Department for
Business, Energy
& Industrial Strategy

2016 Government GHG Conversion Factors for Company Reporting:

Methodology Paper for Emission Factors

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Contents

Tables

Figures

1. General Introduction

1.1. Greenhouse gases (GHG) 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 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 GHG emitted as a result of burning a particular quantity of oil in a heating boiler.

1.3. The 2016 Government Greenhouse Gas (GHG) Conversion Factors for Company Reporting[1] (hereafter the 2016 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 2016 GHG Conversion Factors.

1.4. Values for the non-carbon dioxide (CO_2) GHG, 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 United Nations Framework Convention on Climate Change (UNFCCC). It should be noted that the fourth assessment report by the IPCC (AR4) is used for the GHG Conversion Factors as this is the report which is accepted for use in national GHG reporting under the UNFCCC. Although the IPCC have prepared a newer version since, the methods have not yet been officially accepted for use under the UNFCCC. As this is the basis upon which all emissions are calculated in the UK GHG inventory (GHGI), the conversion factors are therefore consistent with this.

1.5. The GHGI for 2014, on which these 2016 GHG Conversion Factors is available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1605241007_ukghgi-90-14_Issue2.pdf.

1.6. The 2016 GHG Conversion Factors are for one year, from the end of May 2016, and will continue to be reviewed and updated on an annual basis.

1.7. Previously the GHG Conversion Factors have been provided via an online tool. However, this year the factors will be provided from the GOV.UK domain and this tool will no longer be available. The previous http://www.ukconversionfactorscarbonsmart.co.uk/ website will be redirected to the new GOV.UK site: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting. The information which is on the previous site will still be accessible via this new site.

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 2016 GHG

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

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 2016 GHG Conversion Factors together with previous methodology papers is available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting.

Overview of changes since the previous update

1.10. Major changes and updates in terms of methodological approach from the 2015 update 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 2015 update):

a) The overseas CO_2 emission factors are no longer provided. They are available for sale from the “CO_2 Emissions from Fuel Combustion” document from the online data service at the International Energy Agency (IEA) website and by contacting STATS@iea.org.
b) For local buses, a revision in the scope and methodology employed has been necessary due to a reduction in the coverage of the datasets previously used to calculate the annual updates to the emission factors. This has resulted in a step-change increase in the emission factor for non-London buses this year.
c) For UK electricity, a number of revisions have been made to the methodological approach to improve the accuracy and representativeness of the emission factor. These include expanding the coverage of UK electricity used, as well as amendments reflecting improved understanding of the basis of the underlying data sources. Since the previous year there has also been a significant increase in the shares of lower GHG electricity generation (an increase to renewables and gas, and a decrease in the share of coal powered generation). Overall this has resulted in a reduction to the emission factor for UK electricity.

1.11. In addition to the methodological changes there have also been changes to the layout of the 2016 GHG Conversion Factors, these changes are summarised below:

a) Additional explanatory text on the policy for treatment of errors / updates following the publication of the conversion factors at the end of May each year.
b) Colour coding of the different tabs- where Scope 1[2] factors are in green, Scope 2[3] are in blue and Scope 3[4] are orange. This will aid users in finding the factors they require;
c) Changes to the layout of the fuels and WTT fuel factors, to simplify and streamline the presentation and remove unnecessary empty cells;
d) An index is now provided at the front of the data sheets, for improved navigation.

[2] Scope 1 (direct emissions) emissions are those from activities owned or controlled by your organisation.

[3] Scope 2 (energy indirect) emissions are those released into the atmosphere that are associated with your consumption of purchased electricity, heat, steam and cooling. These indirect emissions are a consequence of your organisation’s energy use, but occur at sources you do not own or control.

[4] Scope 3 (other indirect) emissions are a consequence of your actions that occur at sources you do not own or control and are not classed as Scope 2 emissions.

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. for many factors this is +-10% since the 2015 GHG Conversion Factors, though a lower threshold is used in some cases where a much lower degree of annual variation is expected). 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 2016 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.

1.14. It is important to note that this methodology paper's primary aim is to provide information on the methodology used in creating the Government GHG Conversion Factors for Company Reporting (GCF). It does not provide guidance on the approach or methodology required for GHG reporting.

Structure of this methodology paper

1.15. The following Sections 2 to 12 provide methodological summary for the data tables contained in the GCF.

Area covered	Location in this document
Fuel Emission Factors	see Section 2
UK Electricity, Heat and Steam Emission Factors	see Section 3
Refrigerant and Process Emission Factors	see Section 4
Passenger Land Transport Emission Factors	see Sections 5
Freight Land Transport Emission Factors	see Sections 6
Sea Transport Emission Factors	see Section 7
Air Transport Emission Factors	see Section 8
Bioenergy and Water	see Section 9
Overseas Electricity Emission Factors	see Section 10
Material Consumption/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 changes since the previous update are the changes to the layout of the fuels conversion factors as discussed above, and the provision of factors in a wider number of units for certain fuels (using standard conversions).

Direct Emissions

2.2. All the fuel conversion factors for direct emissions presented in the 2016 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2014 (managed by Ricardo Energy & Environment[5]).

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 in the 2016 GHG Conversion Factors 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) (see definition of Gross CV and Net CV in the footnote below[6]) from BEIS's Digest of UK Energy Statistics (DUKES) 2015[7].

2.5. As mentioned above there are three tables presented in the new layout for 2016 GHG Conversion Factors, the first of which provides emission factors for gaseous fuels, the second for liquid fuels and the final table provides the emission factors for solid fuels.

2.6. When making calculations based on energy use, it is important to check (e.g. with your fuel supplier) whether these values were calculated on a Gross CV or Net CV basis and use the appropriate factor. Natural Gas consumption figures quoted in kWh by suppliers in the UK are generally calculated (from the volume of gas used) on a Gross CV basis[8]. 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

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[5] UK Greenhouse Gas Inventory for 2014 (Ricardo Energy & Environment), available at: http://naei.defra.gov.uk/data/emission-factors

[6] 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).

[7] Available at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

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

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 a specific UK-based set of fuel lifecycle emissions factors, information from JEC Well-To-Wheels (2014) was used as a basis for the factors in the 2016 GHG Conversion Factors[9]. This is the preeminent European study carried out in this area and covers a wide variety of fuels. The 2014 report (Version 4a) used for 2016 GHG Conversion Factors is an update of the same version (Version 4) used in the derivation of the 2015 GHG Conversion Factors.

2.9. For fuels covered by the 2016 GHG Conversion Factors where no fuel lifecycle emission factor was available in JEC WTW (2014), these were estimated based on similar fuels, according to the assumptions in Table 2.

2.10. The methodology for calculating the indirect/WTT emission factors for natural gas and CNG is different to the other fuels as it takes into account 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 3 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 2016 update. These figures have been used to calculate the revised figures for Natural Gas and CNG WTT emission factors provided in Table 2 below.

2.11. 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 (2.43% by unit volume, 2.24% by unit energy – see Table 4). These estimates have been made based on BEIS's Quarterly Energy Statistics for Renewables[10].

2.12. 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 (4.60% by unit volume, 3.04% by unit energy – see Table 4). These estimates have also been made based on BEIS's Quarterly Energy Statistics for Renewables.

2.13. The final combined emission factors (in $kgCO_2e/GJ$, Net CV basis) are presented in Table 2. 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 2016 GHG Conversion Factors alongside the emission factor data tables.

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

[9] "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4a, May 2014. Report EUR 26236 EN– 2014. http://iet.jrc.ec.europa.eu/about-jec/

[10] Department for Transport, Table RTFO 01: Volumes of fuels by fuel type. Data used here comes from two different versions of the report: Year 7 report 6 (final version) and Year 8 report 2, both published in February 2016. Available at: - https://www.gov.uk/government/collections/biofuels-statistics

Fuel	Indirect/WTT EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Aviation Turbine Fuel [1]	14.55	Estimate	Kerosene fuel, estimate based on average of petrol and diesel factors
Burning Oil[1]	14.55	Estimate	Kerosene, as above
CNG (excl. LNG imports) [2]	8.70	JEC WTW (2011)[3]	CNG from natural gas EU mix
CNG	11.37	JEC WTW (2011,2014)	Factors in UK % share LNG imports
Coal (domestic)	14.75	JEC WTW (2014)	Emission factor for coal
Coal (electricity generation)	14.75	JEC WTW (2014)	Emission factor for coal
Coal (industrial)	14.75	JEC WTW (2014)	Emission factor for coal
Coal (electricity generation – home imports)	14.75	JEC WTW (2014)	Emission factor for coal
Coking Coal	14.75	Estimate	Assume same as factor for coal
Diesel	15.35	JEC WTW (2014)	
Fuel Oil [4]	14.55	Estimate	Assume same as factor for kerosene, as above (estimate based on average of petrol and diesel factors)
Gas Oil [5]	15.35	Estimate	Assume same as factor for diesel
LPG	8.04	JEC WTW (2014)	
LNG [6]	21.05	JEC WTW (2014)	
Lubricants	9.53	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Marine fuel oil	14.55	Estimate	Assume same as factor for fuel oil
Marine gas oil	15.35	Estimate	Assume same as factor for gas oil
Naphtha	14.10	JEC WTW (2014)	
Natural Gas (excl. LNG imports)	5.90	JEC WTW (2011)	Natural gas EU mix
Natural Gas	7.71	JEC WTW (2011,2014)	Factors in UK % share LNG imports[6]
Other Petroleum Gas	6.96	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Petrol	13.76	JEC WTW (2014)	
Petroleum Coke	12.13	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Processed fuel oils - distillate oil	9.18	Estimate	As above
Processed fuel oils - residual oil	9.66	Estimate	As above
Refinery miscellaneous	8.78	Estimate	As above
Waste oils	9.53	Estimate	As above

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) The 2014 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).
(4) Fuel oil is used for stationary power generation. Also use this emission factor for similar marine fuel oils.
(5) 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.
(6) LNG = Liquefied Natural Gas, usually shipped into the UK by tankers. LNG is usually used within the UK gas grid; however, it can also be used as an alternative transport fuel.

Table 2: Basis of the indirect/WTT emissions factors for different fuels

	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
2010	35.40%	39.33%	**18.87%**
2011	47.21%	42.04%	**30.24%**
2012	27.94%	47.23%	**17.50%**
2013	19.55%	50.07%	**12.06%**
2014	26.64%	44.90%	**16.05%**

Source: DUKES 2015, (1) Table 4.1 - Commodity balances and (2) Table 4.5 - Natural gas imports and exports.

Table 3: Imports of LNG into the UK as a share of imports and net total natural gas supply

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	Conventional Fuel	per unit mass	per unit volume	per unit energy
Diesel/Biodiesel	693	27,777	2.58%	2.43%	2.24%
Petrol/Bioethanol	800	16,579	4.98%	4.60%	3.04%

Source: Department for Transport, Table RTFO 01: Volumes of fuels by fuel type. Data used here comes from two different versions of the report: Year 7 report 6 (final version) and Year 8 report 2, both published in February 2016.

Available at: - https://www.gov.uk/government/collections/biofuels-statistics

Table 4: Liquid biofuels for transport consumption: 4th quarter 2014 – 3rd quarter 2015

3. UK Electricity, Heat and Steam Emission Factors

Summary of changes since the previous update

3.1. There have been several methodological improvements made since the previous 2015 update, implemented to improve the accuracy and representativeness of the emission factors:

a) Estimates for the emissions and electricity supply from oil and other thermal source autogenerators has now been included in the calculations. Previously, this small component (typically 1-2%) of overall electricity supply was excluded, as emissions were not directly available from the National Atmospheric Emissions Inventory (NAEI) for these generators.
b) Revisions to the calculations for emissions and electricity supplied to the grid from autogenerators have been made as a result of improved understanding of the underlying DUKES Table 5.5 dataset. This revised methodology now factors in a better accounting for the electricity used by the autogenerators themselves.
c) Emissions resulting from electricity generation by Crown Dependencies has been removed from the calculation, following clarification from BEIS's DUKES team that no electricity generated in Crown Dependencies is included in the underlying Table 5.5 dataset. This has a negligible overall impact on the final emission factor.
d) The calculation of the impact of net imports of electricity over the interconnects is now based on a weighted average of the emission factor components from France, Ireland and the Netherlands. Previously the calculation was based only on the emission factor for France, as this accounts for the majority of imports – and this was previously close to 100% of imports when this methodology was first developed.

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.

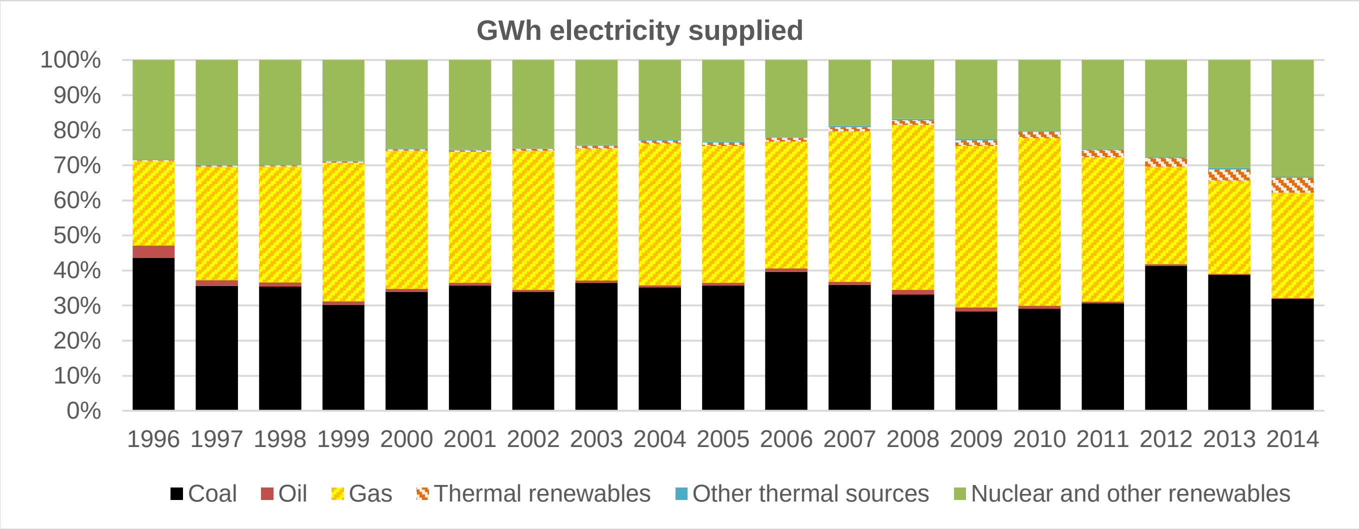
3.3. A detailed summary of the methodology used to calculate individual electricity emission factors is provided in the following subsections

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, the Netherlands 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. The UK grid electricity 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. This fluctuation in UK electricity generation mix is illustrated in Figure 1 below.



Notes: The chart presents data for actual years; the emissions factors for a given GHG Conversion Factor update year correspond to the data for the actual year 2 years previous, i.e. the 2016 emission factors are based on 2014 data.

Figure 1: Time series of the mix of UK electricity generation by type

3.6. The UK electricity conversion factors provided in the 2016 GHG Conversion Factors are based on emissions from sector 1A1a (power stations) and 1A2f (autogenerators) in the UK Greenhouse Gas Inventory (GHGI) for 2014 (Ricardo Energy & Environment) according to the amount of CO_2, CH_4 and N_2O emitted per unit of electricity consumed (from DUKES 2015)[11]. These emissions from the GHGI only include autogeneration from coal and natural gas fuels, and do not include emissions for electricity generated and supplied by autogenerators using oil or other thermal non-renewable fuels[12]. In previous updates, this was accounted for by removing this component from the DUKES GWh data. However, for the first time in the 2016 update, estimates of the emissions due to these components have been made using standard NAEI emission factors, and information from DUKES Table 5.5, and BEIS's DUKES team on the total fuel use (and shares by fuel type) for this component. An additional correction is made to account for the share of autogeneration electricity that is exported to the grid (~17.5% for the 2014 data year), which varies significantly from year-to-year.

3.7. The UK is a net importer of electricity from the interconnectors with France and Netherlands, and a net exporter of electricity to Ireland according to DUKES (2015). For the 2016 GHG Conversion Factors the total net electricity imports were calculated from DUKES (2015) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2014). The net shares of imported electricity over the interconnects are calculated from data from DUKES (2015) Table 5B (Net Imports via interconnectors, GWh).

3.8. An average imported electricity emission factor is calculated from the individual factors for the relevant countries (from the IEA) weighted by their respective share of net imports. This average electricity emission factor – including losses – is used to account for the net import of electricity, as it will also have gone through the relevant countries' distribution systems. Note that this method effectively reduces the UK's electricity emission factors as the

[11] DUKES (2015): https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[12] Other thermal non-renewable fuels include the following (with ~2016 update % share): blast furnace gas (~49%), chemical waste (~13%), coke oven gas (~12%) and municipal solid waste (MSW, ~26%)

resulting average net imported electricity emission factor 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, and accounts for the largest share of the net imports.

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.

3.10. 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. This dataset also reflects the changes in the methodological approach implemented for the 2016 update, and applied across the whole time series.

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
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

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
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
2014*	2016*	297,897	8.30%	126,358	4.769	2.166

Notes:

(1) **From 1990-2013**: Based upon calculated total for centralised electricity generation (GWh supplied) from DUKES Table 5.5 Electricity fuel use, generation and supply for year 1990 to 2014. The total is consistent with UNFCCC emissions reporting categories 1A1a+1A2f includes (according to Table 5.5 categories) GWh supplied (gross) from all '*Major power producers*'; plus, GWh supplied from thermal renewables + coal and gas thermal sources, hydro-natural flow and other non-thermal sources from '*Other generators*'. * **From 2014 onwards**: based on the **total** for **all** electricity generation (GWh supplied) from DUKES (2015) Table 5.5, with a reduction of the total for autogenerators based on unpublished data from the BEIS DUKES team on the share of this that is actually exported to the grid (~17% in 2014).

(2) Based upon calculated net grid losses from data in DUKES Table 5.1.2 (long term trends, only available online).

(3) **From 1990-2013**: 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, for the GHGI for 2013 (Ricardo-AEA, 2015) for the 2013 data year. * **From 2014 onwards**: Excludes emissions from Crown Dependencies and also includes an accounting (estimate) for autogeneration emissions not specifically split out in the NAEI, consistent with the inclusion of the GWh supply for these elements also from 2014 onwards. Data is from the GHGI for 2014 (Ricardo Energy & Environment, 2016) for the 2014 data year.

Table 5: Base electricity generation emissions data

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports
	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
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
2014	0.42417	0.00040	0.00217	0.42673	0.03837	0.00004	0.00020	0.03860	0.46254	0.00044	0.00236	0.46534	**6.44%**

Notes: * From 1990-2013 the emission factor used was for French electricity only, and is as published in previous methodology papers. The methodology was updated from 2014 onwards with new data on the contribution of electricity from the other interconnects, hence these figures are based on a weighted average emission factor of the emission factors for France, the Netherlands and Ireland, based on the % share supplied. The individual country factors may not be published due to restrictions in republication of the underlying IEA datasets.

Time series data in light grey is locked/fixed for the purposes of company reporting and has not been updated in the database in the 2016 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$_2$e / kWh												% Net Elec Imports
	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
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Elec Imports
	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
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%**
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%**
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%**
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%**
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%**
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%**
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%**
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%**
2013	0.4585	0.00035	0.00334	0.46219	0.03786	0.00003	0.00028	0.03816	0.49636	0.00038	0.00362	0.50035	**4.10%**
2014	0.40957	0.00039	0.00209	0.41205	0.03705	0.00003	0.00019	0.03727	0.44662	0.00042	0.00228	0.44932	6.44%

Notes: * From 1990-2013 the emission factor used was for French electricity only. The methodology was updated from 2014 onwards with new data on the contribution of electricity from the other interconnects, hence these figures are based on a weighted average emission factor of the emission factors for France, the Netherlands and Ireland, based on the % share supplied. The individual country factors may not be published due to restrictions in republication of the underlying IEA datasets.

Time series data in light grey is locked/fixed for the purposes of company reporting and has not been updated in the database in the 2016 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 7: Base electricity generation emissions factors (including imported electricity)

Indirect/WTT Emissions from UK Grid Electricity

3.11. 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.

3.12. 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, 2015. 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 (those prior to the current update) are based on data reported in previous versions of DUKES and following the convention set from 2013, historic time series factors/data have not been updated. The relevant time series source data and emission factors that are fixed/locked have therefore been highlighted in light grey and are unchanged since the last update (i.e. in 2015).

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
2014	280,452	6,167	218,395	19,934	275,426	800,374

Source: For the latest 2014 data year, Table 5.5, Digest of UK Energy Statistics (DUKES) 2015 (BEIS, 2015), available at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes#2015. Earlier years are based on data reported in previous versions of DUKES and following the new convention set from 2013 update (2011 data year), historic time series factors/data (i.e. prior to the very latest year) 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%
2014	35.04%	0.77%	27.29%	2.49%	34.41%	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 generatio n	Weighted Average	Direct CO_2 ((kg CO_2/ kWh)	Calc Indirect /WTT (kg CO_2e/ kWh
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
2014	16.38%	18.45%	13.61%	12.59%	15.11%	**15.11%**	0.40957	0.06188

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

3.13. Updated time-series emission factors for the supply of purchased heat or steam have been provided for the 2016 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[13] 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.

3.14. 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 2016 GHG Conversion Factors.

Fuel allocation to electricity from CHP

3.15. 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)

3.16. Under the UK's Climate Change Agreements[14] (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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[13] See https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme

[14] 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).

3.17. 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.

3.18. 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

3.19. 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[15]), but that the boiler uses the same fuel mix as the actual fuel mix to the CHP to determine the CO_2 emissions.

3.20. 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.

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

3.22. 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

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

CO_2 emission from Fuel for Electricity

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

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

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

3.23. 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.

3.24. 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.

3.25. 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 47.0% on a GCV basis[16].

3.26. 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

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

CHP Electricity Emission factor

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

[16] Digest of UK Energy Statistics (DUKES) 2015, Chapter 5, Table 5.9. Plant loads, demands and efficiency in 2014.

Calculation of CO_2 Emissions Factor for CHP Fuel Input, FuelMixCO_2factor

3.27. 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

3.28. 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 ($kgCO_2/kWh_{th}$)
Biodiesel, bioethanol etc	0.000
Biomass (such as woodchips, chicken litter etc)	0.000
Blast furnace gas	1.009
Coal and lignite	0.319
Coke oven gas	0.138
Domestic refuse (raw)	0.132
Ethane	0.188
Fuel oil	0.267
Gas oil	0.254
Hydrogen	0.000
Methane	0.184
Mixed refinery gases	0.245
Natural gas	0.184
Other Biogas (e.g_ gasified woodchips)	0.000
Other gaseous waste	0.184
Other liquid waste (non-renewable)	0.198
Other liquid waste (renewable)	0.000
Other solid waste	0.247
Refuse-derived Fuels (RDF)	0.132
Sewage gas	0.000
Unknown process gas	0.188
Waste exhaust heat from high temperature processes	0.000
Waste heat from exothermic chemical reactions	0.000
Wood Fuels (woodchips, logs, wood pellets etc)	0.000

Sources: Defra/BEIS GHG Conversion Factors for Company Reporting (2016 update) and National Atmospheric Emissions Inventory (NAEI).

Note: For waste derived fuels the emission factor can vary significantly according to the waste mix. Therefore, if you have site-specific data it is recommended that you use that instead of the waste derived fuel emissions factors in this table.

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

3.29. 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 2016 GHG Conversion Factors, for consistency with DUKES. However, results are provided for comparison according to all three methods in Table 12.

3.30. As for the electricity emission factors, the historic time series source data and emission factors from previous updates have been fixed/locked, highlighted in light grey in the table below, 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 2016 GHG Conversion Factors is based on the data year of 2014 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
2014	0.20245	0.22963	0.04394	0.21541	0.18534	0.39076

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

3.31. 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).

3.32. 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 (see Indirect/WTT Emissions from Fuels section for more information). Where fuels are not included in the set of indirect/WTT GHG emission factors provided in the 2016 GHG Conversion Factors, the value for the closest/most similar alternative fuel was utilised instead.

3.33. The complete final emission factors for supplied heat or steam utilised are presented in the 'Heat and Steam' tables of the 2016 GHG Conversion Factors, and are counted as Scope 2 emissions under the GHG Protocol.

3.34. For district heating systems, the location of use of the heat will often be some distance from the point of production and therefore 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

Global Warming Potentials of Greenhouse Gases

4.1. Although revised GWP values have since been published by the IPCC in the Fifth Assessment Report (2013), 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.

Greenhouse Gases Listed in the Kyoto Protocol

4.2. *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[17], 52% HFC143a and 4% HFC134a is [3500 x 0.44] + [4470 x 0.52] + [1430x 0.04] = 3922). A limited selection of common blends is presented in the Refrigerant tables.

Other Greenhouse Gases

4.3. *CFCs and HCFCs[18]:* 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.

[17] HFC: Hydrofluorocarbon

[18] CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons

5. Passenger Land Transport Emission Factors

Summary of changes since the previous update

5.1. For local buses, a revision to the scope and methodology employed has been necessary due to a reduction in the coverage of the datasets previously used to calculate the annual updates to the emission factors. This has resulted in a step-change increase in the emission factor for non-London buses this year.

5.2. There are no other methodological changes since the previous update to the other passenger land transport emission factors. All other factors have simply been updated with more recent data in the latest 2016 GHG Conversion Factors.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

5.3. SMMT (Society for Motor Manufacturers and Traders)[19] provides numbers of registrations and averages of the NEDC[20] gCO_2/km figures for new vehicles registered from 1998 to 2015[21]. The dataset represents a good indication of the relative NEDC gCO_2/km by size category. Table 13 presents the 1998-2015 average CO_2 emission factors and number of vehicle registrations.

Vehicle Type	Engine size	Size label	NEDC gCO_2 per km	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	131.7	12,736,284	52%
	1.4 - 2.0 l	Medium	168.1	10,209,174	41%
	> 2.0 l	Large	252.8	1,716,721	7%
Average petrol car		***All***	***160.3***	**24,662,179**	***100%***
Diesel car	<1.7 l	Small	113.1	4,372,199	31%
	1.7 - 2.0 l	Medium	142.6	6,871,696	48%
	> 2.0 l	Large	180.3	3,078,604	21%
Average diesel car		***All***	***145.7***	**14,322,499**	**100%**

Table 13: Average CO_2 emission factors and total registrations by engine size for 1998 to 2015 (based on data sourced from SMMT)

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

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

[21] 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.

5.4. For the 2016 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 (the ANPR dataset is only updated in the NAEI on a bi-annual basis, so is unchanged since the 2015 update).

5.5. 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.

5.6. 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 2016 GHG Conversion Factors' emission factors for petrol and diesel passenger cars were subsequently calculated based upon the equation below:

$$2016 \text{ update gCO}_2/\text{km} = \Sigma\left(gCO_2/km_{yr\,reg} \times \frac{ANPR_{yr\,reg}}{ANPR_{total\;2011}}\right)$$

5.7. 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.

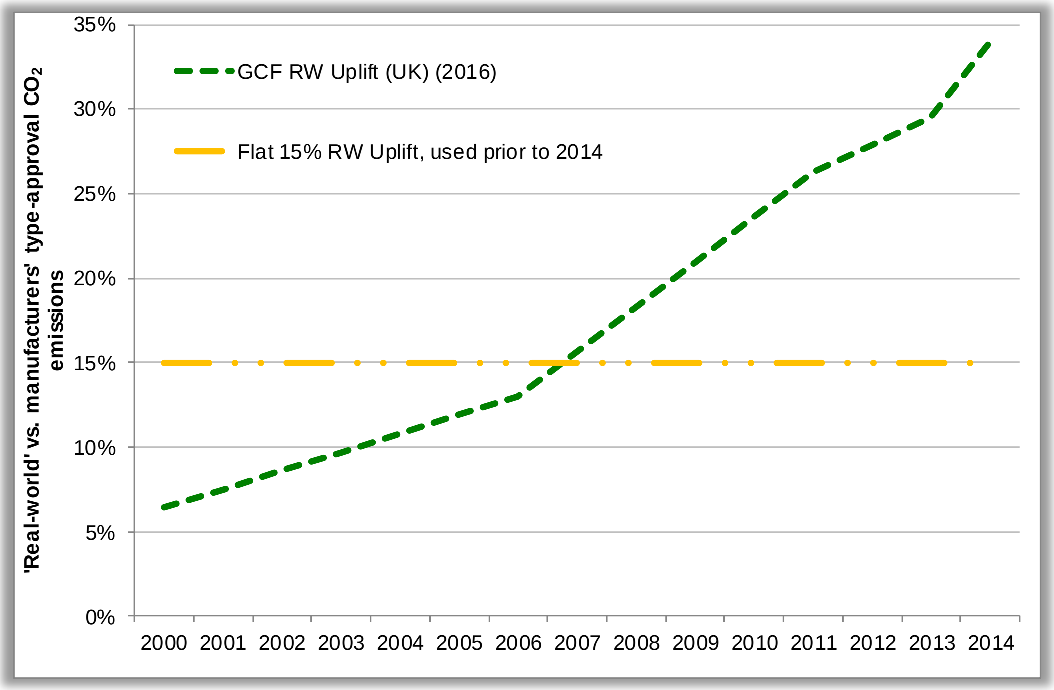
5.8. An uplift factor of +15% over NEDC based gCO_2/km factors, applied in updates prior to 2014, was agreed previously with DfT in 2007 to take into account the combined 'real-world' effects on fuel consumption. This flat factor was replaced from the 2014 update onwards to take into account new evidence on the magnitude of this effect and its change over time. The uplift applied now varies over time and is based on work performed by ICCT (2015)[22]: this study used data on almost 600,000 vehicles from eleven data sources and six countries, covering the fuel consumption/CO_2 from actual real-world use and the corresponding type-approval values. The values used are based on average data from the two UK-based sources analysed in the ICCT study, as summarised in Table 14 below, and illustrated in Figure 2 alongside the source data / chart reproduced from the ICCT (2015) report. This was an update of the previous reports used for the 2014 and 2015 updates to the GHG Conversion Factors. The methodology for the revised approach was also agreed with DfT upon its introduction in 2014.

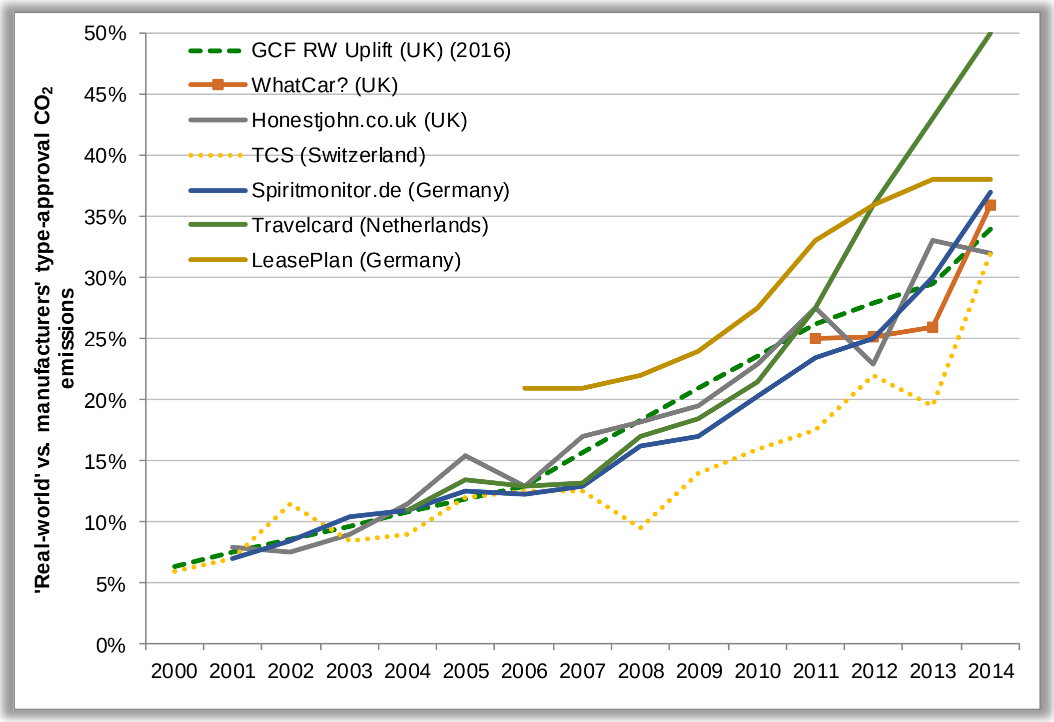
[22] 'FROM LABORATORY TO ROAD: A 2015 update of official and 'real-world' fuel consumption and CO_2 values for cars in Europe' a report by the ICCT, September 2015. Available at: http://www.theicct.org/laboratory-road-2015-update

Model year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014+
RW uplift %	6.4 %	7.5 %	8.6 %	9.7 %	10.8%	11.9%	13.0%	15.7%	18.3%	21.0%	23.6%	26.3%	27.9%	29.5%	34.0 %

Table 14: Average GCF 'real-world' uplift for the UK, applied to the NEDC-based gCO_2/km data

5.9. The above uplifts have been applied to the ANPR weighted SMMT gCO_2/km to give the *New 'Real-World'* 2016 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. The final average equivalent uplift averaged across all vehicles was 21.6% on top of NEDC gCO_2/km.





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 2: Updated GCF 'Real world' uplift values for the UK based on ICCT (2015)

5.10. 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 52.9% petrol and 47.1% diesel, and can be compared to the respective total registrations of the different vehicle types for 1999-2015, which were 63.3% petrol and 36.7% diesel.

5.11. Emission factors for CH_4 and N_2O have been updated for all vehicle classes and are based on the emission factors from the NAEI. Note that when compared with the 2015 update, changes in the CH_4 and N_2O emission factors have occurred as a result of updates to the NAEI methodology. The emission factors used in the NAEI are now based on COPERT 4 version 11[23].

5.12. The final 2016 emission factors for petrol and diesel passenger cars by engine size are presented in the ‘passenger vehicles’ and ‘business travel- land’ tables of the 2016 GHG Conversions Factors.

Hybrid, LPG and CNG Passenger Cars

5.13. The methodology used in the 2016 update for medium and large hybrid petrol/diesel electric cars is similar to that used previously, and is calculated in a similar way to conventional petrol and diesel vehicles. The emission factors are based on datasets on the numbers of registrations and averages of the NEDC[24] gCO_2/km figures from SMMT for new hybrid vehicles registered between 2000 and 2015.

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 are available. In the 2016 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 emission factors on a unit energy (Net CV) 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 2016 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 NAEI (produced by Ricardo Energy & Environment) and are presented together with an overall total emission factors in the ‘passenger vehicles’ and ‘business travel- land’ tables of the 2016 GHG Conversion Factors.

Emission Factors by Passenger Car Market Segments

5.16. For the 2016 GHG Conversion Factors, the market classification split (according to SMMT classifications) was derived using detailed SMMT data on new car registrations

[23] COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport, see: http://emisia.com/products/copert-4.

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

between 1999 and 2015 split by fuel[25], presented in Table 15, 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 2016 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 emission factors used in the NAEI are now based on COPERT 4 version 11[26]. The factors are presented together with the overall total emission factors in the tables of the 2016 GHG Conversion Factors.

Fuel Type	Market Segment	Example Model	1999-2015		
			gCO_2/km	# registrations	% Total
Diesel	A. Mini	Smart Fortwo	90.2	9,323	0.1%
	B. Super Mini	VW Polo	109.5	1,760,199	12%
	C. Lower Medium	Ford Focus	122.2	4,343,614	30%
	D. Upper Medium	Toyota Avensis	139.1	3,445,131	24%
	E. Executive	BMW 5-Series	152.2	1,175,302	8%
	F. Luxury Saloon	Bentley Continental GT	188.5	67,227	0.5%
	G. Specialist Sports	Mercedes SLK	137.1	98,039	1%
	H. Dual Purpose	Land Rover Discovery	181.8	2,241,705	16%
	I. Multi-Purpose	Renault Espace	150.9	1,181,960	8%
	All	**Total**	**145.7**	**14,322,499**	**100%**
Petrol	A. Mini	Smart Fortwo	116.1	806,768	3%
	B. Super Mini	VW Polo	134.3	11,341,595	46%
	C. Lower Medium	Ford Focus	159.3	6,694,431	27%
	D. Upper Medium	Toyota Avensis	187.2	2,720,501	11%
	E. Executive	BMW 5-Series	212.1	684,663	3%
	F. Luxury Saloon	Bentley Continental GT	295.4	107,799	0.4%
	G. Specialist Sports	Mercedes SLK	212.5	862,471	3%
	H. Dual Purpose	Land Rover Discovery	222.1	742,359	3%
	I. Multi-Purpose	Renault Espace	171.3	762,232	3%
	All	**Total**	**160.3**	**24,662,179**	**100%**
Unknown Fuel (Diesel + Petrol)	A. Mini	Smart Fortwo	114.9	816,091	2%
	B. Super Mini	VW Polo	129.6	13,101,794	34%
	C. Lower Medium	Ford Focus	141.6	11,038,045	28%
	D. Upper Medium	Toyota Avensis	152.9	6,165,632	16%

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

[26] COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport, see: http://emisia.com/products/copert-4.

Fuel Type	Market Segment	Example Model	1999-2015		
	E. Executive	BMW 5-Series	167.3	1,859,965	5%
	F. Luxury Saloon	Bentley Continental GT	239.0	175,026	0.4%
	G. Specialist Sports	Mercedes SLK	197.5	960,510	2%
	H. Dual Purpose	Land Rover Discovery	188.9	2,984,064	8%
	I. Multi-Purpose	Renault Espace	158.2	1,944,192	5%
	All	**Total**	**152.7**	**38,984,678**	**100%**

Table 15: Average car CO_2 emission factors and total registrations by market segment for 1999 to 2015 (based on data sourced from SMMT)

Direct Emissions from Taxis

5.18. The emission factors for black cabs are based on data provided by Transport for London (TfL)[27] 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 methodology accounts for the significantly different operational cycle of black cabs/taxis in the real world when compared to the NEDC (official vehicle type-approval) values, which significantly increases the emission factor (by ~40% vs NEDC).

5.19. The emission factors (per passenger km) for regular taxis were estimated on the basis of the average type-approval CO_2 factors for medium and large cars, uplifted by the same factor as for black cabs (i.e. 40%, based on TfL data) to reflect the difference between the type-approval figures and those operating a real-world taxi cycle (i.e. based on different driving conditions to average car use), plus an assumed average passenger occupancy of 1.4 (CfIT, 2002[28]).

5.20. 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 emission factors per vehicle km are also presented in the 'business travel- land' tables of the 2016 GHG Conversion Factors.

5.21. Emission factors for CH_4 and N_2O have been updated for all taxis for the 2016 update. These figures are, as before, based on the emission factors for diesel cars from the latest UK GHG Inventory and are presented together with overall total emission factors in the tables of the 2016 GHG Conversion Factors.

5.22. 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.

[27] The data was provided by TfL in a personal communication and is not available in a public TfL source.

[28] 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

Direct Emissions from Vans/Light Goods Vehicles (LGVs)

5.23. Average emission factors by fuel, for light good vehicles (LGVs: N1 vehicles, vans up to 3.5 tonnes gross vehicle weight) and by size class (I, II or III) are presented in Table 16 (and in the "delivery vehicles" section of the 2016 GHG Conversion Factors). These have been updated for 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) from an extraction from the SMMT MVRIS (Motor Vehicle Registration Information System) data set used in previous work for the DfT. The assumed split of petrol van stock between size classes uses the split of registrations from this dataset.

5.24. Emission factors for petrol and diesel LGVs are based upon emission factors and vehicle km from the NAEI for 2014. Changes to the dataset/cost curve basis in the NAEI in 2014 (i.e. to COPERT 4 version 11) mean that these factors are no longer split out by LGV class, therefore the ratio of emissions between the different classes is assumed to be the same as in previous updates. These emission factors are further uplifted by 15% to represent 'real-world' emissions (i.e. also factoring in typical vehicle loading versus unloaded test-cycle based results), 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). In a future update it is envisaged this uplift will be further reviewed.

5.25. In the 2016 GHG Conversion Factors, CO_2 emission factors for CNG and LPG vans are calculated from the emission factors for conventionally fuelled vans 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 2014, as presented in Table 16.

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.

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	255.3	0.57	1.47	257.3	38.37%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	284.5	0.57	1.47	286.5	48.63%	0.72
Petrol (Class III)	Over 1.740 tonne	343.8	0.57	1.47	345.8	13.00%	1.29
Petrol (average)	**Up to 3.5 tonne**	**281.0**	**0.57**	**1.47**	**283.0**	**100.00%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	152.5	0.02	1.87	154.4	6.18%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	241.0	0.02	1.87	242.9	25.74%	0.98
Diesel (Class III)	Over 1.740 tonne	282.7	0.02	1.87	284.5	68.08%	1.29
Diesel (average)	**Up to 3.5 tonne**	**263.9**	**0.02**	**1.87**	**265.8**	**100.00%**	**1.17**
LPG	Up to 3.5 tonne	277.1	0.13	1.89	279.1		1.17
CNG	Up to 3.5 tonne	250.7	2.88	1.89	255.5		1.17
Average		**264.6**	**0.0**	**1.9**	**266.5**		**1.15**

Table 16: New emission factors for vans for the 2016 GHG Conversion Factors

Direct Emissions from Buses

5.27. The 2015 and earlier updates used data from DfT from the Bus Service Operators Grant (BSOG) in combination with DfT bus activity statistics (vehicle km, passenger km, average passenger occupancy) 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) could be calculated from this, which when combined with DfT statistics on total vehicle km, bus occupancy and passenger km allows the calculation of emission factors[29].

5.28. From the 2016 update onwards, it was necessary to make some methodological changes to the calculations due to changes in the scope/coverage of the underlying DfT datasets, which include:

5.29. BSOG datasets are now only available for commercial services, and not also local authority supported services.

5.30. BSOG datasets are now only available for England, outside of London: i.e. datasets are no longer available for London, due to a difference in how funding for the city is managed/provided, nor for other parts of the UK.

5.31. Briefly, the main calculation for local buses can be summarised as follows:

Total fuel consumption (Million litres) = Total BSOG (£million) / BSOG fuel rate (p/litre) x 100

Total bus passenger-km (Million) = Total activity (Million vkm) x Average bus occupancy (#)

Average fuel consumption (litres/pkm) = Total fuel consumption / Total bus passenger-km

Average bus emission factor = Average fuel consumption x Emission Factor ($kgCO_2e$/litre)

5.32. Whilst the overall the fundamental approach used in the 2016 update is similar to that previously used (i.e. as outlined above), the scope of coverage of the underlying data is different, which has resulted in step-change increase in emission factors for non-London local buses. In addition, since no BSOG data is available for London any more, the emission factors for London buses are taken directly from TfL's environmental reporting. Overall average emission factors for all local buses are estimated from DfT statistics on the relative passenger-km activity for London and non-London local buses[30].

5.33. As a final additional step, this year an accounting for biofuel use has been included in the calculation of the final bus emission factors.

5.34. Emission factors for coach services were estimated based on figures from National Express, who provide the majority of scheduled coach services in the UK. In the 2016 update, an additional accounting for the share of biofuels included in retail fuels has also been made.

5.35. 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 17.

[29] The robustness of the BSOG data has reduced over the years because of the changes to the way BSOG is paid to operators and local authorities. Approximations have been made in recent update years where data was not available (based on previous year data) and a revised methodology has commenced from 2016.

[30] DfT Bus statistics, Table BUS0302b "Passenger kilometres on local bus services by metropolitan area status and country: Great Britain, annual from 2004/05", available at: https://www.gov.uk/government/statistical-data-sets/bus03-passenger-distance-travelled

5.36. Table 17 gives a summary of the 2016 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.

Bus type	Average passenger occupancy	gCO_2e per passenger km			
		CO_2	CH_4	N_2O	Total
Local bus (not London)	9.66	119.02	0.08	0.76	119.86
Local London bus	20.51	73.40	0.04	0.36	73.80
Average local bus	**12.21**	**101.06**	**0.06**	**0.60**	**101.72**
Coach	17.56*	28.29	0.03	0.35	28.67

Notes: Average load factors/passenger occupancy mainly taken from DfT Bus statistics, Table BUS0304 “Average bus occupancy on local bus services by metropolitan area status and country: Great Britain, annual from 2004/05”. * Combined figure based on data from DfT for non-local buses and coaches combined calculated based on an average of the last 5 years for which this was available (up to 2007). Actual occupancy for coaches alone is likely to be significantly higher.

Table 17: Emission factors for buses for the 2015 GHG Conversion Factors

Direct Emissions from Motorcycles

5.37. 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.

5.38. 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).

5.39. Since the 2009 update the emission factors have been calculated based on a large dataset kindly provided by Clear (2008)[31], based on a mix of magazine road test reports and user reported data. A summary is presented in Table 18, with the corresponding complete emission factors developed for motorcycles are presented in the ‘passenger vehicles’ tables of the 2016 GHG Conversion Factors. The total average has been calculated weighted by the relative number of registrations of each category in 2008 according to DfT licencing statistics for 2014[32]. In the absence of newer information, the methodology and dataset are unchanged for the 2016 GHG Conversion Factors.

5.40. These emission factors are based predominantly upon data derived from real-world riding conditions (rather than 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 other figures based upon test-cycle

[31] 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.

[32] DfT Vehicle Licencing Statistics, Table VEH0306 “Licensed motorcycles by engine size, Great Britain, annually: 1994 to 2014”, available at: https://www.gov.uk/government/collections/vehicles-statistics

data from ACEM[33] (+9%) is smaller than the corresponding differential previously used to uplift car and van test cycle data to real-world equivalents (+15%).

5.41. Emission factors for CH_4 and N_2O were updated for the 2016 GHG Conversion Factors based on the emission factors from the 2014 UK GHG Inventory (Ricardo Energy & Environment, 2016). These factors are also presented together with overall total emission factors in the tables of the 2016 GHG Conversion Factors.

CC Range	Model Count	Number	Av. gCO_2/km	Av. MPG*
Up to 125cc	24	58	85.0	80.2
125cc to 200cc	3	13	77.8	87.6
200cc to 300cc	16	57	93.1	73.2
300cc to 400cc	8	22	112.5	60.6
400cc to 500cc	9	37	122.0	55.9
500cc to 600cc	24	105	139.2	48.9
600cc to 700cc	19	72	125.9	54.1
700cc to 800cc	21	86	133.4	51.1
800cc to 900cc	21	83	127.1	53.6
900cc to 1000cc	35	138	154.1	44.2
1000cc to 1100cc	14	57	135.6	50.3
1100cc to 1200cc	23	96	136.9	49.8
1200cc to 1300cc	9	32	136.6	49.9
1300cc to 1400cc	3	13	128.7	53.0
1400cc to 1500cc	61	256	132.2	51.5
1500cc to 1600cc	4	13	170.7	39.9
1600cc to 1700cc	5	21	145.7	46.8
1700cc to 1800cc	3	15	161.0	42.3
1800cc to 1900cc	0	0	0	0
1900cc to 2000cc	0	0	0	0
2000cc to 2100cc	1	5	140.9	48.4
<125cc	***24***	***58***	**85.0**	80.2
126-500cc	***36***	***129***	**103.2**	66.1
>500cc	***243***	***992***	**137.2**	49.7
Total	**303**	**1179**	**117.0**	**58.2**

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. * MPG has been calculated from the supplied gCO_2/km dataset, using the fuel properties for petrol from the latest conversion factors dataset.

Table 18: Summary dataset on CO_2 emissions from motorcycles based on detailed data provided by Clear (2008)

[33] The European Motorcycle Manufacturers Association

Direct Emissions from Passenger Rail

5.42. Emission factors for passenger rail services have been updated and provided in the "Business travel – land" section of the 2016 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 2016 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

5.43. The international rail factor is based on a passenger-km weighted average of the emission factors for the following Eurostar routes: London-Brussels, London-Paris, London-Marne Le Vallee (Disney), London-Avignon and the ski train from London-Bourg St Maurice[34]. The emission factors were provided by Eurostar for the 2016 update, together with information on the basis of the electricity figures used in their calculation.

5.44. 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 from the last freely available version of the IEA CO_2 Emissions from Fuel Combustion highlights dataset (from 2013).

5.45. The new figure from Eurostar is $12.071gCO_2$/pkm.

5.46. 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

5.47. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2014-15. The factor is sourced from information from the Office of the Rail Regulator's National rail trends for 2014-15 (ORR, 2015)[35]. 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).

5.48. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation and diesel rail (from the UK GHG Inventory), proportional to the CO_2 emission factors. The emission factors were calculated based on the relative passenger km proportions of diesel and electric rail provided by DfT for 2006-7 (since no newer datasets have been made available by DfT).

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[34] Although there are now also direct Eurostar routes to Lyon and Marseille, information relating to these routes has not been provided in 2016.

[35] Available from the ORR's website at: https://dataportal.orr.gov.uk/displayreport/html/html/31212a97-cf7a-42d5-9fe3-a134b5c08b6a

Light Rail

5.49. 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 19.

5.50. Figures for the DLR, London Overground and Croydon Tramlink for 2014/15 based on figures kindly provided by Transport for London, adjusted to the new 2016 grid electricity CO_2 emission factor.

5.51. The factors for Midland Metro, Tyne and Wear Metro, the Manchester Metrolink and Supertram were calculated based on annual passenger km data from DfT's Light rail and tram statistics'[36] and the new 2016 grid electricity CO_2 emission factor.

5.52. 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 2016 grid electricity CO_2 emission factor, for consistency.

5.53. The average emission factor was estimated based on the relative passenger km of the four different rail systems (see Table 19).

5.54. 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.

	Type	Electricity use kWh/pkm	gCO_2e per passenger km				Million pkm
			CO_2	CH_4	N_2O	Total	
DLR (Docklands Light Rail)	Light Rail	0.128	51.40	0.05	0.26	51.71	593.63
Glasgow Underground	Light Rail	0.164	73.37	0.07	0.37	73.82	12.70
Midland Metro	Light Rail	0.135	60.43	0.06	0.31	60.79	46.10
Tyne & Wear Metro	Light Rail	0.233	91.70	0.09	0.47	92.26	324.80
London Overground	Light Rail	0.097	38.99	0.04	0.20	39.23	861.17
Croydon Tramlink	Tram	0.112	44.93	0.04	0.23	45.20	159.83
Manchester Metrolink	Tram	0.078	35.14	0.03	0.18	35.35	325.90
Nottingham Express Transit	No data						
Sheffield- Supertram	Tram	0.350	156.32	0.15	0.80	157.27	74.60
Average*		**0.130**	**53.31**	**0.05**	**0.27**	**53.64**	**2398.73**

Notes: * Weighted by relative passenger km

Table 19: GHG emission factors, electricity consumption and passenger km for different tram and light rail services

London Underground

5.55. The London Underground rail factor was provided from Transport for London, which was based on the 2016 UK electricity emission factor, so was therefore adjusted to be consistent with the 2016 grid electricity CO_2 emission factor.

5.56. 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.

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

Indirect/WTT Emissions from Passenger Land Transport

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

Indirect/WTT (Well-To-Tank) emissions factors 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 emission factors and the indirect/WTT emission factors for the relevant fuels from the "Fuels" section and the corresponding direct CO_2 emission factors for vehicle types using these fuels in the "Passenger vehicles", "Business travel – land" and "Business travel – air" sections in the 2016 GHG Conversion Factors.

Rail

5.57. Indirect/WTT emission factors for international rail (Eurostar), light rail and the London Underground were derived using a simple ratio of the direct CO_2 emission factors and the indirect/WTT emission factors for grid electricity from the "UK Electricity" section and the corresponding direct CO_2 emission factors for vehicle types in the "passenger vehicles", "Business travel – land" and "Business travel – air" sections in the GHG Conversion Factors.

5.58. The emission factors for national rail services are based on a mixture of emissions from diesel and electric rail. Indirect/WTT emission factors 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

Direct Emissions from Heavy Goods Vehicles (HGVs)

6.1. The factors are based on road freight statistics from the Department for Transport (DfT, 2015)[37] for Great Britain (GB), from a survey on different sizes of rigid and articulated HGVs in the fleet in 2014. 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.

6.2. 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 2016 GHG Conversion Factors tables. Table RFS0117 of DfT (2015) shows the percent loading factors are on average between 40-73% 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 20 showing the change in CO_2 emissions for a vehicle completely empty (0% load) or fully laden (100% load) on a weight basis compared with the emissions at half-load (50% load). The data show the effect of load is symmetrical and largely independent of the HGVs Euro emission classification and type of drive cycle. So, for example, a >17t rigid HGV emits 18% more CO_2 per kilometre when fully laden and 18% less CO_2 per kilometre when empty relative to emissions at half-load.

6.3. The refrigerated/temperature-controlled HGVs included a 19.3% and 16.1% uplift which is applied to rigid and arctic refrigerated/temperature-controlled HGVs respectively. The refrigerated/temperature-controlled average factors have a 17.6% uplift applied. This is based on average data for different sizes of refrigerated HGV from Tassou et al (2009)[38].This accounts for the typical additional energy needed to power refrigeration equipment in such vehicles over similar non-refrigerated alternatives[39].

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[37] "Transport Statistics Bulletin: Road Freight Statistics 2011-2014, (DfT, 2015). Available at: https://www.gov.uk/government/statistics/road-freight-statistics-2014

[38] *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

[39] '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

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

6.4. 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. These are shown in the final factors presented in sections "Delivery vehicles" and "Freighting goods" of the 2016 GHG Conversion Factors.

6.5. The loading factors in Table 20 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.

6.6. It might be surprising to see that the CO_2 factor for a >17t rigid HGV is greater than for a >33t articulated HGV. However, these factors merely reflect the estimated MPG figures from DfT statistics that consistently show worse mpg fuel efficiency, on average, for large rigid HGVs than large articulated HGVs once the relative degree of loading is taken into account. This 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 2016 GHG Conversion Factors. Thus the factors in "Delivery vehicles" and "Freighting goods", linked to the DfT (2015) statistics on MPG (estimated by DfT from the survey data) reflect each HGV class's typical usage pattern on the GB road network.

6.7. UK average factors for all rigid and articulated HGVs are also provided in sections "Delivery vehicles" and "Freighting goods" of the 2016 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 2014. These are derived directly from the mpg values for rigid and articulated HGVs in Table RFS0141of DfT (2015).

6.8. 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.

6.9. The conversion factors provided in “Delivery vehicles” of the 2016 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.

6.10. 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 2016 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”. 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 44%. The 2016 GHG Conversion Factors, include factors in tonne km (tkm) for all loads, (0%, 50%, 100% and average).

6.11. 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 2016 GHG Conversion Factors for the relevant HGV class.

6.12. Emission factors for CH_4 and N_2O have been updated for all HGV classes. These are based on the emission factors from the 2014 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 2016 GHG Conversion Factors.

Direct Emissions from Vans/Light Goods Vehicles (LGVs)

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

6.14. The typical / average capacities and average payloads agreed with DfT that are used in the calculation of van emission factors per tonne km are presented in Table 21. These are based on quantitative assessment of a van database used by Ricardo Energy & Environment previously in a variety of policy assessments for DfT.

Van fuel	Van size, Gross Vehicle Weight	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

Van fuel	Van size, Gross Vehicle Weight	Vkm % split	Av. Capacity tonnes	Av. Payload tonnes
Average			**1.15**	**0.46**

Table 21: Typical van freight capacities and estimated average payload

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

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[40]

Table 22: Utilisation of vehicle capacity by company-owned LGVs: annual average 2003 – 2005 (proportion of total vehicle kilometres travelled)

6.16. Emission factors for CH_4 and N_2O have been updated for all van classes in the 2016 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.

6.17. 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 21 and the earlier emission factors per vehicle-km in the “Delivery vehicles” and “Freighting goods” sections of the 2016 GHG Conversion Factors.

[40] 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

6.18. Data provided by the Office of the Rail Regulator's (OPR) Table 2.10 Sustainable development: Estimates of normalised passenger and freight CO_2e emissions or 2014-15 (ORR, 2015)[41] has been used to update the rail freight emission factors for the 2016 GHG Conversion Factors. This factor is presented in "Freighting goods" in the 2016 GHG Conversion Factors. There have been no further updates to the methodology in the 2016 update.

6.19. 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 95% of the total for 2014-15 (ORR,2015).

6.20. 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).

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

6.22. 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

6.23. Indirect/WTT emission factors 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 emission factors and the indirect/WTT emission factors for the relevant fuels and the corresponding direct CO_2 emission factors for vehicle types using these fuels.

Rail

6.24. The emission factors for freight rail services are based on a mixture of emissions from diesel and electric rail. Indirect/WTT emission factors were therefore calculated in a similar way to the other freight transport modes, except from combining indirect/WTT emission factors 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 in table 2.101 Sustainable development: Estimates of passenger and freight energy consumption and CO_2e emissions (2015).

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[41] Available from the ORR's website here: https://dataportal.orr.gov.uk/displayreport/html/html/31212a97-cf7a-42d5-9fe3-a134b5c08b6a

7. Sea Transport Emission Factors

Direct Emissions from RoPax Ferry Passenger Transport and freight

7.1. Direct emission factors from RoPax passenger ferries and ferry freight transport is based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[42]. No new methodology or updated dataset has been identified for the 2016 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[43]
Average weight of passenger + luggage, total	0.100	MCA, 2007[43]
Average Freight Unit*, total	22.173	BFF, 2007[44]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[45]

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

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 from this figure and the total number of passenger km, and is presented in the “Business travel – sea” section of the 2016 GHG Conversion Factors. A further split has been provided between foot-only passengers and passengers with cars in the 2016 GHG Conversion Factors, again on a weight allocation basis.

[42] 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.

[43] 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

[44] 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.

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

7.5. 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 2016 GHG Conversion Factors tables.

7.6. 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).

7.7. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the 2014 UK GHG Inventory, proportional to the CO_2 emissions.

Direct Emissions from Other Marine Freight Transport

7.8. 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)[46] report on GHG emissions from ships. The figures in "Freighting goods" of the 2016 GHG Conversion Factors represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.

7.9. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the UK GHG Inventory for 2014, proportional to the CO_2 emissions.

Indirect/WTT Emissions from Sea Transport

7.10. Indirect/WTT emissions factors 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 emission factors and the indirect/WTT emission factors for the relevant fuels and the corresponding direct CO_2 emission factors for ferries and ships using these fuels.

[46] "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 no significant changes made to methodology for the conversion factors for flights to/from the UK in the 2016 update. Updates this year have been limited to updating the underlying statistical datasets/analysis, and in a few cases amendments to the specific aircraft types included in the calculations where relevant (i.e. for representative coverage). The methodology for emissions factors for international passenger flights between non-UK destinations, first introduced in the 2015 update, is also fundamentally unchanged.

Passenger Air Transport Direct CO_2 Emission Factors

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

8.3. Additionally, a brand new set of aviation factors was also added for international flights between non-UK destinations in the 2015 update. This relatively high level analysis allows users to choose a different factor for passenger 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 and so international freight factors was assumed to be equal to the current UK long haul air freight factors[47].

8.4. The 2016 update of the average factors (presented at the end of this section) has been calculated using the same updated data source as in 2015. The EUROCONTROL small emitters tool was used as the basis for calculating the CO_2 emissions factors resulting from fuel burn over average flights for different aircraft. The principal advantages of the source are:

   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 wide range of aircraft, including many newer (and more efficient) aircraft increasingly used in flights to/from the UK, and also 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.

8.5. 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,

[47] 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.

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) [48];

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.

8.6. New and high-profile efficient aircraft such as the Airbus A380-800 and Boeing 787-800 Dreamliner have been added in Table 24 for the first time this year as they now account for a significant share of pkm to/from the UK. However, they are not currently included in the EUROCONTROL small emitters tool, so estimates for their CO_2 emissions/fuel burn were made based on information from other sources on their performance relative to other aircraft:

8.7. *Airbus A380-800:* 91.4% of the aircraft fuel burn rate (in kg/km) for a long-haul flight in comparison to a Boeing 747-400 aircraft[49];

8.8. *Boeing 787-800:* 63.5% of the aircraft fuel burn rate (in kg/km) for a long-haul flight in comparison to a Boeing 777-300ER aircraft[49].

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	EF, $kgCO_2$/vkm	Av. flight length, km
Domestic Flights					
AIRBUS A319	190	76%	40%	15.0	458
AIRBUS A320-100/200	256	66%	23%	16.0	474
AIRBUS A321	244	75%	5%	17.3	504
BOEING 737-400	197	74%	2%	15.0	536
BOEING 737-800	262	70%	2%	15.3	432
BOEING 767-300ER/F	202	91%	2%	26.5	537
BOMBARDIER DASH 8 Q400	107	70%	16%	6.9	361
EMB ERJ175 (170-200)	108	68%	1%	9.0	579
EMBRAER ERJ190	136	70%	3%	12.3	554
EMBRAER ERJ195	176	66%	1%	14.8	360
SAAB 2000	80	62%	2%	6.6	383
SAAB FAIRCHILD 340	53	62%	1%	4.2	262
Average	***190***	***72%***	***100%*(total)***	***12.0***	***415***
Short-haul Flights					
AIRBUS A319	177	81%	16%	11.6	1,020
AIRBUS A320-100/200	221	77%	24%	11.7	1,405
AIRBUS A321	263	76%	11%	12.8	1,793
BOEING 737-300	158	88%	3%	11.2	1,579

[48] 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

[49] Calculated based on collected datasets on fuel consumption per seat-km for specific aircraft at: https://en.wikipedia.org/wiki/Fuel_economy_in_aircraft. This sourced used data from the following sources: http://www.aspireaviation.com/2015/06/08/airbus-a350-is-the-xtra-making-the-difference/ (for the A380-800), and http://airwaysnews.com/blog/2016/03/17/boeing-787-8-a330-800neo-far-from-dead/ (for the B787-800).

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	EF, $kgCO_2$/vkm	Av. flight length, km
BOEING 737-400	186	80%	2%	12.3	1,276
BOEING 737-800	226	81%	33%	11.5	1,457
BOEING 757-200	271	84%	8%	14.5	2,390
BOEING 767-300ER/F	263	86%	3%	20.4	2,308
EMBRAER ERJ190	138	72%	1%	10.6	890
Average	***222***	***80%***	***100%*(total)***	***12.1***	***1,385***
Long-haul Flights					
AIRBUS A320-100/200	372	77%	5%	21.4	6,652
AIRBUS A330-300	493	64%	5%	22.1	5,734
AIRBUS A340-300	339	76%	1%	25.3	8,386
AIRBUS A340-600	421	76%	5%	31.6	7,460
AIRBUS A380-800	609	81%	11%	34.7	7,519
BOEING 747-400	490	76%	20%	38.0	7,142
BOEING 757-200	236	80%	2%	13.7	5,084
BOEING 767-300	301	73%	6%	19.2	6,208
BOEING 767-400	339	73%	1%	20.7	6,043
BOEING 777-200ER	391	71%	17%	25.4	6,844
BOEING 777-300ER	497	73%	21%	30.1	7,232
BOEING 787-800 DREAMLINER	297	84%	5%	19.1	6,959
Average	***447***	***75%***	***100%*(total)***	***27.4***	***6,797***

Notes: Figures on seats, load factors, % tkm and av. flight length have been calculated from 2015 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 93% of domestic pkm, 93% of short-haul pkm and 95% of long-haul pkm.

Table 24: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2016

8.9. **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 (2015) 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		

Area	Destination Airport	Distance, km
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 2014.

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

Taking Account of Freight

8.10. 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 over 4 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.

8.11. 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	100.00%	135.5	99.7%	135.1	99.7%	135.1
Short-haul flights	100.00%	83.2	98.2%	81.7	98.2%	81.7
Long-haul flights	100.00%	114.0	66.4%	75.4	81.6%	92.9

Table 26: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2016 GHG Conversion Factors

8.12. 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 weight per passenger seat used in the calculations for the 2016 GHG Conversion Factors were calculated for the specific aircraft used and are on average over twice the weight per passenger and their luggage alone. In the **Option 2** methodology the derived ratio for different aircraft types were used to upscale the CAA passenger tonne km data, increasing this as a percentage of the total tonne km – as shown in Table 26.

8.13. 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**.

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

8.15. Validation checks using the derived emission factors calculated using the EUROCONTROL small emitters tool 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).

8.16. The final average emission factors for aviation are presented in Table 27. The figures in 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 2016 GHG Conversion Factor data tables.

Mode	Factors for 2016	
	Load Factor%	gCO_2 /pkm
Domestic flights	72.0%	135.10
Short-haul flights	80.0%	81.68
Long-haul flights	75.0%	92.91

Notes: Load factors based on data provided by DfT that contains detailed analysis of CAA 2014 statistical returns

Table 27: Final average CO_2 emission factors for passenger flights for 2016 GHG Conversion Factors (excluding distance and RF uplifts)

Seating Class Factors

8.17. 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.

8.18. There is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, previously (in 2008) a review was carried out of the seating configurations from a selection of 16 major airlines and average seating configuration information from Boeing and Airbus websites. This evaluation was used to form a basis for the seating class based emission factors provided in Table 28, together with additional information obtained either directly from airline websites or from other specialist websites that had already collated such information for most of the major airlines.

8.19. 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[50] the space taken up by the basic economy seating. 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 scaling is to lower the economy seating emission factor in relation to the average, and increase the business and first class factors.

8.20. The relative share in the number of seats by class for short-haul and long-haul flights was updated/revised in 2015 using data provided by DfT's aviation team, following checks conducted by them on the validity of the current assumptions based on more recent data.

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

Flight type	Cabin Seating Class	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**72.0%**	**135.1**	**1.00**	**100.0%**	**100.0%**
Short-haul	**Average**	**80.0%**	**81.7**	**1.02**	**100.0%**	**100.0%**
	Economy class	80.0%	80.0	1.00	98.0%	96.7%
	First/Business class	80.0%	120.1	1.50	147.0%	3.3%
Long-haul	**Average**	**75.0%**	**92.9**	**1.31**	**100.0%**	**100.0%**
	Economy class	75.0%	71.2	1.00	76.6%	83.0%
	Economy+ class	75.0%	113.9	1.60	122.6%	3.0%
	Business class	75.0%	206.4	2.90	222.1%	11.9%
	First class	75.0%	284.7	4.00	306.4%	2.0%

Notes: Load factors based on data provided by DfT that contains detailed analysis of CAA 2014 statistical returns

Table 28: Seating class based CO_2 emission factors for passenger flights for 2016 GHG Conversion Factors (excluding distance and RF uplifts)

Freight Air Transport Direct CO_2 Emission Factors

8.21. 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.

8.22. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2015). These data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts approximately for 83% 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.

8.23. 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

8.24. 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 2016 update for the GHG Conversion Factors – presented in 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 2016 GHG Conversion Factor data tables.

Mode	Revised factors for 2016	
	Load Factor%	$kgCO_2$ /tkm
Domestic flights	46.53%	2.43
Short-haul flights	74.75%	1.05
Long-haul flights	74.62%	0.67

Notes: Load factors based on Annual UK Airlines Statistics by Aircraft Type – CAA 2012 (Equivalent datasets after this are unavailable due to changes to CAA's confidentiality rules)

Table 29: Revised average CO_2 emission factors for dedicated cargo flights for 2016 GHG Conversion Factors (excluding distance and RF uplifts)

8.25. The updated factors have been calculated in the same basic methodology as for the passenger flights, which was updated in 2015 to use the aircraft specific fuel consumption /emission factors calculated using the EUROCONTROL small emitters tool[51]. 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 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%	55.2%	6.65	246
BAE 146-200/QT	10.0	34%	0.0%	0.00	0
Boeing 737-300	15.2	45%	30.5%	27.95	153
Boeing 757-200	23.2	56%	3.3%	22.04	155
Boeing 747-8 (freighter)	126.9	19%	0.0%	0.00	217
Boeing 767-300ER/F	58.0	47%	11.0%	26.80	517
Average	***16.2***	***47%***	***100% (total)***	***12.20***	***379***
Short-haul Flights					
BAE ATP	8.0	43%	2.1%	5.51	536
Boeing 757-200	22.0	77%	71.4%	18.02	750
Boeing 747-8 (freighter)	124.3	33%	1.8%	59.83	707
Boeing 767-300ER/F	30.8	75%	24.7%	20.77	1,910
Average	***25.7***	***75%***	***100% (total(***	***17.55***	***1,432***
Long-haul Flights					
BAE ATP	8.0	43%	2.1%	5.79	416
Boeing 757-200	22.0	77%	71.4%	15.87	1,296
Boeing 747-8 (freighter)	124.3	33%	1.8%	36.58	5,314
Boeing 767-300ER/F	30.8	75%	24.7%	19.37	5,147
Average	***73.3***	***75%***	***100% (total)***	***20.93***	***4,381***

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

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 2016 GHG Conversion Factors

Emission Factors for Freight on Passenger Services

8.26. 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 2016 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 $kgCO_2$ /tkm	PS Freight tkm, % total	Overall $kgCO_2$ /tkm
Domestic flights	2.79%	97.21%	0.27%	2.42	0.27%	2.42
Short-haul flights	23.72%	76.28%	1.75%	1.06	1.75%	1.06
Long-haul flights	82.94%	17.06%	33.59%	0.93	18.38%	0.68

Table 31: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2016 GHG Conversion Factors (excluding distance and RF uplifts)

8.27. 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[52] (in 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 almost 50% higher than the comparable figure given in Table 29 for **Option 1**, but is almost the same as the figure for **Option 2**. This would mean that under **Option 1**, freight transported on a passenger aircraft could be said to result in much more 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.

8.28. **Option 2** was selected as the preferred methodology for freight allocation for the 2008 update, when this analysis was original performed. The same methodology has been

[52] Although freight only flights generally adjust course less frequently in order to avoid turbulence.

applied in subsequent updates and is included in all of the presented emission factors for 2016.

Average Emission Factors for All Air Freight Services

8.29. The following Table 32 presents the final average air freight emission factors for all air freight for the 2016 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 2016 GHG Conversion Factor data tables (discussed later).

Mode	% Total Air Freight tkm		All Air Freight $kgCO_2/tkm$
	Passenger Services	Cargo Services	
Domestic flights	2.79%	97.21%	2.42
Short-haul flights	23.72%	76.28%	1.06
Long-haul flights	82.94%	17.06%	0.68

Notes: % Total Air Freight tkm based on CAA statistics for 2014 (T0.1.6 All Services)

Table 32: Final average CO_2 emission factors for all air freight for 2016 GHG Conversion Factors (excluding distance and RF uplifts)

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

8.30. 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 2014 (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 2016 GHG Conversion Factors are presented in Table 34 for passengers and Table 35 for freight.

	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	1.71	99.01%	0.0009	0.05%	0.016	0.94%
Aircraft - international	32.61	99.06%	0.0022	0.01%	0.309	0.94%

Table 33: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2014

Emissions of N_2O

8.31. 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 2014 (see Table 33), and the corresponding CO_2 emission factors. The resulting air transport emission factors for the 2016 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 2016 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**	**135.1**	**0.1**	**1.3**	**136.4**
Short-haul flights	**Average**	**81.7**	**0.0**	**0.8**	**82.5**
	Economy	80.0	0.0	0.8	80.8
	First/Business	120.1	0.0	1.1	121.2
Long-haul flights	**Average**	**92.9**	**0.0**	**0.9**	**93.8**
	Economy	71.2	0.0	0.7	71.8
	Economy+	113.9	0.0	1.1	115.0
	Business	206.4	0.0	2.0	208.4
	First	284.7	0.0	2.7	287.4
International flights (non-UK)	**Average**	**86.8**	**0.0**	**0.8**	**87.6**
	Economy	66.5	0.0	0.6	67.1
	Economy+	106.4	0.0	1.0	107.4
	Business	192.8	0.0	1.8	194.6
	First	265.9	0.0	2.5	268.5

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 2016 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	1.86727	0.00093	0.01767	1.88588
Short-haul flights	1.11348	0.00007	0.01054	1.12409
Long-haul flights	0.68819	0.00005	0.00651	0.69475
Dedicated Cargo				
Domestic flights	2.43072	0.00121	0.02300	2.45494
Short-haul flights	1.04567	0.00007	0.00989	1.05564
Long-haul flights	0.66508	0.00004	0.00629	0.67142
All Air Freight				

Air Freight Mode	CO_2 $kgCO_2/tkm$	CH_4 $kgCO_2e/tkm$	N_2O $kgCO_2e/tkm$	Total GHG $kgCO_2e/tkm$
Domestic flights	2.41501	0.00120	0.02285	2.43906
Short-haul flights	1.06176	0.00007	0.01005	1.07187
Long-haul flights	0.68425	0.00005	0.00647	0.69077

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 2016 GHG Conversion Factors (excluding distance and RF uplifts)

Indirect/WTT Emission Factors from Air Transport

8.32. Indirect/WTT emissions factors 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 emission factors and the indirect/WTT emission factors for aviation turbine fuel (kerosene) and the corresponding direct CO_2 emission factors 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

8.33. 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.

8.34. 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. DfT has indicated (in discussions with their Aviation team) that 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 that has been used since the 2014 update, and therefore also in the 2016 GHG Conversion Factors.

8.35. 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 approach) to take into account of indirect flight paths and delays/congestion/circling. This is the methodology recommended to be used with the GHG Conversion Factors and is applied already to the emission factors presented in the 2016 GHG Conversion Factors tables.

Non-CO_2 impacts and Radiative Forcing

8.36. The emission factors provided in the 2016 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.

8.37. 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.

8.38. 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.

8.39. 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[53] and in analysis by Lee et al (2009) reported on by the Committee on Climate Change (2009)[54].

> **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.*

8.40. 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"

[53] 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

[54] 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/

Notes: Estimates for scaling CO_2 emissions to account for Radiative Forcing impacts are

		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

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)

	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. Some of the WTT bioenergy factors have been updated to align with the update of the Ofgem Solid and Gaseous Biomass Carbon Calculator v2[55]. There have been some alterations within the Ofgem calculator which has caused quite large differences between the 2015 and the 2016 GHG WTT bioenergy Conversion Factors.

General Methodology

9.2. The 2016 GHG Conversion Factors provide tables of emission factors for: water supply and treatment; biofuels; and biomass and biogas.

9.3. The emission factors presented in the tables incorporate emissions from the fuel life-cycle and include net CO_2, CH_4, N_2O emissions and Indirect/WTT emissions factors. These are presented for biofuels, biomass and biogas.

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

Water

9.5. The emission factors for water supply and treatment in sections “Water supply” and “Water treatment” of the 2016 GHG Conversion Factors were sourced from Water UK (for reporting in 2008, 2009, 2010 and 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.

9.6. 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 2016 update is unchanged since the 2012 GHG Conversion Factors values.

Biofuels

9.7. 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[56]. Therefore, all direct emissions from biofuels provided in the GHG Conversion Factors dataset are only made up of CH_4 and N_2O emissions.

9.8. Unlike the direct emissions of CO_2, CH_4 and N_2O 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

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[55] Found here: https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator

[56] This is a convention required by international GHG Inventory guidelines and formal accounting rules

combusting the corresponding fossil fuels (i.e. diesel, petrol or CNG) from the "Fuels" section.

9.9. The indirect/WTT/fuel lifecycle emission factors for biofuels were based on UK average factors from the Quarterly Report (2014/15)[57] on the Renewable Transport Fuel Obligation (RTFO). These average factors and the direct CH_4 and N_20 factors are presented in Table 38.

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	18.78	0.02	0.58	19.38	75.30
Bioethanol	32.28	0.21	0.12	32.61	71.60
Biomethane	10.00	0.08	0.03	10.11	55.28
Biodiesel (from used cooking oil)	14.36	0.02	0.58	14.96	75.30
Biodiesel (from Tallow)	14.12	0.02	0.58	14.72	75.30

Notes:
(1) Based on UK averages from the RTFO Quarterly Report (2014/15) 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 Biomass Energy Centre (BEC) (2012)

Table 38: Fuel lifecycle GHG Conversion Factors for biofuels

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

9.11. 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 2016 GHG Conversion Factors (see table and the table footnote), based on data sourced from the Biomass Energy Centre (BEC, 2012)[58].

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[57] These cover the period from April 2014 - April 2015, and were the most recent figures available at the time of production of the 2016 GHG Conversion Factors. The report is available from the GOV. website at: https://www.gov.uk/government/collections/biofuels-statistics

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

Other biomass and biogas

9.12. A number of different bioenergy/biomass 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 2016 GHG Conversion Factors.

9.13. All indirect/WTT/fuel lifecycle emission factors here, except for wood logs, are sourced from the Ofgem carbon calculators[59]. These calculators have been developed to support operators determining the GHG emissions associated with the cultivation, processing and transportation of their biomass fuels.

9.14. Indirect/WTT/fuel lifecycle emission factors for wood logs, which are not covered by the Ofgem tool, were obtained from the Biomass Energy Centre’s (BEC) tool, $BEAT_2$[60], provided by Defra.

9.15. The direct CH_4 and N_2O emission factors presented in the 2016 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2014 (managed by Ricardo Energy & Environment.

9.16. In some cases, calorific values were required to convert the data into the required units. The most appropriate source was used and this was either from the BEC or from DUKES (Table A.1). 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 2016 GHG Conversion Factors (see “Outside of scopes” and the relevant notes on the page), also based on data from sourced from BEC (2013).

Biomass	Moisture content	Net calorific value (GJ/tonne)	Source
Wood chips	25% moisture	13.6	BEC
Wood logs	Air dried 20% moisture	14.7	BEC
Wood pellets	10% moisture	15.3	DUKES
Grass/Straw	10% moisture	13.4	DUKES
Biogas/Landfill gas	BEIS GHG values - based on 60% CH_4	30	BEIS GHG values - based on 60% CH_4

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

[59]Ofgem carbon calculator tools: 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

[60] Biomass Energy Centre’s (BEC) tool, $BEAT_2$: http://www.biomassenergycentre.org.uk/portal/page?_pageid=74,153193&_dad=portal&_schema=PORTAL

10. Overseas Electricity Emission Factors

Summary of changes since the previous update

10.1. There have been no new methodological changes to this section; however, the overseas electricity factors are no longer available, due to a change in the licencing conditions for the underlying International Energy Association (IEA) dataset upon which they were based. Instead these can be purchased from the IEA[61] .

10.2. These conversion factors supplied by the IEA are for the electricity supplied to the grid that organisations purchase; this does not include the emissions associated with electricity losses during transmission and distribution of electricity between the power station and an organisation's site(s). These are still provided within the 2016 update (see below for more detail). Likewise, the conversion factors supplied by the IEA also do not include the emissions associated with the extraction, refining and transportation of primary fuels before their use in the generation of electricity (WTT emissions). These are also still available.

Direct Emissions from Overseas Electricity Generation

10.3. 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 considerably.

10.4. The dataset on electricity and heat emission factors from the IEA, provided from the IEA website, 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. As stated these can be purchased from the IEA website.

Transmission and distribution losses from Overseas Electricity Generation

10.5. CO_2 emission factors, per kWh, associated with the LOSSES in electricity transmission/distribution grids can be found in the "Transmission and distribution" (T&D) part of the GHG conversion factors tables.

10.6. The T&D LOSSES factors are 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. The electricity GENERATED figure used in this equation is the overseas emission factor figures published previously in the 2015 Update. The factors in the 2015 and 2014 update were taken from the last publically available overseas emission factors data set published by the IEA in 2013[62]. In 2015 these figures were extrapolated to provide the 2015 overseas emission factors.

[61] Available here: http://www.oecdbookshop.org/browse.asp?pid=title-detail&lang=en&ds=CO2-Emissions-from-Fuel-Combustion-2015&K=5JRTCR8FQK6F

[62] IEA (2013), CO2 Emissions from Fuel Combustion Highlights.

10.8. The electricity T&D LOSSES figure comes from the 2013 country energy balances available at the IEA website. This figure is calculated from the 'Distribution Losses' and 'Total Fuel Consumption' (TFC) figures from the Energy Balance data tables.

10.9. Emission factors have been provided for all EU Member States and major UK trading partners.

Indirect/WTT Emissions from Overseas Electricity Generation

10.10. 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 "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.

10.11. 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. 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 15.1%).

11. Material Consumption/Use and Waste Disposal

Summary of changes since the previous update

11.1. There have been no new methodological changes to this section since last year's (2015) update.

11.2. Two updates have also been made to some of the factors reflecting more recent source data in the latest 2016 GHG Conversion Factors. These are;

a. Revisions to the ecoprofiles for a range of plastics by PlasticsEurope[63]

b. The estimate for Methane capture from landfill waste has increased to 61%[64]. This affects all landfill emissions for most organic materials.

Emissions from Material Use and Waste Disposal

11.3. Since 2012 the greenhouse gas emission factors for material consumption / use and waste disposal have been Aligned with the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard ('the Scope 3 Standard')[65]. This sets down rules on accounting for emissions associated with material consumption and waste management.

11.4. 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.

11.5. 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).

11.6. 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[66] CO_2 has also been excluded from these figures.

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

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

[64] MacCarthy J, Broomfield M, Brown P, Buys G, Cardenas L, Murrells T, Pang Y, Passant N, Thistlethwaite G, Watterson J (2015) UK Greenhouse Gas Inventory, 1990 to 2013: Annual Report for submission under the Framework Convention on Climate Change

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

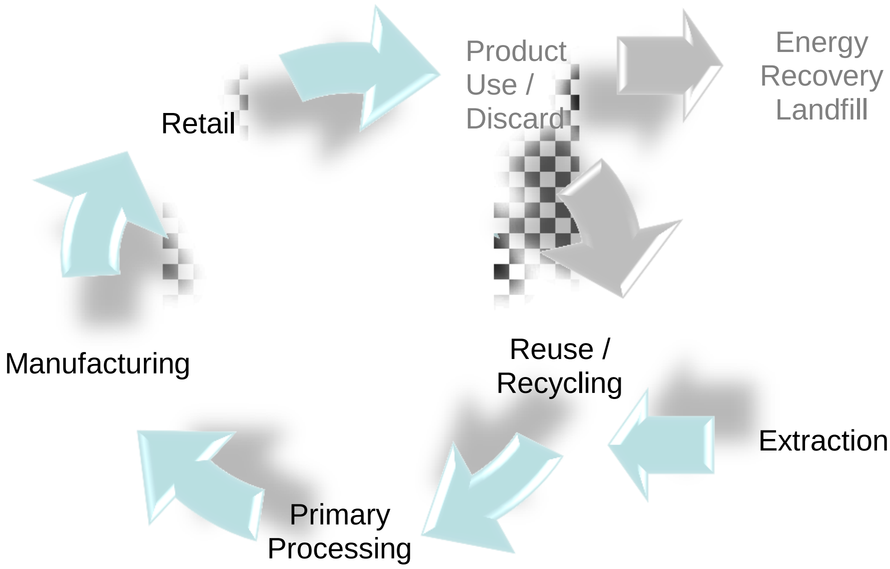
[66] Biogenic CO_2 is the CO_2 absorbed and released by living organisms during and at the end of their life. By convention, this is assumed to be in balance in sustainably managed systems.

11.8. 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.

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

Material Consumption/Use

11.10. Figure 3 shows the boundary of greenhouse gas emissions summarised in the material consumption table.



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

Figure 3: Boundary of material consumption data sets

11.11. 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.

11.12. 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.

11.13. 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.

11.14. 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.

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

11.16. Table 40 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 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)[67] 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)[68] IGD (2008)[69]

Table 40: Distances and transportation types used in EF calculations

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

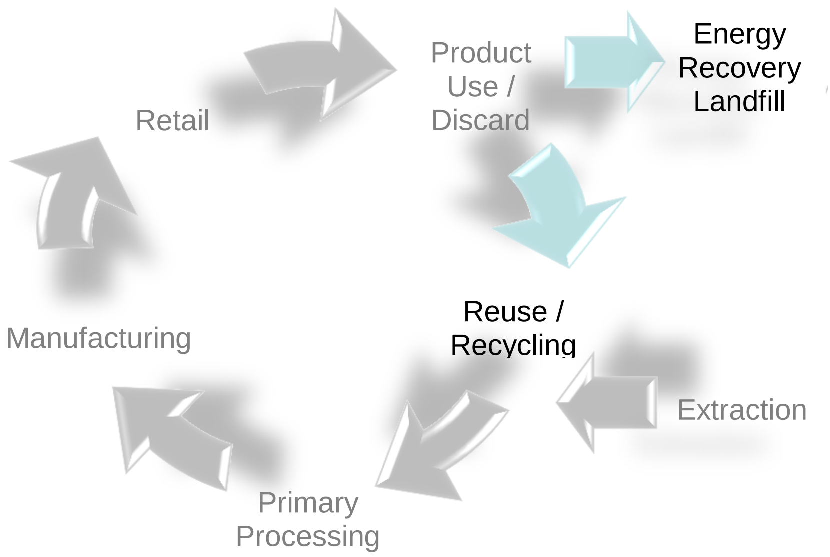
Waste Disposal

11.18. Figure 4 shows the boundary of greenhouse gas emissions summarised in the waste disposal table.

[67] 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

[68] 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

[69] 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/



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

Figure 4: Boundary of waste disposal data sets

11.19. 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.

11.20. 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.

11.21. 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.

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

11.23. 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 41.

Destination / Intermediate Destination	One Way	Mode of transport	Source

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

	Distance		
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 41: Distances used in calculation of emission factors

11.24. 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/BEIS (2009)[71]. Waste vehicles leave a depot empty and return fully laden. A 50% loading assumption reflects the change in load over a collection round which could be expected.

11.25. 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 61% of methane is captured[72]. 10% of uncaptured methane is assumed to be oxidised at the cap. Key data sources for waste disposal emissions are identified in Appendix 1.

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

[71] Defra/BEIS (2009). Greenhouse Gas Conversion Factors. Available at: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2009

[72] MacCarthy J, Broomfield M, Brown P, Buys G, Cardenas L, Murrells T, Pang Y, Passant N, Thistlethwaite G, Watterson J (2015) UK Greenhouse Gas Inventory, 1990 to 2013: Annual Report for submission under the Framework Convention on Climate Change

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

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

12. Fuel Properties

12.1. No new updates were made to the fuel properties section in the 2016 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 BEIS's Digest of UK Energy Statistics (DUKES) 2015.[75]

12.4. The fuel properties (GCV, NCV and density) for CNG and LNG is assumed to be the same as natural gas.

12.5. The fuel properties of 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 4a, 2014 (Report EUR 26236 EN - 2014).[76] The exception is for methyl-ester based biodiesels and bioethanol, where values for NCV and GCV are taken from DUKES 2015.

12.6. Fuel properties for wood logs (20% moister content) and wood chips (25% moister content) are sourced from the Biomass Energy Centre (BEC), which is owned and managed by the UK Forestry Commission, via Forest Research, its research agency[77]. The fuel properties of the other forms of biomass are taken from DUKES 2015.

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[75] Available at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

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

[77] 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=PORTALand http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,177178&_dad=portal&_schema=PORTAL

Appendix 1. Additional Methodological Information on the Material Consumption/Use and Waste Disposal Factors

This section explains the methodology for the choice of data used in the calculation of carbon emissions used in the waste management 2016 GHG Conversion Factors. Section 1.1 details the indicators used to assess whether data met the data quality standards required for this project. Section 1.2 states the sources used to collect data. Finally, Section 1.3 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
Consistency	The methodology has been applied consistently.	

Data Quality Indicator	Requirement	Comments
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

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[78] 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.

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[79]. 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

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

[79] 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

combination with information on the composition of wood waste in the UK[80] 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.

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.

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[80] 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

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	
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	

Material	Reference	
Scrap Metal	British Metals Recycling Association (*website*[81]) 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
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

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

Material	Reference	
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 (2015) *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
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)	Based on split in AMA Research (2009) *Plastics Recycling Market UK 2009-2013*, UK; Cheltenham	WRAP (2008) *LCA of Mixed Waste Plastic Management Options*; WRAP, Banbury
Average plastic rigid (inch bottles)		
Clothing	BIO IS (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	Huisman, J., et al (2008) *2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment* – Study No. 07010401/2006/442493/ETU/G4, United Nations University, Bonn Germany	
WEEE – Mixed		
WEEE – Small		
Batteries (Post Consumer Non-Automotive)	-	DEFRA (2006) *Battery Waste Management Life Cycle Assessment*, prepared by ERM; WRAP, Banbury
Paint	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	

Material	Reference
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*

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	280,234	**8.08%**	205,866	2.945	3.796
1991	283,201	**8.27%**	202,448	2.778	3.741
1992	281,223	**7.55%**	190,457	2.667	3.520
1993	284,350	**7.17%**	174,143	2.620	3.002
1994	289,126	**9.57%**	169,773	2.715	2.861
1995	299,196	**9.07%**	166,959	2.763	2.756
1996	313,070	**8.40%**	166,218	2.761	2.558
1997	311,220	**7.79%**	153,835	2.611	2.200
1998	320,740	**8.40%**	158,558	2.775	2.263
1999	323,873	**8.25%**	150,626	2.783	1.975
2000	331,553	**8.38%**	163,047	2.990	2.214
2001	342,686	**8.56%**	173,636	3.248	2.438
2002	342,338	**8.26%**	168,250	3.202	2.297
2003	354,225	**8.47%**	180,875	3.367	2.531
2004	349,312	**8.71%**	178,461	3.367	2.445
2005	350,778	**7.25%**	177,155	3.843	2.565
2006	349,211	**7.21%**	186,183	3.969	2.778
2007	352,778	**7.34%**	183,513	3.969	2.581
2008	348,876	**7.43%**	178,930	4.161	2.421
2009	338,983	**7.86%**	157,904	4.034	2.095
2010	343,766	**7.42%**	162,596	4.165	2.177
2011	329,071	**7.89%**	149,890	4.052	2.182
2012	324,315	**8.15%**	163,758	4.400	2.768
2013	319,125	**7.63%**	151,057	4.626	2.620
2014	297,897	**8.30%**	126,358	4.769	2.166

Notes:

(1) Based upon calculated **total** for **all** electricity generation (GWh supplied) from DUKES (2015) Table 5.5, with a reduction of the total for autogenerators based on unpublished data from the BEIS DUKES team on the share of this that is actually exported to the grid (~17% in 2014).

(2) Based upon calculated net grid losses from data in DUKES (2015) Table 5.1.2 (long term trends, only available online).

(3) Emissions from UK centralised power generation (excluding Crown Dependencies and Overseas Territories) listed under UNFCC reporting category 1A1a and autogeneration - exported to grid (UK Only) listed under UNFCC reporting category 1A2f from the UK Greenhouse Gas Inventory for 2012 (Ricardo-AEA, 2014), with data from the GHGI for 2014 (Ricardo Energy & Environment, 2016) for the 2014 data year. Also includes an accounting (estimate) for autogeneration emissions not specifically split out in the NAEI, consistent with the inclusion of the GWh supply for these elements also.

Table 42: Base electricity generation emissions data - most recent datasets for time series

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports	Average 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	0.73462	0.00026	0.00404	0.73892	0.06455	0.00002	0.00035	0.06492	0.79917	0.00029	0.00439	0.80384	**4.08%**	0.11300
1991	0.71486	0.00025	0.00394	0.71904	0.06445	0.00002	0.00035	0.06482	0.77930	0.00027	0.00429	0.78386	**5.48%**	0.12790
1992	0.67724	0.00024	0.00373	0.68121	0.05528	0.00002	0.00030	0.05560	0.73253	0.00026	0.00403	0.73682	**5.60%**	0.10097
1993	0.61242	0.00023	0.00315	0.61580	0.04730	0.00002	0.00024	0.04756	0.65972	0.00025	0.00339	0.66336	**5.55%**	0.06828
1994	0.58719	0.00023	0.00295	0.59038	0.06216	0.00002	0.00031	0.06250	0.64936	0.00026	0.00326	0.65288	**5.52%**	0.06899
1995	0.55803	0.00023	0.00274	0.56100	0.05567	0.00002	0.00027	0.05597	0.61370	0.00025	0.00302	0.61697	**5.26%**	0.07830
1996	0.53093	0.00022	0.00243	0.53358	0.04871	0.00002	0.00022	0.04895	0.57963	0.00024	0.00266	0.58253	**5.08%**	0.08212
1997	0.49430	0.00021	0.00211	0.49661	0.04178	0.00002	0.00018	0.04198	0.53608	0.00023	0.00228	0.53859	**5.06%**	0.07552
1998	0.49435	0.00022	0.00210	0.49667	0.04531	0.00002	0.00019	0.04552	0.53966	0.00024	0.00230	0.54219	**3.74%**	0.10497
1999	0.46508	0.00021	0.00182	0.46711	0.04183	0.00002	0.00016	0.04201	0.50690	0.00023	0.00198	0.50912	**4.21%**	0.09039
2000	0.49177	0.00023	0.00199	0.49398	0.04501	0.00002	0.00018	0.04521	0.53677	0.00025	0.00217	0.53919	**4.10%**	0.08117
2001	0.50669	0.00024	0.00212	0.50905	0.04744	0.00002	0.00020	0.04766	0.55413	0.00026	0.00232	0.55671	**2.95%**	0.06743
2002	0.49147	0.00023	0.00200	0.49371	0.04422	0.00002	0.00018	0.04442	0.53570	0.00025	0.00218	0.53813	**2.40%**	0.07114
2003	0.51062	0.00024	0.00213	0.51299	0.04724	0.00002	0.00020	0.04746	0.55787	0.00026	0.00233	0.56045	**0.61%**	0.08363
2004	0.51089	0.00024	0.00209	0.51322	0.04874	0.00002	0.00020	0.04897	0.55964	0.00026	0.00228	0.56219	**2.10%**	0.07244
2005	0.50503	0.00027	0.00218	0.50749	0.03945	0.00002	0.00017	0.03964	0.54448	0.00030	0.00235	0.54713	**2.32%**	0.08482
2006	0.53315	0.00028	0.00237	0.53581	0.04146	0.00002	0.00018	0.04166	0.57461	0.00031	0.00256	0.57747	**2.11%**	0.07754
2007	0.52019	0.00028	0.00218	0.52266	0.04119	0.00002	0.00017	0.04139	0.56139	0.00030	0.00235	0.56404	**1.46%**	0.08121
2008	0.51288	0.00030	0.00207	0.51524	0.04117	0.00002	0.00017	0.04136	0.55404	0.00032	0.00223	0.55660	**3.06%**	0.07784
2009	0.46582	0.00030	0.00184	0.46796	0.03973	0.00003	0.00016	0.03991	0.50554	0.00032	0.00200	0.50787	**0.84%**	0.08417
2010	0.47299	0.00030	0.00189	0.47518	0.03793	0.00002	0.00015	0.03811	0.51092	0.00033	0.00204	0.51328	**0.77%**	0.08540
2011	0.45550	0.00031	0.00198	0.45778	0.03901	0.00003	0.00017	0.03921	0.49451	0.00033	0.00214	0.49699	**1.86%**	0.16380
2012	0.50494	0.00034	0.00254	0.50782	0.04482	0.00003	0.00023	0.04508	0.54976	0.00037	0.00277	0.55289	**3.53%**	0.23103
2013	0.47335	0.00036	0.00245	0.47616	0.03908	0.00003	0.00020	0.03931	0.51243	0.00039	0.00265	0.51547	**4.33%**	0.21174
2014	0.42417	0.00040	0.00217	0.42673	0.03837	0.00004	0.00020	0.03860	0.46254	0.00044	0.00236	0.46534	**6.44%**	0.19764

Notes: * The updated 2016 methodology uses data on the contribution of electricity from the different interconnects, hence these figures are based on a weighted average emission factor of the emission factors for France, the Netherlands and Ireland, based on the % share supplied. The individual country factors may not be published due to restrictions in republication of the underlying IEA datasets.

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)[82],

Table 43: Base electricity generation emission factors (excluding imported electricity) – fully consistent time series dataset

Data Year	Emission Factor, kgCO$_2$e / kWh												% Net Electricity Imports	Average 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$_2$e / kWh
1990	0.70928	0.00025	0.0039	0.71343	0.06232	0.00002	0.00034	0.06268	0.77160	0.00027	0.00424	0.77611	**4.08%**	0.11300
1991	0.68271	0.00023	0.00376	0.6867	0.06155	0.00002	0.00034	0.06191	0.74426	0.00025	0.00410	0.74861	**5.48%**	0.12790
1992	0.64496	0.00023	0.00355	0.64874	0.05265	0.00002	0.00029	0.05296	0.69761	0.00025	0.00384	0.70170	**5.60%**	0.10097
1993	0.5822	0.00022	0.00299	0.58541	0.04496	0.00002	0.00023	0.04521	0.62716	0.00024	0.00322	0.63062	**5.55%**	0.06828
1994	0.55859	0.00022	0.00281	0.56162	0.05913	0.00002	0.0003	0.05945	0.61772	0.00024	0.00311	0.62107	**5.52%**	0.06899
1995	0.53279	0.00022	0.00262	0.53563	0.05315	0.00002	0.00026	0.05343	0.58594	0.00024	0.00288	0.58906	**5.26%**	0.07830
1996	0.50813	0.00021	0.00233	0.51067	0.04661	0.00002	0.00021	0.04684	0.55474	0.00023	0.00254	0.55751	**5.08%**	0.08212
1997	0.47312	0.0002	0.00202	0.47534	0.03999	0.00002	0.00017	0.04018	0.51311	0.00022	0.00219	0.51552	**5.06%**	0.07552
1998	0.47978	0.00021	0.00204	0.48203	0.04397	0.00002	0.00019	0.04418	0.52375	0.00023	0.00223	0.52621	**3.74%**	0.10497
1999	0.44929	0.00021	0.00176	0.45126	0.04041	0.00002	0.00016	0.04059	0.48970	0.00023	0.00192	0.49185	**4.21%**	0.09039
2000	0.47493	0.00022	0.00192	0.47707	0.04347	0.00002	0.00018	0.04367	0.51840	0.00024	0.00210	0.52074	**4.10%**	0.08117
2001	0.49375	0.00023	0.00207	0.49605	0.04623	0.00002	0.00019	0.04644	0.53998	0.00025	0.00226	0.54249	**2.95%**	0.06743
2002	0.48139	0.00023	0.00196	0.48358	0.04332	0.00002	0.00018	0.04352	0.52471	0.00025	0.00214	0.52710	**2.40%**	0.07114
2003	0.50803	0.00024	0.00212	0.51039	0.047	0.00002	0.0002	0.04722	0.55503	0.00026	0.00232	0.55761	**0.61%**	0.08363

[82] The slight differences in the CONSUMED figure shown in the table and the figure which can be calculated using the Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES) in the table is due to rounding. The CONSUMED figure in the table is considered to be more accurate.

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports	Average 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
2004	0.50169	0.00024	0.00205	0.50398	0.04787	0.00002	0.0002	0.04809	0.54956	0.00026	0.00225	0.55207	**2.10%**	0.07244
2005	0.4953	0.00027	0.00214	0.49771	0.03869	0.00002	0.00017	0.03888	0.53399	0.00029	0.00231	0.53659	**2.32%**	0.08482
2006	0.52355	0.00028	0.00233	0.52616	0.04071	0.00002	0.00018	0.04091	0.56426	0.00030	0.00251	0.56707	**2.11%**	0.07754
2007	0.5138	0.00028	0.00215	0.51623	0.04069	0.00002	0.00017	0.04088	0.55449	0.00030	0.00232	0.55711	**1.46%**	0.08121
2008	0.49955	0.00029	0.00201	0.50185	0.0401	0.00002	0.00016	0.04028	0.53965	0.00031	0.00217	0.54213	**3.06%**	0.07784
2009	0.46262	0.0003	0.00183	0.46475	0.03946	0.00003	0.00016	0.03965	0.50208	0.00033	0.00199	0.50440	**0.84%**	0.08417
2010	0.47001	0.0003	0.00188	0.47219	0.03769	0.00002	0.00015	0.03786	0.50770	0.00032	0.00203	0.51005	**0.77%**	0.08540
2011	0.45008	0.0003	0.00195	0.45233	0.03855	0.00003	0.00017	0.03875	0.48863	0.00033	0.00212	0.49108	**1.86%**	0.16380
2012	0.49526	0.00033	0.00249	0.49808	0.04396	0.00003	0.00022	0.04421	0.53922	0.00036	0.00271	0.54229	**3.53%**	0.23103
2013	0.46203	0.00035	0.00239	0.46477	0.03814	0.00003	0.0002	0.03837	0.50017	0.00038	0.00259	0.50314	**4.33%**	0.21174
2014	0.40957	0.00039	0.00209	0.41205	0.03705	0.00003	0.00019	0.03727	0.44662	0.00042	0.00228	0.44932	**6.44%**	0.19764

Notes: * The updated 2016 methodology uses data on the contribution of electricity from the different interconnects, hence these figures are based on a weighted average emission factor of the emission factors for France, the Netherlands and Ireland, based on the % share supplied. The individual country factors may not be published due to restrictions in republication of the underlying IEA datasets.

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 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	0.23458	0.25939	0.06962	0.23104	0.19939	0.44141
2002	0.22577	0.24924	0.07095	0.23423	0.20545	0.42413
2003	0.22885	0.25664	0.04819	0.22878	0.19678	0.43673
2004	0.22260	0.25090	0.05265	0.23574	0.20390	0.42695
2005	0.21591	0.24226	0.04996	0.23375	0.20540	0.41225
2006	0.22529	0.24943	0.06076	0.25076	0.22528	0.42445
2007	0.22582	0.24900	0.03953	0.23877	0.21575	0.42372
2008	0.21991	0.24248	0.03935	0.23079	0.20805	0.41263
2009	0.21694	0.24009	0.04404	0.23456	0.21127	0.40855
2010	0.21316	0.23502	0.05714	0.23861	0.21601	0.39993
2011	0.25727	0.27072	0.08599	0.25736	0.24140	0.46067
2012	0.20043	0.23268	0.03089	0.20817	0.17246	0.39594
2013	0.20177	0.23094	0.04987	0.21678	0.18293	0.39299
2014	0.20245	0.22963	0.04394	0.21541	0.18534	0.39076

Table 45: Comparison of calculated Electricity and Heat/Steam CO_2 emission factors for the 3 different allocation method – fully consistent time series dataset

Appendix 3. Major Changes to the Conversion Factors

The following table provides a summary of major changes in emission factors for the 2016 GHG Conversion Factors, compared to the equivalent factors provided in the 2015 GHG Conversion Factors, and a short explanation for the reason for the change. We have considered major changes to be those greater than 5% for most Scope 1 and 2 emission sources and greater than 10% for Scope 3 emission sources.

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
Fuels						
1	CNG	CH_4	All	-9%	Changes to the underlying activity data within the NAEI.	Section 2
2	LNG	CH_4	All	-9%	As above	Section 2
3	LPG	CH_4	All	-23% to -24%	Largely driven by significant decrease in the emission factor from road transport, within the underlying NAEI data set.	Section 2
4		N_2O	All	-19% to -21%	As above	Section 2
5	Natural gas	CH_4	All	-6% to -9%	Changes to the underlying activity data within the NAEI.	Section 2

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
6	Aviation spirit	CH_4	All	-9%	As above	Section 2
7	Diesel (average biofuel blend)	CH_4	All	-6% to -14%	Implementation of COPERT 4v11 emission factors for road transport within the NAEI.[83]	Section 2
8	Diesel (100% mineral diesel)	CH_4	All	-6% to -14%	As above	Section 2
9	Fuel oil	CH_4	All	24% to 25%	Amendment to calculation to exclude marine fuel oil activity/emission factors and an increase in activity data within the NAEI.	Section 2
10		N_2O	All	-17% to -18%	Amendment to calculation to exclude marine fuel oil activity/emission factors and largely due to a decrease in activity from sources with lower emission factors within the NAEI.	Section 2
11	Gas oil	CH_4	All	5% to 6%	Amendment to calculation to exclude marine gas oil activity/emission factors.	Section 2
12		N_2O	All	31%	Amendment to calculation to exclude marine gas oil activity/emission factors and an increase in the underlying emission factor in the NAEI.	Section 2
13	Petrol (average biofuel blend)	CH_4	All	99% to 105%	Due to a significant increase in the emission factor from cars and change to using COPERT 4v11 emission factors for road transport within the NAEI.	Section 2
14		N_2O	All	-12% to -14%	Largely driven by a decrease in emission	Section 2

[83] COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport, see: http://emisia.com/products/copert-4.

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
					factor from cars within the NAEI.	
15	Petrol (100% mineral petrol)	CH_4	All	99% to 105%	Due to a significant increase in emission factor from cars and change to using COPERT 4v11 emission factors for road transport within the NAEI.	Section 2
16		N_2O	All	-13% to -14%	Largely driven by a decrease in emission factor from cars within the NAEI.	Section 2
17	Processed fuel oils - residual oil	CH_4	All	24% to 25%	Amendment to the calculation to exclude marine fuel activity/emission factors and an increase in activity data within the NAEI.	Section 2
18		N_2O	All	-17% to -18%	Amendment to the calculation to exclude marine fuel activity/emission factors and to a decrease in activity from sources with lower emission factors within the NAEI.	Section 2
19	Processed fuel oils - distillate oil	CH_4	All	5% to 6%	Amendment to the calculation to exclude marine fuel activity/emission factors.	Section 2
20		N_2O	All	31%	Amendment to the calculation to exclude marine fuel activity/emission factors and an increase in the underlying emission factor in the NAEI.	Section 2
21	Coal (industrial)	CH_4	All	268% to 271%	Due to changes to the NAEI methodology where it is now using IPCC Tier 1 default for public/commercial combustion.	Section 2
22		N_2O	All	-72%	Largely driven by decrease in the emission factor in the Inventory for power stations.	Section 2

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
23	Coal (electricity generation)	CH_4	All	21% to 24%	Due to changes to the NAEI methodology where it is now using IPCC Tier 1 default for public/commercial combustion.	Section 2
24		N_2O	All	-31%	Due to changes to the NAEI methodology where it is now using IPCC Tier 1 default for public/commercial combustion.	Section 2
25	Coal (domestic)	CH_4	All	-53%	Due to changes to the NAEI methodology where they it is now using IPCC Tier 1 default for domestic combustion.	Section 2
26		CO_2e	All	-7%	The decrease in CH_4 has caused a decrease in the CO_2e factors.	Section 2
27	Coking coal	CH_4	All	55%	Driven by an increase in the underlying emission factor in the NAEI, which has changed due to using IPCC Tier 1 default values.	Section 2
28		N_2O	All	-74%	Driven by a decrease in the underlying emission factor in the NAEI, which has changed due to using IPCC default values.	Section 2
29	Petroleum coke	CH_4	All	6%	Increase in activity from domestic combustion within the NAEI which has a higher emission factor than other sources.	Section 2
30		N_2O	All	-70%	Largely due to significant decrease in the emission factor from refineries, within the underlying NAEI data.	Section 2
31	Coal (electricity	CH_4	All	16% to 26%	Due to changes to the NAEI methodology	Section 2

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
	generation - home produced coal only)				where it is now using IPCC Tier 1 default for public/commercial combustion.	
32		N_2O	All	-31%	Due to changes to the NAEI methodology where it is now using IPCC Tier 1 default for public/commercial combustion.	Section 2
Bioenergy						
33	Bioethanol	CO_2e	All	35%	Due to an increase in emissions for petrol within the NAEI which this factors are based on for CH_4 and N_2O.	Section 9
34	Wood pellets	CO_2e	Tonnes	-10%	Now uses the fuel properties from DUKES to be consistent with the other bioenergy factors..	Section 9
35	Grass/straw	CO_2e	Tonnes	-16%	As above	Section 9
Refrigerants and other						
36	R600A = isobutane	CO_2e	Kg	299,900%	New data sources show that this value is 3 and not 0.001 as previously thought.	Section 4
37	R1234yf	CO_2e	kg	~-75%	This is a relatively new refrigerant and new research has been undertaken to show that the GWP is below 1 Kg CO_2e.	Section 4
38	R1234ze	CO_2e	Kg	~-85%	As above	Section 4
Passenger Vehicles						
39	Petrol cars	CH_4	km &miles	169% to 172%	Increase due to change in emission factors used in the NAEI to COPERT 4v11.	Section 5

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
40		N_2O	km &miles	28% to 29%	As above	Section 5
41	Diesel cars	CH_4	km &miles	-84% to -88%	Change in CH_4 and N_2O due to change in emission factors used in the NAEI to COPERT 4v11.	Section 5
42		N_2O	km &miles	14%	As above	Section 5
43	Hybrid cars	CH_4	km &miles	54% to171%	As above	Section 5
44		N_2O	km &miles	149% to 282%	As above	Section 5
45	LPG cars	CH_4	km &miles	-64% to -67%	As above	Section 5
46		N_2O	km &miles	-34%	As above	Section 5
47	CNG cars	CH_4	km &miles	172%	As above	Section 5
48		N_2O	km &miles	-34%	As above	Section 5
49	Small motorbike	CH_4	km &miles	-26%	Reduction in emissions is mainly due to evolution of fleet, including a larger proportion of higher Euro standards since the previous year. In addition, due to a change in the source/basis of the emission factors in the 2014 update, there was some re-assignment of motorcycles to different size categories.	Section 5
50		N_2O	km &miles	-17%	As above	
Delivery Vehicles						
51	Diesel vans all classes	CH_4	km or mile	-69%	Due to change in emission factors to COPERT 4v11, within the NAEI.	Section 6
52	Diesel vans - Class I	N_2O	km or mile	89%	As above	Section 6

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
	(up to 1.305 tonnes)					
53	Diesel vans - Class II (1.305 to 1.74 tonnes)	N_2O	km or mile	20% to 89%	As above	Section 6
56	Petrol vans all classes	CO_2	km or mile	34%	Increase due to change in emission factors to COPERT 4v11, within the NAEI.	Section 6
57		CH_4	km or mile	161 to 191%	As above	Section 6
58		N_2O	km or mile	-11% to 112%	Due to changes in emission factors to COPERT 4v11, within the NAEI and the inclusion of cold starts	Section 6
59	CNG, average class	CH_4	km or mile	190%	As above	Section 6
60	LPG, average class	CH_4	km or mile	-65%	As above	Section 6
61	Unknown van type	CH_4	km or mile	-35%	As above	Section 6
62		N_2O	km or mile	11%	As above	Section 6
63	HGVs (all diesel) all laden percentages, refrigerated and un-refrigerated	CH_4	km or mile	-15% to 70%	As above	Section 6
64		N_2O	km or mile	-16% to 20%	As above	Section 6
UK Electricity						
65	UK Electricity	CO_2	kWh	-11%	There was a significant decrease in coal generation, and an increase in gas and renewables generation since the previous year.	Section 2
66		CH_4	kWh	11%	The decrease in coal generation and increase in gas consumption is offset by an	Section 2

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
					changes in the NAEI default factors leading to increases in CH_4 emissions from power generation.	
67		N_2O	kWh	-37%	There was a significant decrease in coal generation, and an increase in gas and renewables generation since the previous year. Plus changes in NAEI default factors led to a further reduction in the emission factor.	Section 2
68		CO_2e	kWh	-11%	As above.	Section 2
Heat and Steam						
69	Onsite and district heating	CH_4	kWh	35%	Changes to the underlying NAEI data.	Section 2
70		N_2O	kWh	-95%	As above	Section 2
WTT- fuels						
There are no significant changes to the WTT fuel factors						
WTT- bioenergy						
71	Biomethane	CO_2e	All	-28%	Decrease in the carbon intensity of biogas within the DfT renewable transport fuels statistics.	Section 9
72	Wood chips	CO_2e	All	-52%	Changes to the Ofgem tool assumptions	Section 9
73	Wood pellets	CO_2e	All	17%	Changes to the Ofgem tool assumption.	Section 9

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
74	Grass/straw	CO_2e	All	-19%	Cultivation assumptions within the Ofgem tool have changed for miscanthus.	Section 9
75	Biogas	CO_2e	kWh	-33%	Methdology improvement- last year the NET CV value used in the calculation came from a different source. This CO_2e value now comes directly from the OFGEM tool, for consistency with the other WTT biomass sources.	Section 9
Transmission and distribution- UK Electricity						
76	UK Electricity T&D Losses	CO_2	kWh	-2%	The increase in lower GHG electricity generation was partially offset by an increase in losses from the grid.	Section 2
77		N_2O	kWh	-32%	The increase in lower GHG electricity generation was partially offset by an increase in losses from the grid.	Section 2
78		CO_2e	kWh	-2%	As above.	Section 2
Transmission and distribution- Overseas						
79	T&D -Electricity: Singapore	CO_2	kWh	-70%	Losses have decreased.	Section 10
80	T&D Electricity: Iceland	CO_2	kWh	-60%	As above	Section 10
81	T&D Electricity: Slovak Republic	CO_2	kWh	-43%	As above	Section 10
82	T&D Electricity: Malaysia	CO_2	kWh	-37%	As above	Section 10

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
83	T&D Electricity: Chinese Taipei	CO_2	kWh	-24%	As above	Section 10
84	T&D Electricity: Saudi Arabia	CO_2	kWh	-22%	As above	Section 10
85	T&D Electricity: Malta	CO_2	kWh	-16%	As above	Section 10
86	T&D Electricity: Denmark	CO_2	kWh	-12%	As above	Section 10
87	T&D Electricity: Philippines	CO_2	kWh	-11%	As above	Section 10
88	T&D Electricity: Greece	CO_2	kWh	158%	Losses have increased substantially this year.	Section 10
89	T&D Electricity: Cyprus	CO_2	kWh	53%	Losses increased and total final consumption decreased compared to last year.	Section 10
90	T&D Electricity: Israel	CO_2	kWh	43%	As above	Section 10
91	T&D Electricity: Canada	CO_2	kWh	30%	As above	Section 10
92	T&D Electricity: Australia	CO_2	kWh	19%	As above	Section 10
93	T&D Electricity: Portugal	CO_2	kWh	18%	As above	Section 10
94	T&D Electricity: India	CO_2	kWh	12%	Losses have decreased, but total consumption has increased.	Section 10

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
5% loss strict heat and steam						
95	Distribution- onsite and district heating- 5% loss	CH_4	kWh	35%	Changes to the underlying NAEI data.	Section 2
96		N_2O	kWh	-95%	As above	Section 2
WTT- UK & overseas electricity						
97	WTT UK Electricity	CO_2e	kWh	-10%	Directly linked to fluctuations in the UK generation factor -there was a significant decrease in coal generation, and an increase in gas and renewables generation since the previous year. Plus there has been an increase imports of LNG.	Section 2
WTT- overseas electricity (generation)						
No significant changes – all are below 2%						
WTT- overseas electricity (T&D)						
98	WTT T&D Electricity: Singapore	CO_2e	kWh	-70%	Losses have decreased.	Section 10
99	WTT T&D Electricity: Slovak Republic	CO_2e	kWh	-44%	As above	Section 10
100	WTT T&D Electricity: Malaysia	CO_2e	kWh	-38%	As above	Section 10
101	WTT T&D Electricity:	CO_2e	kWh	-25%	As above	Section 10

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
	Chinese Taipei					
102	WTT T&D Electricity: Saudi Arabia	CO_2e	kWh	-23%	As above	Section 10
103	WTT T&D Electricity: Malta	CO_2e	kWh	-17%	As above	Section 10
104	WTT T&D Electricity: Denmark	CO_2e	kWh	-13%	As above	Section 10
105	WTT T&D Electricity: Philippines	CO_2e	kWh	-12%	As above	Section 10
106	WTT T&D Electricity: Middle East (average)	CO_2e	kWh	-11%	As above	Section 10
107	WTT T&D Electricity: Finland	CO_2e	kWh	-10%	As above	Section 10
108	WTT T&D Electricity: Austria	CO_2e	kWh	-10%	As above	Section 10
109	WTT T&D Electricity: Greece	CO_2e	kWh	154%	Losses have increased substantially this year.	Section 10
110	WTT T&D Electricity: Cyprus	CO_2e	kWh	50%	Losses increased and total final consumption decreased compared to last year.	Section 10
111	WTT T&D Electricity: Israel	CO_2e	kWh	41%	As above	Section 10
112	WTT T&D Electricity: Canada	CO_2e	kWh	28%	As above	Section 10

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
113	WTT T&D Electricity: Australia	CO_2e	kWh	17%	As above	Section 10
114	WTT T&D Electricity: Portugal	CO_2e	kWh	17%	As above	Section 10
WTT- heat and steam						
No significant changes – all are at -4% vs the 2015 update						
Water supply						
No Changes						
Water treatment						
No Changes						
Material use						
No significant changes (some minor changes to the plastics due to revisions to the ecoprofiles for a range of plastics by PlasticsEurope						
Waste disposal						
115	Books, landfill	CO_2e	tonnes	-36%	The estimate for CH_4 capture from landfill waste has increased to 61%. This affects all landfill emissions for organic materials.	Section 11
116	Clothing, landfill	CO_2e	tonnes	-32%	As above	Section 11
117	Refuse: Organic garden waste, landfill	CO_2e	tonnes	-18%	As above	Section 11
118	Paper and board: all types, landfill	CO_2e	tonnes	-36%	As above	Section 11

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per “unit” of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
Business travel- air						
119	Domestic flight- average passenger, with and without RF	CH_4	passenger .km	17%	Due to changes to the underlying NAEI dataset.	Section 8
120	International flights, all classes, with and without RF	N_2O	passenger .km	-12%	As above	Section 8
WTT- business travel air						
121	International flights, all classes, with and without RF	CO_2e	passenger .km	-12%	Due to changes to the underlying NAEI dataset.	Section 8
Business travel- sea						
122	Ferry, all types	CH_4	passenger .km	17 to 21%	Changes to the underlying NAEI emissions data.	Section 7
WTT-Business travel- sea						
No significant changes						
Business travel- land						
123	Cars	See the reason recorded for passenger vehicles, above ,as the values are identical.				
124	Motorbikes					
125	Regular taxi	CH_4	passenger .km	-83%	Increase due to change in emission factors used in the NAEI to COPERT 4v11.	Section 5
126			km	-88%	As above	Section 5

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
127		N_2O	passenger .km and km	14%	As above	Section 5
128	Black cab	CH_4	passenger .km	-80%	As above	Section 5
129		CH_4	km	-88%	As above	Section 5
130		N_2O	passenger .km and km	14%	As above	Section 5
131	Local bus (not London)	CO_2 and CO_2e	passenger .km	10%	Due to changes in the methodology that were necessary because of changes in the availability/basis of underlying DfT statistical datasets. This includes a change in the scope of the data from GB-basis to England-basis, and coverage limited to commercial services (~80% of all local bus services). Also a small decrease in average occupancy for the equivalent dataset time-series.	Section 5
132		CH_4 and N_2O	passenger .km	-11 and -12% respectively	Changes to the underlying NAEI emissions data for the latest update.	Section 5
133	Local London bus	CH_4 and N_2O	passenger .km	-20% and -29%, respectively	Changes to the underlying NAEI emissions data for the latest update.	Section 5
134	Average local bus	CH_4 and	passenger .km	-25% and	As above	Section 5

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
		N_2O		-21%, respectively		
135	Coach	CH_4 and N_2O	passenger .km	-40% and -36%, respectively	As above	Section 5
136	National rail	CH_4	tonne.km	25%	Due to an increase in CH_4 emissions for trains in the underlying NAEI data and the increase in CH_4 values of electricity.	Section 5
137		N_2O	tonne.km	59%	Due to a significant increase in N_2O emissions for trains in the underlying NAEI data.	Section 5
138	International rail	N_2O	tonne.km	-33%	Due to the large decrease in N_2O for electricity.	Section 5
139	Light rail and tram	CH_4	tonne.km	25%	Due to the increase in CH_4 for electricity.	Section 5
140		N_2O	tonne.km	-33%	Due to the large decrease in N_2O for electricity.	Section 5
141	London underground	CH_4	tonne.km	25%	Due to the increase in CH_4 for electricity.	Section 5
142		N_2O	tonne.km	-29%	Due to the large decrease in N_2O for electricity.	Section 5
Freighting goods						
143	Vans	See delivery vehicles above. (The tonne.km magnitude of change is the same as the km and miles changes).				
144	HGV (all diesel)					
145	HGV refrigerated (all					

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per “unit” of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
	diesel)					
146	Domestic and short-haul flights	CH_4	passenger .km	>15%	Due to changes in emission factors for N_2O and CH_4 used in the UK GHGI.	Section 8
147		N_2O	passenger .km	<12%	As above	Section 8
148	Long-haul flights	CO_2	passenger .km	10%	The amount of Cargo uplifted by dedicated services (i.e. not on passenger aircraft) dropped by almost 50%, whilst passenger freight increased slightly 2013 to 2014 according to CAA stats. The emission factor for cargo on passenger services is higher than dedicated freight, which has increased the overall emission factor to a greater degree than reduction in this emission factor due to this.	Section 8
149		CH_4	passenger .km	53%	As above, and due to changes in emission factors for N_2O and CH_4 used in the UK GHGI.	Section 8
150		N_2O	passenger .km	6%	As above	Section 8
151		CO_2e	passenger .km	10%	As above but for CO_2.	Section 8
152	Freight train	CO_2e	kg CO_2e	13%	Change to the Office of Rail and Road data (ORR data).	Section 6
153		CO_2	kg CO_2	13%	As above	Section 6

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per “unit” of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
154		CH_4	kg CH_4	-25%	Amendment to methodological basis for estimating CH_4 emissions from freight rail, to bring into closer consistency with passenger rail.	Section 6
155		N_2O	kg N_2O	271%	Change to the Office of Rail and Road data (ORR data).	Section 6
156	Sea tanker, all types	CH_4	passenger .km	18% to 100%	Changes to the underlying NAEI emissions data for the latest update.	Section 7
157	Cargo ship, all types	CH_4	passenger .km	14% to 100%	As above	Section 7
WTT passenger vehicles and WTT business travel- land						
158	Diesel dual purpose car	CO_2e	km	-10%	Mainly due to higher rate of annual reduction in CO_2 emissions seen in this segment in the source SMMT dataset.	Section 5
159	Unknown fuel sports car	CO_2e	km	14%	In previous years analysis there was an inconsistency in the approach to calculating the average WTT emissions component for 'Unknown' fuel type, which led to underestimation of WTT emissions for Sports vehicles.	Section 5
160	Regular taxi	CO_2e	Passenger .km and km	-11%	Improvement in the performance of average cars flows through to assumptions for taxis.	Section 5

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per "unit" of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
WTT delivery vehicles & freighting goods						
161	Petrol LGVs, all classes	CO_2e	tonne.km, km or mile	35%	Increase due to change in emission factors to COPERT 4v11, in the NAEI.	Section 6
162	WTT HGV refrigerated and non-refrigerated, rigid >17 tonnes, 50% and 100% laden	CO_2e	tonne.km	-15%	Changes to the underlying DfT statistical datasets leading to increased average tonnes goods carried per vehicle in this category (This equals a decrease in emissions per tkm). Also decrease in the WTT emission factor for diesel fuel.	Section 6
163	WTT HGV refrigerated and non-refrigerated, All rigids,50% and 100% laden	CO_2e	tonne.km	-19%	As above.	Section 6
164	WTT HGV refrigerated and non-refrigerated, All HGVs, 50% and 100% laden	CO_2e	tonne.km	-12%	As above.	Section 6
165	WTT freight flights, domestic	CO_2e	tonne.km	-11%	Due to improvement in efficiency to domestic freight transport, driven by the addition of accounting for more efficient B767 dedicated cargo flights in the calculations from 2016.	Section 6

Ref number.	Emission factor	GHG	Unit (all units are $kgCO_2e$ per “unit” of GHG, unless stated)	Magnitude of change vs 2015 update	Reason for change	For more information see:
Managed assets- electricity						
See "UK electricity (which is identical for managed assets electricity)						
Managed assets- vehicles						
166	Managed cars (by market segment)	See passenger vehicles above (the values are identical to these)				
167	Managed cars (by size)					
168	Managed vans	See delivery vehicles above (the values are identical to these)				
169	Managed HGV (all diesel)					
170	Managed HGV refrigerated (all diesel)					
171	Managed motorbikes	See passenger vehicles above (the values are identical to these)				
Outside of Scope						
172	Diesel (average biofuel blend)	CO_2	All	-30%	The litres of biodiesel consumed this year has decreased by 27%, causing the percentage of biodiesel within the diesel blend to be less (30% less) and therefore the emissions associated with the biodiesel are proportionately less.	Section 1
173	Wood pellets	CO_2	Tonnes	-10%	Methodology change - NCV from DUKES are now used rather than the values from Biomass Energy Centre (BEC).	Section 9

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