JEC WTW (2013)	
LNG [9]	21.05	JEC WTW (2013)	
Lubricants	9.54	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Marine fuel oil	14.93	Estimate	Assume same as factor for fuel oil
Marine gas oil	16.10	Estimate	Assume same as factor for gas oil
Naphtha	14.10	JEC WTW (2013)	
Natural Gas (excl. LNG imports)	5.66	JEC WTW (2013)	Natural gas EU mix
Natural Gas	7.66	JEC WTW (2013)	Factors in UK % share LNG imports8
Other Petroleum Gas	6.89	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Petrol	13.76	JEC WTW (2013)	
Petroleum Coke	11.92	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Recycled fuel oil	9.54	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Refinery Miscellaneous	8.78	Estimate	Based on LPG figure, scaled relative to direct emissions ratio

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) This emission factor should only be used for domestically coal supplied for electricity generation (UK power stations only). Coal supplied for domestic or industrial purposes have different emission factors.
(7) Fuel oil is used for stationary power generation. Also use this emission factor for similar marine fuel oils.
(8) 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.
(9) 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 3: Basis of the indirect/WTT emissions factors for different fuels

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	Conventional Fuel	per unit mass	per unit volume	per unit energy
Diesel/Biodiesel	954	26,512	3.15%	3.47%	2.88%
Petrol/Bioethanol	814	16,924	4.97%	4.59%	3.03%

Source: DECC's Renewable Energy Statistics, 2015 – Energy Trends, Quarterly tables – data used here released in March 2015; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/415778/qep_mar_15.pdf

Table 4: Liquid biofuels for transport consumption: 4th quarter 2013 – 3rd quarter 2014

3. UK Electricity, Heat and Steam Emission Factors

Summary of changes since the previous update

3.1. There have been no methodological changes and additions since the previous 2014 update.

3.2. From 2013 onwards the emission factors per unit of electricity consumed were no longer provided, since these were being previously misused. Equivalent emission factors can still be calculated separately by adding the corresponding figures for electricity generated and for transmission and distribution losses together.

3.3. 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

3.4. The electricity conversion factors given represent the average CO_2 emission from the UK national grid per kWh of electricity generated (Scope 2 of the GHG Protocol and separately for electricity transmission and distribution losses (Scope 3 of the GHG Protocol). 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 and from autogenerators (the latter added for the first time in the 2013 GHG Conversion Factors), 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.).

3.5. This factor changes from year to year as the fuel mix consumed in UK power stations (and autogenerators) 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, in previous years the factor presented was the 'Grid Rolling Average' of the grid conversion factor over the previous 5 years. However, from 2013 a decision was made to switch to the actual in-year (i.e. non-rolling average) emission factors, and only these have be provided since then, and should be used in all reporting from this point onwards. One of the key reasons for the change was to provide an emission factor that was as close as possible to the actual year of reporting as possible. More information on the significance of this was provided in the 2013 methodology paper. However, one of the results was that it will require a baseline/reference year adjustment for those companies reporting in years before this point. Further information on this is also provided within the 2013, 2014 and 2015 GHG Conversion Factors.

3.6. The UK electricity conversion factors provided in the 2015 GHG Conversion Factors are based on emissions from sector 1A1a (power stations) and 1A2f (autogenerators) in the

UK Greenhouse Gas Inventory (GHGI) for 2013 (Ricardo-AEA) according to the amount of CO_2, CH_4 and N_2O emitted per unit of electricity consumed (from DUKES 2014)[13].

3.7. The UK is a net importer of electricity from the interconnector with France, and a net exporter of electricity to Ireland according to DUKES (2014). For the 2015 GHG Conversion Factors net electricity imports were calculated from DUKES (2014) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2013).

3.8. The electricity emission factor for France (from the Overseas Electricity emissions factors tables) – 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.

3.9. The source data and calculated emissions factors are summarised in the following Table 5, Table 6 and Table 7. Time series source data and emission factors that were fixed/locked from the 2013 update onwards have been highlighted in light grey. The tables provide the data and emission factors against the relevant data year. Table 5 also provides a comparison of how the data year reads across to the GHG conversion factors update / reporting year to which the data and emission factors are applied, which is two years ahead of the data year. For example, the most recent emission factor for the 2015 GHG Conversion Factors is based on a data year of 2013. A full time series of data using the most recently available GHGI and DUKES datasets for all years is also provided in Appendix 2 of this report. This is provided for purposes **other than company reporting**, where a fully consistent data time series is desirable, e.g. for policy impact analysis.

Data Year	Applied to Reporting Year*	Electricity Generation (1) GWh	Total Grid Losses (2) %	UK electricity generation emissions (3), ktonne		
				CO_2	CH_4	N_2O
1990	1992	290,666	8.08%	204,614	2.671	5.409
1991	1993	293,743	8.27%	201,213	2.499	5.342
1992	1994	291,692	7.55%	189,327	2.426	5.024
1993	1995	294,935	7.17%	172,927	2.496	4.265
1994	1996	299,889	9.57%	168,551	2.658	4.061
1995	1997	310,333	9.07%	165,700	2.781	3.902
1996	1998	324,724	8.40%	164,875	2.812	3.612
1997	1999	324,412	7.79%	152,439	2.754	3.103

[13] DUKES (2014): http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Data Year	Applied to Reporting Year*	Electricity Generation (1) GWh	Total Grid Losses (2) %	UK electricity generation emissions (3), ktonne		
				CO_2	CH_4	N_2O
1998	2000	335,035	8.40%	157,171	2.978	3.199
1999	2001	340,218	8.25%	149,036	3.037	2.772
2000	2002	349,263	8.38%	160,927	3.254	3.108
2001	2003	358,185	8.56%	171,470	3.504	3.422
2002	2004	360,496	8.26%	166,751	3.490	3.223
2003	2005	370,639	8.47%	177,044	3.686	3.536
2004	2006	367,883	8.71%	175,963	3.654	3.414
2005	2007	370,977	7.25%	175,086	3.904	3.550
2006	2008	368,314	7.21%	184,517	4.003	3.893
2007	2009	365,252	7.34%	181,256	4.150	3.614
2008	2010	356,887	7.45%	176,418	4.444	3.380
2009	2011	343,418	7.87%	155,261	4.450	2.913
2010	2012	348,812	7.32%	160,385	4.647	3.028
2011	2013	330,128	7.88%	148,153	4.611	3.039
2012	2014	320,470	8.04%	161,903	5.258	3.934
2013	2015	308,955	7.63%	146,852	4.468	3.595

Notes:

(1) Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES (2013) / DUKES (2014) Table 5.5 Electricity fuel use, generation and supply for 1990-2013 / 2014 respectively. The total is consistent with UNFCCC emissions reporting categories 1A1a+1A2f includes (according to Table 5.5 categories) GWh supplied (gross) from all thermal sources from '*Major power producers*' plus Hydro-natural flow; plus GWh supplied from thermal renewables + coal and gas thermal sources, hydro-natural flow and other non-thermal sources from '*Other generators*'.

(2) Based upon calculated net grid losses from data in DUKES (2013, 2014) 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 and autogeneration - exported to grid (UK Only) listed under UNFCC reporting category 1A2f from the UK Greenhouse Gas Inventory for 2012 (Ricardo-AEA, 2014) for data years 1990-2012 and for the GHGI for 2013 (Ricardo-AEA, 2015) for the 2013 data year.

Table 5: Base electricity generation emissions data

Data 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	0.70395	0.00019	0.00577	0.70991	0.05061	0.00001	0.00042	0.05104	0.7658	0.00021	0.00628	0.77229	**3.85%**	0.113
1991	0.685	0.00018	0.00564	0.69081	0.04318	0.00001	0.00033	0.04352	0.74675	0.00019	0.00615	0.75309	**5.18%**	0.1279
1992	0.64907	0.00017	0.00534	0.65458	0.05678	0.00002	0.00042	0.05722	0.70205	0.00019	0.00578	0.70801	**5.29%**	0.10097
1993	0.58632	0.00018	0.00448	0.59098	0.05101	0.00002	0.00037	0.0514	0.6316	0.00019	0.00483	0.63662	**5.25%**	0.06828
1994	0.56204	0.00019	0.0042	0.56643	0.04471	0.00002	0.0003	0.04502	0.62154	0.00021	0.00464	0.62639	**5.22%**	0.06899
1995	0.53394	0.00019	0.0039	0.53803	0.03813	0.00001	0.00024	0.03839	0.58721	0.00021	0.00429	0.5917	**4.97%**	0.0783
1996	0.50774	0.00018	0.00345	0.51137	0.04182	0.00002	0.00026	0.0421	0.55432	0.0002	0.00376	0.55828	**4.80%**	0.08212
1997	0.46989	0.00018	0.00297	0.47304	0.03816	0.00002	0.00022	0.0384	0.50961	0.00019	0.00322	0.51302	**4.76%**	0.07552
1998	0.46912	0.00019	0.00296	0.47226	0.04084	0.00002	0.00024	0.04111	0.51211	0.0002	0.00323	0.51555	**3.51%**	0.10497
1999	0.43806	0.00019	0.00253	0.44077	0.04375	0.00002	0.00027	0.04404	0.47745	0.0002	0.00275	0.48041	**3.94%**	0.09039
2000	0.46076	0.0002	0.00276	0.46372	0.04083	0.00002	0.00024	0.04109	0.50293	0.00021	0.00301	0.50616	**3.82%**	0.08117
2001	0.47872	0.00021	0.00296	0.48189	0.04398	0.00002	0.00027	0.04427	0.52354	0.00022	0.00324	0.52701	**2.78%**	0.0655
2002	0.46256	0.0002	0.00277	0.46554	0.04487	0.00002	0.00027	0.04516	0.50418	0.00022	0.00302	0.50742	**2.24%**	0.07114
2003	0.47767	0.00021	0.00296	0.48084	0.03621	0.00002	0.00023	0.03646	0.52187	0.00023	0.00323	0.52533	**0.57%**	0.07478
2004	0.47831	0.00021	0.00288	0.4814	0.03831	0.00002	0.00025	0.03857	0.52395	0.00023	0.00315	0.52733	**1.97%**	0.07244
2005	0.47196	0.00022	0.00297	0.47515	0.03884	0.00002	0.00024	0.0391	0.50883	0.00024	0.0032	0.51226	**2.16%**	0.08482
2006	0.50098	0.00023	0.00328	0.50448	0.03883	0.00002	0.00023	0.03908	0.53993	0.00025	0.00353	0.54371	**1.97%**	0.07754
2007	0.49625	0.00024	0.00307	0.49956	0.03838	0.00002	0.00022	0.03863	0.53555	0.00026	0.00331	0.53911	**1.37%**	0.08121
2008	0.49433	0.00026	0.00294	0.49752	0.03611	0.00002	0.00021	0.03634	0.53414	0.00028	0.00317	0.53759	**2.91%**	0.07784
2009	0.45211	0.00027	0.00263	0.45501	0.03783	0.00002	0.00024	0.03809	0.49074	0.0003	0.00285	0.49389	**0.80%**	0.08403
2010	0.4598	0.00028	0.00269	0.46277	0.05061	0.00001	0.00042	0.05104	0.49613	0.0003	0.0029	0.49933	**0.73%**	0.0851
2011	0.44877	0.00029	0.00285	0.45192	0.04318	0.00001	0.00033	0.04352	0.48715	0.00032	0.0031	0.49056	**1.76%**	0.0851
2012	0.5052	0.00034	0.00381	0.50935	0.04418	0.00003	0.00033	0.04454	0.54938	0.00037	0.00414	0.55389	**3.40%**	0.06522
2013	0.4753	0.0004	0.0035	0.4791	0.0392	0.0000	0.0003	0.0396	0.5146	0.0004	0.0038	0.5187	**4.10%**	0.0637

Notes: Time series data in light grey is locked/fixed for the purposes of company reporting and has not been updated be updated in the database in the 2015 update.

Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) / (1 - %Electricity Total Grid LOSSES)

Emission Factor (Electricity LOSSES) = Emission Factor (Electricity CONSUMED) - Emission Factor (Electricity GENERATED)

⇒ Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES),

Table 6: Base electricity generation emission factors (excluding imported electricity)

Data 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 Elec Imports	Imported Elec 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	0.6812	0.00019	0.00558	0.68697	0.05985	0.00002	0.00049	0.06036	0.74106	0.0002	0.00607	0.74733	**3.85%**	0.113
1991	0.65616	0.00017	0.0054	0.66174	0.05915	0.00002	0.00049	0.05966	0.71532	0.00019	0.00589	0.72139	**5.18%**	0.1279
1992	0.62005	0.00017	0.0051	0.62532	0.05061	0.00001	0.00042	0.05104	0.67066	0.00018	0.00552	0.67636	**5.29%**	0.10097
1993	0.55913	0.00017	0.00428	0.56358	0.04318	0.00001	0.00033	0.04352	0.60232	0.00018	0.00461	0.6071	**5.25%**	0.06828
1994	0.53633	0.00018	0.00401	0.54051	0.05678	0.00002	0.00042	0.05722	0.59311	0.0002	0.00443	0.59773	**5.22%**	0.06899
1995	0.5113	0.00018	0.00373	0.51521	0.05101	0.00002	0.00037	0.0514	0.56231	0.0002	0.0041	0.56661	**4.97%**	0.0783
1996	0.48731	0.00017	0.00331	0.4908	0.04471	0.00002	0.0003	0.04502	0.53202	0.00019	0.00361	0.53582	**4.80%**	0.08212
1997	0.45112	0.00017	0.00285	0.45414	0.03813	0.00001	0.00024	0.03839	0.48925	0.00019	0.00309	0.49253	**4.76%**	0.07552
1998	0.45633	0.00018	0.00288	0.45939	0.04182	0.00002	0.00026	0.0421	0.49816	0.0002	0.00314	0.5015	**3.51%**	0.10497
1999	0.42438	0.00018	0.00245	0.427	0.03816	0.00002	0.00022	0.0384	0.46254	0.0002	0.00267	0.46541	**3.94%**	0.09039
2000	0.44628	0.00019	0.00267	0.44914	0.04084	0.00002	0.00024	0.04111	0.48712	0.00021	0.00292	0.49024	**3.82%**	0.08117
2001	0.46725	0.0002	0.00289	0.47034	0.04375	0.00002	0.00027	0.04404	0.511	0.00022	0.00316	0.51438	**2.78%**	0.0655
2002	0.45378	0.0002	0.00272	0.4567	0.04083	0.00002	0.00024	0.04109	0.49461	0.00022	0.00296	0.49779	**2.24%**	0.07114
2003	0.47537	0.00021	0.00294	0.47853	0.04398	0.00002	0.00027	0.04427	0.51936	0.00023	0.00322	0.5228	**0.57%**	0.07478
2004	0.47033	0.00021	0.00283	0.47337	0.04487	0.00002	0.00027	0.04516	0.51521	0.00022	0.0031	0.51853	**1.97%**	0.07244
2005	0.46359	0.00022	0.00291	0.46673	0.03621	0.00002	0.00023	0.03646	0.49981	0.00023	0.00314	0.50318	**2.16%**	0.08482

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Elec Imports	Imported Elec EF
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)					
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
2006	0.49263	0.00022	0.00322	0.49608	0.03831	0.00002	0.00025	0.03857	0.53094	0.00024	0.00347	0.53465	**1.97%**	0.07754
2007	0.49054	0.00024	0.00303	0.49381	0.03884	0.00002	0.00024	0.0391	0.52939	0.00025	0.00327	0.53291	**1.37%**	0.08121
2008	0.48219	0.00026	0.00286	0.48531	0.03883	0.00002	0.00023	0.03908	0.52102	0.00028	0.00309	0.52439	**2.91%**	0.07784
2009	0.44917	0.00027	0.00261	0.45205	0.03838	0.00002	0.00022	0.03863	0.48755	0.00029	0.00284	0.49068	**0.80%**	0.08403
2010	0.45706	0.00028	0.00267	0.46002	0.03611	0.00002	0.00021	0.03634	0.49317	0.0003	0.00289	0.49636	**0.73%**	0.0851
2011	0.44238	0.00029	0.00281	0.44548	0.03783	0.00002	0.00024	0.03809	0.4802	0.00031	0.00305	0.48357	**1.76%**	0.0851
2012	0.49023	0.00033	0.00369	0.49426	0.04287	0.00003	0.00032	0.04322	0.5331	0.00036	0.00402	0.53748	**3.40%**	0.06522
2013	0.4585	0.00035	0.00334	0.46219	0.03785	0.00003	0.00028	0.03816	0.49629	0.00038	0.00362	0.50029	4.10%	0.06522

Notes: Time series data in light grey is locked/fixed for the purposes of company reporting and has not been updated be updated in the database in the 2015 update.

Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) / (1 - %Electricity Total Grid LOSSES)

Emission Factor (Electricity LOSSES) = Emission Factor (Electricity CONSUMED) - Emission Factor (Electricity GENERATED)

$\Rightarrow$ Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES)

Table 7: Base electricity generation emissions factors (including imported electricity)

Indirect/WTT Emissions from UK Grid Electricity

3.10. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect/WTT emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect/WTT / fuel lifecycle emissions as included in the Fuels WTT tables). 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.

3.11. Average indirect/WTT emission factors for electricity have been calculated using the corresponding fuels indirect/WTT emission factors and data on the total fuel consumption by type of generation from Table 5.5, DUKES, 2014. The data used in these calculations are presented in Table 8, Table 9 and Table 10, together with the final indirect/WTT emission factors for electricity. As for the direct emission factors presented in the previous section, earlier years are based on data reported in previous versions of DUKES and following the new convention set from 2013, historic time series factors/data have not been updated. The relevant time series source data and emission factors that were fixed/locked from the 2013 update onwards have therefore been highlighted in light grey and are unchanged since the last update.

Data Year	Fuel Consumed in Electricity Generation, GWh					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Total
1990 to 1995	N/A	N/A	N/A	N/A	N/A	N/A
1996	390,938	45,955	201,929	16,066	243,574	898,462
1997	336,614	25,253	251,787	16,066	257,272	886,992
1998	347,696	17,793	267,731	16,046	268,184	917,450
1999	296,706	17,920	315,548	16,187	256,159	902,520
2000	333,429	18,023	324,560	15,743	228,045	919,800
2001	367,569	16,545	312,518	12,053	249,422	958,107
2002	344,552	14,977	329,442	12,343	244,609	945,923
2003	378,463	13,867	323,926	17,703	241,638	975,597
2004	364,158	12,792	340,228	16,132	228,000	961,309
2005	378,846	15,171	331,658	21,877	233,705	981,257
2006	418,018	16,665	311,408	18,038	224,863	988,991
2007	382,857	13,491	355,878	14,613	189,813	956,652
2008	348,450	18,393	376,810	13,074	167,638	924,366
2009	286,820	17,597	359,303	11,551	213,450	888,721
2010	297,290	13,705	373,586	9,322	202,893	896,796
2011	302,729	10,514	307,265	8,913	232,146	861,567
2012	399,253	9,076	214,146	12,926	230,227	865,628
2013	365,697	6,849	202,325	15,198	239,526	829,594

Source: For the latest 2013 data year, Table 5.5, Digest of UK Energy Statistics (DUKES) 2014 (DECC, 2014), available at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes#2014. Earlier years are based on data reported in previous versions of DUKES and following the new convention set from 2013, historic timeseries factors/data have not been updated.

Table 8: Fuel Consumed in electricity generation (GWh), by year

Data Year	Fuel Consumed in Electricity Generation, % Total					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Total
1990	43.50%	5.10%	22.50%	1.80%	27.10%	100.00%
1991	38.00%	2.80%	28.40%	1.80%	29.00%	100.00%
1992	37.90%	1.90%	29.20%	1.70%	29.20%	100.00%
1993	32.90%	2.00%	35.00%	1.80%	28.40%	100.00%
1994	36.30%	2.00%	35.30%	1.70%	24.80%	100.00%
1995	38.40%	1.70%	32.60%	1.30%	26.00%	100.00%
1996	36.40%	1.60%	34.80%	1.30%	25.90%	100.00%
1997	38.80%	1.40%	33.20%	1.80%	24.80%	100.00%
1998	37.90%	1.30%	35.40%	1.70%	23.70%	100.00%
1999	38.60%	1.50%	33.80%	2.20%	23.80%	100.00%
2000	42.30%	1.70%	31.50%	1.80%	22.70%	100.00%
2001	40.00%	1.40%	37.20%	1.50%	19.80%	100.00%
2002	37.70%	2.00%	40.80%	1.40%	18.10%	100.00%
2003	32.30%	2.00%	40.40%	1.30%	24.00%	100.00%
2004	33.20%	1.50%	41.70%	1.00%	22.60%	100.00%
2005	35.10%	1.20%	35.70%	1.00%	26.90%	100.00%
2006	46.10%	1.00%	24.70%	1.50%	26.60%	100.00%
2007	43.50%	5.10%	22.50%	1.80%	27.10%	100.00%
2008	38.00%	2.80%	28.40%	1.80%	29.00%	100.00%
2009	37.90%	1.90%	29.20%	1.70%	29.20%	100.00%
2010	32.90%	2.00%	35.00%	1.80%	28.40%	100.00%
2011	36.30%	2.00%	35.30%	1.70%	24.80%	100.00%
2012	46.12%	1.05%	24.74%	1.49%	26.60%	100.00%
2013	44.08%	0.83%	24.39%	1.83%	28.87%	100.00%

Notes: Calculated from figures in Table 8.

Table 9: Fuel consumed in electricity generation as a % of the Total, by year

Data Year	Indirect/WTT Emissions as % Direct CO_2 Emissions, by fuel							
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Weighted Average	Direct CO_2	Calc Indirect /WTT CO_2e
1990	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.6812	0.10012
1991	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.65616	0.09644
1992	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.62005	0.09113
1993	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.55913	0.08218
1994	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.53633	0.07883
1995	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.5113	0.07515
1996	16.50%	18.90%	10.40%	12.50%	14.70%	**14.70%**	0.48731	0.07162
1997	16.50%	18.90%	10.40%	12.50%	14.10%	**14.10%**	0.45112	0.06345
1998	16.50%	18.90%	10.40%	12.50%	14.00%	**14.00%**	0.45633	0.06372
1999	16.50%	18.90%	10.40%	12.50%	13.50%	**13.50%**	0.42438	0.0573
2000	16.50%	18.90%	10.40%	12.50%	13.60%	**13.60%**	0.44628	0.06079
2001	16.50%	18.90%	10.40%	12.50%	13.80%	**13.80%**	0.46725	0.06452
2002	16.50%	18.90%	10.40%	12.50%	13.60%	**13.60%**	0.45378	0.06184
2003	16.50%	18.90%	10.40%	12.50%	13.80%	**13.80%**	0.47537	0.06545
2004	16.50%	18.90%	10.40%	12.50%	13.60%	**13.60%**	0.47033	0.06413
2005	16.50%	18.90%	10.40%	12.50%	13.70%	**13.70%**	0.46359	0.06368
2006	16.50%	18.90%	10.40%	12.50%	14.00%	**14.00%**	0.49263	0.06888
2007	16.50%	18.90%	10.40%	12.50%	13.60%	**13.60%**	0.49054	0.06694
2008	16.50%	18.90%	10.40%	12.50%	13.50%	**13.50%**	0.48219	0.06492
2009	16.50%	18.90%	12.40%	12.50%	14.30%	**14.30%**	0.44917	0.06423
2010	16.50%	18.90%	13.90%	12.50%	15.10%	**15.10%**	0.45706	0.069
2011	16.50%	18.90%	15.30%	12.50%	15.90%	**15.90%**	0.44238	0.07033
2012	16.40%	18.80%	13.45%	12.59%	15.35%	**15.35%**	0.49023	0.07527
2013	16.38%	18.92%	12.62%	12.59%	15.02%	15.02%	0.4585	0.0689

Notes: Indirect/WTT emissions as % direct CO_2 emissions is based on information for specific fuels. Weighted average is calculated from the figures for fuels from both Table 9 and Table 10.

Table 10: Indirect/WTT emissions share for fuels used for electricity generation and the calculated average indirect/WTT emission factor, by year

Emission Factors for the Supply of Purchased Heat or Steam

3.12. Updated time-series emission factors for the supply of purchased heat or steam have been provided for the 2015 GHG Conversion Factors. These conversion factors represent the average emission from the heat and steam supplied by the UK CHPQA (Combined Heat and Power Quality Assurance) scheme[14] 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.

3.13. 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 2015 GHG Conversion Factors.

Fuel allocation to electricity from CHP

3.14. 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)

3.15. Under the UK's Climate Change Agreements[15] (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%.

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

[15] 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).

3.16. 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.

3.17. 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

3.18. Under this convention it is assumed that the heat generated by the CHP displaces heat raised by a boiler with an efficiency of 81% on a GCV basis (90% NCV basis[16]), but that the boiler uses the same fuel mix as the actual fuel mix to the CHP to determine the CO_2 emissions.

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

$$Heat\_Energy = \left(\frac{Heat\_Output}{0.81} \right)$$

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

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

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

CO_2 emission from Fuel for Boiler

$$= \left(\frac{QHO}{0.81} \right) * Fuelmix\_CO2\_Factor$$

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

$$= \left(\frac{Fuelmix\_CO2\_Factor}{0.81} \right)$$

[16] Annex II, EU Decision (2011/877/EU) establishing harmonised efficiency reference values for separate production of electricity and heat.

CO_2 emission from Fuel for Electricity

$$= \{TFI - \left(\frac{QHO}{0.81}\right)\} * Fuelmix\_CO2\_factor$$

3 - CHP Electricity EF

$$= \{\{TFI - \left(\frac{QHO}{0.81}\right)\} * Fuelmix\_CO2\_factor\} / TPO$$

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

Method 3: Power Station Displacement Method

3.22. 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.

3.23. 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.

3.24. 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, which has been taken to be 47.7% on a GCV basis[17].

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

CO_2 emission from Fuel for Boiler

$$= \{TFI - \left(\frac{Electricity\_Output}{0.477}\right)\} * Fuelmix\_CO2\_factor$$

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

$$= \left(\frac{TPO}{0.477}\right) * Fuelmix\_CO2\_factor$$

[17] Digest of UK Energy Statistics (DUKES) 2014, Chapter 5, Table 5.10. Thermal Efficiency for CCGT Power Stations in 2013

CHP Electricity Emission factor

$$= \left(\frac{Fuelmix\_CO2\_Factor}{0.477} \right)$$

Calculation of CO_2 Emissions Factor for CHP Fuel Input, FuelMixCO_2factor

3.26. 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

3.27. Fuel inputs and emissions factors are evaluated on a Gross Calorific Value (Higher Heating Value) basis. The following Table 11 provides the individual fuel types considered and their associated emissions factors, consistent with other reporting under the CHP QA scheme.

Fuel	CO_2 Emissions Factor ($kgCO_2/kWh_{th}$)
Biomass (e.g. woodchips, chicken litter)	-
Biodiesel	0.988
Blast furnace gas	0.324
Coal and lignite	0.140
Coke oven gas	0.158
Domestic refuse (raw)	0.188
Ethane	0.269
Fuel oil	0.256
Gas oil	-
Hydrogen	0.186
Methane	0.247
Mixed refinery gases	0.186
Natural gas	-
Other Biogas (e.g. gasified woodchips)	0.188
Other gaseous waste	0.257
Other liquid waste	-
Other solid waste	0.348
Refuse-derived Fuels (RDF)	0.158
Sewage gas	-

Fuel	CO_2 Emissions Factor ($kgCO_2/kWh_{th}$)
Unknown process gas	0.188
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 (2014 update) and National Atmospheric Emissions Inventory (NAEI).

Table 11: Fuel types and associated emissions factors used in determination of FuelMixCO_2factor

3.28. The 1/3 : 2/3 method was utilised in deriving the new heat/steam emission factors provided in the Heat and Steam tables of the 2015 GHG Conversion Factors, for consistency with DUKES. However, results are provided for comparison according to all three methods in Table 12.

3.29. As for the electricity emission factors, the relevant time series source data and emission factors that were fixed/locked from the 2013 update onwards have been highlighted in light grey and are unchanged since the last update. Also similarly to electricity, the GHG conversion factors update / reporting year to which the data and emission factors are applied is two years ahead of the data year. For example, the most recent emission factor for the 2015 GHG Conversion Factors is based on the data year of 2013 in the table.

Data 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
2011	0.21518	0.23876	0.05898	0.24351	0.21894	0.40629
2012	0.20539	0.23419	0.04379	0.21689	0.18452	0.39852
2013	0.20763	0.23209	0.0582	0.2229	0.1948	0.3949

Table 12: Comparison of calculated Electricity and Heat/Steam CO_2 emission factors for the 3 different allocation method

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

3.30. 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).

3.31. Indirect/WTT GHG emission factors have been estimated relative to the CO_2 emissions, based upon activity weighted average indirect/WTT GHG emission factor values for each CHP fuel used. Where fuels are not included in the set of indirect/WTT GHG emission factors provided in the 2015 GHG Conversion Factors, the value for the closest/most similar alternative fuel was utilised instead.

3.32. The complete final emission factors for supplied heat or steam utilised are presented in the 'Heat and Steam' tables of the 2015 GHG Conversion Factors, and are counted as Scope 2 emissions under the GHG Protocol.

3.33. 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 and are counted as Scope 3 emissions under the GHG Protocol (similar to the treatment of transmission and distribution losses for electricity).

4. Refrigerant and Process Emission Factors

Summary of changes since the previous update

4.1. There have been two changes made to refrigeration conversion factors in the 2015 update. First, there have been some additional refrigerants added to those previously listed. There has also there have been changes to GWP factors due to the switch from using the IPCC's second Assessment Report (AR2) to the more recent fourth Assessment Report (AR4).

4.2. The list of additional refrigerant factors now published are the following:

- HFC-152;
- HFC-161;
- HFC-236cb;
- HFC-236ea;
- HFC-245ca;
- HFC-365mfc;
- R-403a blend (HCFC 22 -75% HC 290 - 5% FC 218 -20%);
- HFCF-21;
- Perfluorocyclopropane.

Global Warming Potentials of Greenhouse Gases

Greenhouse Gases Listed in the Kyoto Protocol

4.3. The conversion factors in the Refrigerant tables incorporate (GWP) values relevant to reporting under UNFCCC, as published by the IPCC in its Fourth Assessment Report that is required to be used in inventory reporting.

4.4. *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 the Refrigerant tables.

Other Greenhouse Gases

4.5. Revised GWP values have since been published by the IPCC in the Fifth Assessment Report (2013) but current UNFCCC Guidelines on Reporting and Review, adopted before the publication of the Fifth Assessment Report, require emission estimates to be based on the GWPs in the IPCC Fourth Assessment Report.

4.6. *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 also listed in the provided tables.

5. Passenger Land Transport Emission Factors

Summary of changes since the previous update

5.1. No methodological changes were made in this section since the 2014 GHG Conversion Factors.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

5.2. SMMT (Society for Motor Manufacturers and Traders)[18] provides numbers of registrations and averages of the NEDC[19] gCO_2/km figures for new vehicles registered from 1998 to 2014[20]. The dataset represents a good indication of the relative NEDC gCO_2/km by size category. Table 13 presents the 1998-2014 average CO_2 emission factors and number of vehicle registrations.

5.3. For the 2015 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 2013.

5.4. 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, 2010, 2011 and 2013. 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.

5.5. Data for the UK car fleet were extracted from the 2013 ANPR dataset and categorised according to their engine size, fuel type and year of registration. The 2015 GHG Conversion Factors' emission factors for petrol and diesel passenger cars were subsequently calculated based upon the equation below:

$$2015 \text{ update gCO}_2/\text{km} = \Sigma \left(gCO_2/km_{yr\ reg} \times \frac{ANPR_{yr\ reg}}{ANPR_{total\ 2011}} \right)$$

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

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

[20] 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.

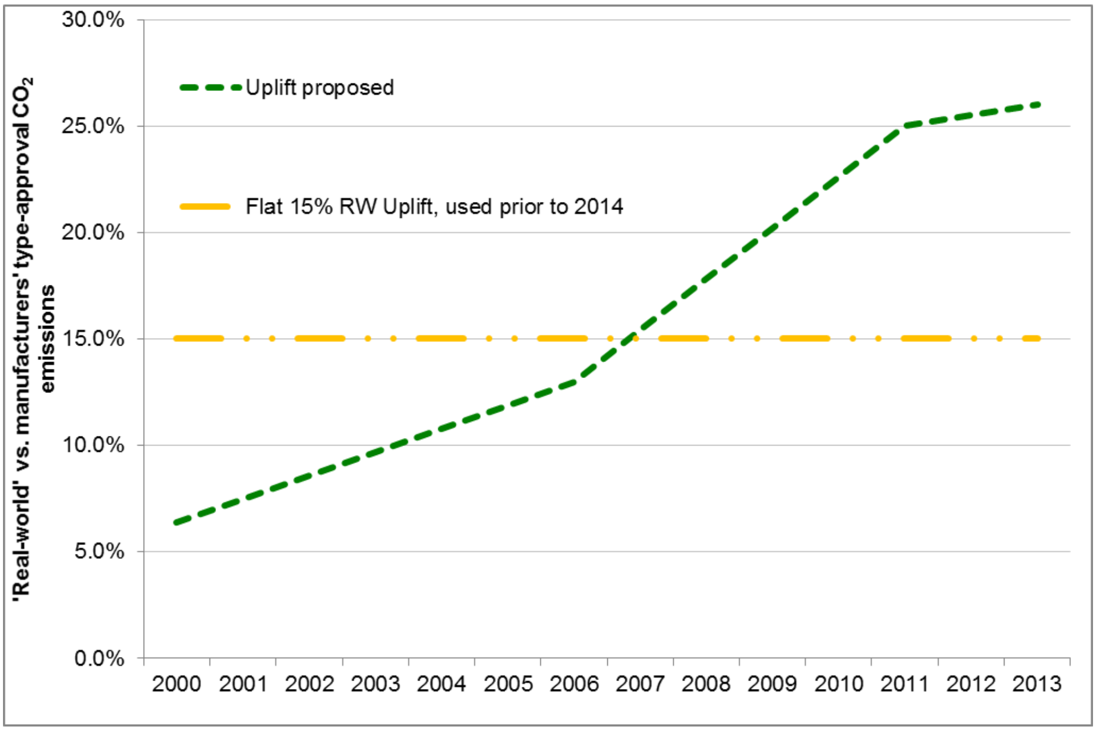
Vehicle Type	Engine size	Size label	gCO_2 per km	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	141.3	12,543,200	49%
	1.4 - 2.0 l	Medium	180.9	10,879,377	43%
	> 2.0 l	Large	257.8	1,859,775	7%
Average petrol car			***166.9***	***25,282,352***	***100%***
Diesel car	<1.7 l	Small	118.6	3,834,801	28%
	1.7 - 2.0 l	Medium	150.7	6,678,977	50%
	> 2.0 l	Large	196.3	2,875,222	21%
Average diesel car			***151.3***	***13,389,000***	***100%***

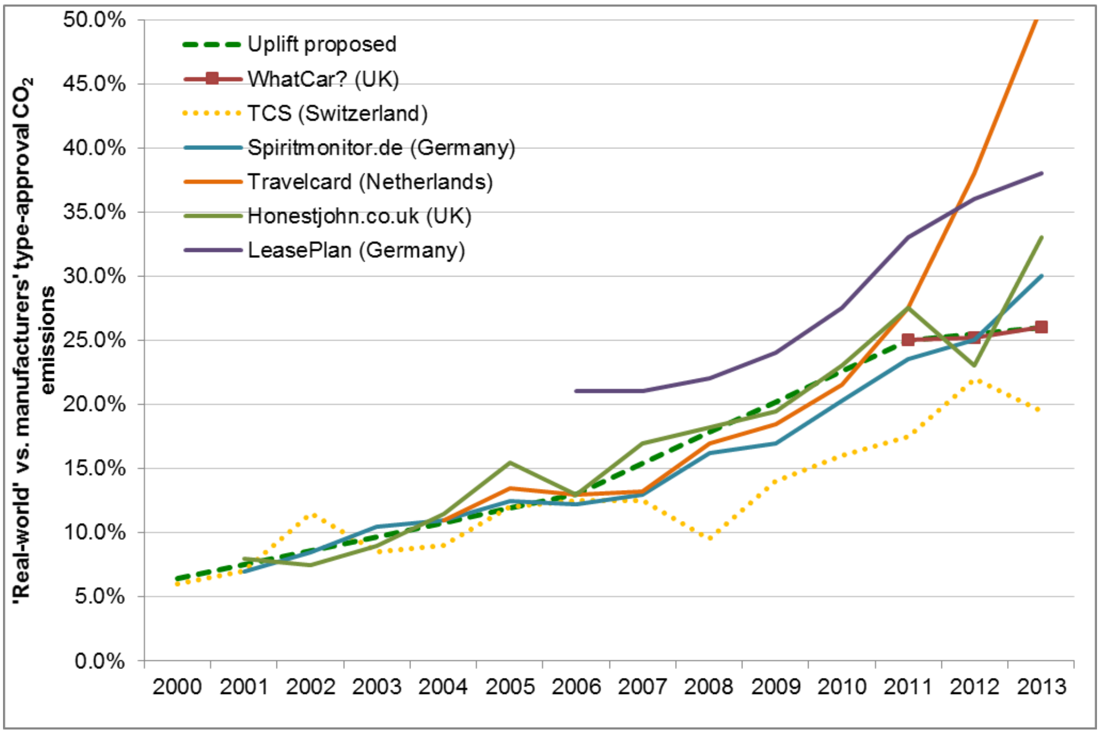
Table 13: Average CO_2 emission factors and total registrations by engine size for 1998 to 2014 (based on data sourced from SMMT)

5.6. 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.

5.7. An uplift factor of **+15% over NEDC based gCO_2/km** factors, applied in updates prior to 2014, was agreed previously with DfT in 2007 to take into account the combined 'real-world' effects on fuel consumption. This flat factor was replaced from the 2014 update onwards to take into account new evidence on the magnitude of this effect and its change over time. The uplift applied now varies over time to align with work performed by ICCT (2014)[21], illustrated in Figure 1 alongside the source data / chart reproduced from the ICCT (2014) report (which was an update of the previous report used for the 2014 update to the GHG Conversion Factors).

[21] 'FROM LABORATORY TO ROAD: A 2014 UPDATE - A comparison of official and 'real-world' fuel consumption and CO_2 values for cars in Europe and the United States' a report by the ICCT, September 2014. Available at: http://www.theicct.org/laboratory-road-2014-update





Notes: In the above charts a y-axis value of 0% would mean no difference between the CO_2 emissions per km experienced in 'real-world' driving conditions and those from official type-approval testing.

Figure 1: Updated 'Real world' uplift values based on ICCT (2014)

5.8. The above uplifts have been applied to the ANPR weighted SMMT gCO_2/km to give the *New 'Real-World'* 2015 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.

5.9. Figures for the aggregated average emission factors by engine type and fuel type (as well as the overall average) were calculated based on weighting by the relative mileage of the different categories. This calculation utilised 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 55.1% petrol and 44.9% diesel, and can be compared to the respective total registrations of the different vehicle types for 1998-2014, which were 66.4% petrol and 33.6% diesel.

5.10. Emission factors 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 2014 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[22].

5.11. The final 2015 emission factors for petrol and diesel passenger cars by engine size are presented in the ‘passenger vehicles’ and ‘business travel- land’ tables of the 2015 GHG Conversions Factors.

5.12. Due to the change in methodology in this section and subsequent revision of the ‘real world’ uplift, the 2014 and 2015 GHG Conversion Factors are not directly comparable with those from previous versions of the greenhouse gas conversion factors (i.e. prior to the 2014 update). Therefore, whilst the overall factors and the factors for some vehicle sizes / market segments have continued to reduce, the conversion factors for certain vehicle types/classifications have gone up this year. The changes in the CH_4 and N_2O emission factors in the 2015 update mean these are also not comparable with those reported in all previous updates.

Hybrid, LPG and CNG Passenger Cars

5.13. The methodology used in the 2015 update for medium and large hybrid petrol/diesel electric cars is similar to that in the 2011 - 2014 updates, having received numbers of registrations and averages of the NEDC[23] gCO_2/km figures from SMMT for new hybrid vehicles registered in 2014.

5.14. 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 2015 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 on a unit energy basis. For example, for a Medium car run on CNG:

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

5.15. For the 2015 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 (produced by Ricardo-AEA) and are presented

[22] 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

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

together with an overall total emission factors in the 'passenger vehicles' and 'business travel- land' tables of the 2015 GHG Conversion Factors.

Emission Factors by Passenger Car Market Segments

5.16. For the 2015 GHG Conversion Factors, the market classification split (according to SMMT classifications) was derived using detailed SMMT data on new car registrations between 1998 and 2014 split by fuel[24], presented in Table 14, and again combining this with information extracted from the 2013 ANPR dataset. These data were then uplifted to take into account 'real-world' impacts, consistent with the methodology used to derive the car engine size emission factors. The supplementary market segment based emission factors for passenger cars are presented in the 'passenger vehicles' and 'business travel-land' tables of the 2015 GHG Conversion Factors.

5.17. 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 the tables of the 2015 GHG Conversion Factors.

Fuel Type	Market Segment	Example Model	1998-2014		
			gCO_2/km	# registrations	% Total
Diesel	A. Mini	Smart Fortwo	89.1	9,323	0%
	B. Super Mini	VW Polo	117.5	1,644,384	12%
	C. Lower Medium	Ford Focus	133.2	4,085,346	31%
	D. Upper Medium	Toyota Avensis	149.0	3,345,521	25%
	E. Executive	BMW 5-Series	166.8	1,080,010	8%
	F. Luxury Saloon	Bentley Continental GT	200.8	62,426	0%
	G. Specialist Sports	Mercedes SLK	140.0	82,687	1%
	H. Dual Purpose	Land Rover Discovery	204.4	1,977,105	15%
	I. Multi Purpose	Renault Espace	164.1	1,102,199	8%
	All	**Total**	**151.3**	**13,389,001**	**100%**
Petrol	A. Mini	Smart Fortwo	126.0	760,346	3%
	B. Super Mini	VW Polo	142.1	11,112,030	44%
	C. Lower Medium	Ford Focus	170.2	7,012,660	28%
	D. Upper Medium	Toyota Avensis	197.5	3,128,363	12%
	E. Executive	BMW 5-Series	231.2	780,409	3%
	F. Luxury Saloon	Bentley Continental GT	296.1	121,047	0%
	G. Specialist Sports	Mercedes SLK	216.9	899,799	4%

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

Fuel Type	Market Segment	Example Model	1998-2014		
			gCO_2/km	# registrations	% Total
	H. Dual Purpose	Land Rover Discovery	242.2	768,457	3%
	I. Multi Purpose	Renault Espace	189.9	759,881	3%
	All	**Total**	**166.9**	**25,342,992**	**100%**
Unknown Fuel (Diesel + Petrol)	A. Mini	Smart Fortwo	125.5	769,669	2%
	B. Super Mini	VW Polo	138.9	12,756,414	33%
	C. Lower Medium	Ford Focus	156.5	11,098,006	29%
	D. Upper Medium	Toyota Avensis	172.4	6,473,884	17%
	E. Executive	BMW 5-Series	193.8	1,860,419	5%
	F. Luxury Saloon	Bentley Continental GT	263.7	183,473	0%
	G. Specialist Sports	Mercedes SLK	210.4	982,486	3%
	H. Dual Purpose	Land Rover Discovery	215.0	2,745,562	7%
	I. Multi Purpose	Renault Espace	174.6	1,862,080	5%
	All	**Total**	**161.5**	**38,731,993**	**100%**

Table 14: Average car CO_2 emission factors and total registrations by market segment for 1998 to 2013 (based on data sourced from SMMT)

Direct Emissions from Taxis

5.18. The emission factors for black cabs and taxis have been revised for the 2015 update.

5.19. The new emission factors for black cabs based on data provided by Transport for London (TfL) on the testing of emissions from black cabs using real-world London Taxi cycles, and an average ***passenger*** occupancy of 1.5 (average 2.5 people per cab, including the driver, from LTI, 2007). This revised methodology accounts for the significantly different operational cycle of black cabs/taxis in the real world when compared to their NEDC (official type-approval) values, which significantly increases the emission factor (by ~40% vs NEDC).

5.20. The new emission factors (per passenger km) for taxis were estimated on the basis of the average type-approval CO_2 factors for medium and large cars, uplifted by the (40%) difference between the type-approval figures and real-world taxi cycle emission factors for the vehicles tested by TfL, plus an assumed average passenger occupancy of 1.4 (CfIT, 2002[25]).

5.21. Since the 2013 update, emission factors per passenger km for taxis and black cabs are presented in the 'business travel- land' tables of the GHG Conversion Factors. The base

[25] 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://webarchive.nationalarchives.gov.uk/20110304132839/http://cfit.independent.gov.uk/pubs/2002/psbi/lek/index.htm

emission factors per vehicle km are also presented in the ‘business travel- land’ tables of the 2015 GHG Conversion Factors.

5.22. Emission factors for CH_4 and N_2O have been updated for all taxis for the 2015 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 the tables of the 2015 GHG Conversion Factors.

5.23. It should be noted that the current emission factors for taxis still don’t take into account emissions spent from “cruising” for fares. Currently robust data sources do not exist that could inform such an "empty running" factor. If suitably robust sources are identified in the future, the methodology for taxis may be revisited and revised in a future update to account for this.

Direct Emissions from Vans

5.24. 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 15 (and in the “delivery vehicles” section of the 2015 GHG Conversion Factors), have been updated for the this year’s update. 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.

5.25. These test cycle based emission factors are uplifted by 15% to represent ‘real-world’ emissions, consistent with the previous approach used for cars, and agreed with DfT in the absence of a similar time-series dataset of ‘real-world’ vs type-approval emissions from vans (see earlier section on passenger cars). Emission factors for petrol and diesel LGVs are based upon emission factors and vehicle km from the NAEI for 2013. In the 2015 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 2013, as presented in Table 15.

5.26. 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.

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	189.8	0.20	0.70	190.7	38.37%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	211.5	0.20	0.70	212.4	48.63%	0.72
Petrol (Class III)	Over 1.740 tonne	255.6	0.22	1.66	257.5	13.00%	1.29
Petrol (average)	**Up to 3.5 tonne**	**208.9**	**0.20**	**0.82**	**209.9**	**100.00%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	143.4	0.05	0.99	144.5	6.18%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	226.7	0.05	1.56	228.3	25.74%	0.98
Diesel (Class III)	Over 1.740 tonne	265.9	0.05	1.83	267.7	68.08%	1.29
Diesel (average)	**Up to 3.5 tonne**	**248.2**	**0.05**	**1.71**	**250.0**	**100.00%**	**1.17**
LPG	Up to 3.5 tonne	260.6	0.37	2.04	263.1		1.17
CNG	Up to 3.5 tonne	235.8	0.99	2.04	238.9		1.17
Average		**246.6**	**0.1**	**1.7**	**248.3**		**1.15**

Table 15: New emission factors for vans for the 2015 GHG Conversion Factors

Direct Emissions from Buses

5.27. The 2015 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[26].

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

5.29. 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 16.

5.30. Table 16 gives a summary of the 2015 updated emission factors and average passenger occupancy. 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.

[26] The robustness of the BSOG data is now reducing because of the changes to the way BSOG is paid to operators and local authorities. Approximations have been made this year where data was not available (based on previous year data) and a revised methodology will commence next year (2016).

Bus type	Average passenger occupancy	gCO2e per passenger km			
		CO_2	CH_4	N_2O	Total
Local bus	9.5	119.1	0.1	0.9	120.1
Local London bus	16.8	80.6	0.1	0.5	81.2
Average local bus	**10.8**	**108.1**	**0.1**	**0.8**	**108.9**
Coach	16.2*	28.7	0.1	0.6	29.3

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 2015 GHG Conversion Factors

Direct Emissions from Motorcycles

5.31. 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.

5.32. 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)

5.33. For the 2009 update the emission factors were calculated based on a large dataset kindly provided by Clear (2008)[27]. This dataset was more comprehensive compared to the one previously used, containing almost 1200 data points (over 300 different bikes from 50-1500cc and from 25 manufacturers) from a mix of magazine road test reports and user reported data compared to only 42 data points in the previous dataset. A summary is presented in Table 17, with the corresponding complete emission factors developed for motorcycles are presented in the 'passenger vehicles' tables of the 2015 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)[28]. In the absence of new information the methodology and dataset are unchanged for the 2015 GHG Conversion Factors.

5.34. 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

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

[28] "Compendium of Motorcycling Statistics: 2008", available at: http://webarchive.nationalarchives.gov.uk/+/dft.gov.uk/pgr/statistics/datatablespublications/vehicles/motorcycling/motorcyclingstats2008.html

from ACEM[29] (+9%) is smaller than the corresponding differential used to uplift cars test cycle data to real-world equivalents (+15%).

5.35. Emission factors for CH_4 and N_2O were updated for the 2015 GHG Conversion Factors based on the emission factors from the 2013 UK GHG Inventory (Ricardo-AEA, 2015). These factors are also presented together with overall total emission factors in the tables of the 2015 GHG Conversion Factors.

CC Range	Model Count	Number	Av. gCO_2/km	Av. MPG
Up to 125cc	24	58	85.0	76.2
125cc to 200cc	3	13	77.8	83.3
200cc to 300cc	16	57	93.1	69.6
300cc to 400cc	8	22	112.5	57.6
400cc to 500cc	9	37	122.0	53.1
500cc to 600cc	24	105	139.2	46.5
600cc to 700cc	19	72	125.9	51.5
700cc to 800cc	21	86	133.4	48.6
800cc to 900cc	21	83	127.1	51.0
900cc to 1000cc	35	138	154.1	42.0
1000cc to 1100cc	14	57	135.6	47.8
1100cc to 1200cc	23	96	136.9	47.3
1200cc to 1300cc	9	32	136.6	47.4
1300cc to 1400cc	3	13	128.7	50.4
1400cc to 1500cc	61	256	132.2	49.0
1500cc to 1600cc	4	13	170.7	38.0
1600cc to 1700cc	5	21	145.7	44.5
1700cc to 1800cc	3	15	161.0	40.3
1800cc to 1900cc	0	0		
1900cc to 2000cc	0	0		
2000cc to 2100cc	1	5	140.9	46.0
<125cc	***24***	***58***	**85.0**	**76.2**
126-500cc	***36***	***129***	**103.2**	**62.8**
>500cc	***243***	***992***	**137.2**	**47.2**
Total	**303**	**1179**	**116.7**	**55.5**

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

Table 17: Summary dataset on CO_2 emissions from motorcycles based on detailed data provided by Clear (2008)

[29] The European Motorcycle Manufacturers Association

Direct Emissions from Passenger Rail

5.36. Emission factors for passenger rail services have been updated and provided in the "Business travel – land" section of the 2015 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 2015 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

5.37. The international rail factor is based on a passenger-km weighted average of the emission factors for all of the Eurostar routes. These are London-Brussels, London-Paris, London-Marne Le Vallee (Disney), London-Avignon and the ski train from London-Bourg St Maurice. The emission factors were provided by Eurostar for the 2015 update, together with information on the basis of the electricity figures used in their calculation.

5.38. 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 all Eurostar 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 GHG Conversion Factors and the France/Belgium grid averages.

5.39. The new figure from Eurostar is 12.05 gCO_2/pkm, and is consistent with Ricardo-AEA's previous methodology for calculating emissions for the GHG Conversion Factors. Eurostar's previously published figure (from 2010) is 7.71 gCO_2/pkm differs from the figure quoted in the 2010-2014 GHG Conversion Factors as it was calculated using the individual conversion factors as specified by each electricity supplier across each network section upon which they operate, rather than the grid average. For further information please visit: http://www.eurostar4agents.com/treadlightly/greener.html

5.40. 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

5.41. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2013-14. The factor is sourced from information from the Office of the Rail Regulator's National rail trends for 2013-14 (ORR, 2014)[30]. This has been calculated based on total electricity and diesel consumed by the railways for the year (sourced from ATOC), and the total number of passenger kilometres (from National Rail Trends).

5.42. 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

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

passenger km proportions of diesel and electric rail provided by DfT for 2006-7 (since no newer datasets have been made available by DfT).

Light Rail

5.43. 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.

5.44. Figures for the DLR, London Overground and Croydon Tramlink for 2011/12 based on figures kindly provided by Transport for London, adjusted to the new 2015 grid electricity CO_2 emission factor.

5.45. 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'[31] and the new 2015 grid electricity CO_2 emission factor.

5.46. 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 2015 grid electricity CO_2 emission factor, for consistency.

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

5.48. 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.

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

	Type	Electricity use kWh/pkm	gCO2e per passenger km				Million pkm
			CO_2	CH_4	N_2O	Total	
DLR (Docklands Light Rail)	Light Rail	0.1047	51.95	0.040	0.38	52.37	537
Glasgow Underground	Light Rail	0.1643	81.54	0.062	0.59	82.20	41
Midland Metro	Light Rail	0.1353	67.15	0.051	0.49	67.69	49
Tyne & Wear Metro	Light Rail	0.2053	101.91	0.078	0.74	102.73	295
London Overground	Light Rail	0.0675	33.51	0.026	0.24	33.78	840
Croydon Tramlink	Tram	0.0786	39.01	0.030	0.28	39.32	162
Manchester Metrolink	Tram	0.0787	39.05	0.030	0.28	39.36	303
Nottingham Express Transit	Tram	No data					
Supertram	Tram	0.3500	173.72	0.133	1.27	175.12	82
Average*		**0.1091**	**54.17**	**0.041**	**0.40**	**54.61**	**2309**

Notes: * Weighted by relative passenger km

Table 18: GHG emission factors, electricity consumption and passenger km for different tram and light rail services

London Underground

5.49. The London Underground rail factor was provided from Transport for London corrected to the 2015 grid electricity CO_2 emission factor.

5.50. 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.

Indirect/WTT Emissions from Passenger Land Transport

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

5.51. Indirect/WTT 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/WTT emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect/WTT EFs for the relevant fuels from the "Fuels" section and the corresponding direct CO_2 EFs for vehicle types using these fuels in the "Passenger vehicles", "Business travel – land" and "Business travel – air" sections of the new tables format used in the 2015 GHG Conversion Factors.

Rail

5.52. Indirect/WTT 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/WTT EFs for grid electricity from the "UK Electricity" section and the corresponding direct CO_2 EFs for vehicle types using these fuels in the "passenger vehicles", "Business travel – land" and "Business travel – air" sections of the table format used in the GHG Conversion Factors..

5.53. The EFs for national rail services are based on a mixture of emissions from diesel and electric rail. Indirect/WTT 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).

6. Freight Land Transport Emission Factors

Summary of changes since the previous update

6.1. The only change of note here is the update to DfT statistics for HGVs. Since 2011 the same set of road freight statistics from DfT were being used (in the absence of subsequent updates). However, an update of these in February of 2015 meant that more accurate fuel consumption data can be used in the 2015 GHG Conversion Factors.

6.2. All other factors have been updated with more recent data in the latest 2015 GHG Conversion Factors.

Direct Emissions from Heavy Goods Vehicles (HGVs)

6.3. 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 2008-13 GHG Conversion Factors. The new factors for the 2015 GHG Conversion Factors are presented in sections “Delivery Vehicles” and “Freighting Goods”.

6.4. The factors are based on road freight statistics from the Department for Transport (DfT, 2015)[32] for Great Britain (GB), from a survey on different sizes of rigid and articulated HGVs in the fleet in 2013. 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.

6.5. The miles per gallon (MPG) figures in Table RFS0141 of DfT (2015) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the 2015 GHG Conversion Factors tables. Table RFS0117 of DfT (2015) shows the percent loading factors are on average between 40-60% in the UK HGV fleet. Figures from the ARTEMIS project show that the effect of load becomes proportionately greater for heavier classes of HGVs. In other words, the relative difference in fuel consumption between running an HGV completely empty or fully laden is greater for a large >33t HGV than it is for a small <7.5t HGV. From analysis of the ARTEMIS data, it was possible to derive the figures in Table 19 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.

6.6. The previous factors are also included for refrigerated/temperature-controlled HGVs included a 20% increase in fuel consumption to the standard “all diesel” factors. This accounts for the typical additional energy needed to power refrigeration equipment in such

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[32] “Transport Statistics Bulletin: Road Freight Statistics 2011-2013, (DfT, 2015). Available at: https://www.gov.uk/government/statistics/road-freight-statistics-2011-to-2013

vehicles over similar non-refrigerated alternatives[33]. The methodology for estimating conversion factors from refrigerated / temperature controlled HGVs has been modified to improve the accuracy of reporting where users do not already have the specific fuel consumption available from their vehicles. New uplifts of 19.2% and 16.2% are now applied to rigid and arctic refrigerated/temperature-controlled HGVs respectively. Finally, the refrigerated/temperature-controlled average factors now have a revised 17.7% uplift applied. These updates are based on average data for different sizes of refrigerated HGV from Tassou et al (2009)[34].

6.7. As previously stated, new conversion factors by 0%, 50% and 100% vehicle laden weight have been added for all rigid HGVs, all artic HGVs and all HGVs from this year, calculated on a similar basis.

	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

Table 19: Change in CO_2 emissions caused by +/- 50% change in load from average loading factor of 50%

6.8. 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 sections "Delivery vehicles" and "Freighting goods" of the 2015 GHG Conversion Factors.

6.9. The loading factors in Table 19 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in the above sections. 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.

6.10. 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

[33] 'Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy', a report for EC DG CLIMA by AEA Technology plc and Ricardo, February 2011. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf

[34] *Food transport refrigeration – Approaches to reduce energy consumption and environmental impacts of road transport*, by S.A. Tassou, G. De-Lille, and Y.T. Ge. Applied Thermal Engineering, Volume 29, Issues 8–9, June 2009, Pages 1467–1477. Available at: http://www.sciencedirect.com/science/article/pii/S135943110800286X

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 is likely to be a result of 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 “Delivery vehicles” and “Freighting goods” of the 2015 GHG Conversion Factors. Thus the factors in “Delivery vehicles” and “Freighting goods”, 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.

6.11. UK average factors for all rigid and articulated HGVs are also provided in sections “Delivery vehicles” and “Freighting goods” of the 2015 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 2013. These are derived directly from the mpg values for rigid and articulated HGVs in Table RFS0141of DfT (2015).

6.12. 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 (2015). 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.

6.13. The conversion factors provided in “Delivery vehicles” of the 2015 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.

6.14. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO_2 factors in tonne km (tkm) units. The “Freighting goods” section of the 2015 GHG Conversion Factors also 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 fleet average gCO_2 per vehicle km factors in “Delivery vehicles”. Prior to the 2014 update, previous updates only included factors for the UK average laden weight for each HGV class in tonne km (tkm).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, 2015). Dividing the tkm by the vkm figures gives the average tonnes freight lifted by each HGV class For example a rigid HGV, >3.5-7.5t has an average load of 46%. In the 2015 GHG Conversion Factors, this has been expanded to include factors in tonne km (tkm) for all loads, (0%, 50%, 100% and average) since 2014.

6.15. 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 “Freighting goods” of the 2015 GHG Conversion Factors for the relevant HGV class.

6.16. Emission factors for CH_4 and N_2O have been updated for all HGV classes. These are based on the emission factors from the 2013 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 sections "Delivery vehicles" and "Freighting goods" of the 2015 GHG Conversion Factors.

Direct Emissions from Light Goods Vehicles (LGVs)

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

6.18. 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 20. These are based on quantitative assessment of the van database used by Ricardo-AEA in a variety of policy assessments for DfT.

Van fuel	Van size	Vkm % split	Av. Capacity tonnes	Av. Payload tonnes
Petrol (Class I)	Up to 1.305 tonne	38.37%	0.64	0.24
Petrol (Class II)	1.305 to 1.740 tonne	48.63%	0.72	0.26
Petrol (Class III)	Over 1.740 tonne	13.00%	1.29	0.53
Petrol (average)	**Up to 3.5 tonne**	**100.00%**	**0.76**	**0.31**
Diesel (Class I)	Up to 1.305 tonne	6.18%	0.64	0.24
Diesel (Class II)	1.305 to 1.740 tonne	25.74%	0.98	0.36
Diesel (Class III)	Over 1.740 tonne	68.08%	1.29	0.53
Diesel (average)	**Up to 3.5 tonne**	**100.00%**	**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**

Table 20: Typical van freight capacities and estimated average payload

6.19. The average load factors assumed for different vehicle types used to calculate the average payloads in Table 20 are summarised in Table 21, on the basis of DfT statistics from a survey of company owned vans.

Average van loading	Utilisation of vehicle volume capacity				
	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[35]

Table 21: Utilisation of vehicle capacity by company-owned LGVs: annual average 2003 – 2005 (proportion of total vehicle kilometres travelled)

6.20. Emission factors for CH_4 and N_2O have been updated for all van classes in the 2015 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.

6.21. Emission factors per tonne km 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 20 and the earlier emission factors per vehicle-km in the “Delivery vehicles” and “Freighting goods” sections of the 2015 GHG Conversion Factors.

[35] TSG/UW, 2008. “Using official data sources to analyse the light goods vehicle fleet and operations in Britain” a report by Transport Studies Group, University of Westminster, London, November 2008. Available at: http://www.greenlogistics.org/SiteResources/61debf21-2b93-4082-ab15-84787ab75d26_LGV%20activity%20report%20(final)%20November%202008.pdf

Direct Emissions from Rail Freight

6.22. Data from Table 9.1 of the Office of the Rail Regulator's National Rail Trends Yearbook for 2013-14 (ORR, 2014)[36] has been used to update the rail freight emission factors for the 2015 GHG Conversion Factors. This factor is presented in "Freighting goods" in the 2015 GHG Conversion Factors. There have been no further updates to the methodology in the 2015 update.

6.23. The factor can be expected to vary with rail traffic route, speed and train weight. Freight trains are hauled by electric and diesel locomotives, but the vast majority of freight is carried by diesel rail and correspondingly CO_2 emissions from diesel rail freight are over 93% of the total for 2013-14 (ORR, 2014).

6.24. 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).

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

6.26. 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.

Indirect/WTT Emissions from Freight Land Transport

Vans and HGVs

6.27. Indirect/WTT emission factors (EFs) for vans and HGVs include only emissions resulting from the fuel lifecycle (i.e. production and distribution of the relevant transport fuel). These indirect/WTT emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect/WTT EFs for the relevant fuels and the corresponding direct CO_2 EFs for vehicle types using these fuels.

Rail

6.28. The EFs for freight rail services are based on a mixture of emissions from diesel and electric rail. Indirect/WTT EFs were therefore calculated in a similar way to the other freight transport modes, except from combining indirect/WTT 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 from ORR (2014).

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[36] Available from the ORR's website at: http://orr.gov.uk/

7. Sea Transport Emission Factors

Direct Emissions from RoPax Ferry Passenger Transport

7.1. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[37]. No new methodology or updated dataset has been identified for the 2015 GHG Conversion Factors.

7.2. 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.

7.3. 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.

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[38]
Average weight of passenger + luggage, total	0.100	MCA, 2007[38]
Average Freight Unit*, total	22.173	BFF, 2007[39]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[40]

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

Table 22: Assumptions used in the calculation of ferry emission factors

7.4. 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

[37] 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.

[38] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.dft.gov.uk/mca/mcga07-home/shipsandcargoes/mcga-shipsregsandguidance/marinenotices/mcga-mnotice.htm?textobjid=82A572A99504695B

[39] 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.

[40] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006.

from this figure and the total number of passenger km, and is presented in the "Business travel – sea" section of the 2015 GHG Conversion Factors. A further split has been provided between foot-only passengers and passengers with cars in the 2015 GHG Conversion Factors, again on a weight allocation basis.

7.5. 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 (which were excluded from the BFF, 2007 work).

7.6. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the 2013 UK GHG Inventory, proportional to the CO_2 emissions.

Direct Emissions from RoPax Ferry Freight Transport

7.7. 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 2015 GHG Conversion Factors.

7.8. 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.

7.9. 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.

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[41]
Average weight of passenger + luggage, total	0.100	MCA, 2007[41]
Average Freight Unit*, total	22.173	BFF, 2007[42]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[43]

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

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

[41] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.dft.gov.uk/mca/mcga07-home/shipsandcargoes/mcga-shipsregsandguidance/marinenotices/mcga-mnotice.htm?textobjid=82A572A99504695B

[42] 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.

[43] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006.

7.10. 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 “Freighting goods” in the 2015 GHG Conversion Factors tables.

7.11. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2013, proportional to the CO_2 emissions.

Direct Emissions from Other Marine Freight Transport

7.12. 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 2015 update.

7.13. 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)[44] report on GHG emissions from ships. The figures in ”Freighting goods” of the 2015 GHG Conversion Factors represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.

7.14. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2013, proportional to the CO_2 emissions.

Indirect/WTT Emissions from Sea Transport

7.15. Indirect/WTT emissions factors (EFs) for ferries and ships include only emissions resulting from the fuel lifecycle (i.e. production and distribution of the relevant transport fuel). These indirect/WTT emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect/WTT EFs for the relevant fuels and the corresponding direct CO_2 EFs for ferries and ships using these fuels.

[44] “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/blast/blastDataHelper.asp?data_id=26046&filename=4-7.pdf

8. Air Transport Emission Factors

Summary of changes since the previous update

8.1. There have been two changes made to the conversion factors for flights to/from the UK in the 2015 update:

a) First, the data sources and assumptions are now better aligned with those used in the current Department for Transport (DfT) aviation model and second, DfT data on passenger cabin class split (%) by haul type (Domestic, Short-Haul and Long-Haul) has been used to improve/update our assumptions in this area.

b) Additionally, a brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international passenger flights between non-UK destinations.

8.2. No other changes to the structure of the air transport emission factors has been made this year. However additional information is provided in the sections below on the uncertainty in the radiative forcing (RF) uplift applied to the emission factors provided from 2013 onwards.

Passenger Air Transport Direct CO_2 Emission Factors

8.3. There have been two changes made to the conversion factors for flights to/from the UK in the 2015 update. First, the data sources and assumptions are now better aligned with those used in the current Department for Transport (DfT) aviation model and second, DfT data on passenger cabin class split (%) by haul type (Domestic, Short-Haul and Long-Haul) has been used to improve/update our assumptions in this area.

8.4. Additionally, a brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations. This is a relatively high level analysis and allows users to choose a different factor for air travel if flying between countries outside of the UK. All factors presented are for direct (non-stop) flights only. This analysis was only possible for passenger air travel however in the interests of consistency with the air freight travel, international freight factors have been included this year. These factors have been set equal to the current UK, long haul freight factors[45].

8.5. The 2015 update of the average factors (presented at the end of this section) has been calculated using the same data source as in 2014. The 2014 update used a similar basic methodology as previously, but instead of using the aircraft specific fuel consumption/emission factors from AEIG (2006)[46], a more recent source - the

[45] Please note - The international factors included are an average of short and long-haul flights which explains the difference between the UK factors and the international ones.

[46] EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (2006), available at the EEA website at: http://www.eea.europa.eu//publications/emep-eea-emission-inventory-guidebook-2009

EUROCONTROL small emitters tool - was used. The principal advantages of the new source were that:

a. The tool is based on a methodology designed to estimate the fuel burn for an entire flight, is updated on a regular basis in order to improve when possible its accuracy, and has been validated using actual fuel consumption data from airlines operating in Europe.

b. The tool covers a wider range of aircraft than the previous source, including many newer (and more efficient) aircraft increasingly used in flights to/from the UK. It also includes more variants in aircraft families.

c. The tool is approved for use for flights falling under the EU ETS via the Commission Regulation (EU) No. 606/2010.

8.6. A full summary of the 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 (subsequently aggregated to totals for domestic, short- and long-haul flights) have all been calculated from detailed UK Civil Aviation Authority (CAA, 2015) statistics for UK registered airlines for the year 2014 (the most recent complete dataset available at the time of calculation), split by aircraft and route type (Domestic, European Economic Area, other International) [47];

c. 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.

8.7. New and high-profile efficient aircraft such as the Airbus A380-800 and Boeing 787-800 Dreamliner are not currently included in Table 24 as:

a. Currently they do not account for a significant share of pkm to/from the UK (and have only been introduced into CAA statistics from year 2013);

b. A more significant volume of observed data is needed to enable their inclusion in the EUROCONTROL small emitters tool (where they are currently absent).

[47] This dataset was provided by DfT for the purposes of the Conversion Factors calculations, and provides a breakdown by both aircraft and route type, which is unavailable in publically available sources, e.g. Annual Airline Statistics available from the CAA's website at: http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&pageid=1&sglid=1

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	EF, kgCO_2/vkm	Av. flight length, km
Domestic Flights					
AIRBUS A319	199	72%	42%	14.9	462
AIRBUS A320-100/200	271	62%	18%	16.2	464
AIRBUS A321	253	72%	5%	17.5	487
BOEING 737-300	207	70%	5%	15.4	494
BOEING 737-400	290	63%	2%	15.8	398
BOEING 767-300	202	92%	3%	26.6	530
BOMBARDIER DASH 8 Q400	124	61%	13%	7.0	347
EMB ERJ175 (170-200)	137	62%	3%	9.8	448
SAAB 2000	85	58%	1%	6.6	384
SAAB FAIRCHILD 340	55	60%	2%	4.2	263
EMBRAER ERJ190	144	66%	3%	11.6	556
EMBRAER ERJ195	144	66%	3%	11.6	556
Total	***198***	***68%***	***100%****	***12.1***	***414***
Short-haul Flights					
AIRBUS A319	178	80%	17%	11.5	1,056
AIRBUS A320-100/200	223	76%	23%	11.7	1,416
AIRBUS A321	261	76%	10%	12.9	1,650
BOEING 737-300	160	86%	3%	11.3	1,509
BOEING 737-400	187	78%	2%	12.4	1,198
BOEING 737-800	235	78%	31%	11.5	1,415
BOEING 757-200	266	86%	10%	14.5	2,407
BOEING 767-300ER/F	255	88%	3%	20.4	2,286
Total	***225***	***79%***	***100%****	***12.1***	***1,385***
Long-haul Flights					
AIRBUS A320-100/200	360	78%	6%	21.4	6,571
AIRBUS A330-300	453	69%	5%	22.1	5,763
AIRBUS A340-300	359	76%	2%	25.4	7,246
AIRBUS A340-600	401	79%	5%	31.6	7,519
AIRBUS A380-800	625	80%	9%	42.1	7,666
BOEING 747-400	467	79%	24%	37.9	7,536
BOEING 757-200	239	81%	3%	13.7	5,057
BOEING 767-300	271	80%	8%	19.2	6,339
BOEING 767-400	319	77%	2%	20.7	6,154
BOEING 777-200ER	374	73%	19%	25.4	6,756
BOEING 777-300ER	487	75%	18%	30.1	7,126
Total	***431***	***77%***	***100%****	***28.0***	***6,785***

Notes: Figures on seats, load factors, % tkm and av. flight length have been calculated from 2014 CAA statistics for UK registered airlines for the different aircraft types. Figures of kgCO_2/vkm were calculated using the average flight lengths in the EUROCONTROL small emitters tool. * 100% denotes the pkm share of the aircraft included in the assessment - as listed in the table. The aircraft listed in the table above account for 87% of domestic pkm, 92% of short-haul pkm and 80% of long-haul pkm.

Table 24: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2015

8.1. **Allocating flights into short- and long-haul:** Domestic flights are those that start and end in the United Kingdom, which are simple to categorise. However, allocating flights into short- and long-haul is more complicated. In earlier versions of the GHG Conversion Factors it was suggested at a crude level to assign all flights <3700km to short haul and all >3700km to long-haul (on the basis of the maximum range of a Boeing 737). However, this approach was relatively simplistic, difficult to apply without detailed flight distance calculations, and was not completely consistent with CAA statistical dataset used to define the emission factors. The current preferred definition is to assume that all fights to 'Europe' (or those of similar distance, up to a 3,700km maximum) are short-haul, and those that are to non-European destinations (or for flights over 3,700km) should be counted as long-haul. Some examples of such 'long-haul' flights have been provided in the following Table 25 below (as previously provided within the 2012 Annexes in the old format), updated with the most recent (2014) CAA statistical dataset. The methodology/basis has been unchanged since 2013, and it is up to users of the GHG Conversion Factors to use their best judgement on which category to allocate particular flights into.

Area	Destination Airport	Distance, km
Short-haul		
Europe	Amsterdam, Netherlands	400
Europe	Prague (Ruzyne), Czech Rep	1,000
Europe	Malaga, Spain	1,700
Europe	Athens, Greece	2,400
Average (CAA statistics)		***1,227***
Long-haul		
North Africa	Abu Simbel/Sharm El Sheikh, Egypt	3,300
Southern Africa	Johannesburg/Pretoria, South Africa	9,000
Middle East	Dubai, UAE	5,500
North America	New York (JFK), USA	5,600
North America	Los Angeles California, USA	8,900
South America	Sao Paulo, Brazil	9,400
Indian sub-continent	Bombay/Mumbai, India	7,200
Far East	Hong Kong	9,700
Australasia	Sydney, Australia	17,000
Average (CAA statistics)		***5,107***

Notes: Distances based on International Passenger Survey (Office for National Statistics) calculations using airport geographic information. Average distances calculated from CAA statistics for all flights to/from the UK in 2013.

Table 25: Illustrative short- and long- haul flight distances from the UK

Taking Account of Freight

8.2. 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.

8.3. 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 26:

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.

Freight Weighting: Mode	None		Option 1: Direct		Option 2: Equivalent	
	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%	145.5	99.4%	144.4	99.4%	144.4
Short-haul flights	100.0%	83.9	98.0%	82.3	98.0%	82.3
Long-haul flights	100.0%	116.0	67.7%	78.1	83.0%	96.0

Table 26: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2015 GHG Conversion Factors

8.4. 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/freighter configurations account for the vast majority (99% of tkm) of long-haul freight services (and over 90% of all tkm for dedicated freight services). In comparing the freight capacities of the cargo configuration compared to passenger configurations we may assume that the difference represents the tonne capacity for passenger transport. This 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. The derived average weight per passenger seat used in the calculations for the 2015 GHG Conversion Factors is around 266 kg. This is almost 3 times the weight per passenger and their luggage alone. In the **Option 2** methodology the derived ratio of 2.66 is used to upscale the CAA passenger tonne km data, increasing this as a percentage of the total tonne km – as shown in Table 26.

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

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

8.7. Under the previous methodology it had been necessary to provide an additional uplift to the emission factors calculated using data from the EMEP/CORINAIR Emissions Inventory Guidebook (EIG 2007)[48]. This was due to perceived underestimation of emissions from key aircraft types. It has not been necessary to apply any uplifts to the emission factors calculated using the EUROCONTROL small emitters tool, as validation checks using the derived emission factors and CAA flights data have shown a very close comparison in derived CO_2 emissions with those from the UK GHG Inventory (which is scaled using actual fuel supplied).

8.8. The final average emission factors for aviation are presented in Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

8.9. Table 27. The figures in Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

8.10. Table 27 DO NOT include the 8% uplift for Great Circle distance NOR the uplift to account for additional impacts of radiative forcing which are applied to the emission factors provided in the 2015 GHG Conversion Factor data tables.

Mode	Factors for 2015	
	Load Factor%	gCO_2 /pkm
Domestic flights	67.8%	144.4
Short-haul flights	78.8%	82.3
Long-haul flights	76.7%	96.0

Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

Table 27: Final average CO_2 emission factors for passenger flights for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

[48] Available at the EEA website at: http://www.eea.europa.eu//publications/emep-eea-emission-inventory-guidebook-2009

Seating Class Factors

8.11. 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.

8.12. At the moment there is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, for the 2008 update a review was carried out of the seating configurations from a selection of 16 major airlines[49] and average seating configuration information from Boeing and Airbus websites. 24 different aircraft variants were considered including those from the Boeing 737, 747, 757, 767 and 777 families, and the Airbus A319/320, A330 and A340 families. These represent a mix of the major representative short-, medium- and long- haul aircraft types. The different seating classes were assessed on the basis of the space occupied relative to an economy class seat for each of the airline and aircraft configurations. This evaluation was used to form a basis for the seating class based emission factors provided in Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

8.13. Table 28. 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[50], UK-AIR.NET[51], FlightComparison[52] and SeatMaestro[53]).

8.14. For long-haul flights, the relative space taken up by premium seats can vary by a significant degree between airlines and aircraft types. The variation is at its most extreme for First class seats, which can account for from 3 to over 6 times[54] the space taken up by the basic economy seating. Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

8.15. Table 28 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

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[49] The list of airline seating configurations was selected on the basis of total number of passenger km from CAA statistics, supplemented by additional non-UK national carriers from some of the most frequently visited countries according to the UK's International Passenger Survey. The list of airlines used in the analysis included: BA, Virgin Atlantic, Continental Airlines, Air France, Cathay Pacific, Gulf Air, Singapore Airlines, Emirates, Lufthansa, Iberia, Thai Airways, Air New Zealand, Air India, American Airlines, Air Canada, and United Airlines.

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

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

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

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

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

scaling is to lower the economy seating emission factor in relation to the average, and increase the business and first class factors.

Flight type	Cabin Seating Class	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**67.8%**	**144.4**	**1.00**	**100.0%**	**100.0%**
Short-haul	**Average**	**78.8%**	**82.3**	**1.02**	**100.0%**	**100.0%**
	Economy class	78.8%	80.6	1.00	98.0%	96.7%
	First/Business class	78.8%	121.0	1.50	147.0%	3.3%
Long-haul	**Average**	**76.7%**	**96.0**	**1.31**	**100.0%**	**100.0%**
	Economy class	76.7%	73.6	1.00	76.6%	80.0%
	Economy+ class	76.7%	117.7	1.60	122.6%	3.0%
	Business class	76.7%	213.4	2.90	222.1%	12.0%
	First class	76.7%	294.3	4.00	306.4%	5.0%

Notes: Load factors based on data provided by DECC that contains detailed analysis of CAA 2013 statistical returns

Table 28: Seating class based CO_2 emission factors for passenger flights for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

Freight Air Transport Direct CO_2 Emission Factors

8.16. Freight Air Transport Direct CO_2 Emission Factors 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.

8.17. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2014). These data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts approximately for 70% 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.

8.18. 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

8.19. 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 previous updates. These have been updated for the 2015 update for the GHG Conversion Factors – presented in Notes: *Load factors based on Annual UK Airlines Statistics by Aircraft Type – CAA 2012 (Equivalent 2013 dataset was unavailable due to changes to CAA's confidentiality rules)*

8.20. Table 29. As with the passenger aircraft methodology the factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2015 GHG Conversion Factor data tables.

Mode	Revised factors for 2015	
	Load Factor%	$kgCO_2$ /tkm

Domestic flights	44.83%	2.66
Short-haul flights	71.78%	1.12
Long-haul flights	73.75%	0.42

Notes: Load factors based on Annual UK Airlines Statistics by Aircraft Type – CAA 2012 (Equivalent 2013 dataset was unavailable due to changes to CAA's confidentiality rules)

Table 29: Revised average CO_2 emission factors for dedicated cargo flights for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

8.21. The updated factors have been calculated in the same basic methodology as for the passenger flights, which has been updated this year to use the aircraft specific fuel consumption /emission factors calculated using the EUROCONTROL small emitters tool[55]. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 30. The key features of the calculation methodology, data and assumptions for the 2008 and all 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 2014 (the latest available complete dataset).

	Average Cargo Capacity, tonnes	Av. Load Factor	Proportion of tonne km	EF, kgCO_2 /vkm	Av. flight length, km
Domestic Flights					
BAE ATP	8.0	47%	57.2%	6.56	257.37
BAE 146-200/QT	10.0	34%	13.2%	12.32	605.20
Boeing 737-300	15.2	45%	25.7%	28.38	149.49
Boeing 757-200	23.2	56%	3.1%	22.04	151.82
Boeing 747-8 (freighter)	126.9	19%	0.0%	0.00	0.00
Lockheed L188 Electra	11.6	39%	0.9%	12.90	215.37
Total	***10.60***	***45%***	***100%***	***11.37***	***379.47***
Short-haul Flights					
BAE ATP	8.0	43%	2.9%	5.47	559.91
Boeing 757-200	22.0	77%	87.9%	18.12	734
Boeing 747-400F	103.0	10%	0.0%	0.00	0.00
Boeing 747-8 (freighter)	124.3	33%	9.0%	59.16	725.20

[55] The EUROCONTROL small emitters tool is available at: https://www.eurocontrol.int/articles/small-emitters-tool

	Average Cargo Capacity, tonnes	Av. Load Factor	Proportion of tonne km	EF, kgCO₂ /vkm	Av. flight length, km
Lockheed L188 Electra	11.9	51%	0.3%	10.16	536.95
Total	***30.7***	***72%***	***100%***	***17.83***	***1,432***
Long-haul Flights					
BAE ATP	8.0	15.8%	0.0%	5.74	434.51
Boeing 757-200	21.6	78.8%	7.1%	15.93	1,269
Boeing 747-400F	111.5	118.8%	0.0%	0.00	0
Boeing 747-8 (freighter)	129.4	73.4%	92.9%	36.49	5,449
Total	***121.8***	***74%***	***100%***	***30.11***	***4,381***

Notes: Figures on cargo, load factors, % tkm and av. flight length have been calculated from 2014 CAA statistics for UK registered airlines for different aircraft. Figures of $kgCO_2$/vkm were calculated using the average flight lengths in the EUROCONTROL small emitters tool.

Table 30: Assumptions used in the calculation of average CO_2 emission factors for dedicated cargo flights for the 2015 GHG Conversion Factors

Emission Factors for Freight on Passenger Services

8.22. 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 31 with the two different allocation options for long-haul services. The factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2015 GHG Conversion Factor data tables (discussed later).

Freight Weighting: Mode	% Total Freight tkm		Option 1: Direct		Option 2: Equivalent	
	Passenger Services (PS)	Cargo Services	PS Freight tkm, % total	Overall kgCO₂ /tkm	PS Freight tkm, % total	Overall kgCO₂ /tkm
Domestic flights	3.3%	96.7%	0.6%	2.64	0.6%	2.64
Short-haul flights	22.2%	77.8%	2.0%	1.12	2.0%	1.12
Long-haul flights	68.7%	31.3%	32.3%	0.86	17.0%	0.62

Table 31: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

8.23. It is useful to compare the emission factors calculated for freight carried on passenger services (in Table 31) with the equivalent factors for freight carried on dedicated cargo services[56] (in Notes: *Load factors based on Annual UK Airlines Statistics by Aircraft Type – CAA 2012 (Equivalent 2013 dataset was unavailable due to changes to CAA's confidentiality rules)*

8.24. Table 29). 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 31 is around 2.6 times the comparable figure given in Notes: *Load factors based on Annual UK Airlines Statistics by Aircraft Type – CAA 2012 (Equivalent 2013 dataset was unavailable due to changes to CAA's confidentiality rules)*

8.25. Table 29 for **Option 1**, but is much closer to (around 50% higher than) 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 2.6 times as much CO_2 being emitted than if the same freight was carried on a cargo/freighter 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.

8.26. **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

8.27. The following Notes: % Total Air Freight tkm based on CAA statistics for 2013 (T0.1.6 All Services)

8.28. Table 32 presents the final average air freight emission factors for all air freight for the 2015 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. The factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2015 GHG Conversion Factor data tables (discussed later).

Mode	% Total Air Freight tkm		All Air Freight kgCO_2/tkm
	Passenger Services	Cargo Services	
Domestic flights	3.28%	96.72%	2.64
Short-haul flights	22.17%	77.83%	1.12
Long-haul flights	68.70%	31.30%	0.62

Notes: % Total Air Freight tkm based on CAA statistics for 2013 (T0.1.6 All Services)

Table 32: Final average CO_2 emission factors for all air freight for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

56 Although freight only flights generally adjust course less frequently in order to avoid turbulence.

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

8.29. Total emissions of CO_2, CH_4 and N_2O are calculated in detail and reported at an aggregate level for aviation as a whole are reported from the UK GHG inventory. Therefore the relative proportions of total CO_2 and CH_4 emissions from the UK GHG inventory for 2013 (see Table 33) were used to calculate the specific CH_4 emission factors per passenger km or tonne-km relative to the corresponding CO_2 emission factors. The resulting air transport emission factors for the 2015 GHG Conversion Factors are presented in Table 34 for passengers and Table 35 for freight.

2012	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	1.80	98.99%	0.0007	0.04%	0.02	0.97%
Aircraft - international	31.91	99.02%	0.0017	0.01%	0.31	0.97%

Table 33: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2013

Emissions of N_2O

8.30. Similar to those for CH_4, emission factors for N_2O per passenger-km or tonne-km were calculated on the basis of the relative proportions of total CO_2 and N_2O emissions from the UK GHG inventory for 2013 (see Table 33), and the corresponding CO_2 emission factors. The resulting air transport emission factors for the 2015 GHG Conversion Factors are presented in Table 34 for passengers and Table 35 for freight. The factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2015 GHG Conversion Factor data tables (discussed later).

Air Passenger Mode	Seating Class	CO_2 gCO_2/pkm	CH_4 gCO_2e/pkm	N_2O gCO_2e/pkm	Total GHG gCO_2e/pkm
Domestic flights	**Average**	**144.4**	**0.06**	**1.42**	**145.9**
Short-haul flights	**Average**	**82.3**	**0.00**	**0.81**	**83.1**
	Economy	80.6	0.00	0.79	81.4
	First/Business	121.0	0.01	1.19	122.2
Long-haul flights	**Average**	**96.0**	**0.01**	**0.95**	**97.0**
	Economy	73.6	0.00	0.72	74.3
	Economy+	117.7	0.01	1.16	118.9
	Business	213.4	0.01	2.10	215.5
	First	294.3	0.02	2.90	297.2

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 all air passenger transport for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

Air Freight Mode	CO_2 $kgCO_2/tkm$	CH_4 $kgCO_2e/tkm$	N_2O $kgCO_2e/tkm$	Total GHG $kgCO_2e/tkm$
Passenger Freight				
Domestic flights	2.01453	0.00080	0.01983	2.03516
Short-haul flights	1.11251	0.00006	0.01095	1.12353
Long-haul flights	0.70966	0.00004	0.00699	0.71668
Dedicated Cargo				
Domestic flights	2.64229	0.00105	0.02601	2.66935
Short-haul flights	1.12124	0.00006	0.01104	1.13233
Long-haul flights	0.62028	0.00003	0.00611	0.62642
All Air Freight				
Domestic flights	2.64229	0.00105	0.02601	2.66935
Short-haul flights	1.12124	0.00006	0.01104	1.13233
Long-haul flights	0.62028	0.00003	0.00611	0.62642

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

Table 35: Final average CO_2, CH_4 and N_2O emission factors for air freight transport for 2015 GHG Conversion Factors (excluding distance and RF uplifts)

Indirect/WTT Emission Factors from Air Transport

8.31. Indirect/WTT 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/WTT emission factors were derived using simple ratios of the direct CO_2 EFs and the indirect/WTT EFs for aviation turbine fuel (kerosene) and the corresponding direct CO_2 EFs for air passenger and air freight transport in sections “Business travel – air” and “Freighting goods”.

Other Factors for the Calculation of GHG Emissions

Great Circle Flight Distances

8.32. 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.

8.33. A 9% uplift factor has previously been 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. Recent analysis for DfT has suggested that a lower uplift of 8% is more appropriate for flights arriving and departing from the UK and this is the factor being used since the 2014 update, and in the 2015 GHG Conversion Factors.

8.34. 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 8% 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 already to the emission factors presented in the 2015 GHG Conversion Factors tables.

Non-CO_2 impacts and Radiative Forcing

8.35. The emission factors provided in the 2015 GHG Conversion Factors sections “Business travel – air” and “Freighting goods” 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 accounted for by applying a multiplier in some cases.

8.36. 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.

8.37. 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.

8.38. 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 36 and the GWP_{100} figure (consistent with UNFCCC reporting convention) from the ATTICA research presented in Table 37 below[57] and in analysis by Lee et al (2009) reported on by the Committee on Climate Change (2009)[58].

From CCC (2009): *"The recent European Assessment of Transport Impacts on Climate Change and Ozone Depletion (ATTICA, http://ssa-attica.eu) was a series of integrated studies investigating atmospheric effects and applicable climate metrics for aviation, shipping and land traffic. Results have been published which provide metrics to compare the different effects across these sectors in an objective way, including estimates of Global Warming Potentials (GWPs) and Global Temperature Potentials (GTPs) over different time horizons (20, 50 and 100 years). [*Table 37*] shows the 20-year and 100-year GWPs, plus 100-year GTPs, for each forcing agent from aviation. Based on estimates of fuel usage and emission indices for 2005, the emission equivalent of each agent for these metrics is given on the right, and on the bottom right is the overall ratio of total* CO_2*-equivalent emissions to* CO_2 *emissions for aviation in 2005.*

8.39. It is important to note that **the value of this 1.9 multiplier is subject to significant uncertainty** and should only be applied to the CO_2 component of direct emissions (i.e. not also to the CH_4 and N_2O emissions components). The 2015 GHG Conversion Factors now provide separate emission factors including this radiative forcing uplift in separate tables in sections "Business travel – air" and "Freighting goods"

		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

Table 36: Impacts of radiative forcing according to R. Sausen et al. (2005)

[57] 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

[58] CCC (2009). Meeting the UK Aviation target – options for reducing emissions to 2050, http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/

	Metric values			CO_2e emissions ($MtCO_2e/yr$) for 2005			LOSU
	GWP_{20}	GWP_{100}	GTP_{100}	GWP_{20}	GWP_{100}	GTP_{100}	
CO_2	1	1	1	641	641	641	High
Low NOx	120	-2.1	-9.5	106	-1.9	-8.4	Very low
High NOx	470	71	7.6	415	63	6.7	Very low
Water vapour	0.49	0.14	0.02	123	35	5.0	–
Sulphate	-140	-40	-5.7	-25	-7	-1.0	–
Black carbon	1600	460	64	10	2.8	0.38	–
Contrail	0.74	0.21	0.03	474	135	19	Low
AIC	2.2	0.63	0.089	1410	404	57	Very low
				CO_2e/CO_2 emissions for 2005			
Low NOx, inc. AIC				4.3	1.9	1.1	Very low
High NOx, inc. AIC				4.8	2.0	1.1	Very low
Low NOx, exc. AIC				2.1	1.3	1.0	Very low
High NOx, exc. AIC				2.6	1.4	1.0	Very low

Source: Adapted by CCC (2009) from Lee et al. (2009) Transport impacts on atmosphere and climate; Aviation, *Atmospheric Environment*. The level of scientific understanding (LOSU) is given for each process in the right column. Values are presented for both high and low GWP values for NOx reflecting the wide uncertainties in current estimates. The ratios on the bottom right are presented both including and excluding aviation induced cloudiness (AIC) because of uncertainties both in estimates of the magnitude of this effect and in the future incidence of AIC due to air traffic. The different time horizons illustrate how a unit emission of CO_2 increases in importance relative to shorter-lived effects as longer timescales are considered.

Notes: GWP = Global Warming Potential, GTP = Global Temperature Potential

Table 37: Findings of ATTICA project

9. Bioenergy and Water

Summary of changes since the previous update

9.1. There have been two changes made to bioenergy conversion factors in the 2015 update to improve the accuracy of reporting (and in response to requests):

a. First, the addition of two well to tank (WTT)-bioenergy conversion factors (Scope 3) for biodiesel sourced from used cooking oil (UCO) and tallow.

b. The addition of two outside of scopes conversion factors for biodiesel sourced from used cooking oil and tallow is the second amendment.

9.2. All other factors have been updated with more recent data in the latest 2015 GHG Conversion Factors.

General Methodology

9.3. The 2015 GHG Conversion Factors provides tables of emission factors for water supply and treatment, biofuels, and for biomass and biogas.

9.4. 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. Indirect/WTT emissions factors are also presented for biofuels/biomass/biogas which are directly comparable with the total lifecycle (direct + indirect/WTT) emission factors in other tables.

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

Water

9.6. The emission factors for water supply and treatment in sections “Water supply” and “Water treatment” of the 2015 GHG Conversion Factors were sourced from Water UK (for reporting in 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.

9.7. 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 were split between Water supply and Water treatment using the same proportional split from previous years. However, since this publication, Water UK has discontinued its “Sustainability Indicators” report and so no longer produces further updates to these emission factors. Therefore the 2015 update is unchanged since the 2012 GHG Conversion Factors values.

Biofuels

9.8. The emission factors for biofuels were based on UK average factors from the Quarterly Report (2013/14)[59] on the Renewable Transport Fuel Obligation (RTFO). These average factors are presented in Table 38.

9.9. The indirect/WTT/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 the "Fuels" section.

9.10. Biofuels are defined as "net carbon zero" or "carbon neutral" as any CO_2 expelled during the burning of the fuel is cancelled out by the CO_2 absorbed by the feedstock used to produce the fuel during growth. Therefore all direct emissions from biofuels provided in the GHG Conversion Factors dataset are only made up of CH_4 and N_2O emissions whereas the indirect/WTT emissions are based on the RTFO database values.

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	18.780	0.019	0.578	19.38	75.3
Bioethanol	32.590	0.105	0.140	32.84	71.6
Biomethane	13.918	0.085	0.030	14.03	55.408
Biodiesel (from used cooking oil)	14.505	0.019	0.578	15.10	75.3
Biodiesel (from Tallow)	14.184	0.019	0.578	14.78	75.3

Notes:

(1) Based on UK averages from the RTFO Quarterly Report (2013/14) from DfT
(2) Based on corresponding emission factors for diesel, petrol or CNG.
(3) The Total GHG emissions outside of the GHG Protocol Scope 1, 2 and 3 is the actual amount of CO_2 emitted by the biofuel when combusted. This will be counter-balanced by /equivalent to the CO_2 absorbed in the growth of the biomass feedstock used to produce the biofuel. These factors are based on data from BEC (2013)

Table 38: Fuel lifecycle GHG Conversion Factors for biofuels

9.11. 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/WTT emission factors by source/supplier are provided and updated regularly in the Quarterly

[59] These cover the period from April 2013 - April 2014, and were the most recent figures available at the time of production of the 2015 GHG Conversion Factors. The report is available from the DfT website at: http://www.dft.gov.uk/topics/sustainable/biofuels/rtfo/

Reports on the RTFO, available from DfT's website at: https://www.gov.uk/government/organisations/department-for-transport/series/biofuels-statistics

9.12. In addition to the direct and indirect/WTT emission factors provided in Table 38, emission factors for the out of scope CO_2 emissions have also been provided in the 2015 GHG Conversion Factors (see table and the table footnote), based on data sourced from the Biomass Energy Centre (BEC, 2013)[60].

Other biomass and biogas

9.13. 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 the "Bioenergy" section of the 2015 GHG Conversion Factors.

9.14. All emission factors here except for wood logs are sourced from the Ofgem carbon calculators[61], since logs were not covered them. These calculators have been developed to support operators determining the GHG emissions associated with the cultivation, processing and transportation of their biomass fuels.

9.15. Emission factors for wood logs were obtained from the Biomass Energy Centre's (BEC) tool, BEAT2[62], provided by Defra.

9.16. In some cases calorific values were required to convert the data into the required units. These were also sourced from BEC (2013). The values used and their associated moisture contents are provided in Table 39.

9.17. In addition to the direct and indirect/WTT emission factors provided, emission factors for the out of scope CO_2 emissions are also provided in the 2015 GHG Conversion Factors (see "Outside of scopes" and the relevant notes on the page), also based on data from sourced from BEC (2013).

Source	Moisture content	Net calorific value (GJ/tonne)
Wood chips	25% moisture	13.6
Wood logs	Air dried 20% moisture	14.7
Pellets	10% moisture	16.9
Straw	10% moisture	15.1
Miscanthus (grass)	10% moisture	16
Biogas	DECC GHG values - based on 60% CH_4	30

[60] BEC (2013). 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

[61] https://www.ofgem.gov.uk/publications-and-updates/uk-bioliquid-carbon-calculator and https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator

[62] http://www.biomassenergycentre.org.uk/portal/page?_pageid=74,153193&_dad=portal&_schema=PORTAL

Table 39: Fuel sources and properties used in the calculation of biomass and biogas emission factors

10. Overseas Electricity Emission Factors

Summary of changes since the previous update

10.1. There have been no new methodological changes to this section since last year's (2014) update.

Direct Emissions from Overseas Electricity Generation

10.2. 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.

10.3. The dataset on electricity and heat emission factors from the IEA, provided mainly from the IEA website[63], was identified as the best available consistent dataset for electricity emissions factors. These factors are a time series of combined electricity CO_2 emission factors per kWh GENERATED. Therefore they exclude losses from the transmission and distribution grid, which are also accounted for separately in the GHG Conversion Factors dataset.

10.4. The 2015 Conversion Factors have been updated using 2012 country energy balances available at the IEA website[64]. Data on the proportion of electricity[65] (for 2012) is used to estimate the weighted net losses in the distribution of electricity for different countries.

10.5. An example of the format for the Energy Balances data source from the IEA is provided in Table 40 for the UK (columns for other forms of energy have been removed). These data are for 2008. The percentage distribution losses for electricity are calculated from the '*Distribution Losses*' and 'Total Fuel Consumption' (*TFC*) figures from the Energy Balance tables (the net total electricity GENERATED that is supplied to the grid can be calculated from these two figures also).

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[63] Emission factor data is from the International Energy Agency (IEA) Data Services, 2014 for "CO_2 Emissions per kWh from electricity generation" , from the IEA publication "*CO_2 Emissions from Fuel Combustion Highlights (2014 Edition)"*, found here https://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2014.pdf

[64] Energy balances information is available at: http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Balances

[65] Information is available at: http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Electricity/Heat

SUPPLY and CONSUMPTION	Electricity, ktoe
Production	0
Imports	1057
Exports	-109
International Marine Bunkers**	0
Stock Changes	0
TPES	**948**
Transfers	0
Statistical Differences	0
Electricity Plants	30859
CHP Plants	2274
Heat Plants	0
Gas Works	0
Petroleum Refineries	0
Coal Transformation	0
Liquefaction Plants	0
Other Transformation	0
Own Use	-2283
Distribution Losses	-2425
TFC	**29374**
Industry sector	**9766**
Transport sector	**725**
Other sectors	**18883**
Residential	10134
Commercial and Public Services	8399
Agriculture / Forestry	350
Fishing	0
Non-Specified	0
Non-Energy Use	**0**
- of which	
Petrochemical Feedstocks	*0*

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

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

Table 40: 2008 Energy Balances for Electricity for the United Kingdom

[66] Energy balances information is available at: http://www.iea.org/Textbase/stats/prodresult.asp?PRODUCT=Balances

10.6. The emission factors for overseas electricity in “Overseas electricity” of the 2015 GHG Conversion Factors are presented as electricity CO_2 emission factors per kWh GENERATED (i.e. before losses in transmission/distribution). CO_2 emission factors per kWh due to LOSSES in electricity transmission/distribution grids can be found in the “Transmission and distribution” (T&D) part of the GHG conversion factors tables. The T&D LOSSES data can be calculated using the following formulae:

(1) Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) / (1 - %Electricity Total T&D LOSSES)

(2) Emission Factor (Electricity T&D LOSSES) = Emission Factor (Electricity CONSUMED) - Emission Factor (Electricity GENERATED)

10.7. Emission factors have been provided for all EU Member States and major UK trading partners. Additional emission factors for other countries not included in this list can be found at the GHG Protocol website[67], though it should be noted that the figures supplied there do not include losses from transmission and distribution of heat and electricity.

Indirect/WTT Emissions from Overseas Electricity Generation

10.8. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect/WTT emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect/WTT / fuel lifecycle emissions as included in the “Fuel” section). 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.

10.9. Average indirect/WTT emission factors for UK electricity were calculated and included in ”UK electricity” by using the “Fuels” sections indirect/WTT 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 “Overseas electricity”. As an approximation therefore, the indirect/WTT (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%).

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

11. Material Consumption/Use and Waste Disposal

Summary of changes since the previous update

11.1. Two changes have been made to the 2015 material use factors to assist users in interpreting and understanding how to use these factors:

a. It was decided to remove the values in ‘compost source’ (now set as 'N/A') for all factors. In 2014, and earlier updates, these were given values, however it is now thought this was misleading as it is not possible for any of these materials to come from a compost source.

b. The sources “Organic: mixed food and garden waste” and "Organic: garden waste” have been changed to “Compost derived from garden and food waste” and “Compost derived from garden waste” respectively, for clarity. The source name of "Organic: food and drink waste" has also been changed to simply "Food and Drink". In doing this (as mentioned above) the "Compost source" column has been removed from the "Refuse" table as the change in material source means these factors can now be listed as emissions from "Primary material production" only.

11.2. A number of updates have also been made to some of the other factors reflecting more recent source data in the latest 2015 GHG Conversion Factors. These are;

a. Revised data from the European Aluminium Association[68] on the impact of aluminium production, plus an amendment to production of cans.

b. Revisions to the ecoprofiles for a range of plastics by PlasticsEurope[69].

c. Update to paper and card manufacturing emissions[70].

d. Wood data has been updated based on Corrim (2013)[71].

e. The estimate for Methane capture from landfill waste reduced from 70% to 59%[72]. This affects all landfill emissions for organic materials, whilst the quantity of methane generated has been updated in line with the European Life Cycle Database third

[68] European Aluminium Association (2013) Environmental Profile Report for the European Aluminium Industry http://www.alueurope.eu/wp-content/uploads/2011/10/Environmental-Profile-Report-for-the-European-Aluminium-Industry-April-2013.pdf PE Americas (2010) Life Cycle Impact Assessment of Aluminium Beverage Cans http://www.aluminum.org/Content/ContentFolders/LCA/LCA_REPORT.pdf

[69] http://www.plasticseurope.org/plasticssustainability/eco-profiles/browse-by-list.aspx

[70] Procarton (2013) Carbon footprint for cartons http://sustainability.procarton.com/?section=carbon_footprint FEFCO (2012) European database for Corrugated Board Life Cycle Studies http://www.fefco.org/index.php?id=175

[71] http://www.corrim.org/pubs/reports/2013/phase1_updates/index.asp

[72] Webb N, Broomfield M, Buys G, Cardenas L, Murrells T, Pang Y, Passant N, Thistlethwaite G, Watterson J (2014) *UK Greenhouse Gas Inventory, 1990 to 2012: Annual Report for submission under the Framework Convention on Climate Change* http://naei.defra.gov.uk/reports/reports?report_id=789

iteration[73]. The updated change to GWP factors for CH4 and N2O has also created a significant increase in landfill emissions for a range of materials.

f. The composition of mixed municipal waste and mixed C&I waste has been updated, resulting in a change to the associated GHG emissions[74].

Emissions from Material Use and Waste Disposal

11.3. 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')[75] sets down rules on accounting for emissions associated with material consumption and waste management.

11.4. Prior to the 2012 update, 'avoided emissions' from energy recovery and sending materials for recycling had been shown, these 'avoided emissions' are considered outside of the account of the company producing these wastes .They are instead exclusively within the scope of the company using these materials.

11.5. Whereas in previous editions negative carbon numbers were presented to show savings from recycling and energy recovery, all figures presented in the 2012 update onwards are positive, showing only emissions from processing materials with no avoided impacts accounted for. This is line with the Scope 3 Standard.

11.6. 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.

11.7. 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 has previously indicated that separate figures appropriate for informing decision making on waste disposal would be provided in the future. However, these are still pending.

11.8. All figures expressed are kilograms of carbon dioxide equivalent (CO_2e) per tonne of material. This includes the Kyoto protocol basket of greenhouse gases. Please note that biogenic[76] CO_2 has also been excluded from these figures.

11.9. The information for material consumption presented in the GHG Conversion Factor tables has been separated out from the emissions associated with waste disposal in order

[73] ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009 http://eplca.jrc.ec.europa.eu/ELCD3/processList.xhtml;jsessionid=2C1600E1D6A24EE681B458287B6EADEB,

[74] DEFRA (2015) UK Statistics on Waste 2010-12 DEFRA https://www.gov.uk/government/statistical-data-sets/env23-uk-waste-data-and-management

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

[76] 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.

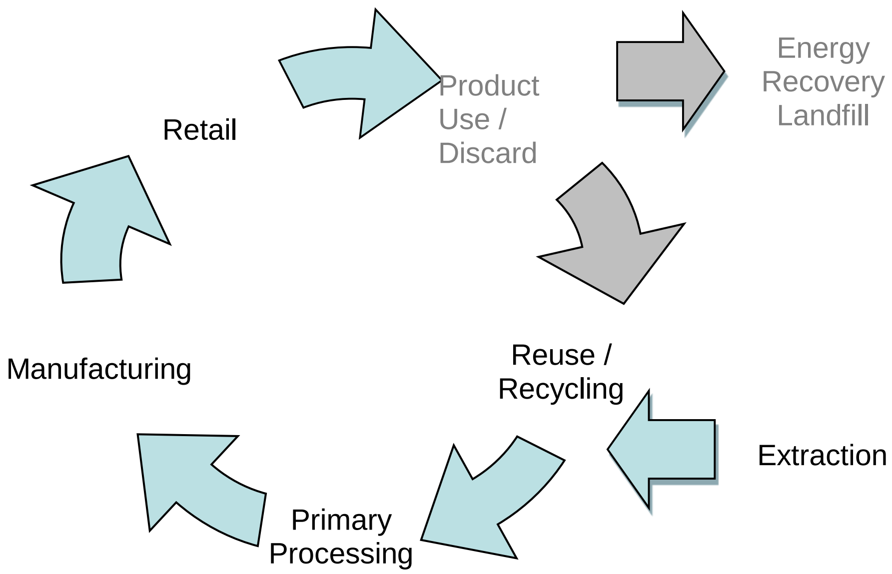
to allow separate reporting of these emission sources, in compliance with the Scope 3 Standard.

11.10. 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.

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

Material Consumption/Use

11.12. Figure 2 shows the boundary of greenhouse gas emissions summarised in the material consumption table.



Notes: Arrows represent transportation stages; greyed items are excluded.

Figure 2: Boundary of material consumption data sets

11.13. 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 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 the tables are confidential we are unable to publish a more detailed breakdown. However, the standard assumptions made are described below.

11.14. 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.

11.15. 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

11.16. 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 Appendix 1 to this report. 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.

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

11.18. Table 41 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. The transportation tables and Greenhouse Gas Protocol[77] guidelines on vehicle emissions have been used for most vehicle emission factors.

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Transport of raw materials to factory	112km	Average, all HGVs	Department for Transport (2009)[78] 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)[79] IGD (2008)[80]

Table 41: Distances and transportation types used in EF calculations

11.19. Transport of goods by consumers is excluded from the factors presented, as is use of the product.

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

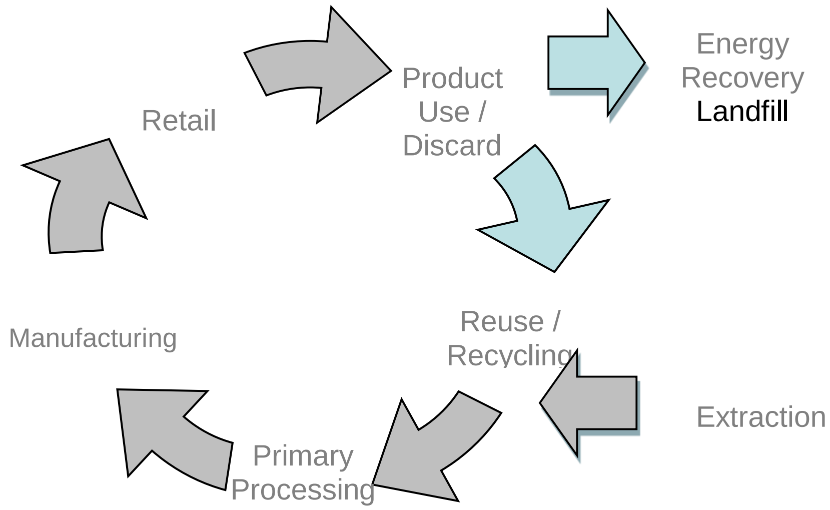
[78] Department for Transport (2009) *Transport Statistics Bulletin: Road Freight Statistics 2008* National Statistics Table 1.14d. Available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/freight/goodsbyroad/roadfreightstatistics2008

[79] 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.greenlogistics.org/SiteResources/77a765d8-b458-4e5f-b9e0-1827e34f2f1f_Review%20of%20Transport%20KPI%20programme%20(WCTR%202007).pdf

[80] IGD (2008) UK Food & Grocery Retail Logistics Overview Date Published: 15/01/2008. Available at: http://www.igd.com/our-expertise/Supply-chain/Logistics/3457/UK-Food--Grocery-Retail-Logistics-Overview/

Waste Disposal

11.20. Figure 3 shows the boundary of greenhouse gas emissions summarised in the waste disposal table.



Notes: Arrows represent transportation stages; greyed items are excluded.

Figure 3: Boundary of waste disposal data sets

11.21. Whereas the 2011 factors covered the whole life cycle of products and materials, the factors presented in the 2012 guidelines onwards 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.

11.22. The final emissions factor data summarised in the tables 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.

11.23. 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.

11.24. Figures for Refuse Collection Vehicles have been taken from the Environment Agency's Waste and Resource Assessment Tool for the Environment (WRATE)[81].

11.25. 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.

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)

Table 42: Distances used in calculation of EFs

11.26. 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)[82]. 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.

11.27. 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[83]. 10% of uncaptured methane is assumed to be oxidised at the cap. Key data sources for waste disposal emissions are identified in Appendix 1.

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

[82] DEFRA (2009). Greenhouse Gas Conversion Factors. Available at: http://archive.defra.gov.uk/environment/business/reporting/pdf/20090928-guidelines-ghg-conversion-factors.pdf

[83] 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

11.28. Emissions from the landfill of different materials are calculated using WRATE and the LandGem model[84]. Methane generation rate constants have been taken from IPCC[85].

12. Fuel Properties

12.1. No new updates were made to the fuel properties section in the 2015 GHG Conversion Factors.

12.2. Information on standard fuel properties of key fuels is also provided in the GHG Conversion Factors for:

a. Gross Calorific Value (GCV) in units of GJ/tonne and kWh/kg

b. Net Calorific Value (NCV) in units of GJ/tonne and kWh/kg

c. Density in units of litres/tonne and kg/m3

12.3. The standard emission factors from the UK GHGI in units of mass have been converted into different energy and volume units for the various data tables using information on these fuel properties (i.e. Gross and Net Calorific Values (CV), and fuel densities in litres/tonne) from DECC's Digest of UK Energy Statistics (DUKES) 2013.[86]

12.4. Fuel properties (GCV, NCV and density) for CNG and most biofuels are predominantly based on data from JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4, 2013 (Report EUR 26028 EN - 2013).[87] The exception is for methyl-ester based biodiesels and bioethanol, where values for NCV and GCV are taken from (DUKES) 2013.

12.5. Fuel properties for various forms of wood bioenergy are based on average information on wood pellets, wood chips, grasses/straw (bales) sourced from the BIOMASS Energy Centre (BEC), which is owned and managed by the UK Forestry Commission, via Forest Research, its research agency.[88]

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

[85] 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/

[86]Available at: https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes

[87] Available at: http://iet.jrc.ec.europa.eu/about-jec/

[88] 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

APPENDIX 1: Additional Methodological Information on the Material Consumption/Use and Waste Disposal Factors

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. 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.

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.

Table 1-1: Data Quality Indications for the waste management GHG factors

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 11. Data on waste management options has been modelled using SimaPro[89] 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 each dataset is explained. The most common data quality issues encountered concerned data age and availability.

[89] SimaPro (2015). Life Cycle Assessment Software. Available at: http://www.lifecycles.com.au/#!simapro/c1il2

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[90]. 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[91] 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.

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.

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[90] WRAP (2006) Environmental Benefits of Recycling and WRAP (2010) Environmental Benefits of Recycling – 2010 update. WRAP; Banbury. Available at: http://www.wrap.org.uk/sites/files/wrap/Executive_summary_Environmental_benefits_of_recycling_-_2010_update.d1af1398.8671.pdf

[91] WRAP (2009) Wood Waste Market in the UK WRAP; Banbury. Available at: http://www.wrap.org.uk/sites/files/wrap/Wood%20waste%20market%20in%20the%20UK.pdf

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 (2013) *Environmental Profile Report for the European Aluminium Industry*, European Aluminium Association PE Americas (2010) Life Cycle Impact Assessment of Aluminium Beverage Cans	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Steel Cans	World Steel Association (2009) World Steel Life Cycle Inventory	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Mixed Cans	Estimate based on aluminium and steel data.	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Glass	PE International (2009) *Life Cycle Assessment of Container Glass in Europe* FEVE; Brussels	

Material	Reference	
	Material Consumption	**Waste Disposal**
Wood	Corrim (2013) *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 ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Aggregates (Rubble)	WRAP CO_2 Emissions Estimator Tool Environment Agency (2007) Construction Carbon Calculator	
Paper	Swiss Centre for Life Cycle Inventories (2014) *Ecoinvent v3.0*	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Books	Estimate based on paper	
Board	FEFCO (2012) *European Database for Corrugated Board Life Cycle Studies*, FEFCO Procarton (2013) *Carbon Footprint for Cartons*, Zurich, Switzerland	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Mixed paper and board	Estimate based on above	
Scrap Metal	British Metals Recycling Association (*website*[92]) Swiss Centre for Life Cycle Inventories (2014) *Ecoinvent v3.0*	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
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

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

Material	Reference	
	Material Consumption	Waste Disposal
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) DEFRA (unpublished) (information on composting impacts) ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Garden Waste	-	
Plastics:		
HDPE, LDPE and LLDPE	Plastics Europe (2014) *Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers High-density Polyethylene (HDPE), Low-density Polyethylene (LDPE), Linear Low-density Polyethylene (LLDPE)* Plastics Europe, Brussels	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
PP (excel forming)	Plastics Europe (2014) *Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polypropylene* (PP). Plastics Europe, Brussels	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
PVC (excel forming)	Boustead (2006) *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)	Plastics Europe (2012) *Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polystyrene (High Impact)* (HIPS). Plastics Europe, Brussels	PWC (2002) *Life Cycle Assessment of Expanded Polystyrene Packaging*, Umps

Material	Reference	
	Material Consumption	**Waste Disposal**
PET (excel forming)	Plastics Europe (2010) *Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polyethylene Terephthalate* (PET). Plastics Europe, Brussels	WRAP (2010) *LCA of Example Milk Packaging Systems*; WRAP, Banbury
Average plastic film (inch bags) Average plastic rigid (inch bottles)	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
Clothing	BIO IS (2009) *Environmental Improvement Potentials of Textiles (IMPRO-Textiles),* EU Joint Research Commission	Farrant (2008) *Environmental Benefit from Reusing Clothes*, ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Footwear	Albers, K., Canapé, P., Miller, J. (2008) *Analysing the Environmental Impacts of Simple Shoes*, University of Santa Barbara, California	
Furniture	WRAP (2015) Benefits of Reuse	
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	Swiss Centre for Life Cycle Inventories (2014) *Ecoinvent v3.0*	-
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 (2014) *Ecoinvent v3.0*	
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

APPENDIX 2: Updated full time series – Electricity and Heat and Steam Factors

The tables below provide the fully updated and consistent time series data for electricity, heat and steam emission factors. This is provided for organisations wishing to use fully consistent time series data for purposes OTHER than for company reporting (e.g. policy analysis).

Data Year	Electricity Generation (1)	Total Grid Losses (2)	UK electricity generation emissions (3), ktonne		
	GWh	%	CO_2	CH_4	N_2O
1990	290,666	**8.08%**	204,440	2.552	5.407
1991	293,743	**8.27%**	201,045	2.390	5.341
1992	291,692	**7.55%**	189,152	2.307	5.023
1993	294,935	**7.17%**	172,553	2.313	4.260
1994	299,889	**9.57%**	168,179	2.427	4.050
1995	310,333	**9.07%**	164,798	2.479	3.889
1996	324,724	**8.40%**	163,966	2.498	3.599
1997	324,412	**7.79%**	151,366	2.385	3.086
1998	335,035	**8.40%**	156,141	2.547	3.172
1999	340,218	**8.25%**	147,874	2.585	2.744
2000	349,263	**8.38%**	159,292	2.747	3.079
2001	358,185	**8.56%**	169,759	2.975	3.393
2002	360,496	**8.26%**	165,244	2.958	3.193
2003	370,639	**8.47%**	174,658	3.065	3.506
2004	367,881	**8.71%**	174,023	3.086	3.388
2005	370,976	**7.25%**	173,614	3.591	3.549
2006	368,313	**7.21%**	182,875	3.696	3.872
2007	365,252	**7.34%**	178,952	3.597	3.568
2008	356,778	**7.43%**	174,144	3.800	3.321
2009	343,403	**7.87%**	152,604	3.694	2.848
2010	348,610	**7.31%**	157,792	3.881	2.963
2011	330,054	**7.78%**	145,261	3.773	2.964
2012	320,470	**8.04%**	158,996	4.166	3.824
2013	308,955	**7.63%**	146,852	4.468	3.595

Notes:

(1) Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES (2014) Table 5.5 Electricity fuel use, generation and supply. The total consistent with UNFCCC emissions reporting categories 1A1a+1A2f includes (according to Table 5.5 categories) GWh supplied (net) from all thermal and non-thermal sources except 'wind and solar'; plus GWh supplied from thermal renewables + coal and gas thermal sources, hydro-natural flow and other non-thermal sources from 'Other generators'.

(2) Based upon calculated net grid losses from data in DUKES (2014) 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 and autogeneration - exported to grid (UK Only) listed under UNFCC reporting category 1A2f from the UK Greenhouse Gas Inventory for 2013 (Ricardo-AEA, 2015)

Table 43: Base electricity generation emissions data - most recent datasets for time series

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports	Imported Electricity EF
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)					
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
1990	0.70335	0.00022	0.00554	0.70911	0.06180	0.00002	0.00049	0.06230	0.76515	0.00024	0.00603	0.77142	**3.85%**	0.11300
1991	0.68443	0.00020	0.00542	0.69005	0.06170	0.00002	0.00049	0.06221	0.74613	0.00022	0.00591	0.75226	**5.18%**	0.12790
1992	0.64847	0.00020	0.00513	0.65380	0.05293	0.00002	0.00042	0.05337	0.70140	0.00021	0.00555	0.70716	**5.29%**	0.10097
1993	0.58506	0.00020	0.00430	0.58955	0.04518	0.00002	0.00033	0.04553	0.63024	0.00021	0.00464	0.63508	**5.25%**	0.06828
1994	0.56081	0.00020	0.00402	0.56503	0.05937	0.00002	0.00043	0.05982	0.62017	0.00022	0.00445	0.62485	**5.22%**	0.06899
1995	0.53104	0.00020	0.00373	0.53497	0.05298	0.00002	0.00037	0.05337	0.58401	0.00022	0.00411	0.58834	**4.97%**	0.07830
1996	0.50494	0.00019	0.00330	0.50843	0.04632	0.00002	0.00030	0.04664	0.55126	0.00021	0.00361	0.55508	**4.80%**	0.08212
1997	0.46659	0.00018	0.00283	0.46960	0.03944	0.00002	0.00024	0.03969	0.50602	0.00020	0.00307	0.50930	**4.76%**	0.07552
1998	0.46604	0.00019	0.00282	0.46906	0.04271	0.00002	0.00026	0.04299	0.50876	0.00021	0.00308	0.51204	**3.51%**	0.10497
1999	0.43464	0.00019	0.00240	0.43724	0.03909	0.00002	0.00022	0.03932	0.47373	0.00021	0.00262	0.47656	**3.94%**	0.09039
2000	0.45608	0.00020	0.00263	0.45890	0.04174	0.00002	0.00024	0.04200	0.49782	0.00021	0.00287	0.50090	**3.82%**	0.08117
2001	0.47394	0.00021	0.00282	0.47697	0.04438	0.00002	0.00026	0.04466	0.51832	0.00023	0.00309	0.52163	**2.78%**	0.06550
2002	0.45838	0.00021	0.00264	0.46122	0.04125	0.00002	0.00024	0.04150	0.49963	0.00022	0.00288	0.50273	**2.24%**	0.07114
2003	0.47124	0.00021	0.00282	0.47426	0.04360	0.00002	0.00026	0.04388	0.51484	0.00023	0.00308	0.51814	**0.57%**	0.07478
2004	0.47304	0.00021	0.00274	0.47599	0.04513	0.00002	0.00026	0.04541	0.51817	0.00023	0.00301	0.52141	**1.97%**	0.07244
2005	0.46799	0.00024	0.00285	0.47109	0.03656	0.00002	0.00022	0.03680	0.50455	0.00026	0.00307	0.50788	**2.16%**	0.08482
2006	0.49652	0.00025	0.00313	0.49991	0.03861	0.00002	0.00024	0.03887	0.53513	0.00027	0.00338	0.53878	**1.97%**	0.07754
2007	0.48994	0.00025	0.00291	0.49310	0.03880	0.00002	0.00023	0.03905	0.52874	0.00027	0.00314	0.53214	**1.37%**	0.08121
2008	0.48810	0.00027	0.00277	0.49114	0.03915	0.00002	0.00022	0.03940	0.52726	0.00029	0.00300	0.53054	**2.91%**	0.07784
2009	0.44439	0.00027	0.00247	0.44713	0.03795	0.00002	0.00021	0.03818	0.48233	0.00029	0.00268	0.48531	**0.80%**	0.08417
2010	0.45263	0.00028	0.00253	0.45544	0.03568	0.00002	0.00020	0.03590	0.48831	0.00030	0.00273	0.49134	**0.73%**	0.08540
2011	0.44011	0.00029	0.00268	0.44307	0.03712	0.00002	0.00023	0.03737	0.47723	0.00031	0.00290	0.48044	**1.76%**	0.06522
2012	0.49613	0.00033	0.00356	0.50001	0.04339	0.00003	0.00031	0.04372	0.53952	0.00035	0.00387	0.54374	**3.40%**	0.06374
2013	0.47532	0.00036	0.00347	0.47915	0.03925	0.00003	0.00029	0.03956	0.51457	0.00039	0.00375	0.51871	**4.10%**	0.06374

Notes: The dataset above uses the most recent, consistent data sources across the entire time series.

Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) / (1 - %Electricity Total Grid LOSSES)

Emission Factor (Electricity LOSSES) = Emission Factor (Electricity CONSUMED) - Emission Factor (Electricity GENERATED)

⇒ Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES),

Table 44: Base electricity generation emission factors (excluding imported electricity) – fully consistent time series dataset

Data Year	Emission Factor, kgCO₂e / kWh												% Net Electricity Imports	Imported Electricity EF
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)					
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	kgCO₂e / kWh
1990	0.68063	0.00021	0.00536	0.68620	0.05980	0.00002	0.00047	0.06029	0.74043	0.00023	0.00584	0.74650	**3.85%**	0.11300
1991	0.65562	0.00019	0.00519	0.66101	0.05911	0.00002	0.00047	0.05959	0.71473	0.00021	0.00566	0.72060	**5.18%**	0.12790
1992	0.61948	0.00019	0.00490	0.62457	0.05057	0.00002	0.00040	0.05098	0.67005	0.00020	0.00530	0.67555	**5.29%**	0.10097
1993	0.55793	0.00019	0.00410	0.56223	0.04309	0.00001	0.00032	0.04342	0.60102	0.00020	0.00442	0.60564	**5.25%**	0.06828
1994	0.53515	0.00019	0.00384	0.53919	0.05665	0.00002	0.00041	0.05708	0.59181	0.00021	0.00425	0.59627	**5.22%**	0.06899
1995	0.50854	0.00019	0.00358	0.51231	0.05073	0.00002	0.00036	0.05111	0.55927	0.00021	0.00393	0.56341	**4.97%**	0.07830
1996	0.48465	0.00018	0.00317	0.48800	0.04446	0.00002	0.00029	0.04477	0.52911	0.00020	0.00346	0.53277	**4.80%**	0.08212
1997	0.44797	0.00018	0.00272	0.45087	0.03786	0.00001	0.00023	0.03811	0.48584	0.00019	0.00295	0.48898	**4.76%**	0.07552
1998	0.45337	0.00018	0.00274	0.45630	0.04155	0.00002	0.00025	0.04182	0.49492	0.00020	0.00300	0.49812	**3.51%**	0.10497
1999	0.42110	0.00018	0.00233	0.42361	0.03787	0.00002	0.00021	0.03810	0.45897	0.00020	0.00254	0.46170	**3.94%**	0.09039
2000	0.44177	0.00019	0.00254	0.44451	0.04043	0.00002	0.00023	0.04068	0.48220	0.00021	0.00278	0.48519	**3.82%**	0.08117
2001	0.46260	0.00020	0.00276	0.46556	0.04331	0.00002	0.00026	0.04359	0.50592	0.00022	0.00301	0.50915	**2.78%**	0.06550
2002	0.44969	0.00020	0.00259	0.45248	0.04046	0.00002	0.00023	0.04071	0.49016	0.00022	0.00282	0.49320	**2.24%**	0.07114
2003	0.46897	0.00021	0.00281	0.47199	0.04339	0.00002	0.00026	0.04367	0.51237	0.00022	0.00307	0.51566	**0.57%**	0.07478
2004	0.46516	0.00021	0.00270	0.46807	0.04438	0.00002	0.00026	0.04466	0.50954	0.00023	0.00296	0.51273	**1.97%**	0.07244
2005	0.45971	0.00024	0.00280	0.46275	0.03591	0.00002	0.00022	0.03615	0.49562	0.00026	0.00302	0.49890	**2.16%**	0.08482

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports	Imported Electricity EF
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)					
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL	$kgCO_2e$ / kWh
2006	0.48826	0.00025	0.00308	0.49159	0.03797	0.00002	0.00024	0.03822	0.52623	0.00027	0.00332	0.52981	**1.97%**	0.07754
2007	0.48432	0.00024	0.00288	0.48744	0.03835	0.00002	0.00023	0.03860	0.52267	0.00026	0.00311	0.52604	**1.37%**	0.08121
2008	0.47614	0.00026	0.00271	0.47911	0.03819	0.00002	0.00022	0.03843	0.51434	0.00028	0.00292	0.51754	**2.91%**	0.07784
2009	0.44151	0.00027	0.00246	0.44423	0.03770	0.00002	0.00021	0.03793	0.47921	0.00029	0.00266	0.48217	**0.80%**	0.08417
2010	0.44995	0.00028	0.00252	0.45274	0.03547	0.00002	0.00020	0.03569	0.48541	0.00030	0.00272	0.48843	**0.73%**	0.08540
2011	0.43351	0.00028	0.00264	0.43643	0.03656	0.00002	0.00022	0.03681	0.47007	0.00031	0.00286	0.47324	**1.76%**	0.06522
2012	0.48142	0.00032	0.00345	0.48518	0.04210	0.00003	0.00030	0.04243	0.52351	0.00034	0.00375	0.52761	**3.40%**	0.06374
2013	0.45844	0.00035	0.00334	0.46213	0.03785	0.00003	0.00028	0.03816	0.49629	0.00038	0.00362	0.50029	**4.10%**	0.06374

Notes: The dataset above uses the most recent, consistent data sources across the entire time series.

Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) / (1 - %Electricity Total Grid LOSSES)

Emission Factor (Electricity LOSSES) = Emission Factor (Electricity CONSUMED) - Emission Factor (Electricity GENERATED)

$\Rightarrow$ Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES)

Table 45: Base electricity generation emissions factors (including imported electricity) – fully consistent time series dataset

Data 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	0.23894	0.26422	0.07091	0.23533	0.2031	0.44961
2002	0.22997	0.25387	0.07227	0.23858	0.20926	0.432
2003	0.23243	0.26066	0.04894	0.23235	0.19986	0.44355
2004	0.22661	0.25542	0.0536	0.23998	0.20757	0.43464
2005	0.22	0.24686	0.05091	0.23818	0.20929	0.42007
2006	0.2293	0.25386	0.06184	0.25521	0.22928	0.43199
2007	0.23003	0.25364	0.04027	0.24322	0.21977	0.43162
2008	0.22418	0.2472	0.04011	0.23527	0.21209	0.42065
2009	0.22109	0.24468	0.04489	0.23904	0.21531	0.41636
2010	0.21778	0.24012	0.05838	0.24379	0.2207	0.40861
2011	0.26062	0.27424	0.08711	0.26071	0.24454	0.46666
2012	0.21132	0.23958	0.06161	0.2386	0.20669	0.40768
2013	0.20763	0.23209	0.05824	0.22293	0.19476	0.39495

Table 46: Comparison of calculated Electricity and Heat/Steam CO_2 emission factors for the 3 different allocation method – fully consistent time series dataset

APPENDIX 3: Summary and Explanation of Major Changes to Emission Factors Compared to the 2013 GHG Conversion Factors

The following table provides a summary of major changes (i.e. greater than 10% change) in emission factors for the 2015 GHG Conversion Factors, compared to the equivalent factors provided in the 2013 GHG Conversion Factors, and a short explanation for the reason for the change.

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
Fuels							
1	CNG	CH_4 and N_2O	Tonnes and kWh	-10% to -11%	All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.	Section 2	/
2	LNG	CH_4 and N_2O	All	-10% to -11%	As above	Section 2	/
3	LPG	CH_4	All	166% to 170%	As above	Section 2	/
4		N_2O		10% to 11%	As above	Section 2	/
5	Natural gas	N_2O	Tonnes and kWh	-10% to -11%	As above	Section 2	/

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
6	Other petroleum gas	CH_4	Tonnes and kWh	-49% to -50%	As above	Section 2	/
7		N_2O		-10% to -18%	As above	Section 2	/
8	Aviation spirit	CH_4	All	25% to 26%	As above	Section 2	/
9	Aviation turbine fuel	CH_4	All	11%	As above	Section 2	/
10	Burning oil	CH_4	All	16% to 17%	As above	Section 2	/
11	Gas oil	CH_4	All	14% to 16%	As above	Section 2	/
12	Lubricants	CH_4	kWh and tonnes	66% to 70%	As above	Section 2	/
13		N_2O	kWh	-10%	As above	Section 2	/
14	Naphtha	CH_4	kWh and tonnes	25% to 27%	As above	Section 2	/
15	Petrol (average biofuel blend)	CH_4	All	12% to 15%	As above	Section 2	/
16		N_2O		-11% to -13%	As above	Section 2	/
17	Petrol (100% mineral petrol)	CH_4	All	13% to 15%	As above	Section 2	/
18		N_2O		-12% to -13%	As above	Section 2	/
19	Processed fuel oils - distillate oil	CH_4	kWh and tonnes	14% to 16%	As above	Section 2	/
20	Refinery miscellaneous	CH_4	kWh	24% to 26%	As above	Section 2	/
21	Waste oils	CH_4	kWh and tonnes	16% to 19%	As above	Section 2	/
22		N_2O		503%	For waste oils, the methodology was reviewed and updated, in line with the new GL as well.	Section 2	/

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
23	Coal (industrial)	CH_4	kWh and tonnes	19% to 20%	All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.	Section 2	/
24		N_2O		17% to 18%	As above	Section 2	/
25	Coal (electricity generation)	CH_4	kWh and tonnes	15% to 21%	As above	Section 2	/
26		N_2O		-4%	As above	Section 2	/
27	Coal (electricity generation - home produced coal only)	CH_4	kWh and tonnes	17% to 27%	As above	Section 2	/
28		N_2O		-3% to -4%	As above	Section 2	/
29	Coal (domestic)	CH_4	kWh and tonnes	19% to 22%	As above	Section 2	/
30		N_2O		-4%	As above	Section 2	/
31	Coking coal	CH_4 and N_2O	kWh and tonne	23% and -4% respectively	As above	Section 2	/
32	Petroleum coke	CH_4	kWh and tonnes	26% to 28%	As above	Section 2	/
33		N_2O		-72%	As above	Section 2	/
WTT- fuels (former Annex 1 tables)							
No significant changes							

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
Bioenergy							
34	Biomethane	CO_2e	GJ and kg	-10%	As above	Section 9	*I*
35	Biodiesel (from UCO)	CO_2e	All	n/a	New factor added	Section 9	*II*
36	Biodiesel (from Tallow)	CO_2e	All	n/a	As above	Section 9	*II*
37	Wood logs	CO_2e	All	12%	All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.	Section 9	*I*
38	Wood chips	CO_2e	kWh	12%	As above	Section 9	*I*
39	Wood pellets	CO_2e	Tonnes and kWh	11% and 12% respectively	As above	Section 9	*I*
40	Grass/straw	CO_2e	Tonnes and kWh	26% and 14% respectively	As above	Section 9	*I*
WTT - Bioenergy							
41	Biodiesel	CO_2e	All	14%	Difference in the Renewable Transport Fuels Obligation (RTFO) figures between years this year and the previous year, caused by a change I the carbon intensity of the fuels.	Section 9	*III*
42	Biomethane	CO_2e	All	-55%	As above	Section 9	*III*
43	Biodiesel (from UCO)	CO_2e	All	n/a	New factor added	Section 9	*IV*
44	Biodiesel (from Tallow)	CO_2e	All	n/a	As above	Section 9	*IV*
Outside of scopes							

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	***Major changes ref for more detail***
45	Diesel (average biofuel blend)	CO_2e	All	38%	Change due to difference in DUKES data, causing an increase in the average percentage biofuel blend. This is due to an increase in biofuel sales versus conventional fuel sales	Section 9	*V*
46	Biodiesel (from UCO)	CO_2e	All	n/a	New factor added	Section 9	*IV*
47	Biodiesel (from Tallow)	CO_2e	All	n/a	As above	Section 9	*IV*
Refrigerant & other							
48	Methane	CO_2e	kg	19%	Updated in line with 4th IPCC assessment report (AR4).	Section 4	*VI*
49	HFC-23	CO_2e	kg	26%	As above	Section 4	*VI*
50	HFC-41	CO_2e	kg	-39%	As above	Section 4	*VI*
51	HFC-125	CO_2e	kg	25%	As above	Section 4	*VI*
52	HFC-143	CO_2e	kg	18%	As above	Section 4	*VI*
53	HFC-143a	CO_2e	kg	18%	As above	Section 4	*VI*
54	HFC-152a	CO_2e	kg	-11%	As above	Section 4	*VI*
55	HFC-227ea	CO_2e	kg	11%	As above	Section 4	*VI*
56	HFC-236fa	CO_2e	kg	56%	As above	Section 4	*VI*
57	HFC-245fa	CO_2e	kg	84%	As above	Section 4	*VI*
58	HFC-43-I0mee	CO_2e	kg	26%	As above	Section 4	*VI*
59	Perfluoromethane (PFC-14)	CO_2e	kg	14%	As above	Section 4	*VI*
60	Perfluoroethane (PFC-116)	CO_2e	kg	33%	As above	Section 4	*VI*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
61	Perfluoropropane (PFC-218)	CO_2e	kg	26%	As above	Section 4	*VI*
62	Perfluorocyclobutane (PFC-318)	CO_2e	kg	18%	As above	Section 4	*VI*
63	Perfluorobutane (PFC-3-1-10)	CO_2e	kg	27%	As above	Section 4	*VI*
64	Perfluoropentane (PFC-4-1-12)	CO_2e	kg	22%	As above	Section 4	*VI*
65	Perfluorohexane (PFC-5-1-14)	CO_2e	kg	26%	As above	Section 4	*VI*
66	R404A	CO_2e	kg	20%	As above	Section 4	*VI*
67	R407A	CO_2e	kg	19%	As above	Section 4	*VI*
68	R407C	CO_2e	kg	16%	As above	Section 4	*VI*
69	R407F	CO_2e	kg	17%	As above	Section 4	*VI*
70	R408A	CO_2e	kg	13%	As above	Section 4	*VI*
71	R410A	CO_2e	kg	21%	As above	Section 4	*VI*
72	R507	CO_2e	kg	21%	As above	Section 4	*VI*
73	R508B	CO_2e	kg	29%	As above	Section 4	*VI*
74	HFC-152	CO_2e	kg	N/A	New factor added	Section 4	*VII*
75	HFC-161	CO_2e	kg	N/A	New factor added	Section 4	*VII*
76	HFC-236cb	CO_2e	kg	N/A	New factor added	Section 4	*VII*
77	HFC-236ea	CO_2e	kg	N/A	New factor added	Section 4	*VII*
78	HFC-245ca	CO_2e	kg	N/A	New factor added	Section 4	*VII*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
79	HFC-365mfc	CO_2e	kg	N/A	New factor added	Section 4	*VII*
80	R-403a	CO_2e	kg	N/A	New factor added	Section 4	*VII*
81	HFCF-21	CO_2e	kg	N/A	New factor added	Section 4	*VII*
82	Perfluorocyclopropane	CO_2e	kg	N/A	New factor added	Section 4	*VII*
Passenger vehicles							
83	Cars -Mini Diesel	CH_4	km & miles	60%	All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.	Section 5	*I*
84	Cars -Mini Petrol	N_2O	km & miles	-30%	As above	Section 5	*I*
85	Cars -Mini Unknown	N_2O	km & miles	-20%	As above	Section 5	*I*
86	Cars -supermini - Diesel	CH_4	km & miles	60%	As above	Section 5	*I*
87	Cars -supermini - Petrol	N_2O	km & miles	-30%	As above	Section 5	*I*
88	Cars -supermini - Unknown	N_2O	km & miles	-14%	As above	Section 5	*I*
89	Cars - Lower medium - Diesel	CH_4	km & miles	60%	As above	Section 5	*I*
90	Cars - Lower medium - Petrol	N_2O	km & miles	30%	As above	Section 5	*I*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
91	Cars - Lower medium - Unknown	CH_4 and N_2O	km & miles	10% & -14% respectively	As above	Section 5	/
92	Cars - Upper medium - Diesel	CH_4	km & miles	80%	As above	Section 5	/
93	Cars - Upper medium - Petrol	N_2O	km & miles	30%	As above	Section 5	/
94	Cars - Upper medium - Unknown	CH_4 and N_2O	km & miles	10% & -12% respectively	As above	Section 5	/
95	Cars - Executive - Diesel	CH_4	km & miles	80%	As above	Section 5	/
96	Cars - Executive - Petrol	N_2O	km & miles	-30%	As above	Section 5	/
97	Cars - Executive - Unknown	CH_4	km & miles	10%	As above	Section 5	/
98	Cars - Luxury - Diesel	CH_4	km & miles	80%	As above	Section 5	/
99	Cars - Luxury - Petrol	N_2O	km & miles	-30%	As above	Section 5	/
100	Cars - Luxury - Unknown	CH_4	km & miles	25%	As above	Section 5	/
101	Cars - Sports - Diesel	CH_4	km & miles	80%	As above	Section 5	/
102	Cars - Sports - Petrol	N_2O	km & miles	-30%	As above	Section 5	/
103	Cars - Sports - Unknown	CH_4	km & miles	25%	As above	Section 5	/

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
104	Cars - Dual purpose 4X4 - Diesel	CH_4	km & miles	80%	As above	Section 5	/
105	Cars - Dual purpose 4X4 - Petrol	N_2O	km & miles	-30%	As above	Section 5	/
106	Cars - Dual purpose 4X4 - Unknown	CH_4	km & miles	25%	As above	Section 5	/
107	Cars - MPV - Diesel	CH_4	km & miles	80%	As above	Section 5	/
108	Cars - MPV - Petrol	N_2O	km & miles	-30%	As above	Section 5	/
109	Cars - MPV - Unknown	CH_4	km & miles	11%	As above	Section 5	/
110	Cars (by size) - Small car -Diesel	CH_4	km & miles	60%	As above	Section 5	/
111	Cars (by size) - Small car -Petrol	N_2O	km & miles	-30%	As above	Section 5	/
112	Cars (by size) - Small car -Hybrid	N_2O	km & miles	-30%	As above	Section 5	/
113	Cars (by size) - Small car -Unknown	N_2O	km & miles	-14%	As above	Section 5	/
114	Cars (by size) - Medium car -Diesel	CH_4	km & miles	60%	As above	Section 5	/

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
115	Cars (by size) - Medium car -Petrol	N_2O	km & miles	-30%	As above	Section 5	*I*
116	Cars (by size) - Medium car -Hybrid	N_2O	km & miles	-30%	As above	Section 5	*I*
117	Cars (by size) - Medium car -CNG	N_2O	km & miles	-22%	As above	Section 5	*I*
118	Cars (by size) - Medium car -LPG	CH_4 and N_2O	km & miles	-35% & -22% respectively	As above	Section 5	*I*
119	Cars (by size) - Large car -Diesel	CH_4	km & miles	60%	As above	Section 5	*I*
120	Cars (by size) - Large car -Petrol	N_2O	km & miles	-30%	As above	Section 5	*I*
121	Cars (by size) - Large car -Hybrid	CO_2e	km & miles	-12%	As above and CO_2 reduction for large hybrid cars. This is due to new hybrid models on the market, also includes plug-in hybrids (have much lower emissions as run on grid electricity part of the time)	Section 5	*I, VIII*
122		CO2	km & miles	88%	CO_2 reduction for large hybrid cars. This is due to new hybrid models on the market, also includes plug-in hybrids (have much lower emissions as run on grid electricity part of the time)	Section 5	*VIII*
123		CH_4	km & miles	-19%	The IPCC Guidelines were updated in 2006, and formally adopted for use by the UNFCCC in the 2015 inventory. The update reflects the latest science. All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.	Section 5	*I*
124		N_2O	km & miles	-30%	As above	Section 5	*I*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
125	Cars (by size) - Large car -CNG	N_2O	km & miles	-22%	As above	Section 5	/
126	Cars (by size) - Large car - LPG	CH_4 and N_2O	km & miles	-35% & -22% respectively	As above	Section 5	/
127	Cars (by size) - Large car -Unknown	CH_4	km	13%	As above	Section 5	/
128			miles	12%	As above	Section 5	/
129	Cars (by size) - Average car -Diesel	CH_4	km & miles	60%	As above	Section 5	/
130	Cars (by size) - Average car -Petrol	N_2O	km & miles	-30%	As above	Section 5	/
131	Cars (by size) - Average car -Hybrid	N_2O	km & miles	-30%	As above	Section 5	/
132	Cars (by size) - Average - CNG	N_2O	km & miles	-22%	As above	Section 5	/
133	Cars (by size) - Average - LPG	CH_4 and N_2O	km & miles	-35% & -22% respectively	As above	Section 5	/
134	Cars (by size) - Average car -Unknown	N_2O	km & miles	-10%	As above	Section 5	/
135	Motorbike - Small - Diesel	CH_4	km & miles	18%	As above	Section 5	/
Delivery vehicles							

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
136	Vans Class I and II - petrol	N_2O	km & miles	-11%	Reduction in N_20 conversion factor for vans driven by improvements to fleet composition (higher proportion of Euro 4/5/6 vehicles in fleet).	Section 6	*IX*
137	Vans Average class - petrol	N_2O	km & miles	10%	As above	Section 6	*IX*
138	Vans Average class - CNG	CH_4 and N_2O	km & miles	390% & -55% respectively	Correction to the calculation	Section 6	*X*
139	Vans Average class - LPG	CH_4 and N_2O	km & miles	443% & -16% respectively	Correction to the calculation	Section 6	*X*
140	HGV refrigerated and non-refrigerated (all diesel) - all 'rigids' and all loadings	CH_4	km & miles	109-125%	Correction to the calculation	Section 6	*X*
141	HGV refrigerated and non-refrigerated (all diesel) - all 'articulates' and all loadings	CH_4	km & miles	29-37%	Increase in CH_4 value due to changes in composition of fleet (there are less Euro 4 HGVs in fleet this year)	Section 6	*XI*
UK electricity generation							
142	Electricity generated - UK	CO_2e	kWh	-7%	Decrease in carbon emissions caused by a decrease in coal powered electricity generation in 2013 (the inventory year for which the 2014 GHG Conversion Factor was derived).	Section 3	*XII*
Overseas electricity generation							
143	Overseas electricity generation	CO_2e	kWh	Ranges from -71% to 152%	Electricity factors are prone to fluctuate from year to year as the fuel mix consumed in power stations (and auto-generators) and the proportion of net imported electricity changes.	Section 3	*XII*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
Heat and steam							
144	Heat and steam only and district heat and steam	CH_4 and N_2O	kWh	-49% & 54% respectively	As with the "Fuels" factors - methodology for calculating conversion factors for CH_4 and N_2O have changed this year	Section 3	*I*
Transmission & distribution							
145	Transmission& distribution - UK electricity	CO_2e, CO_2 and N_2O	kWh	-12%. -12% & -13% respectively	Reduction in 2013 levels of electricity generated from power stations coupled with reduction of losses in transmission and distribution	Section 3	*XIII*
146	Transmission & distribution- overseas electricity- various countries	CO_2e	kWh	Ranges from -71% to 152%	Due to a decrease or increase in transmission and distribution losses.	Section 10	*XIV*
147	Distribution - district heat & steam - 5% loss	CO_2, CH_4 and N_2O	kWh	-14%, -45% & 947% respectively	These values are equal to 5% of the values published in "Heat and steam", see reason above. Changes to N_2O here are extremely sensitive as the values are of the order 10^-5.	Section 3	*I*
WTT- Overseas electricity							
148	Well to tank - UK electricity (T&D)	CO_2e	kWh	-14%	Driven by reduction above and reduction in transmission losses	Section 10	*XV*
149	Well to tank- overseas electricity (T&D) - all countries	CO_2e	kWh	Varies from -28% to -90%	Error identified in 2014 update resulted in this change	Section 10	*XVI*
Water supply							
No changes							
Water treatment							

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
No changes							
Material use							
150	Construction materials -wood, primary material production	CO_2e	tonnes	-35%	Wood data has been updated based on Corrim (2013)	Section 11	*XVI*
151	Construction materials -wood, primary material production	CO_2e	tonnes	-22%	As above	Section 11	*XVI*
152	Construction, Other, organic and paper	CO_2e	tonnes	N/A	The compost source removed as this was misleading to users.	Section 11	*XVII*
153	Organic material use	CO_2e	tonnes	N/A	Renamed from refuse to organic as this was misleading to users.	Section 11	*XVII*
154	Other - food and drink material use	CO_2e	tonnes	N/A	The organic 'food and drink waste' category has been moved to 'other'.	Section 11	*XVII*
155	Aluminium cans and foil (excl. forming) - Closed loop source	CO_2e	tonnes	147%	Revised data from the European Aluminium Association on the impact of aluminium production, plus an amendment to production of cans.	Section 11	*XVIII*
156	Mixed cans - Primary material production	CO_2e	tonnes	31%	As above	Section 11	*XVIII*
157	Mixed cans - Closed loop source	CO_2e	tonnes	72%	As above	Section 11	*XVIII*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
158	Scrap metal -Primary material production	CO_2e	tonnes	21%	As above	Section 11	*XVIII*
159	Scrap metal -Closed loop source	CO_2e	tonnes	55%	As above	Section 11	*XVIII*
160	Metal: steel cans - Closed loop source	CO_2e	tonnes	15%	As above	Section 11	*XVIII*
161	Plastics: average plastics	CO_2e	tonnes	23%	Revisions to the 'ecoprofiles' for a range of plastics by PlasticsEurope	Section 11	*XIX*
162	Plastics: average plastic film - Closed loop source	CO_2e	tonnes	15%	As above	Section 11	*XIX*
163	Plastics: average plastic rigid - Closed loop source	CO_2e	tonnes	16%	As above	Section 11	*XIX*
164	Plastics: HDPE (incl. forming) - Closed loop source	CO_2e	tonnes	31%	As above	Section 11	*XIX*
165	Plastics: LDPE and LLDPE (incl. forming) - Closed loop source	CO_2e	tonnes	15%	As above	Section 11	*XIX*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
166	Plastics: PET (incl. forming) - Closed loop source	CO_2e	tonnes	19%	As above	Section 11	*XIX*
Waste disposal							
167	Construction materials -wood, landfill	CO_2e	tonnes	-23%	A reduction due to the change in degradability in the European Reference Life Cycle Database (ELCD).	Section 11	*XX*
168	Others - books - landfill	CO_2e	tonnes	-11%	The estimate for Methane capture from landfill waste reduced from 70% to 59%. This affects all landfill emissions for organic materials.	Section 11	*XXI*
169	Municipal waste - landfill	CO_2e	tonnes	58%	The composition of mixed municipal waste and mixed C&I waste has been updated, resulting in a change to the associated GHG emissions.	Section 11	*XXII*
170	Organic: food and drink waste - landfill	CO_2e	tonnes	27%	The estimate for Methane capture from landfill waste reduced from 70% to 59%. This affects all landfill emissions for organic materials.	Section 11	*XXI*
171	Organic: mixed food and garden waste - landfill	CO_2e	tonnes	31%	As above	Section 11	*XXI*
172	Commercial and industrial waste - landfill	CO_2e	tonnes	-53%	In March 2015 DEFRA published a revised waste composition for the UK and this has been used to recalculate the composition of C&I waste.	Section 11	*XXIII*
173	All paper - landfill	CO_2e	tonnes	-11%	A reduction due to the change in degradability in the European Reference Life Cycle Database (ELCD).	Section 11	*XX*
Business travel- air							

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
174	International, to/from non-UK	All	passenger.km	N/A	A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations.	Section 8	*XXIV*
WWT - Business travel- air							
175	International, to/from non-UK	All	passenger.km	N/A	A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations.	Section 8	*XXIV*
Business travel- sea							
No significant changes							
WTT- business travel sea							
No significant changes							
Business travel- land							
176	Cars (by market segment)	See passenger vehicles above					*I*
177	Cars (by size)						
178	Motorbike						
179	Regular taxi	CH_4	passenger.km	50%	As with the "Fuels" factors - methodology for calculating conversion factors for CH_4 and N_2O have changed this year.	Section 5	*I*
180			km	60%	As above	Section 5	*I*
181	Black cab	CH_4	passenger.km	67%	As above	Section 5	*I*
182			km	60%	As above	Section 5	*IV*
183	Light rail and tram	CO_2e, CO_2 and N_2O	passenger.km	-11%, -11% & -13% respectively	Decrease in emissions from power stations (electricity production) in the NAEI.	Section 5	*XII, XXVI*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
184	London Underground	CO_2e, CO_2 and N_2O	passenger.km	-11%, -11% & -13% respectively	Reduction in gCO_2/pkm for London Underground (from TfL Sustainability report). Also a reduction in electricity emission factors per kWh.	Section 5	*XXV*
WTT passenger vehicles and business travel- land							
185	WTT- Large car, hybrid	CO_2e	km and miles	-13%	CO_2 reduction for large hybrid cars. This is due to new hybrid models on the market, also includes plug-in hybrids (have much lower emissions as run on grid electricity part of the time).	Section 5	*VIII*
186	WTT- rail, London Underground	CO_2e	passenger.km	-13%	Driven by reduction in CO_2 from direct emissions	Section 5	*VIII*
187	WTT- rail, Light rail and tram	CO_2e	passenger.km	-13%	Driven by reduction in CO_2 from direct emissions	Section 5	*VIII*
Freighting goods							
188	Vans	See delivery vehicles above. (Where applicable the tonne.km magnitude of change is the same as the km and miles changes).					*I*
189	HGV (all diesel)						*I*
190	HGV refrigerated (all diesel)						*I*
191	Freight flights - Domestic, to/from UK. With and without RF	CO_2e, CO_2 and N_2O	tonne.km	14%	Increase is driven by shift in proportion of tonne-km of aircrafts being analysed. In 2015, higher proportion of tonne-km flown by smaller aircrafts leading to increased tonne.km conversion factor.	Section 8	*XXVII*
192	Freight flights - Short-haul, to/from UK. With and without RF	CO_2e, CO_2 and N_2O	tonne.km	10%	As above	Section 8	*XXVII*
193		CH4		20%	As above	Section 8	*XXVII*
194	Freight flights - International, to/from non-UK	All	tonne.km	N/A	A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being	Section 8	*XXIV*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
					presented for international flights between non-UK destinations.		
WTT - Delivery vehicles and freighting goods							
195	WTT - Refrigerated and non-refrigerated rigid (>17 tonnes) HGV- 50% and 100% laden	CO_2e	tonne.km	13%	Reduction in average tonnes goods carried per vehicle. Also Increase in CH_4 value due to changes to the composition of fleet (less Euro 4 HGVs this year).	Section 6	*XI, XXVIII*
196	WTT - Refrigerated and non-refrigerated All rigids HGV- 50%,100% and average laden	CO_2e	tonne.km	11%, 11% & -14% respectively.	As above	Section 6	*XI, XXVIII*
197	WTT - Refrigerated and non-refrigerated rigid - Articulated HGV (>3.5 - 33t) - average laden	CO_2e	tonne.km	-17%	As above	Section 6	*XI, XXVIII*
198	WTT- freight flights, Domestic, With and without RF	CO_2e	tonne.km	14%	Driven by increase in direct CO_2 emissions.	Section 8	*XI, XXIX*
199	WTT- freight flights, Short-haul, With and without RF	CO_2e	tonne.km	10%	Driven by increase in direct CO_2 emissions.	Section 8	*XI, XXIX*

Ref	Emission factor	GHG	Unit	Magnitude of change vs 2014 update	Reason for change	For more information see:	*Major changes ref for more detail*
200	WTT- freight flights, International, to/from non-UK. With and without RF	CO_2e	tonne.km	N/A	A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations.	Section 8	*XXIV*
Managed assets- electricity							
No significant changes							
Managed assets- vehicles							
201	Managed cars (by market segment)	See passenger vehicles above					*I*
202	Managed cars (by size)						*I*
203	Managed vans	See delivery vehicles above					*I*
204	Managed HGV (all diesel)						*I*
205	Managed HGV refrigerated (all diesel)						*I*
206	Managed motorbikes	See passenger vehicles above					*I*

Major changes Reference:

I The IPCC Guidelines were updated in 2006, and formally adopted for use by the UNFCCC in the 2015 inventory. The update reflects the latest science. All default emission factors used in the NAEI that were previously based on the 1996 or 2000 IPCC Guidelines (or in some cases, the EMEP/EEA Guidebook) have been updated to use the new default factors. This has resulted in changes to the CH_4 and N_2O conversion factors.

II	There have been two changes made to bioenergy conversion factors in the 2015 update to improve the accuracy of reporting: 1) The addition of WTT-bioenergy conversion factors (Scope 3) for biodiesel sourced from used cooking oil (UCO) and tallow. 2) The addition to the outside of scopes conversion factors for biodiesel sourced from UCO and tallow. Whilst the Scope 1 emissions for UCO and tallow are the same as the 'Biodiesel' factor the factors for these two fuels have also been added in here for clarity.
III	Difference in the Renewable Transport Fuels Obligation (RTFO) figures between years this year and the previous year, caused by a change in the carbon intensity of the fuels.
IV	There have been two changes made to bioenergy conversion factors in the 2015 update to improve the accuracy of reporting: 1) The addition of WTT-bioenergy conversion factors (Scope 3) for biodiesel sourced from used cooking oil (UCO) and tallow. 2) The addition to the outside of scopes conversion factors for biodiesel sourced from UCO and tallow.
V	Change due to difference in DUKES data, causing an increase in the average percentage biofuel blend. This is due to an increase in biofuel sales versus conventional fuel sales
VI	In the past years the IPCC's Second Assessment Report was used for the Kyoto Protocol listed gases. However, this year these have been updated to use the IPCC Fourth Assessment Report which is in line with how the emissions are calculated under the UK GHG inventory (as required in international reporting).
VII	There has been some additional refrigerants added to those listed. This should improve the accuracy of reporting where users have these refrigerants within their refrigeration systems
VIII	CO_2 reduction for large hybrid cars. This is due to new hybrid models on the market, also includes plug-in hybrids (have much lower emissions as run on grid electricity part of the time)
IX	Reduction in N_20 conversion factor for vans driven by improvements to fleet composition (higher proportion of Euro 4/5/6 vehicles.
X	CH_4 and N_2O difference is due to correction to the calculation. Which has been historically wrong since 2013.
XI	Increase in CH_4 value due to changes in fleet composition (less Euro 4 HGVs this year)
XII	Electricity factors are prone to fluctuate from year to year as the fuel mix consumed in power stations (and auto-generators) and the proportion of net imported electricity 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. Given the importance of this factor the explanation for fluctuations will be presented here henceforth. For the UK - 2014 GHG Conversion Factors there was an 11% increase in the UK electricity factor from the previous year because there was a significant increase in coal powered electricity generation share in 2012 (the inventory year for which the 2014 GHG Conversion Factor was derived). In this 2015 update, the factor has decreased (versus 2014) by 6.5% which is due to a decrease in coal powered electricity generation in 2013.
XIII	Reduction in 2013 levels of electricity generated from power stations coupled with reduction of losses in transmission and distribution
XIV	Due to either a decrease or increase in transmission and distribution losses
XV	Error identified in 2014 update which has now been corrected, thus resulting in this change.
XVI	Wood data has been updated based on Corrim (2013) - http://www.corrim.org/pubs/reports/2013/phase1_updates/index.asp

XVII There have been various improvements to the layout of the material use factors to improve clarity and ease of use:
- The compost source factors were removed as this was misleading to users.
- Refuse factors were renamed organic as this was originally misleading to customers
- The organic 'food and drink waste' has been removed to 'other'

XVIII Revised data from the European Aluminium Association on the impact of aluminium production, plus an amendment to production of cans. References: European Aluminium Association (2013) Environmental Profile Report for the European Aluminium Industry *http://www.alueurope.eu/wp-content/uploads/2011/10/Environmental-Profile-Report-for-the-European-Aluminium-Industry-April-2013.pdf* *PE Americas (2010) Life Cycle Impact Assessment of Aluminium Beverage Cans* *http://www.aluminum.org/Content/ContentFolders/LCA/LCA_REPORT.pdf*

XIX Revisions to the 'ecoprofiles' for a range of plastics by Plastics Europe http://www.plasticseurope.org/plasticssustainability/eco-profiles/browse-by-list.aspx and revisions to forming data.

XX A reduction due to the change in degradability in the European Reference Life Cycle Database (ELCD).

XXI The estimate for Methane capture from landfill waste reduced from 70% to 59%. This affects all landfill emissions for organic materials. Reference: Webb N, Broomfield M, Buys G, Cardenas L, Murrells T, Pang Y, Passant N, Thistlethwaite G, Watterson J (2014) UK Greenhouse Gas Inventory, 1990 to 2012: Annual Report for submission under the Framework Convention on Climate Change http://naei.defra.gov.uk/reports/reports?report_id=789

XXII The composition of mixed municipal waste and mixed C&I waste has been updated, resulting in a change to the associated GHG emissions. The references for the compositions are two DEFRA studies:
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18237 and
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=19118

XXIII In March 2015 DEFRA published a revised waste composition for the UK and this has been used to recalculate the composition of C&I waste. Source: DEFRA 2015 UK Statistics on Waste 2010-12. DEFRA https://www.gov.uk/government/statistical-data-sets/env23-uk-waste-data-and-management.

XXIV A brand new set of aviation factors can also be found in the 2015 update where aviation factors are now being presented for international flights between non-UK destinations. This is a relatively high level analysis and allows users to choose a different factor for air travel if flying between countries outside of the UK. All factors presented are for direct (non-stop) flights only. This analysis was only possible for passenger air travel however in the interests of consistency with the air freight travel, international freight factors have been included this year. These factors have been set equal to the current UK, long haul freight factors. See the 'Freighting goods' and 'WTT- delivery vehs & freight' tabs for these factors.

Please note - The international factors included are an average of short and long-haul flights which explains the difference between the UK factors and the international ones.

XXV Decrease in emissions from power stations (electricity production) in the NAEI.

XXVI Reduction in gCO_2/pkm for London Underground (from TfL Sustainability report). Also a reduction in electricity emission factors per kWh.

XXVII Increase is driven by shift in proportion of tonne km of aircrafts being analysed. In 2015, higher proportion of tonne km flown by smaller aircrafts leading to increased tonne.km conversion factor.

XXVIII 'Reduction in average tonnes goods carried per vehicle.

XXIX Driven by increase in direct CO_2 emissions.

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