

Department for Business, Energy & Industrial Strategy

2018 GOVERNMENT GHG CONVERSION FACTORS FOR COMPANY REPORTING

Methodology paper for emission factors: final report

July 2018

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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 and 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 2018 Government Greenhouse Gas Conversion Factors for Company Reporting¹ (hereafter the 2018 GHG Conversion Factors) represent the current official set of UK 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 2018 GHG Conversion Factors.
- 1.4. Values for the non-carbon dioxide (CO₂) GHGs, methane (CH₄) and nitrous oxide (N₂O), are presented as CO₂ equivalents (CO₂e), using Global Warming Potential (GWP) factors from the Intergovernmental Panel on Climate Change (IPCC)'s fourth assessment report (GWP for CH₄ = 25, GWP for N₂O = 298), consistent with reporting under the United Nations Framework Convention on Climate Change (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 2018 GHG Conversion Factors are therefore consistent with this.
- 1.5. The GHGI for 2016, on which these 2018 GHG Conversion Factors are based on, is available at: <u>https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1804191054_ukghgi-90-16_Main_Issue1.1_UNFCCC.pdf</u>.
- 1.6. The 2018 GHG Conversion Factors are for one year, from the end of May 2018, and will continue to be reviewed and updated on an annual basis.
- 1.7. The GHG Conversion Factors have been provided on the GOV.UK site: <u>https://www.gov.uk/government/collections/government-conversion-factors-for-</u> <u>company-reporting.</u>
- 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 2018 GHG Conversion Factors. The report aims to expand and compliment the information already provided in the data tables themselves. However, it is not intended to be an exhaustively detailed explanation of every calculation performed (this is not practical/possible), nor is it intended to provide guidance on the practicalities of

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

reporting for organisations. Rather, the intention is to provide an overview with key information so that the basis of the emission factors provided can be better understood and assessed.

 Further information about the 2018 GHG Conversion Factors together with previous methodology papers is available at: <u>https://www.gov.uk/government/collections/government-conversion-factors-for-</u> <u>company-reporting</u>.

Overview of changes since the previous update

- 1.10. Major changes and updates in terms of methodological approach from the 2017 update version are summarised below. All other updates are essentially revisions of the previous year's data based on new/improved data whilst using existing calculation methodologies (i.e. using a similar methodological approach as for the 2017 update):
 - a) The emission factors for HGVs and Buses were revised this year as a new technology is developed to enable manufacturers to meet diesel engine emissions standards for NO_x emissions. This technology is known as selective catalytic reduction (SCR) and uses a urea solution to effectively remove NO_x and NO₂ from diesel engines' exhaust gases. Emissions from the consumption of urea in heavy duty vehicles and buses is estimated in the conversion factors for the first time and are included in the estimates for the overall CO₂ emission factors.
 - b) Improvements were made to the Heat & Steam model to make formulae clearer, more concise and easier to trace which assists the QA process. The previous model included hard coded values that were not clearly documented and now these have been changed so that imported data is clearly labelled. The model uses the same data sets as previous years and when combined with the emission factors from other Conversion Factor Workbooks, they are used to:
 - a. Compile a list of emission factors per fuel type contained in the Digest of UK Energy Statistics (DUKES) data.
 - b. Determine the amount of each fuel type used for heat to build a fuel mix emission factor which is used to derive emission factors per MWh heat. Previously, the model was calculating the emission factors per MWh power in the same sheet with the heat and power emission factors via the PowerStation displacement and boiler displacement methods. These calculations are still contained in the workbook but since they do not form part of the model's output, they have been relegated to an 'Other methods' methodology section.
 - c. Report on: kg CO₂ per kWh heat & steam, kg CO₂e (from CH₄) per kWh heat & steam, kg CO₂e (from N₂O) per kWh heat & steam, kg CO₂e (Total direct) per kWh heat & steam and kg CO₂e (WTT) per kWh heat & steam.
 - c) There have been a number of revisions to the output factors from the Waste Disposal model as a result of an upgrade and data changes. The emissions factors for glass landfill / green and mixed organics composting had previously been taken directly from published studies using a different methodology to the other waste factors. New factors are now used and are based on a standardised approach using data on transport emissions to and on site, and MELMod (landfill emissions model) factors for the landfill emissions.
 - d) The Material Use model has also been through a number of revisions due to an upgrade and data changes. Key references for closed loop steel recycling have been

updated and the methodology has been improved. This more recent and improved data directly provides Lifecycle Inventory emissions factors per kg of steel recycled, whereas these were previously derived based on emissions for different grades of recycled steel. In addition, the updated metals recycling factors for construction and demolition have been standardised using the updated closed loop steel recycling factor. The methodology has changed and is now based directly on emissions from metals recycling; previously this had been based on published estimated savings from recycling metals.

- e) Conversion factors for Transmission and Distribution losses for Overseas Electricity use are no longer included in the GHG Conversion Factors from 2018. These emission factors are now calculated and published by the IEA (International Energy Agency) and as such are not duplicated here. The main conversion factors for overseas electricity generation were not provided in the UK's GHG Conversion Factors after 2015, due to changes in the IEA's licencing conditions. Users requiring these data can purchase them directly from the IEA².
- 1.11. 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 plus or minus 10% compared with the 2017 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.
- 1.12. Detailed guidance on how the emission factors provided should be used is contained in the introduction to the 2018 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.
- 1.13. 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.

² Available here: <u>http://www.iea.org/bookshop/729-CO2_Emissions_from_Fuel_Combustion</u>

Structure of this methodology paper

1.14. The following Sections 2 to 13 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
Hotel Stay	see Section 11
Material Consumption/Use and Waste Disposal	see Section 12
Fuel Properties	see Section 13
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 methodology has been improved to remove a double count of activity data in road transport for (petrol and diesel fuels) for cold starts (N₂O) that was present in the underlying NAEI source data presentation. This has resulted in an increase of around 75% for the N₂O emission factor in the 2018 update, compared to 2017. However, the impact on the overall CO_{2e} emission factor is lower than 1%.

Direct Emissions

- 2.2. All the fuel conversion factors for direct emissions presented in the 2018 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2016 (managed by Ricardo Energy & Environment³).
- 2.3. The CO₂ 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 CH₄ and N₂O 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 2018 GHG Conversion Factors are based on an activity-weighted average of all the different CH₄ and N₂O 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 below⁴) from BEIS's Digest of UK Energy Statistics (DUKES) 2017⁵.
- 2.5. There are three tables in the 2018 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

³ UK Greenhouse Gas Inventory for 2016 (Ricardo Energy & Environment), available at: https://uk-air.defra.gov.uk/library/reports?report_id=954.

⁴ 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).

⁵ Available at: <u>https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes</u>

Gross CV basis⁶. Therefore, the emission factor for energy consumption on a Gross CV basis should be used by default for calculation of emissions from natural gas in kWh, unless your supplier specifically states they have used Net CV basis in their calculations instead.

Indirect/WTT Emissions from Fuels

- 2.7. These fuel lifecycle emissions (also sometimes referred to as 'Well-To-Tank', or simply WTT, emissions usually in the context of transport fuels) are the emissions 'upstream' from the point of use of the fuel. They result from the extraction, 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. Last year a newer report: 'Study on Actual GHG Data for Diesel, Petrol, Kerosene and Natural Gas' by Exergia, EM Lab and COWI for DG Ener (2015), was used to calculate the WTT factors for certain fuels. The same report is used within the 2018 Conversion Factors to calculate the WTT factors for the following fuels:
 - Petrol
 - Diesel
 - Kerosene
 - Natural gas
 - CNG
 - LNG.
- 2.9. The Exergia et al report does not contain data on the WTT emissions from Coal, Naphtha and LPG and therefore the JRC Well-To-Wheels (2014)⁷ study is used for these fuels (being the most recent update to this source).
- 2.10. For fuels covered by the 2018 GHG Conversion Factors where no fuel lifecycle emission factor was available in either source, these were estimated based on similar fuels, according to the assumptions in Table 4.
- 2.11. WTT emissions for petrol, diesel and kerosene in the Exergia et al study, used within the 2018 GHG Conversion Factors, are based on:
 - Detailed modelling of upstream emissions associated with 35 crude oils used in EU refining, which accounted for 88% of imported oil in 2012.
 - Estimates of the emissions associated with transport of these crude oils to EU refineries by sea and pipeline, based on location of ports and refineries.
 - Emissions from refining, modelled on a country by country basis, based on the specific refinery types in each country. An EU average is then calculated based on the proportion of each crude oil going to each refinery type.
 - An estimate of emissions associated with imported finished products from Russia and the US.

⁶ See information available on National Grid website: <u>http://www2.nationalgrid.com/UK/Industry-information/Gas-transmission-operational-data/calorific-value-description/</u>

⁷"Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4a, May 2014. Report EUR 26236 EN– 2014. <u>http://iet.jrc.ec.europa.eu/about-jec/</u>

- 2.12. Emission factors are also calculated for diesel as supplied at public and commercial refuelling stations, by factoring in the WTT component due to biodiesel supplied in the UK as a proportion of the total supply of diesel and biodiesel (2.30% by unit volume, 2.12% by unit energy see Table 2). These estimates have been made based on BEIS's Quarterly Energy Statistics for Renewables⁸.
- 2.13. Emission factors are also calculated for petrol as supplied at public and commercial refuelling stations, by factoring in the bioethanol supplied in the UK as a proportion of the total supply of petrol and bioethanol (4.46% by unit volume, 2.95% by unit energy see Table 2). These estimates have also been made based on BEIS's Quarterly Energy Statistics for Renewables.⁸.

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	Conventional Fuel	per unit mass	per unit volume	per unit energy
Diesel/Biodiesel	694.14	29,539	2.44%	2.30%	2.12%
Petrol/Bioethanol	749.43	16,050	4.84%	4.46%	2.95%

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 8 report 6 (final version) and Year9 report 2, both published in February 2018.

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

Table 2: Liquid biofuels for transport consumption: 4th quarter 2016 – 3rd quarter 2017

- 2.14. Emissions for natural gas, LNG and CNG in the Exergia et al study, used within the 2018 GHG Conversion Factors, are based on:
 - Estimates of emissions associated with supply in major gas producing countries supplying the EU. These include both countries supplying piped gas and countries supplying LNG.
 - The pattern of gas supply for each Member State (based on IEA data for natural gas supply in 2012)⁹.
 - Combining the information on emissions associated with sources of gas, with the data on the pattern of gas supply for each Member State, including the proportion of LNG that is imported.
- 2.15. A similar methodology was developed for use in the 2018 GHG Conversion Factors, to allow the value calculated for gas supply in the UK in the Exergia et al study to be updated annually. This allows changes in the sources of imported gas, particularly LNG, to be reflected in the emissions value.
- 2.16. Information on quantities and source of imported gas are available annually from DUKES¹⁰ and can be used to calculate the proportion of gas in UK supply coming from each source. These can then be combined with the Exergia et al emissions factors for gas from each source, to calculate a weighted emissions factor for UK supply.

⁹ IEA, 2014. Natural Gas Information 2014.

¹⁰ From Table 4.1 Commodity balances for natural gas and Table 4.5 Natural gas imports and exports, DUKES 2017

2.17. The methodology for calculating the WTT emission factors for natural gas and CNG is different to the other fuels as it considers 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 2018 update. Small quantities of imported LNG are now re-exported, so a value for **net** imports is used in the methodology. The figures in Table 3 have been used to calculate the revised figures for Natural Gas and CNG WTT emission factors provided in Table 4 below. There was a significant decline in LNG imports in 2016.

Year	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	35.4%	39.3%	19.1%
2011	47.2%	42.0%	29.5%
2012	27.9%	47.2%	17.5%
2013	19.5%	50.1%	12.1%
2014	26.7%	44.7%	15.9%
2015	30.7%	42.0%	18.9%
2016	22.2%	48.5%	13.3%

Source: DUKES 2017, (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

2.18. The final combined emission factors (in kgCO₂e/GJ, Net CV basis) are presented in Table 4. These include WTT emissions of CO₂, N₂O and CH₄ 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 2018 GHG Conversion Factors alongside the emission factor data tables.

Fuel	Indirect/WTT EF (kgCO₂e/GJ, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Aviation Spirit	18.20	Estimate	Similar to petrol
Aviation turbine fuel ¹	15.00	Exergia, EM Lab and COWI (2015)	Emission factor for kerosene
Burning oil ¹	15.00	Estimate	Assume same as factor for Kerosene, as above

Fuel	Indirect/WTT EF (kgCO₂e/GJ, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
CNG ²	11.41	Exergia, EM Lab and COWI (2015)	Factors in UK % share LNG imports
Coal (domestic)	14.81	JEC WTW (2014)	Emission factor for coal
Coal (electricity generation)	14.81	JEC WTW (2014)	Emission factor for coal
Coal (industrial)	14.81	JEC WTW (2014)	Emission factor for coal
Coal (electricity generation - home produced coal only)	14.81	JEC WTW (2014)	Emission factor for coal
Coking coal	14.81	Estimate	Assume same as factor for coal
Diesel (100% mineral diesel)	17.40	Exergia, EM Lab and COWI (2015)	
Fuel oil ⁴	15.00	Estimate	Assume same as factor for kerosene
Gas oil⁵	17.40	Estimate	Assume same as factor for diesel
LPG	8.04	JEC WTW (2014)	
LNG ⁶	19.60	Exergia, EM Lab and COWI (2015)	
Lubricants	9.53	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Marine fuel oil	15.00	Estimate	Assume same as factor for fuel oil
Marine gas oil	17.40	Estimate	Assume same as factor for gas oil
Naphtha	14.10	JEC WTW (2014)	
Natural gas	7.89	Exergia, EM Lab and COWI (2015)	Factors in UK % share LNG imports
Other petroleum gas	6.80	Estimate	Based on LPG figure, scaled relative to direct emissions ratio

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Fuel	Indirect/WTT EF (kgCO₂e/GJ, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Petrol (100% mineral petrol)	18.20	Exergia, EM Lab and COWI (2015)	
Petroleum coke	12.21	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Processed fuel oils - distillate oil	9.18	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Processed fuel oils - residual oil	9.67	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Refinery miscellaneous	8.78	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Waste oils	9.53	Estimate	Based on LPG figure, scaled relative to direct emissions ratio

Notes:

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

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

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

(4) 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.

(5) 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 4: Basis of the indirect/WTT emissions factors for different fuels

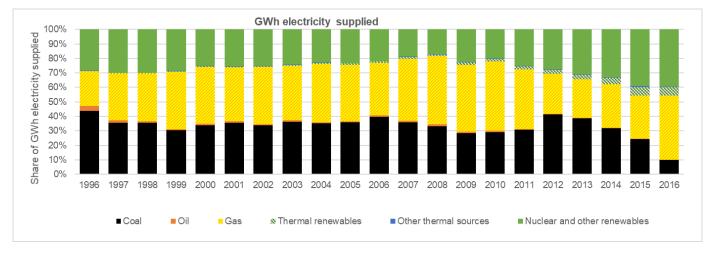
3. UK Electricity, Heat and Steam Emission Factors

Summary of changes since the previous update

- 3.1. The Heat & Steam model was updated in 2018 to streamline its processes. The methodology continues to follow the DUKES CHP method for heat to calculate the 2018 GHG conversion factor for heat & steam.
- 3.2. Additionally, there have been changes to the data that the CHP methodologies depend upon. These comprise changes to DUKES CHP fuel mix, assumptions about the CH₄ and N₂O emissions for certain fuels and changes to the underlying data within NAEI.

Direct Emissions from UK Grid Electricity

- 3.3. The electricity conversion factors given represent the average CO₂ emission from the UK national grid per kWh of electricity generated, classed as Scope 2 of the GHG Protocol and separately for electricity transmission and distribution losses, classed as Scope 3. The calculations also factor in net imports of electricity via the interconnectors with Ireland, the Netherlands and France. These factors include only direct CO₂, CH₄ and N₂O 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.).
- 3.4. 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 2018 emission factors are based on 2016 data.

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

- The UK electricity emission factors provided in the 2018 GHG Conversion Factors 3.5. are based on emissions from sector 1A1ai (power stations) and 1A2b (autogenerators) in the UK Greenhouse Gas Inventory (GHGI) for 2016 (Ricardo Energy & Environment) according to the amount of CO₂, CH₄ and N₂O emitted per unit of electricity consumed (from DUKES 2017)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 fuels¹². In previous updates, this was accounted for by removing this component from the DUKES GWh data. However, since the 2016 update, estimates of the emissions due to these components have been made using standard NAEI emission factors, and information from DUKES Table 5.6, 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 (~15.4% for the 2016 data year), which varies significantly from year-to-year.
- 3.6. The UK is a net importer of electricity from the interconnectors with France and Netherlands, and, to a more limited amount, with Ireland according to DUKES (2017). For the 2018 GHG Conversion Factors the total net electricity imports were calculated from DUKES (2017) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2016). The net shares of imported electricity over the interconnectors are calculated from data from DUKES (2017) Table 5.4 (Net Imports via interconnectors, GWh).
- 3.7. An average imported electricity emission factor is calculated from the individual factors for the relevant countries¹³ weighted by their respective share of net imports.

¹¹ DUKES (2017): <u>https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes</u>

 $^{^{12}}$ Other thermal non-renewable fuels include the following (with ~2017 update % share): blast furnace gas (~32%), chemical waste (~30%), coke oven gas (~5%) and municipal solid waste (MSW, ~35%)

¹³ French electricity factor: Rte. Available at: <u>http://www.rte-france.com/en/eco2mix/eco2mix-telechargement-en</u>. Dutch electricity factor: CBS. Available at: <u>https://www.cbs.nl/nl-nl/achtergrond/2017/06/rendementen-en-co2-</u> emissie-elektriciteitsproductie-2015

Irish electricity factor, SAEI. Available at: http://www.seai.ie/Energy-Data-Portal/Emission_Factors/

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 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.

- 3.8. 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 are fixed/locked from the 2017 GHG Conversion Factor update onwards and 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 2018 GHG Conversion Factors is based on a data year of 2016.
- 3.9. A full-time series of data using the most recently available GHGI and DUKES datasets for all years is also provided in Appendix 1 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 is applied across the whole-time series.

Data Year	Applied to Reporting Year*	orting Year* Generation ⁽¹⁾	Total Grid Losses ⁽²⁾	UK electricit emissions ⁽³⁾		on
		GWh	%	CO ₂	CH ₄	N ₂ O
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

Data Year	Applied to Reporting Year*	Electricity Generation ⁽¹⁾	Total Grid Losses ⁽²⁾	UK electricity emissions ⁽³⁾		on
		GWh	%	CO ₂	CH ₄	N ₂ O
2005	2007	370,977	7.25%	175,086	3.904	3.550
2006	2008	368,314	7.21%	184,517	4.003	3.893
2007	2009	365,252	7.34%	181,256	4.150	3.614
2008	2010	356,887	7.45%	176,418	4.444	3.380
2009	2011	343,418	7.87%	155,261	4.450	2.913
2010	2012	348,812	7.32%	160,385	4.647	3.028
2011	2013	330,128	7.88%	148,153	4.611	3.039
2012	2014	320,470	8.04%	161,903	5.258	3.934
2013	2015	308,955	7.63%	146,852	4.468	3.595
2014*	2016	297,897	8.30%	126,358	4.769	2.166
2015	2017	296,959	8.55%	106,209	7.567	2.136
2016	2018	297,203	7.85%	84,007	7.856	1.532

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 1A1ai+1A2d 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 Table 5.6, 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 (~15% in 2016 data year).

- (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 (Ricardo Energy & Environment, 2018) for the 2016 data year.

Table 5: Base electricity generation emissions data

	Emission	n Factor, k	gCO₂e / k\	Vh									% Net
Data Year		ricity GEN I to the gri			Due to grid transmission /distribution LOSSES			For electricity CONSUMED (includes grid losses)				Electricity Imports	
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	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	0.00020	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%

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	Emission	n Factor, k	gCO ₂ e / kV	Vh									% Net
Data Year	(supplied to the grid)			Due to grid transmission /distribution LOSSES			For electricity CONSUMED (includes grid losses)			Electricity Imports			
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL
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%
2015	0.35766	0.00064	0.00214	0.36044	0.03343	0.00006	0.00020	0.03369	0.39108	0.00070	0.00234	0.39412	6.59%
2016	0.28266	0.00066	0.00154	0.28486	0.02409	0.00006	0.00013	0.02428	0.30675	0.00072	0.00167	0.30913	5.57%

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.

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 2018 GHG Conversion Factors 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)

	Emission	Factor, kg	CO₂e / kWh										% Net
Data Year			RATED (su	pplied to	Due to grid LOSSES	d transmiss	ion /distrib	ution		city CONSL			Elec Imports
	the gria,	plus impor	ts)		LUSSES		1		(includes	grid losses))		
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	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%
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%

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	Emissior	Factor, kg	CO₂e / kWh										% Net
Data Year		ricity GENERATED (supplied to plus imports)		Due to grid transmission /distribution LOSSES			For electricity CONSUMED (includes grid losses)				Elec Imports		
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL
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%
2015	0.34885	0.00062	0.00209	0.35156	0.03261	0.00006	0.00020	0.03287	0.38146	0.00068	0.00229	0.38443	6.59%
2016	0.28088	0.00066	0.00153	0.28307	0.02394	0.00006	0.00013	0.02413	0.30482	0.00072	0.00166	0.3072	5.57%

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.

Time series data in light grey is locked/fixed for the purposes of company reporting and has not been updated in the database in 2018 GHG Conversion Factors update.

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

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

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

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

Indirect/WTT Emissions from UK Grid Electricity

- 3.10. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect/WTT emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect/WTT/ fuel lifecycle emissions as included in the Fuels WTT tables). The average fuel lifecycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel / primary energy used in electricity generation.
- 3.11. Average WTT emission factors for electricity have been calculated using the corresponding fuels WTT emission factors and data on the total fuel consumption by type of generation from Table 5.6, DUKES, 2017. The data used in these calculations are presented in Table 8, Table 9 and Table 10, together with the final 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 2015 data year, 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 2017).

Data Year	Fuel Con	sumed in	Electricity	Generation, GWh		
	Coal	Fuel	Natural	Other thermal	Other	Total
		Oil	Gas	(excl. renewables)	generation	
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
2015	212,336	7,192	212,976	23,050	323,693	779,248

Data Year	Fuel Consumed in Electricity Generation, GWh								
	Coal	Fuel Oil		Other thermal (excl. renewables)	Other generation	Total			
2016	87,669	6,790	298,077	25,319	325,774	743,630			

Source: For the latest 2016 data year, Table 5.6, Digest of UK Energy Statistics (DUKES) 2017 (BEIS, 2017), available at: <u>https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes#2015</u>. 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	Fuel Consu	med in Elec	ctricity Gen	eration, % Total		
Year	Coal	Fuel Oil	Natural	Other thermal	Other	Total
			Gas	(excl. renewables)	generation	
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%
2015	27.25%	0.92%	27.33%	2.96%	41.54%	100.00%
2016	11.79%	0.91%	40.08%	3.40%	43.81%	100.00%

Notes: Calculated from figures in Table 8.

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

Data	Indirect/V	VTT Emiss	ions as % l	Direct CO ₂ Emi	ssions, by fue	əl		
Year	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Weighte d Average	Direct CO _{2 (} (kg CO ₂ / kWh)	Calc Indirect /WTT (kg CO ₂ e/ 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
2015	16.38%	19.01%	16.03%	12.59%	16.07%	16.07%	0.34885	0.05605
2016	16.38%	18.99%	14.63%	12.59%	14.95%	14.95%	0.28088	0.04198

Notes: Indirect/WTT emissions as % direct CO₂ emissions is based on information for specific fuels. Weighted average is calculated from the figures for fuels from both Table 9 and Table 10.

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

Emission Factors for the Supply of Purchased Heat or Steam

- 3.12. Updated emission factors for the supply of purchased heat or steam have been provided for the 2018 GHG Conversion Factors. These conversion factors represent the average emission from the heat and steam supplied by the UK CHPQA scheme¹⁴ operators for a given year. This factor changes from year to year, as the fuel mix consumed changes and is therefore updated annually. No statistics are available that would allow the calculation of UK national average emission factors for the supply of heat and steam from non-CHP operations.
- 3.13. CHP (Combined Heat and Power) simultaneously produces both heat and electricity, and there are several 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 GHG Conversion Factors uses the 1/3 : 2/3 DUKES method (Method 1) to determine emissions from heat. This method, together with the alternative boiler displacement and power displacement methods, is described below. It is important to note that since the GHG Conversion Factor for heat is based on the DUKES method. Methods 2 and 3 are provided for information only.
- 3.14. To determine the amount of fuel attributed to CHP heat (qualifying heat output, or 'QHO'), it is necessary to apportion the total fuel to the CHP scheme to the separate heat and electricity outputs. This then enables the fuel, and therefore emissions, associated with the QHO to be determined. There are three possible methodologies for apportioning fuel to heat and power, which include:
 - a. Method 1: 1/3 : 2/3 Method (DUKES)
 - b. Method 2: Boiler Displacement Method
 - c. Method 3: Power Station Displacement Method

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

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

3.15. Under the UK's Climate Change Agreements (CCAs)¹⁵, 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%.

¹⁴ See <u>https://www.gov.uk/guidance/combined-heat-power-quality-assurance-programme</u>

¹⁵ Climate Change Agreements (CCAs) are agreements between UK energy intensive industries and UK Government, whereby industry undertakes to make challenging, but achievable, improvements in energy efficiency in exchange for a reduction in the Climate Change Levy (CCL).

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

$$Heat_Energy = \left(\frac{Total Fuel Input}{(2 \times Electricity_Output) + Heat_Output}\right) \times Heat_Output$$

$$Electricity_Energy = \left(\frac{2 \times Total \ Fuel \ Input}{(2 \times Electricity_Output) + Heat_Output}\right) \times Electricity_Output$$

Where:

- 'Total Fuel Input (TFI)' is the total fuel to the prime mover.
- 'Heat Output' is the useful heat generated by the prime mover.
- 'Electricity Output' is the electricity (or the electrical equivalent of mechanical power) generated by the prime mover.
- 'Heat Energy' is the fuel to the prime mover apportioned to the heat generated.
- 'Electricity Energy' is the fuel to the prime mover apportioned to the electricity generated.
- 3.17. This method is used only in the UK for accounting for primary energy inputs to CHP where the CHP generated heat and electricity is used within a facility with a CCA.

Method 2: Boiler Displacement Method

- 3.18. Under this convention it is assumed that the heat generated by the CHP displaces heat raised by a boiler with an efficiency of 81% on a GCV basis (90% NCV basis¹⁶), but that the boiler uses the same fuel mix as the actual fuel mix to the CHP to determine the CO₂ emissions.
- 3.19. Mathematically, Method 2 can be represented as follows:

$$Heat_Energy = \left(\frac{Heat_Output}{0.81}\right)$$

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

- 3.20. This method has wider understanding within the European Union and has the advantage that it would be compatible with other allocation methodologies for heat.
- 3.21. Carbon emission factors for Heat and Electricity are calculated according to this method as follows:

CO₂ emission from Fuel for Boiler

$$= \left(\frac{QHO}{0.81}\right) * FuelMixCO2Factor$$

CHP Heat EF = CO₂ emission from Fuel for Boiler / QHO = $\left(\frac{FuelMixCO2Factor}{0.81}\right)$

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

CO2 emission from Fuel for Electricity

$$= \left\{ TFI - \left(\frac{QHO}{0.81}\right) \right\} * FuelMixCO2Factor$$

3 - CHP Electricity EF

$$= \left\{ \left\{ \text{TFI} - \left(\frac{\text{QHO}}{0.81}\right) \right\} * \text{FuelMixCO2Factor} \right\} / \text{QPO}$$

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

Method 3: Power Station Displacement Method

- 3.22. Under this convention it is assumed that the electricity generated by the CHP displaces electricity generated by conventional power only plant with an agreed efficiency (using the UK's fossil fuel fired power stations annual efficiencies, taken into consideration the transmission and distribution losses). This establishes the fuel for electricity and the balance of the fuel to the prime mover is then assumed to be for the generation of heat.
- 3.23. Mathematically, Method 3 can be represented by:

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

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

- 3.24. This method raises the question of which power generation efficiency to use. For comparison in this analysis we have used the power generation efficiency of gas fired power stations, which has been taken to be 49.5% on a GCV basis¹⁷.
- 3.25. Carbon emission factors for Heat and Electricity are calculated according to this method as follows:

CO₂ emission from Fuel for Boiler

$$= \left\{ TFI - \left(\frac{ElectricityOutput}{0.495} \right) \right\} * FuelmixCO2Factor$$

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

$$= \left(\frac{QPO}{0.495}\right) * FuelmixCO2Factor$$

CHP Electricity Emission factor

$$= \left(\frac{FuelmixCO2Factor}{0.495}\right)$$

¹⁷ Digest of UK Energy Statistics (DUKES) 2017, Chapter 5, Table 5.10. Plant loads, demands and efficiency in 2016.

Calculation of CO₂ Emissions Factor for CHP Fuel Input, FuelMixCO₂factor

3.26. The value FuelMixCO₂factor referred to above is the carbon emission factor per unit fuel input to a CHP scheme. This factor is determined using fuel input data provided by CHP scheme operators to the CHPQA programme, which is held in confidence.

The value for FuelMixCO₂factor is determined using the following expression:

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

Where:

- FuelMixCO₂factor is the composite emissions factor (in tCO₂/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 CO₂ Emissions factor is the CO₂ emissions factor (in tCO₂/MWh_{th}) for the fuel considered.
- TFI is total fuel input (in MWh thermal) for all fuels supplied to the prime mover.
- 3.27. Fuel inputs and emissions factors are evaluated on a Gross Calorific Value (Higher Heating Value) basis. The following Table 11 provides the individual fuel types considered under the CHPQA scheme and their associated emissions factors, consistent with other reporting.

Fuel	CO ₂ Emissions Factor (kgCO ₂ /kWh _{th})
Biodiesel, bioethanol etc	0.00
Biomass (such as woodchips, chicken litter etc)	0.00
Blast furnace gas	1.01
Coal and lignite	0.32
Coke oven gas	0.14
Domestic refuse (raw)	0.12
Ethane	0.18
Fuel oil	0.27
Gas oil	0.25
Methane	0.18
Mixed refinery gases	0.25
Natural gas	0.18
Other Biogas (e.g. gasified woodchips)	0.00
Other gaseous waste	0.18
Other liquid waste (non-renewable)	0.19
Other liquid waste (renewable)	0.00
Other solid waste	0.23
Sewage gas	0.00

Fuel	CO ₂ Emissions Factor (kgCO ₂ /kWh _{th})
Waste exhaust heat from high temperature processes	0.00
Waste heat from exothermic chemical reactions	0.00
Other waste heat	0.00
Wood Fuels (woodchips, logs, wood pellets etc)	0.00
Fuel cells	0.18
Syngas / Other Biogas (e.g. gasified woodchips)	0.00
Other Industrial By-Product gases	0.18
Hospital waste	0.23

Sources: Defra/BEIS GHG Conversion Factors for Company Reporting (2017 update) and National Atmospheric Emissions Inventory (NAEI).

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

- 3.28. The 1/3 : 2/3 method (Method 1) was used to calculate the new heat/steam emission factors provided in the Heat and Steam tables of the 2018 GHG Conversion Factors. This is shown in Table 12. It is important to note that the conversion factors update year is two years ahead of the data year. For example, the most recent emission factor for the 2018 GHG Conversion Factors is based on the data year of 2016 in the table.
- 3.29. While not used in the 2018 GHG conversion factors, the factor for heat from CHP and power from CHP was calculated using the other two CHP methods and the DUKES power method. These are: 0.22012 CO₂/kWh heat (Boiler displacement), 0.19233 CO₂/kWh heat (Power station displacement), 0.37236 CO₂/kWh power (DUKES method), 0.30401 CO₂/kWh power (Boiler displacement), 0.35997 CO₂/kWh power (power station displacement).

Data Year	KgCO ₂ /kWh supplied heat/steam	
	Method 1 (DUKES: 2/3rd - 1/3rd)	
2001	0.23770	
2002	0.22970	
2003	0.23393	
2004	0.22750	
2005	0.22105	
2006	0.23072	
2007	0.23118	
2008	0.22441	

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.

Data Year	KgCO ₂ /kWh supplied heat/steam
	Method 1 (DUKES: 2/3rd - 1/3rd)
2009	0.22196
2010	0.21859
2011	0.21518
2012	0.20539
2013	0.20763
2014	0.20245
2015	0.19564
2016	0.18618

Table 12: Heat/Steam CO₂ emission factor for DUKES 1/3 2/3 method.

Calculation of Non-CO2 and Indirect/WTT Emissions Factor for Heat and Steam

- 3.30. CH₄ and N₂O emissions have been estimated relative to the CO₂ emissions, based upon activity weighted average values for each CHP fuel used (using relevant average fuel emission factors from the NAEI). Where fuels are not included in the NAEI, the value for the closest/most similar alternative fuel was utilised instead. There have been some updates to the assumptions here in the 2018 update, although the overall impacts are not significant.
- 3.31. Indirect/WTT GHG emission factors have been estimated relative to the CO₂ emissions, based upon activity weighted average indirect/WTT GHG emission factor values for each CHP fuel used (see Indirect/WTT Emissions from Fuels from Fuels section for more information). Where fuels are not included in the set of indirect/WTT GHG emission factors provided in the 2018 GHG Conversion Factors, the value for the closest/most similar alternative fuel was utilised instead.
- 3.32. The complete final emission factors for supplied heat or steam utilised are presented in the 'Heat and Steam' tables of the 2018 GHG Conversion Factors, and are counted as Scope 2 emissions under the GHG Protocol.
- 3.33. 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

Summary of changes since the previous update

4.1. There are no major changes for the refrigerant factors in the 2018 update.

Global Warming Potentials of Greenhouse Gases

4.2. Although revised GWP values have since been published by the IPCC in the Fifth Assessment Report (2014), 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

4.3. Mixed/Blended gases: GWP values for refrigerant blends are calculated on the basis of the percentage blend composition (e.g. the GWP for R404a that comprises of 44% HFC125¹⁸, 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

4.4. CFCs and HCFCs¹⁹: Not all refrigerants in use are classified as GHGs 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.

¹⁸ HFC: Hydrofluorocarbon

¹⁹ CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons

5. Passenger Land Transport Emission Factors

Summary of changes since the previous update

- 5.1. The emission factors for buses (and other heavy-duty vehicles) were revised this year to account for new technology being deployed on new vehicles to enable manufacturers to meet the most recent diesel engine emissions standards for NO_x emissions. This technology uses a urea solution (also known as 'AdBlue') to effectively reduce NO_x from diesel engines' exhaust gases. Emissions resulting from the consumption of urea in buses is estimated in the conversion factors for the first time in 2018 and are included in the estimates for the overall CO₂ emission factors.
- 5.2. For hybrid cars, a revision has been made to the underlying SMMT (Society of Motor Manufacturers & Traders) source dataset used in the derivation of passenger car emission factors, which has resulted in increased factors for (non-plug-in) hybrid cars in some cases.

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)²⁰ provides numbers of registrations and averages of the NEDC²¹ gCO₂/km figures for new vehicles registered from 1997 to 2017²². The dataset represents a good indication of the relative NEDC gCO₂/km by size category. Table 13 presents the 2001-2017 average CO₂ emission factors and number of vehicle registrations.

²⁰ SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry. http://www.smmt.co.uk/

²¹ NEDC = New European Driving Cycle, which is used in the type approval of new passenger cars.

²² The SMMT gCO₂/km dataset for 1997 represented around 70% of total registrations, which rose to about 99% by 2000 and essentially all vehicles thereafter.

Vehicle Type	Engine size	Size Iabel	NEDC gCO ₂ per km	Total no. of registrations	% Total
	< 1.4 l	Small	126.9	13,055,579	55%
Petrol car	1.4 - 2.0 I	Medium	165.3	8,999,251	38%
	> 2.0	Large	249.4	1,479,185	6%
Average petrol car		All	154.4	23,534,015	100%
	<1.7	Small	110.9	5,308,184	33%
Diesel car	1.7 - 2.0 I	Medium	139.0	7,346,311	46%
	> 2.0	Large	171.7	3,401,926	21%
Average diesel car		All	140.4	16,056,421	100%

Table 13: Average CO_2 emission factors and total registrations by engine size for 2001 to 2017 (based on data sourced from SMMT)

- 5.4. For the 2018 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 2015 (the ANPR dataset is only updated in the NAEI on a bi-annual basis)).
- 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, 2013, 2014 and 2015. Data are not available for 2016, as this dataset is only updated on a bi-annual basis for the NAEI, therefore for the 2018 GHG Conversion Factors the 2015 data have been used. 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 2015 ANPR dataset and categorised according to their engine size, fuel type and year of registration. The 2018 GHG Conversion Factors' emission factors for petrol and diesel passenger cars were subsequently calculated based upon the equation below:

2018 update gCO₂/km =
$$\Sigma \left(gCO_2 / km_{yr reg} \times \frac{ANPR_{yr reg}}{ANPR_{total 2015}} \right)$$

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.

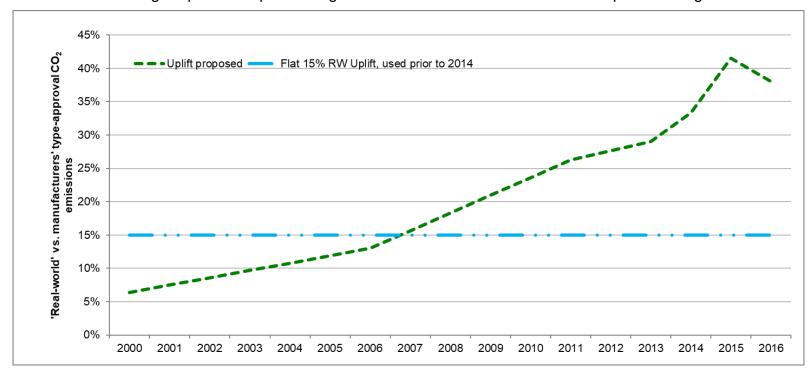
5.8. An uplift factor over NEDC based gCO₂/km factors is applied to take into account the combined 'real-world' effects on fuel consumption. The uplift applied varies over time and is based on work performed by ICCT (2017)²³; this study used data on almost 1.1 million vehicles from fourteen data sources and eight countries, covering the fuel consumption/CO₂ 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 (2017) report. This was an update of the previous report used for the 2017 update to the GHG Conversion Factors. The methodology for the revised approach was also agreed with DfT upon its introduction in 2014.

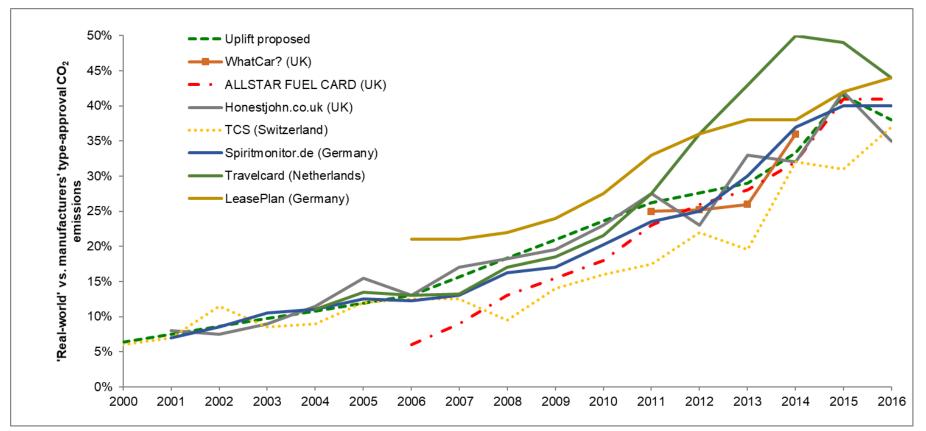
²³ Report by the ICCT, November 2017, FROM LABORATORY TO ROAD: A 2017 update of official and 'real-world' fuel consumption and CO₂ values for passenger cars in Europe, available at: <u>https://www.theicct.org/sites/default/files/publications/Lab-to-road-2017_ICCT-white%20paper_06112017_vF.pdf</u>.

Data year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
RW uplift %	8.60%	9.70%	10.8%	11.9%	13.0%	15.6%	18.3%	21.0%	23.6%	26.2%	27.6%	29.0%	33.3%	41.5%	38.0%

Table 14: Average GCF 'real-world' uplift for the UK, applied to the NEDC-based gCO₂/km data

5.9. The above uplifts have been applied to the ANPR weighted SMMT gCO₂/km to give the new 'Real-World' 2018 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 20.9% on top of NEDC gCO₂/km.





Notes: In the above charts a y-axis value of 0% would mean no difference between the CO₂ 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 (2017)

- 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 50.5% petrol and 49.5% diesel, and can be compared to the respective total registrations of the different vehicle types for 2011-2017, which were 59.4% petrol and 40.6% diesel.
- 5.11. Emission factors for CH₄ and N₂O have been updated for all vehicle classes and are based on the emission factors from the NAEI. The emission factors used in the NAEI are based on COPERT 4 version 11²⁴.
- 5.12. The final 2018 emission factors for petrol and diesel passenger cars by engine size are presented in the 'Passenger vehicles' and 'business travel- land' tables of the 2018 GHG Conversion Factors.

Hybrid, LPG and CNG Passenger Cars

- 5.13. The methodology used in the 2018 update for small, 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 with numbers of registrations and averages of the NEDC gCO₂/km figures from SMMT for new hybrid vehicles registered between 2011 and 2017. In previous years, the SMMT source dataset used in the derivation of passenger car emission factors included plug-in hybrid cars with in the hybrid category. A small revision to this dataset was made in 2018 to exclude these data (as these vehicles are now captured separately), which has resulted in increased factors in some cases.
- 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 2018 GHG Conversion Factors, CO₂ 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 2018 GHG Conversion Factors, the emission factors for CH₄ and N₂O 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 2018 GHG Conversion Factors.

Plug-in Hybrid Electric and Battery Electric Passenger Cars (xEVs)

5.16. Since the number of electric vehicles (xEVs²⁵) in the UK fleet is rapidly increasing (and will continue to increase in the future), at least for passenger cars and vans,

²⁴ COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport, see: <u>http://emisia.com/products/copert-4</u>.

²⁵ xEVs is a generic term used to refer collectively to battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), range-extended electric vehicles (REEVs, or ER-EVs, or REX) and fuel cell electric vehicles (FCEVs).

there is a need for specific emission factors for such vehicles to complement emission factors for vehicles fuelled primarily by petrol, diesel, natural gas or LPG.

- 5.17. Consequently, for the first time in the 2018 GHG Conversion Factors, new emission factors were developed for these vehicle types. The methodology, data sources and key assumptions utilised in the development of these emission factors for xEVs were discussed and agreed with the DfT.
- 5.18. These emission factors are currently presented in a number of data tables in the GHG Conversion Factors workbook, according the type / 'Scope' of the emission component. The following tables / worksheets, shown in Table 15, are required for BEVs (battery electric vehicles) and PHEVs (plug-in hybrid electric vehicles), and related REEVs (range-extended electric vehicles). Since there are still relatively few models available on the market, all PHEVs and REEVs are grouped into a single category. There are not yet meaningful numbers of fuel cell electric vehicles (FCEVs) in use, so these are not included at this time.
- 5.19. Table 15 provides an overview of the GHG Conversion Factor tables that have been developed for the reporting of emissions from electric vehicles, which aligns with current reporting. Whilst most emission factors could be accommodated by simply extending existing tables for cars and vans, two new tables (marked NEW) were needed to account for emissions resulting from electricity consumption, and these were added in the 2017 GHG Conversion Factors.

Emission component	Emissions Scope and Reporting Worksheet	Plug-in hybrid electric vehicles (PHEVs)	Battery electric vehicles (BEVs)
Direct emissions from use of petrol or diesel	Scope 1: • Passenger vehicles • Delivery vehicles	Yes	(Zero emissions)
Emissions resulting from electricity use: (a) Electricity Generation (b) Electricity Transmission & Distribution losses	 (a) Scope 2: UK electricity for EVs [NEW in 2017 update] (b) Scope 3: UK electricity T&D for EVs [NEW in 2017 update] 	Yes	Yes
Upstream emissions from use of liquid fuels and electricity	 Scope 3: WTT- pass vehs & travelland WTT- delivery vehs & freight 	Yes	Yes
Total GHG emissions for all components for not directly owned /controlled assets	 Scope 3: Business travel- land Freighting goods Managed assets- vehicles 	Yes	Yes

Note:

- Scope 1 (direct) emissions are those from activities owned or controlled by your organisation. Examples of Scope 1 emissions include emissions from combustion in owned or controlled boilers, furnaces and vehicles; and emissions from chemical production in owned or controlled process equipment.
- Scope 2 (energy indirect) emissions are those released into the atmosphere that are associated with consumption of purchased electricity, heat, steam and cooling. These indirect emissions are a consequence of an organisation's energy use, but occur at sources the organisation does not own or control.
- Scope 3 (other indirect) emissions are a consequence of your actions that occur at sources an organisation does not own
 or control and are not classed as Scope 2 emissions. Examples of Scope 3 emissions are business travel by means not owned
 or controlled by an organisation, waste disposal, materials or fuels an organisation's purchases. Deciding if emissions from a
 vehicle, office or factory that you use are Scope 1 or Scope 3 may depend on how organisations define their operational
 boundaries. Scope 3 emissions can be from activities that are upstream or downstream of an organisation. More information
 on Scope 3 and other aspects of reporting can be found in the <u>Greenhouse Gas Protocol Corporate Standard</u>.

Table 15: Summary of emissions reporting and tables for new electric vehicle emission factors

Data inputs, sources and key assumptions

- 5.20. A number of data inputs and assumptions were needed in order to calculate the final GHG conversion factors for electric cars and vans. The following table, Table 16, provides a summary of the key data inputs needed, the key data sources and other assumptions used for the calculation of the final xEV emission factors.
- 5.21. The calculation of UK fleet average emission factors for electric vehicles is based upon data obtained from the EEA CO₂ monitoring databases for cars and vans, which are publicly available^{26 27}. This database provides details by manufacturer and vehicle type (and by EU member state) on the annual number of registrations and test cycle performance for average CO₂ emissions (gCO₂/km) and electrical energy consumption (Wh/km, for plug-in vehicles). This allows for the classification of vehicles into market segments and also the calculation of registrations weighted average performance figures. The xEV models included in the current database (which covers registrations up to the end of 2016) and their allocation to different market segments, is provided in Table 16. For the purposes of calculating the corresponding emission factors for the tables split by car 'size' category, it is assumed segments A and B are 'Small' cars, segments C and D are 'Medium' cars and all other segments are 'Large' cars.

Make	Model	Segment	Segment Name	BEV	PHEV
Audi	A3	С	Lower Medium	-	Yes
Audi	Q7	Н	Dual Purpose	-	Yes
BMW	13	В	Supermini	Yes	-
BMW	I3 REEV	В	Supermini	-	Yes
BMW	18	G	Specialist Sports	-	Yes
BMW	Series 2	С	Lower Medium	-	Yes
BMW	Series 3	D	Upper Medium	-	Yes
BMW	Series 5	E	Executive	-	-
BMW	X5	Н	Dual Purpose	-	Yes
BYD	E6Y	С	Lower Medium	Yes	-
Chevrolet	Volt	С	Lower Medium	-	Yes

²⁶ https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-14

²⁷ <u>https://www.eea.europa.eu/data-and-maps/data/vans-10</u>

Make	Model	Segment	Segment Name	BEV	PHEV
Citroen	C-Zero	А	Mini	Yes	-
Ford	Focus	С	Lower Medium	Yes	-
Hyundai	loniq	С	Lower Medium	Yes	-
Kia	Optima	D	Upper Medium	-	Yes
Kia	Soul	В	Supermini	Yes	-
Mahindra	E20PLUS	С	Lower Medium	Yes	-
McLaren	P1	G	Specialist Sports	-	Yes
Mercedes-Benz	B Class	С	Lower Medium	Yes	-
Mercedes-Benz	C Class	D	Upper Medium	-	Yes
Mercedes-Benz	E Class	E	Executive	-	Yes
Mercedes-Benz	GL	Н	Dual Purpose	-	Yes
Mercedes-Benz	S Class	F	Luxury Saloon	-	Yes
Mia	Mia	А	Mini	Yes	-
Mitsubishi	I-MIEV	А	Mini	Yes	-
Mitsubishi	Outlander	Н	Dual Purpose	-	Yes
Nissan	e-NV200	1	Multi Purpose Vehicle	Yes	-
Nissan	Leaf	С	Lower Medium	Yes	-
Opel	Ampera	D	Upper Medium	-	Yes
Peugeot	lon	А	Mini	Yes	-
Porsche	918	G	Specialist Sports	-	Yes
Porsche	Cayenne	Н	Dual Purpose	-	Yes
Porsche	Panamera	F	Luxury Saloon	-	Yes
Renault	Fluence Z.E.	D	Upper Medium	Yes	-
Renault	Kangoo		Multi Purpose Vehicle	Yes	-
Renault	Zoe	С	Lower Medium	Yes	-
Smart	ForTwo	А	Mini	Yes	-
Tesla	Model S	F	Luxury Saloon	Yes	-
Tesla	Model X	Н	Dual Purpose	Yes	-
Tesla	Roadster	G	Specialist Sports	Yes	-
Think	ThinkCity	А	Mini	Yes	-
Toyota	Prius	С	Lower Medium	-	Yes
Volkswagen	E-Up	А	Mini	Yes	-
Volkswagen	Golf	С	Lower Medium	Yes	Yes
Volkswagen	Passat	D	Upper Medium	-	Yes
Volvo	V60	D	Upper Medium	-	Yes
Volvo	XC90	Н	Dual Purpose	-	Yes

Notes: Only includes models with registrations in the UK fleet up to the end of 2016.

 Table 16: xEV car models and their allocation to different market segments

- 5.22. During the course of the derivation of the emission factors, a number of discrepancies were found in the EEA CO₂ monitoring database for the gCO₂/km and Wh/km data for certain models, which were then updated based on other sources of official NEDC type-approval data, for example from manufacturer's websites and the Green Car Guide²⁸.
- 5.23. Consistent with the approach used for the calculation of emission factors for conventionally fuelled passenger cars, the gCO₂/km and Wh/km figures from type approval with NEDC need adjusting to account for real-world performance (charging losses are already accounted for under the type approval methodology²⁹). A number of assumptions are therefore made in order to calculate adjusted 'Real-World' energy consumption and emission factors, consistent with the approach for conventionally fuelled passenger cars. These assumptions were discussed and agreed with DfT.
- 5.24. A further complication for PHEVs is that the real-world electric range is lower than that calculated on the standard regulatory testing protocol, which also needs to be accounted for in the assumption of the average share of total km running on electricity. Figure 3 provides an illustration of the utility function used to calculate the share of electric km based on the electric range of a PHEV. Real-World factors for average gCO₂/km and Wh/km for PHEVs are therefore further adjusted based on the ratio of calculated electric shares of total km under Test-Cycle and Real-World conditions.
- 5.25. The key assumptions used in the calculation of adjusted Real-World gCO₂/km and Wh/km figures are summarised in Table 17. The calculated real-world figures for individual vehicle models are used to calculate the final registrations-weighted average factors for different vehicle segments/sizes. These are then combined with other GHG Conversion Factors to calculate the final set of emission factors for different Scopes/reporting tables (i.e. as summarised in earlier Table 15).

Data type	Raw data source / assumption	Other notes
Numbers of registrations of different vehicle types/models	 Reported for GB by vehicle make/model in EEA CO₂ monitoring databases: Data for 2010-2016 for cars Data for 2012-2016 for vans 	This data is used in conjunction with CO ₂ /km and Wh/km data to calculate registrations- weighted average figures by market segment or vehicle size category.
CO ₂ emissions from petrol or diesel fuel use per km (test-cycle)	As for registrations	Zero for BEVs. For PHEVs the emission factors are for the average share of km driven in charge-sustaining mode / average liquid fuel consumption per km

²⁸ <u>https://www.greencarguide.co.uk/</u>

²⁹ www.vda.de/dam/vda/publications/2014/facts-and-arguments-about-fuel-consumption.pdf

Data type	Raw data source / assumption	Other notes
Wh electricity consumption per km (test-cycle)	As for registrations	Average electricity consumption per average km (i.e. factoring in for PHEVs that only a fraction of total km will be in electric mode).
Test-Cycle to Real-World conversion for gCO ₂ / km	Assumption based on literature, consistent with source used for the car EFs for conventional powertrains.	An uplift of 35% is applied to the test-cycle emission component.
Test-Cycle to Real-World conversion for Wh per km	Assumption based on best available information on the average difference between test-cycle and real-world performance	An uplift of 40% is applied to the test-cycle electrical energy consumption component. This is consistent with the uplift currently being used in analysis for the EC DG CLIMA, developed/agreed with the EC's JRC.
Electric range for PHEVs under Test-Cycle conditions	Available from various public sources for specific models	Values representative of the models currently available on the market are used, i.e. generally between 30-50km. The notable exception is the BMW i3 REX, which was 200km up to 2015.
Electric range for PHEVs under Real-World conditions	Calculated based on Test- Cycle electric range and Test-Cycle to Real-World conversion for Wh per km	Calculated based on Test-Cycle electric range and Test-Cycle to Real-World conversion for Wh/km
Share of electric km on Test-Cycle	Calculated using the standard formula used in type-approval*: Electric km % = 1 – (25 / (25 + Electric km range))	Uses Test-Cycle electric range in km
Share of electric km in Real-World conditions	Calculated using standard formula*: Electric km % = 1 – (25 / (25 + Electric km range))	Uses Real-World electric range in km
Loss factor for electric charging	N/A	Charging losses are already accounted for under the type approval testing protocol in the Wh/km dataset.

Data type	Raw data source / assumption	Other notes
GHG emission factors for electricity consumption	 UK electricity emission factors (kgCO₂e / kWh): Electricity generated Electricity T&D WTT electricity generated WTT electricity T&D 	From the UK GHG Conversion Factors model outputs for UK Electricity
CH ₄ , N ₂ O and WTT CO ₂ e emissions from petrol /diesel use	Calculated based on derived Real-World g/km for petrol /diesel.	Calculation uses GHG Conversion Factors for petrol/diesel: uses ratio of direct CO ₂ emission component to CH ₄ , N ₂ O or WTT CO ₂ e component for petrol/diesel.

Notes: * the result of this formula is illustrated in Figure 3 below.



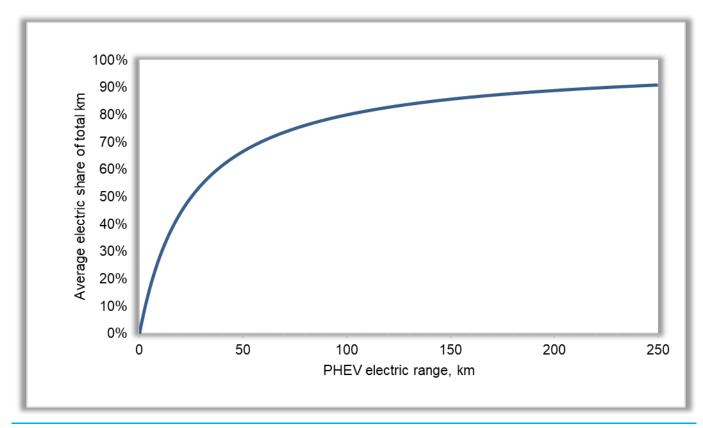


Figure 3: Illustration of the relationship of electric range to average electric share of total km for PHEVs assumed in the calculations

Emission Factors by Passenger Car Market Segments

- 5.26. For the 2018 GHG Conversion Factors, the market classification split (according to SMMT classifications) was derived using detailed SMMT data on new car registrations between 2011 and 2017 split by fuel³⁰, presented in Table 18, and again combining this with information extracted from the 2015 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 2018 GHG Conversion Factors.
- 5.27. Emission factors for CH₄ and N₂O 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 11³¹. The factors are presented together with the overall total emission factors in the tables of the 2018 GHG Conversion Factors.

5.28.	As a final additional step, an accounting for biofuel use has been included in the
	calculation of the final passenger car emission factors.

Fuel		Example	2001 to 2017				
Туре	ype Market Segment	Model	gCO ₂ /km	# registrations	% Total		
	A. Mini	Smart ForTwo	90.4	8,531	0.1%		
	B. Super Mini	VW Polo	106.8	1,896,272	11.81%		
	C. Lower Medium	Ford Focus	118.3	4,796,196	29.87%		
	D. Upper Medium	Toyota Avensis	136.3	3,623,841	22.57%		
	E. Executive	BMW 5-Series	143.3	1,346,631	8.39%		
Diesel	F. Luxury Saloon	Bentley Continental GT	177.2	78,147	0.49%		
	G. Specialist Sports	Mercedes SLK	135.3	115,036	0.72%		
	H. Dual Purpose	Land Rover Discovery	164.5	2,884,603	17.97%		
	I. Multi Purpose	Renault Espace	147.1	1,307,165	8.14%		
	All	Total	140.4	16,056,422	100%		
	A. Mini	Smart ForTwo	113.0	860,929	3.65%		
	B. Super Mini	VW Polo	129.6	11,513,671	48.80%		
Petrol	C. Lower Medium	Ford Focus	153.4	6,272,207	26.58%		
	D. Upper Medium	Toyota Avensis	183.6	2,018,160	8.55%		
	E. Executive	BMW 5-Series	210.9	529,511	2.24%		

³⁰ This data was provided by EST and is based on detailed data sourced from SMMT on new car registrations.

³¹ COPERT 4 is a software tool used world-wide to calculate air pollutant and greenhouse gas emissions from road transport, see: <u>http://emisia.com/products/copert-4</u>.

Fuel		Example	2001 to 20	17	
Туре	Market Segment	Model	gCO ₂ /km	# registrations	% Total
	F. Luxury Saloon	Bentley Continental GT	292.2	91,849	0.39%
	G. Specialist Sports	Mercedes SLK	211.3	796,413	3.38%
	H. Dual Purpose	Land Rover Discovery	212.0	751,592	3.19%
	I. Multi Purpose	Renault Espace	168.8	759,966	3.22%
	All	Total	154.4	23,594,298	100%
	A. Mini	Smart ForTwo	111.8	869,460	2.19%
	B. Super Mini	VW Polo	125.0	13,409,943	33.82%
	C. Lower Medium	Ford Focus	136.3	11,068,403	27.91%
	D. Upper Medium	Toyota Avensis	149.5	5,642,001	14.23%
Unknown	E. Executive	BMW 5-Series	157.2	1,876,142	4.73%
Fuel (Diesel +	F. Luxury Saloon	Bentley Continental GT	227.3	169,996	0.43%
Petrol)	G. Specialist Sports	Mercedes SLK	194.0	911,449	2.30%
	H. Dual Purpose	Land Rover Discovery	171.4	3,636,195	9.17%
	I. Multi Purpose	Renault Espace	154.5	2,067,131	5.21%
	All	Total	147.0	39,650,720	100%

Table 18: Average car CO_2 emission factors and total registrations by market segment for 2001 to 2017 (based on data sourced from SMMT)

Direct Emissions from Taxis

- 5.29. The emission factors for black cabs are based on data provided by Transport for London (TfL)³² 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 a more recent source has not yet been identified). 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).
- 5.30. The emission factors (per passenger km) for regular taxis were estimated on the basis of the average type-approval CO₂ 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, 2002³³).
- 5.31. Emission factors per passenger km for taxis and black cabs are presented in the 'business travel- land' tables of the 2018 GHG Conversion Factors. The base emission factors per vehicle km are also presented in the 'business travel- land' tables of the 2018 GHG Conversion Factors.
- 5.32. Emission factors for CH₄ and N₂O have been updated for all taxis for the 2018 update. These figures are based on the emission factors for diesel cars from the latest UK GHG Inventory and are presented together with the overall total emission factors in the tables of the 2018 GHG Conversion Factors.
- 5.33. 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.

³² The data was provided by TfL in a personal communication and is not available in a public TfL source.

³³ 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.

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)

- 5.34. 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 19 and in the "delivery vehicles" section of the 2018 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.
- 5.35. Emission factors for petrol and diesel LGVs are based upon emission factors and vehicle km from the NAEI for 2016. 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.
- 5.36. In the 2018 GHG Conversion Factors, CO₂ 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 2016, as presented in Table 19.
- 5.37. Emission factors for CH₄ and N₂O were also updated for all van classes, based on the emission factors from the UK GHG Inventory.
- 5.38. As a final additional step, an accounting for biofuel use has been included in the calculation of the final LGVs emission factors.

Man fuel	Ven eize	Direct	gCO ₂ e	per km		vkm	Capacity
Van fuel	Van size	CO ₂	CH ₄	N ₂ O	Total	% split	Tonnes
Petrol (Class I)	Up to 1.305 tonne	232.2	0.28	0.87	233.3	38.37%	0.64
Petrol (Class II)	1.305 to 1.740 tonne	258.7	0.28	0.87	259.9	48.63%	0.72
Petrol (Class III)	Over 1.740 tonne	312.7	0.28	0.87	313.8	13.00%	1.29
Petrol (average)	Up to 3.5 tonne	255.6	0.28	0.87	256.7	0.00%	0.76
Diesel (Class I)	Up to 1.305 tonne	150.5	0.01	1.85	152.4	6.18%	0.64
Diesel (Class II)	1.305 to 1.740 tonne	237.9	0.01	1.85	239.7	25.74%	0.98
Diesel (Class III)	Over 1.740 tonne	279.0	0.01	1.85	280.8	68.08%	1.29
Diesel (average)	Up to 3.5 tonne	260.4	0.01	1.85	262.3	0.00%	1.17
LPG	Up to 3.5 tonne	273.5	0.06	1.04	274.6		1.17
CNG	Up to 3.5 tonne	247.4	1.40	1.04	249.9		1.17
Average		260.3	0.00	1.80	262.1		1.16

 Table 19: New emission factors for vans for the 2018 GHG Conversion Factors

Plug-in Hybrid Electric and Battery Electric Vans (xEVs)

- 5.39. As outlined earlier for cars, since the number of electric cars and vans (xEVs³⁴) in the UK fleet is rapidly increasing, there is now a need to include specific emission factors for such vehicles to complement the existing emission factors for other vehicle types.
- 5.40. The methodology, data sources and key assumptions utilised in the development of the emission factors for xEVs are the same for vans as that outlined earlier for cars. These were discussed and agreed with DfT.
- 5.41. It should be noted that only models with registrations in the UK fleet up to the end of 2016 are included in the model. Notes: Only includes models with registrations in the UK fleet up to the end of 2016
- 5.42. Table 20 provides a summary of the vans models registered into the UK market by the end of 2016 (the most recent data year for the source EEA CO₂ monitoring database at the time of the development of the 2018 GHG Conversion Factors). At this point there are only battery electric vehicle (BEV) models available in the vans marketplace.

Make	Model	Van Segment	BEV	PHEV
Citroen	Berlingo	Class II	Yes	-
Ford	Transit connect	Class III	Yes	-
Mercedes-Benz	Vito	Class III	Yes	-
Mia	Mia	Class I	Yes	-
Nissan	E-nv200	Class II	Yes	-
Peugeot	Partner	Class II	Yes	-
Renault	Kangoo	Class II	Yes	-
Tata	Ace	Class I	Yes	-

Notes: Only includes models with registrations in the UK fleet up to the end of 2016

Table 20: xEV van models and their allocation to different size categories

5.43. All other methodological details are as already outlined for xEV passenger cars.

³⁴ xEVs is a generic term used to refer collectively to battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), range-extended electric vehicles (REEVs, or ER-EVs, or REX) and fuel cell electric vehicles (FCEVs).

Direct Emissions from Buses

- 5.44. 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 CO₂ 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 factors³⁵.
- 5.45. 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:
 - BSOG datasets are now only available for commercial services, and not also for local authority supported services.
 - 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.
- 5.46. In the 2018 update, an additional calculation was also added to the emission factors for buses to account for additional direct CO₂ emissions resulting from the use of a technology developed to enable manufacturers to meet recent diesel engine emissions standards for NOx, known as selective catalytic reduction (SCR). This technology uses a urea solution (also known as 'AdBlue') to effectively remove NO_x and NO₂ from diesel engines' exhaust gases; this process occurs over a specially formulated catalyst. Urea solution is injected into the vehicles' exhaust system before harmful NO_x emissions are generated from the tail pipe. When the fuel is burnt, urea solution is injected into the SCR catalyst to convert the NOx into a less harmful mixture of nitrogen and water vapour; small amounts of carbon dioxide are also produced as a result of this reaction. Emissions from the consumption of urea in buses have been estimated in the conversion factors for the first time for the 2018 update (consistent with the methodology also applied in the UK NAEI for this component) and are included in the estimates for overall CO₂ emission factors for buses. A summary of the key assumptions used in the calculation of emissions from urea is provided in the following Table 21. These are based on assumptions in the EMEP/EEA Emissions Inventory Guidebook.

	CO ₂ EF for urea consumption (kgCO ₂ /kg urea solution) ¹	Percentage of vehicles using urea	Urea consumption rate as a percentage of fuel consumed by vehicles using urea
Euro IV	0.238	75%	4%
Euro V	0.238	75%	6%

³⁵ 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.

	CO ₂ EF for urea consumption (kgCO ₂ /kg urea solution) ¹	Percentage of vehicles using urea	Urea consumption rate as a percentage of fuel consumed by vehicles using urea
Euro VI	0.238	100%	3.5%

Notes: ¹Assumes 32.5% (by mass) aqueous solution of urea

Table 21: Key assumptions used in the calculation of CO₂ emissions from Urea (aka 'AdBlue') use

- 5.47. Briefly, the main calculation for local buses can be summarised as follows:
 - a) Total fuel consumption (Million litres) = Total BSOG (£million) / BSOG fuel rate (p/litre) x 100
 - b) Total bus passenger-km (Million pkm) = Total activity (Million vkm) x Average bus occupancy (#)
 - c) Average fuel consumption (litres/pkm) = Total fuel consumption / Total bus passenger-km
 - Average bus emission factor = Average fuel consumption x Fuel Emission Factor (kgCO₂e/litre) + Average Emission Factor from Urea Use
- 5.48. Whilst the overall fundamental approach used in the 2017 and 2018 updates, apart from the urea addition, 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 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 buses³⁶.
- 5.49. As a final additional step, an accounting for biofuel use has been included in the calculation of the final bus emission factors.
- 5.50. Emission factors for coach services were estimated based on figures from National Express, who provide the majority of scheduled coach services in the UK.
- 5.51. Emission factors for CH₄ and N₂O are based on the emission factors from the UK GHG Inventory. These factors are also presented together with an overall total factor in Table 22.
- 5.52. Table 22 gives a summary of the 2018 GHG Conversion 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.

³⁶ 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: <u>https://www.gov.uk/government/statistical-data-sets/bus03-passenger-distance-travelled</u>

	Average passenger	gCO ₂ e per passenger km				
Bus type	occupancy	CO ₂	CH ₄	N ₂ O	Total	
Local bus (not London)	9.50	119.07	0.04	0.96	120.07	
Local London bus	19.29	71.62	0.02	0.47	72.11	
Average local bus	11.91	100.17	0.03	0.77	100.97	
Coach	17.56*	27.58	0.02	0.41	28.01	

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 22: Emission factors for buses for the 2018 GHG Conversion Factors

Direct Emissions from Motorcycles

- 5.53. Data from type approval is not currently readily available for motorbikes and CO₂ emission measurements were only mandatory in motorcycle type approval from 2005.
- 5.54. For the practical purposes of the GHG Conversion Factors, emission factors for motorcycles are split into 3 categories:
 - Small motorbikes (mopeds/scooters up to 125cc);
 - Medium motorbikes (125-500cc); and
 - Large motorbikes (over 500cc).
- 5.55. Since the 2009 update the emission factors have been calculated based on a large dataset kindly provided by Clear (2008)³⁷, based on a mix of magazine road test reports and user reported data. A summary is presented in Table 23, with the corresponding complete emission factors developed for motorcycles presented in the 'Passenger vehicles' tables of the 2018 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 2016³⁸. In the absence of newer information, the methodology and dataset are unchanged for the 2018 GHG Conversion Factors.
- 5.56. 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 data from ACEM³⁹ (+9%) is smaller than the corresponding differential

³⁷ Dataset of motorcycle fuel consumption compiled by Clear (<u>http://www.clear-offset.com/</u>) for the development of its motorcycle CO₂ model used in its carbon offsetting products.

³⁸ DfT Vehicle Licencing Statistics, Table VEH0306 "Licensed motorcycles by engine size, Great Britain, annually: 1994 to 2016", available at: <u>https://www.gov.uk/government/collections/vehicles-statistics</u>

³⁹ The European Motorcycle Manufacturers Association

previously used to uplift cars and vans test cycle data to real-world equivalents (+15%).

5.57. Emission factors for CH₄ and N₂O were updated for the 2018 GHG Conversion Factors based on the emission factors from the 2016 UK GHG Inventory (Ricardo Energy & Environment, 2018). These factors are also presented together with overall total emission factors in the tables of the 2018 GHG Conversion Factors.

CC Range	Model Count	Number	Av. gCO ₂ /km	Av. MPG*
Up to 125cc	24	58	85.0	76.2
125cc to 200cc	3	13	77.8	83.2
200cc to 300cc	16	57	93.1	69.5
300cc to 400cc	8	22	112.5	57.5
400cc to 500cc	9	37	122.0	53.1
500cc to 600cc	24	105	139.2	46.5
600cc to 700cc	19	72	125.9	51.4
700cc to 800cc	21	86	133.4	48.5
800cc to 900cc	21	83	127.1	50.9
900cc to 1000cc	35	138	154.1	42.0
1000cc to 1100cc	14	57	135.6	47.7
1100cc to 1200cc	23	96	136.9	47.3
1200cc to 1300cc	9	32	136.6	47.4
1300cc to 1400cc	3	13	128.7	50.3
1400cc to 1500cc	61	256	132.2	48.9
1500cc to 1600cc	4	13	170.7	37.9
1600cc to 1700cc	5	21	145.7	44.4
1700cc to 1800cc	3	15	161.0	40.2
1800cc to 1900cc	0	0		0.0
1900cc to 2000cc	0	0		0.0
2000cc to 2100cc	1	5	140.9	46.0
<125cc	24	58	85.0	76.2
126-500cc	36	129	103.2	62.7
>500cc	243	992	137.2	47.2
Total	303	1179	116.2	55.7

Note: Summary data based on data provided by Clear (<u>www.clear-offset.com</u>) from a mix of magazine road test reports and user reported data. * MPG has been calculated from the supplied gCO₂/km dataset, using the fuel properties for petrol from the latest conversion factors dataset.

Table 23: Summary dataset on CO₂ emissions from motorcycles based on detailed data provided by Clear (2008)

Direct Emissions from Passenger Rail

5.58. Emission factors for passenger rail services have been updated and provided in the "Business travel – land" section of the 2018 GHG Conversion Factors. These include updates to the national rail, international rail (Eurostar), light rail schemes and the London Underground. Emission factors for CH₄ and N₂O emissions were also updated in the 2018 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

- 5.59. 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 Maurice⁴⁰. The emission factors were provided by Eurostar for the 2018 update, together with information on the basis of the electricity figures used in their calculation.
- 5.60. 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 kgCO₂ 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 CO₂ Emissions from Fuel Combustion highlights dataset (from 2013).
- 5.61. The new figure from Eurostar is 12.157 gCO₂/pkm.
- 5.62. CH₄ and N₂O emission factors have been estimated from the corresponding emission factors for electricity generation, proportional to the CO₂ emission factors.

National Rail

- 5.63. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2016-17. The factor is sourced from information from the Office of the Rail Regulator's National rail trends for 2016-17 (ORR, 2017)⁴¹. 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).
- 5.64. CH₄ and N₂O emission factors have been estimated from the corresponding emissions factors for electricity generation and diesel rail (from the UK GHG Inventory), proportional to the CO₂ 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 are available from DfT).

⁴⁰ Although there are now also direct Eurostar routes to Lyon and Marseille, information relating to these routes has not been provided in 2018.

⁴¹ Available from the ORR's website at: <u>http://dataportal.orr.gov.uk/browsereports/9</u>

Light Rail

- 5.65. 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 24.
- 5.66. Figures for the London Overground and Croydon Tramlink for 2016/17 are based on figures kindly provided by TfL, adjusted to the new 2018 grid electricity CO₂ emission factor.
- 5.67. The factors for Midland Metro, Tyne and Wear Metro, Manchester Metrolink and Sheffield Supertram were calculated based on annual passenger km data from DfT's Light rail and tram statistics⁴² and the new 2018 grid electricity CO₂ emission factor.
- 5.68. The factor for the Glasgow Underground was calculated based on the annual passenger km data from DfT's Glasgow Underground statistics, and the new 2018 grid electricity CO₂ emission factor.
- 5.69. The average emission factor for light rail and tram was estimated based on the relative passenger km of the eight different rail systems (see Table 24).
- 5.70. CH₄ and N₂O emission factors have been estimated from the corresponding emissions factors for electricity generation, proportional to the CO₂ emission factors.

	Туре	Electricity use			Million pkm		
		kWh/pkm	CO ₂	CH ₄	N ₂ O	Total	
DLR (Docklands Light Rail)	Light Rail	0.105	31.95	0.07	0.17	32.20	656.80
Glasgow Underground	Light Rail	0.164	50.08	0.12	0.27	50.47	35.35
Midland Metro	Light Rail	0.135	41.24	0.10	0.22	41.56	65.60
Tyne and Wear Metro	Light Rail	0.351	107.00	0.25	0.58	107.83	329.70
London Overground	Light Rail	0.075	22.94	0.05	0.12	23.12	1,294.39
London Tramlink	Tram	0.212	64.66	0.15	0.35	65.17	153.56
Manchester Metrolink	Tram	0.078	23.91	0.06	0.13	24.09	395.30
Sheffield Supertram	Tram	0.350	106.69	0.25	0.58	107.52	81.80
Average* or Total		0.129	39.35	0.09	0.21	39.65	3,013

Notes: * Weighted by relative passenger km

Table 24: GHG emission factors, electricity consumption and passenger km for different tram and light rail services

⁴² DfT Light rail and tram statistics, <u>https://www.gov.uk/government/collections/light-rail-and-tram-statistics</u>

London Underground

- 5.71. The London Underground rail factor was provided from DfT, which was based on the 2018 UK electricity emission factor, so was therefore adjusted to be consistent with the 2018 grid electricity CO₂ emission factor.
- 5.72. CH₄ and N₂O emission factors have been estimated from the corresponding emissions factors for electricity generation, proportional to the CO₂ emission factors.

Indirect/WTT Emissions from Passenger Land Transport

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

5.73. Indirect/WTT emission 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 CO₂ emission factors and the indirect/WTT emission factors for the relevant fuels from the "Fuels" section and the corresponding direct CO₂ emission factors for vehicle types using these fuels in the "Passenger vehicles", "Business travel – land" and "Business travel – air" sections in the 2018 GHG Conversion Factors.

Rail

- 5.74. Indirect/WTT emission factors for international rail (Eurostar), light rail and the London Underground were derived using a simple ratio of the direct CO₂ emission factors and the indirect/WTT emission factors for grid electricity from the "UK Electricity" section and the corresponding direct CO₂ emission factors for vehicle types in the "Passenger vehicles", "Business travel land" and "Business travel air" sections in the GHG Conversion Factors.
- 5.75. 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

Summary of changes since the previous update

6.1. The emission factors for Heavy Goods Vehicles were revised this year to account for additional CO₂ emissions resulting from the use of urea by NO_x exhaust emissions control systems in newer vehicles, in a similar way to the emission factors for Buses, as discussed in Section 5.

Direct Emissions from Heavy Goods Vehicles (HGVs)

- 6.2. The HGV factors are based on road freight statistics from the Department for Transport (DfT, 2018)⁴³ for Great Britain (GB), from a survey on different sizes of rigid and articulated HGVs in the fleet in 2016. The statistics on fuel consumption figures (in miles per gallon) have been estimated by DfT from the survey data. For the 2018 GHG Conversion Factors, these are combined with test data from the European ARTEMIS project showing how fuel efficiency, and therefore the CO₂ emissions, varies with vehicle load.
- 6.3. The miles per gallon (MPG) figures in Table RFS0141 of DfT (2018) are converted to gCO₂ per km factors using the standard fuel conversion factor for diesel in the 2018 GHG Conversion Factors tables. Table RFS0117 of DfT (2018) shows the percent loading factors are on average between 36-65% 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 25 showing the change in CO₂ 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 CO₂ per kilometre when fully laden and 18% less CO₂ per kilometre when empty relative to emissions at half-load.
- 6.4. 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 18% uplift applied. This is based on average data for different sizes of refrigerated HGV from Tassou et al (2009)⁴⁴. This accounts for the typical additional energy needed to

⁴³ "Transport Statistics Bulletin: Road Freight Statistics July 2016 to June 2017, (DfT, 2018). Available at: <u>https://www.gov.uk/government/statistics/road-freight-statistics-july-2016-to-june-2017</u>

⁴⁴ 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: <u>http://www.sciencedirect.com/science/article/pii/S135943110800286X</u>

	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%

power refrigeration equipment in such vehicles over similar non-refrigerated alternatives⁴⁵.

Source: EU-ARTEMIS project

Table 25: Change in CO_2 emissions caused by +/- 50% change in load from average loading factor of 50%

- 6.5. Using these loading factors, the CO₂ 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 CO₂ factor shown for each class of HGV. These are shown in the final factors presented in sections "Delivery vehicles" and "Freighting goods" of the 2018 GHG Conversion Factors.
- 6.6. The loading factors in Table 25 were then used to derive corresponding CO₂ factors for 0% and 100% loadings in the above sections. Because the effect of vehicle loading on CO₂ 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 CO₂ factor halfway between the values for 50% and 100% laden factors.
- 6.7. It might be surprising to see that the CO₂ 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 CO2 factors for large rigid HGVs may be lower than indicated in "Delivery vehicles" and "Freighting goods" of the 2018 GHG Conversion Factors. Thus, the factors in "Delivery vehicles" and "Freighting goods", linked to the DfT (2018) statistics on MPG (estimated by DfT from the survey data) reflect each HGV class's typical usage pattern on the GB road network.
- 6.8. UK average factors for all rigid and articulated HGVs are also provided in sections "Delivery vehicles" and "Freighting goods" of the 2018 GHG Conversion Factors if the

⁴⁵ 'Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy', a report AEA Technology for EC DG CLIMA by plc and Ricardo, February 2011. Available at: https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ec hdv ghg strategy en.pdf

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 2016. These are derived directly from the mpg values for rigid and articulated HGVs in Table RFS01410f DfT (2018).

- 6.9. At a more aggregated level, factors for all HGVs are still representing the average MPG for all rigid and articulated HGV classes in Table RFS0141 of DfT (2018). 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 CO₂ emissions in, for example, inter-modal freight transport comparisons.
- 6.10. The conversion factors included in "Delivery vehicles" in the 2018 GHG Conversion Factors are provided in distance units to enable CO₂ emissions to be calculated 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.
- 6.11. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO₂ factors in tonne km (tkm) units. The "Freighting goods" section of the 2018 GHG Conversion Factors also provides such factors for each weight class of rigid and articulated HGV, for all rigid and for all articulated aggregated for all HGVs. These are derived from the fleet average gCO₂ 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, 2018). 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 49%. The 2018 GHG Conversion Factors, include factors in tonne km (tkm) for all loads (0%, 50%, 100% and average).
- 6.12. A tkm is the distance travelled multiplied by the weight of freight carried by the HGV. So, for example, a HGV carrying 5 tonnes freight over 100 km has a tkm value of 500 tkm. The CO₂ 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 CO₂ conversion factor in "Freighting goods" of the 2018 GHG Conversion Factors for the relevant HGV class.
- 6.13. Emission factors for CH₄ and N₂O have been updated for all HGV classes. These are based on the emission factors from the 2015 UK GHG Inventory. CH₄ and N₂O emissions are assumed to scale relative to vehicle class/CO₂ emissions for HGVs. These factors are presented with an overall total factor in sections "Delivery vehicles" and "Freighting goods" of the 2018 GHG Conversion Factors.
- 6.14. In the 2018 update, an additional calculation was added to the emission factors to account for the urea (aka 'AdBlue') use by newer HGVs for control of NOx exhaust emissions (in SCR systems) similar to that for Buses. Therefore, emissions from the consumption of urea in HGVs are estimated in the conversion factors for the first time and are included in the estimates for overall CO₂ emission factors.

Direct Emissions from Vans/Light Goods Vehicles (LGVs)

- 6.15. 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 land transport.
- 6.16. 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 26. 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		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		1.17	0.47
LPG (average)	Up to 3.5 tonne		1.17	0.47
CNG (average)	Up to 3.5 tonne		1.17	0.47
Average (unknown fuel)			1.16	0.47

Table 26: Typical van freight capacities and estimated average payload

6.17. The average load factors assumed for different vehicle types used to calculate the average payloads in Table 26 are summarised in Table 27, on the basis of DfT statistics from a survey of company owned vans.

Average van loading	Utilisati	on of vehic	le 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 % load	ling				
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, 2008⁴⁶

Table 27: Utilisation of vehicle capacity by company-owned LGVs: annual average 2003 – 2005 (proportion of total vehicle kilometres travelled)

- 6.18. Emission factors for CH₄ and N₂O have been updated for all van classes in the 2018 GHG Conversion Factors. These are based on the emission factors from the UK GHG Inventory. N₂O emissions are assumed to scale relative to vehicle class/CO₂ emissions for diesel vans.
- 6.19. 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 26 and the earlier emission factors per vehicle-km in the "Delivery vehicles" and "Freighting goods" sections of the 2018 GHG Conversion Factors.

Direct Emissions from Rail Freight

- 6.20. The data, used to update the rail freight emission factors for the 2018 GHG Conversion Factors, was provided by the Office of the Rail Regulator's (ORR, 2017)⁴⁷. This factor is presented in "Freighting goods" in the 2018 GHG Conversion Factors. There have been no further updates to the methodology in the 2018 update.
- 6.21. 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 CO₂ emissions from diesel rail freight are over 96% of the total for 2016-17 (ORR, 2017).
- 6.22. Traffic-, route- and freight-specific factors are not currently available, though these would present a more appropriate means of comparing modes (e.g. for bulk aggregates, intermodal, other types of freight). The rail freight CO₂ factor will be reviewed and updated if data become available relevant to rail freight movement in the UK.
- 6.23. CH₄ and N₂O emission factors have been estimated from the corresponding emissions for diesel rail from the UK GHG Inventory, proportional to the CO₂ 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

6.24. 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).

⁴⁶ 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

⁴⁷ Available from the ORR's website here: <u>https://dataportal.orr.gov.uk/displayreport/html/html/31212a97-cf7a-42d5-9fe3-a134b5c08b6a</u>

These indirect/WTT emission factors were derived using simple ratios of the direct CO₂ emission factors and the indirect/WTT emission factors for the relevant fuels and the corresponding direct CO₂ emission factors for vehicle types using these fuels.

Rail

6.25. 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 for combining indirect/WTT emission factors for diesel and electricity into a weighted average for freight rail using relative CO₂ 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 CO₂e emissions (2016).

7. Sea Transport Emission Factors

Summary of changes since the previous update

7.1. There are no major changes for the shipping factors in the 2018 update.

Direct Emissions from RoPax Ferry Passenger Transport and freight

- 7.2. 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)⁴⁸. No new methodology or updated dataset has been identified for the 2018 GHG Conversion Factors.
- 7.3. 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 and total fuel consumption.
- 7.4. From the information provided by the operators, figures for passenger km, tonne km and CO₂ emissions were calculated. CO₂ 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 ⁴⁹
Average weight of passenger + luggage, total	0.100	MCA, 2007 ⁴⁹
Average Freight Unit*, total	22.173	BFF, 2007 ⁵⁰
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006 ⁵¹

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

Table 28: Assumptions used in the calculation of ferry emission factors

7.5. CO₂ 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

⁴⁸ 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.

⁴⁹ Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: <u>http://www.dft.gov.uk/mca/mcga07-home/shipsandcargoes/mcga-shipsregsandguidance/marinenotices/mcga-mnotice.htm?textobjid=82A572A99504695B</u>

⁵⁰ 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.

⁵¹ Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006.

passenger km, and is presented in the "Business travel – sea" section of the 2018 GHG Conversion Factors. A further split has been provided between foot-only passengers and passengers with cars in the 2018 GHG Conversion Factors, again on a weight allocation basis.

- 7.6. CO₂ emissions are allocated to freight based on the weight of freight (including freight vehicles/containers) relative to the total weight of 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 2018 GHG Conversion Factors tables.
- 7.7. 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).
- 7.8. CH₄ and N₂O emission factors have been estimated from the corresponding emissions for shipping from the 2016 UK GHG Inventory, proportional to the CO_2 emissions.

Direct Emissions from Other Marine Freight Transport

- 7.9. CO₂ 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)⁵² report on GHG emissions from ships. The figures in "Freighting goods" of the 2018 GHG Conversion Factors represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.
- 7.10. CH₄ and N₂O emission factors have been estimated from the corresponding emissions for shipping from the 2016 UK GHG Inventory, proportional to the CO_2 emissions.

Indirect/WTT Emissions from Sea Transport

7.11. 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 CO₂ emission factors and the indirect/WTT emission factors for the relevant fuels and the corresponding direct CO₂ emission factors for ferries and ships using these fuels.

⁵² "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 CO₂ efficiency for cargo ships, International Maritime Organisation, 2009. Available at: <u>https://www.transportenvironment.org/docs/mepc59_ghg_study.pdf</u>

8. Air Transport Emission Factors

Summary of changes since the previous update

8.1. There are no major changes for the aviation factors in the 2018 update.

Passenger Air Transport Direct CO₂ Emission Factors

- 8.2. Emission factors for non-UK international flights were calculated in a similar way to the main UK flight emission factors, using DfT data on flights between different regions by aircraft type, and emission factors calculated using the EUROCONTROL small emitters tool. Average passenger load factors (79.6%) were taken from IATA (2018) statistics⁵³.
- 8.3. The 2018 update of the average factors (presented at the end of this section) has been calculated using the same updated data source as in 2015, 2016 and 2017. The EUROCONTROL small emitters tool was used as the basis for calculating the CO₂ emissions factors resulting from fuel burn over average flights for different aircraft. The principal advantages of the source are:
 - The tool is based on a methodology designed to estimate the fuel burn for an entire flight, it 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.
 - 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.
 - The tool is approved for use for flights falling under the EU ETS via the Commission Regulation (EU) No. 606/2010.
- 8.4. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 29. Key features of the calculation methodology, data and assumptions include:
 - A wide variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights;
 - 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, 2017) statistics for UK registered airlines for the year 2016 (the most recent complete dataset available at the time of calculation), split by aircraft and route type (Domestic, European Economic Area, other International)⁵⁴;
 - 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.

⁵³ <u>http://www.iata.org/pressroom/pr/Pages/2018-03-08-01.aspx</u>

⁵⁴ 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 publicly available sources, e.g. Annual Airline
Statistics available from the CAA's website at:

http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&pageid=1&sglid=1

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	Emissions Factor, kgCO ₂ /vkm	Av. flight length, km
Domestic Flights					
AIRBUS A319	149	78%	34%	16.2	367
AIRBUS A320-100/200	172	74%	21%	17.0	350
AIRBUS A321	200	70%	4%	19.0	396
ATR72 200/500/600	72	61%	1%	5.5	311
BOEING 737-700	152	67%	1%	13.9	463
BOEING 737-800	189	82%	6%	19.2	288
BOEING 767-300ER/F	259	71%	1%	29.8	349
BOMBARDIER DASH 8 Q400	77	67%	22%	7.1	380
EMB ERJ175 (170-200)	82	66%	1%	10.6	415
EMBRAER ERJ190	99	67%	3%	13.2	388
EMBRAER ERJ195	117	62%	1%	16.0	323
SAAB 2000	37	70%	2%	6.8	363
SAAB FAIRCHILD 340	28	70%	2%	3.9	296
Sikorsky Aircraft S-92	16	87%	1%	3.7	371
Weighted average	136	74%	100%*(total)	11.2	361
Short-haul Flights					
AIRBUS A319	149	80%	14%	10.8	1386
AIRBUS A320-100/200	175	76%	28%	10.9	1728
AIRBUS A321	210	75%	10%	12.7	1805
AIRBUS A330-300	295	70%	0%	24.3	1577
ATR72 200/500/600	69	68%	0%	4.5	969
AVROLINER RJ85	94	64%	0%	12.3	771
BOEING 737-300	147	85%	1%	11.8	1492
BOEING 737-700	139	78%	1%	10.4	1540
BOEING 737-800	188	85%	37%	11.0	2022
BOEING 737-900	184	80%	2%	11.6	1932
BOEING 757-200	199	76%	2%	15.0	1722
BOEING 757-300	280	88%	0%	16.5	2080
BOEING 767-300ER/F	289	75%	1%	20.5	1887
BOEING 787-800 DREAMLINER	315	94%	0%	19.9	2372
BOMBARDIER DASH 8 Q400	78	65%	0%	6.0	763
EMB ERJ175 (170-200)	88	67%	0%	8.1	1054
EMBRAER ERJ195	106	70%	1%	10.2	1429
Fokker F28	72	78%	0%	10.7	1198
Weighted average	180	80%	100%*(total)	11.2	1,677

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	Emissions Factor, kgCO ₂ /vkm	Av. flight length, km
Long-haul Flights		÷			
AIRBUS A310	247	83%	0%	18.5	5002
AIRBUS A320-100/200	180	90%	1%	10.2	3149
AIRBUS A321	174	71%	0%	11.8	3607
AIRBUS A330-200	275	77%	5%	21.0	6332
AIRBUS A330-300	281	72%	5%	21.7	6577
AIRBUS A340-300	267	66%	1%	25.2	6905
AIRBUS A340-600	308	77%	2%	31.5	6702
AIRBUS A350-900	310	84%	0%	23.7	6926
AIRBUS A380-800	495	73%	17%	47.0	6802
BOEING 737-800	167	76%	1%	10.4	3599
BOEING 747-400	354	79%	15%	38.0	7685
BOEING 757-200	170	69%	2%	14.4	5746
BOEING 767-300ER/F	224	64%	4%	19.1	5477
BOEING 767-400	245	68%	1%	20.7	5838
BOEING 777-200	258	71%	14%	25.5	6813
BOEING 777-300	342	72%	14%	28.8	6374
BOEING 777-300ER	308	73%	4%	30.8	7328
BOEING 787-800 DREAMLINER	253	77%	9%	18.4	6670
BOEING 787-900 DREAMLINER	254	78%	6%	19.9	7035
Weighted average	324	74%	100%	27.2	6,523

Notes: Figures on seats, load factors, % tkm and av. flight length have been calculated from 2017 CAA statistics for UK registered airlines for the different aircraft types. Figures of kgCO₂/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 94% of domestic pkm, 94% of short-haul pkm and 95% of long-haul pkm.

Table 29: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2018

- 8.5. 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.
- 8.6. 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 longhaul. Some examples of such 'long-haul' flights have been provided in the following Table 30 (as previously provided within the 2012 Annexes in the old format). The methodology has been unchanged since 2013, and it is up to the users of the GHG Conversion Factors to use their best judgement on which category to allocate particular flights into.

Area	Destination Airport	Distance, km
Short-haul		
Europe	Amsterdam, Netherlands	400
Europe	Prague (Ruzyne), Czech Rep	1,000
Europe	Malaga, Spain	1,700
Europe	Athens, Greece	2,400
Average (CAA statistics)		1,366
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)		6,823

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

 Table 30: Illustrative short- and long- haul flight distances from the UK

8.7. A new set of aviation factors was 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 are assumed to be equal to the current UK long haul air freight factors⁵⁵.

Taking Account of Freight

8.8. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers

⁵⁵ 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.

and their luggage, as well as freight. The CAA data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights. In fact, the quantity of freight carried on scheduled long-haul passenger flights is nearly 8 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 CO₂ between passengers and freight, which was developed for the 2008 update, and has also been applied in subsequent updates.

- 8.9. 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 31:
 - a. **No Freight Weighting:** Assume all the CO₂ is allocated to passengers on these services.
 - b. Freight Weighting Option 1: Use the CAA tonne km (tkm) data directly to apportion the CO₂ 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 tkm 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:	Passenger gCO ₂		Option 1: Direct	:	Option 2: Equivalent		
Mode			Passenger tkm % of total			gCO ₂ /pkm	
Domestic flights	100%	144.9	99.77%	144.6	99.77%	144.6	
Short-haul flights	100%	80.2	98.70%	78.7	98.70%	78.7	
Long-haul flights	100%	122.1	65.71%	79.5	85.13%	103.1	

Table 31: CO₂ emission factors for alternative freight allocation options for passenger flights based on 2018 GHG Conversion Factors

8.10. 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. 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 2018 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 31.

- 8.11. 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.
- 8.12. **Option 2** was selected as the preferred methodology to allocate emissions between passengers and freight for the 2008 and subsequent GHG Conversion Factors.
- 8.13. 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 CO₂ emissions with those from the UK GHG Inventory (which is scaled using actual fuel supplied).
- 8.14. The final average emission factors for aviation are presented in Table 32. The figures in Table 32 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 2018 GHG Conversion Factor data tables.

Mode	Factors for 2018				
	Load Factor%	gCO ₂ /pkm			
Domestic flights	73.7%	144.6			
Short-haul flights	79.9%	78.7			
Long-haul flights	74.0%	103.1			

Notes: Load factors based on data provided by DfT that contains detailed analysis of CAA statistics for the year 2016

Table 32: Final average CO₂ emission factors for passenger flights for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

Taking Account of Seating Class Factors

- 8.15. 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 CO₂ emissions per passenger km.
- 8.16. There is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, 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 33, 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.

- 8.17. 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 times⁵⁶ the space taken up by the basic economy seating. Table 33 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.
- 8.18. 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.

Flight type	Cabin Seating Class	Load Factor%	gCO₂ /pkm	Number of economy seats	% of average gCO ₂ /pkm	% Total seats
Domestic	Weighted average	73.7%	144.6	1.00	100.0%	100.0%
Short-haul	Weighted average	79.9%	78.7	1.02	100.0%	100.0%
	Economy class	79.9%	77.4	1.00	98.4%	96.7%
	First/Business class	79.9%	116.2	1.50	147.5%	3.3%
Long-haul	Weighted average	74.0%	103.1	1.31	100.0%	100.0%
	Economy class	74.0%	78.9	1.00	76.6%	83.0%
	Economy+ class	74.0%	126.3	1.60	122.5%	3.0%
	Business class	74.0%	228.9	2.90	222.1%	11.9%
	First class	74.0%	315.7	4.00	306.3%	2.0%

Notes: Load factors based on data provided by DfT that contains detailed analysis of CAA statistics for the year 2016

Table 33: CO₂ emission factors by seating class for passenger flights for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

Freight Air Transport Direct CO₂ Emission Factors

- 8.19. Air 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.
- 8.20. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2017). These data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts approximately for 89% 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.

⁵⁶ For the first class sleeper seats/beds frequently used in long-haul flights.

8.21. 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

8.22. 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 2018 update for the GHG Conversion Factors – presented in Table 34. 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 2018 GHG Conversion Factor data tables.

Mode	Revised factors for 2018				
	Load Factor%	kgCO ₂ /tkm			
Domestic flights	46.3%	2.9			
Short-haul flights	76.1%	0.9			
Long-haul flights	75.0%	0.8			

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 34: Revised average CO₂ emission factors for dedicated cargo flights for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

- 8.23. 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 tool⁵⁷. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 35. 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 2016 (the latest available complete dataset).

⁵⁷ The EUROCONTROL small emitters tool is available at: <u>https://www.eurocontrol.int/articles/small-emitters-tool</u>

	Average Cargo Capacity, tonnes	Av. Load Factor	Proportion of tonne km	EF, kgCO₂ /vkm	Av. flight length, km
Domestic Flights					
BAE ATP	8.0	47%	8.5%	6.81	231
BAE 146-200/QT	10.0	34%	0.0%	0.00	173
BOEING 737-300	15.2	45%	62.8%	26.33	155
BOEING 757-200	23.2	56%	6.2%	23.41	155
BOEING 747-8 (FREIGHTER)	126.9	19%	0.0%	0.00	173
BOEING 767-300ER/F	58.0	46%	22.5%	26.16	512
Average	24.7	46%	100% (total)	22.70	379
Short-haul Flights					
BAE ATP	8.0	43%	0.2%	5.58	502
BOEING 757-200	22.0	77%	71.3%	16.04	748
BOEING 747-8 (FREIGHTER)	124.3	33%	0.8%	54.81	619
BOEING 767-300ER/F	30.8	76%	27.7%	20.53	1892
Average	25.2	76%	100% (total)	17.05	1,432
Long-haul Flights		·			
BAE ATP	8.0	16%	0.0%	5.87	390
BOEING 757-200	21.6	79%	17.5%	15.22	1294
BOEING 747-8 (FREIGHTER)	129.4	73%	24.8%	37.79	4653
BOEING 767-300ER/F	29.6	75%	57.7%	19.20	5098
Average	53.0	75%	100% (total)	19.39	4,381

Notes: Figures on cargo, load factors, % tkm and av. flight length have been calculated from CAA statistics for UK registered airlines for different aircraft in the year 2016. Figures of kgCO₂/vkm were calculated using the average flight lengths in the EUROCONTROL small emitters tool.

Table 35: Assumptions used in the calculation of average CO_2 emission factors for dedicated cargo flights for the 2018 GHG Conversion Factors

Emission Factors for Freight on Passenger Services

8.24. 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 36 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 2018 GHG Conversion Factor data tables (discussed later).

Freight Weighting:	% Total Freight tkm		Option 1: Dire	ect	Option 2: Equivalent	
Mode	Passenger Services (PS)	Cargo Services	PS Freight tkm, % total	Overall kgCO ₂ /tkm	PS Freight tkm, % total	Overall kgCO ₂ /tkm
Domestic flights	5.1%	94.9%	0.2%	2.8	0.2%	2.8
Short-haul flights	24.1%	75.9%	1.3%	0.9	1.3%	0.9
Long-haul flights	85.9%	14.1%	34.3%	1.3	14.9%	0.6

Table 36: Air freight CO₂ emission factors for alternative freight allocation options for passenger flights for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

- 8.25. CAA statistics include excess passenger baggage in the 'freight' category, which would under **Option 1** result in a degree of under-allocation to passengers. **Option 2** therefore appears to provide the more reasonable means of allocation.
- 8.26. **Option 2** was selected as the preferred methodology for freight allocation for the 2008 update, when this analysis was originally performed. The same methodology has been applied in subsequent updates and is included in all of the presented emission factors for 2018.

Average Emission Factors for All Air Freight Services

8.27. Table 37 presents the final average air freight emission factors for all air freight for the 2018 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 2018 GHG Conversion Factor data tables (discussed later).

Mode	% Total Air Freight tkr	All Air Freight		
	Passenger Services	kgCO ₂ /tkm		
Domestic flights	5.1%	94.9%	2.8	
Short-haul flights	24.1%	75.9%	0.9	
Long-haul flights	85.9%	14.1%	0.6	

Notes: % Total Air Freight tkm based on CAA statistics for 2016 (T0.1.6 All Services)

Table 37: Final average CO₂ emission factors for all air freight for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

Air Transport Direct Emission Factors for CH₄ and N₂O

Emissions of CH₄

8.28. Total emissions of CO₂, CH₄ and N₂O 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 CO₂ and CH₄ emissions from the UK GHG inventory for 2016 (see Table 38) were used to calculate the specific CH₄ emission factors per passenger km or tonne-km relative to the corresponding CO₂ emission

factors. The resulting air transport emission factors for the 2018 GHG Conversion Factors are presented in Table 39 for passengers and Table 40 for freight.

	CO ₂		CH ₄		N ₂ O	
	Mt CO ₂ e	% Total CO ₂ e	Mt CO ₂ e	% Total CO ₂ e	Mt CO ₂ e	% Total CO ₂ e
Aircraft - domestic	1.63	98.98%	0.0013	0.08%	0.015	0.94%
Aircraft - international	33.66	99.06%	0.0022	0.01%	0.318	0.94%

Table 38: Total emissions of CO₂, CH₄ and N₂O for domestic and international aircraft from the UK GHG inventory for 2016

Emissions of N₂O

8.29. Similar to those for CH₄, emission factors for N₂O per passenger-km or tonne-km were calculated on the basis of the relative proportions of total CO₂ and N₂O emissions from the UK GHG inventory for 2016 (see Table 38), and the corresponding CO₂ emission factors. The resulting air transport emission factors for the 2018 GHG Conversion Factors are presented in Table 39 for passengers and Table 40 for freight. The factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2018 GHG Conversion Factor data tables (discussed later).

Air Passenger Mode	Seating Class	CO ₂ gCO ₂ /pkm	CH₄ gCO₂e/pkm	N ₂ O gCO ₂ e/pkm	Total GHG gCO ₂ e/pkm
Domestic flights	Average	144.6	0.1	1.4	146.1
Short-haul flights	Average	78.7	0.0	0.7	79.5
	Economy	77.4	0.0	0.7	78.2
	First/Business	116.2	0.0	1.1	117.3
Long-haul flights	Average	103.1	0.0	1.0	104.1
	Economy	78.9	0.0	0.7	79.7
	Economy+	126.3	0.0	1.2	127.5
	Business	228.9	0.0	2.2	231.1
	First	315.7	0.0	3.0	318.7
International	Average	88.6	0.0	0.8	89.5
flights (non-UK)	Economy	67.9	0.0	0.6	68.5
	Economy+	108.6	0.0	1.0	109.6
	Business	196.8	0.0	1.9	198.7
	First	271.5	0.0	2.6	274.1

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

Table 39: Final average CO₂, CH₄ and N₂O emission factors for all air passenger transport for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

Air Freight Mode	CO ₂ kgCO ₂ /tkm	CH₄ kgCO₂e/tkm	N ₂ O kgCO ₂ e/tkm	Total GHG kgCO₂e/tkm
Passenger Freight				
Domestic flights	1.6040	0.0013	0.0152	1.6205
Short-haul flights	0.9727	0.0001	0.0092	0.9820
Long-haul flights	0.5712	0.0000	0.0054	0.5766
Dedicated Cargo				
Domestic flights	2.8932	0.0023	0.0274	2.9229
Short-haul flights	0.9349	0.0001	0.0088	0.9438
Long-haul flights	0.7568	0.0000	0.0072	0.7640
All Air Freight	·			
Domestic flights	2.8275	0.0023	0.0268	2.8565
Short-haul flights	0.9440	0.0001	0.0089	0.9530
Long-haul flights	0.5974	0.0000	0.0057	0.6031

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

Table 40: Final average CO₂, CH₄ and N₂O emission factors for air freight transport for 2018 GHG Conversion Factors (excluding distance and RF uplifts)

Indirect/WTT Emission Factors from Air Transport

8.30. 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 CO₂ emission factors and the indirect/WTT emission factors for aviation turbine fuel (kerosene) and the corresponding direct CO₂ 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

- 8.31. 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.
- 8.32. 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 2018 GHG Conversion Factors.

8.33. 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 2018 GHG Conversion Factors tables.

Non-CO₂ impacts and Radiative Forcing

- 8.34. The emission factors provided in the 2018 GHG Conversion Factors sections "Business travel – air" and "Freighting goods" refer to aviation's direct CO₂, CH₄ and N₂O emissions only. There is currently uncertainty over the other non-CO₂ 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.
- 8.35. 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 CO₂ emissions alone.
- 8.36. The application of a 'multiplier' to take account of non-CO₂ 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 CO₂, 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.
- 8.37. On the other hand, consideration of the non-CO₂ 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 41 and the GWP₁₀₀ figure (consistent with UNFCCC reporting convention) from the ATTICA research presented in Table 42 below⁵⁸ and in analysis by Lee et al (2009) reported on by the Committee on Climate Change (2009)⁵⁹.

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 42 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

⁵⁸ R. Sausen et al. (2005). Aviation radiative forcing in 2000: An update on IPCC (1999) Meteorologische Zeitschrift 14: 555-561, available at: <u>http://elib.dlr.de/19906/1/s13.pdf</u>

⁵⁹ CCC (2009). Meeting the UK Aviation target – options for reducing emissions to 2050, <u>http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/</u>

bottom right is the overall ratio of total CO_2 -equivalent emissions to CO_2 emissions for aviation in 2005."

8.38. 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 CO₂ component of direct emissions (i.e. not also to the CH₄ and N₂O emissions components). The 2018 GHG Conversion Factors provide separate emission factors including this radiative forcing uplift in separate tables in sections "Business travel – air" and "Freighting goods"

			RF [mW/m ²]						
Year	Study	CO_2	03	CH ₄	H_2O	Direct	Direct	Contrails	Total
	-					Sulphate	Soot		(w/o) Cirrus
1992	IPCC (1999)	18.0	23.0	-14.0	1.5	-3.0	3.0	20.0	48.5
2000	IPCC (1999) scaled to 2000	25.0	28.9	-18.5	2.0	-4.0	4.0	33.9	71.3
2000	TRADEOFF	25.3	21.9	-10.4	2.0	-3.5	2.5	10.0	47.8

Notes: Estimates for scaling CO2 emissions to account for Radiative Forcing impacts are not quoted directly in the table, but are derived as follows: IPCC (1999) = 48.5/18.0 = 2.69 ≈ 2.7; TRADEOFF = 47.8/25.3 = 1.89 ≈ 1.9

Table 41: Impacts of radiative forcing according to R. Sausen et al. (2005)

	Metric values		CO ₂ e emissions (MtCO ₂ e/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 NO _x	120	-2.1	-9.5	106	-1.9	-8.4	Very low
High NO _x	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 ₂ e/CO ₂	emissions	for 2005	
Low NO _x , inc. AIC				4.3	1.9	1.1	Very low
High NO _x , inc. AIC				4.8	2.0	1.1	Very low
Low NO _x , exc. AIC				2.1	1.3	1.0	Very low
High NO _x , 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 CO₂ increases in importance relative to shorter-lived effects as longer timescales are considered.

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

9. Bioenergy and Water

Summary of changes since the previous update

9.1. There are no major changes for the bioenergy and water factors in the 2018 update.

General Methodology

- 9.2. The 2018 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 lifecycle and include net CO₂, CH₄, N₂O 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 2018 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 Conversion Factors have been unchanged since the 2012 GHG Conversion Factors values.

Biofuels

- 9.7. Biofuels are defined as "net carbon zero" or "carbon neutral" as any CO₂ expelled during the burning of the fuel is cancelled out by the CO₂ absorbed by the feedstock used to produce the fuel during growth⁶⁰. Therefore, all direct emissions from biofuels provided in the GHG Conversion Factors dataset are only made up of CH₄ and N₂O emissions.
- 9.8. Unlike the direct emissions of CO₂, CH₄ and N₂O are not offset by adsorption in the growth of the feedstock used to produce the biofuel. In the absence of other information, these emissions factors have been assumed to be equivalent to those produced by combusting the corresponding fossil fuels (i.e. diesel, petrol or CNG) from the "Fuels" section.

⁶⁰ This is a convention required by international GHG Inventory guidelines and formal accounting rules

9.9. The indirect/WTT/fuel lifecycle emission factors for biofuels were based on UK average factors from the Quarterly Report (2015/16)⁶¹ on the Renewable Transport Fuel Obligation (RTFO). These average factors and the direct CH₄ and N₂O factors are presented in Table 43.

Biofuel	Emissions Factor, gCO ₂ e/MJ				
	RTFO Lifecycle ⁽¹⁾	Direct CH ₄ ⁽²⁾	Direct N ₂ O ⁽²⁾	Total Lifecycle	Direct CO ₂ Emissions (Out of Scope ⁽³⁾)
Biodiesel	12.33	0.01	0.59	12.93	75.30
Bioethanol	30.32	0.22	0.11	30.65	71.60
Biomethane	10.00	0.08	0.03	10.11	55.28
Biodiesel (from used cooking oil)	11.56	0.01	0.59	12.17	75.30
Biodiesel (from Tallow)	14.03	0.01	0.59	14.63	75.30

Notes:

(1) Based on UK averages from the RTFO Quarterly Report (2015/16) 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 CO₂ emitted by the biofuel when combusted. This will be counter-balanced by /equivalent to the CO₂ absorbed in the growth of the biomass feedstock used to produce the biofuel. These factors are based on data from Forest Research, the Forestry Commission's research agency (previously BEC), (2016)

 Table 43: 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 43, emission factors for the out of scope CO₂ emissions have also been provided in the 2018 GHG Conversion Factors (see table and the table footnote), based on data sourced from Forest Research, the Forestry Commission's research agency (previously BEC), (2016)⁶².

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

⁶¹ These cover the period from April 2015 - April 2016, and were the most recent figures available at the time of production of the 2018 GHG Conversion Factors. The report is available from the GOV. website at: <u>https://www.gov.uk/government/collections/biofuels-statistics</u>

⁶². Carbon emissions of different fuels; available at: <u>https://www.forestry.gov.uk/fr/beeh-abslby</u>

biogas. Emission factors produced for these bioenergy sources are presented in the "Bioenergy" section of the 2018 GHG Conversion Factors.

- 9.13. All indirect/WTT/fuel lifecycle emission factors here, except for wood logs, are sourced from the Ofgem carbon calculators⁶³. 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 Environmental Assessment Tool (BEAT₂)⁶⁴, provided by Defra.
- 9.15. The direct CH₄ and N₂O emission factors presented in the 2018 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2015 (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 Forest Research, DUKES (Table A.1) or Swedish Gas Technology Centre 2012 (which is also backed up by other data sources). The values used and their associated moisture contents are provided in Table 44.
- 9.17. In addition to the direct and indirect/WTT emission factors provided, emission factors for the out of scope CO₂ emissions are also provided in the 2018 GHG Conversion Factors (see "Outside of scopes" and the relevant notes on the page), also based on data from sourced from Forest Research, the Forestry Commission's research agency (previously BEC) (2016)⁶⁵.

Biomass	Moisture content	Net calorific value (GJ/tonne)	Source
Wood chips	25% moisture	13.6	Forest Research
Wood logs	Air dried 20% moisture	14.7	DUKES
Wood pellets	10% moisture	16.85	DUKES
Grass/Straw	10% moisture	13.4	DUKES
Biogas	Based on 65% CH₄	20	Swedish Gas Technology Centre
Landfill gas	Based on 40% CH ₄	12.3	Swedish Gas Technology Centre

Table 44: Fuel sources and properties used in the calculation of biomass and biogas emission factors

⁶³ Ofgem carbon calculator tools: <u>https://www.ofgem.gov.uk/publications-and-updates/uk-bioliquid-carbon-calculator</u> and <u>https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator</u>

⁶⁴ Biomass Environmental Assessment Tool, BEAT₂: <u>https://www.forestry.gov.uk/fr/beeh-9uynmd</u>

⁶⁵ Carbon emissions of different fuels; available at: <u>https://www.forestry.gov.uk/fr/beeh-abslby</u>

10.Overseas Electricity Emission Factors

Summary of changes since the previous update

- 10.1. There have been no new methodological changes to this section, the overseas electricity factors have not been provided after the 2015 update 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 IEA⁶⁶.
- 10.2. The conversion factors supplied by the IEA for electricity supplied to the grid can be purchased by organisations. Since this year (from 2017/18) the emissions associated with electricity losses during transmission and distribution of electricity between the power station and an organisation's site(s) are also provided in the IEA dataset, these are also now no longer provided in the UK GHG Conversion Factors dataset.
- 10.3. The conversion factors supplied by the IEA 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 still available in the 2018 GHG Conversion Factors.

Direct Emissions and Emissions resulting from Transmission and Distribution Loses from Overseas Electricity Generation

- 10.4. UK companies reporting on their emissions may need to include emissions resulting from overseas activities. Whilst many of the fuel emission factors are likely to be similar for fuels used in other countries, electricity emission factors vary considerably.
- 10.5. The dataset on electricity emission factors from the IEA, provided from the IEA website, has previously been identified as the best available consistent dataset for electricity emissions factors. These factors are a time series of combined electricity CO₂ emission factors per kWh GENERATED (Scope 2), and also corresponding emission factors for losses in Transmission and Distribution (T&D) (Scope 3). As stated these can be purchased from the IEA website.

Indirect/WTT Emissions from Overseas Electricity Generation

- 10.6. 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.
- 10.7. 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 CO₂ emission factors as for the UK (which is 16.0%).

⁶⁶ Available here: <u>http://www.iea.org/bookshop/729-CO2_Emissions_from_Fuel_Combustion</u>

11.Hotel Stay

Summary of changes since the previous update

11.1. A number of factors have been added to the 2018 GHG Conversion Factors which can be used to report emissions associated with an overnight hotel stay. These complement the existing emission factors for business travel. The emission factors are provided for a range of countries on a 'room per night' basis. Due to changes in the underlying data source used for the Hotel Stay emission factors since the 2017 update, the values and range of factors available has changed quite significantly. However, the underlying methodological basis of this source is largely unchanged.

Direct emissions from a hotel stay

- 11.2. All the hotel stay emission factors presented in the 2018 GHG Conversion Factors are in CO₂e. These are taken directly from the Cornell Hotel Sustainability Benchmarking Index (CHSB) Tool, produced by the International Tourism Partnership (ITP) and Greenview.
- 11.3. The factors use annual data from hotel companies comprising of 6,202 hotels from eleven international hotel organisations: Brighton Management, Hilton Worldwide, Host Hotels & Resorts, Hyatt Hotels Corporation, InterContinental Hotels Group, Mandarin Oriental Hotel Group, Marriott International, Park Hotel Group, Saunders Hotel Group, Six Senses Hotels Resorts Spas, the Hongkong and Shanghai Hotels and Wyndham Worldwide.
- 11.4. For the 2018 GHG Conversion Factors the average benchmark for each country, for all hotel classes included within the tool, was used.
- 11.5. The following five steps were carried out in the CHSB study to arrive at the emission factors included within the 2018 GHG Conversion Factors:
 - a. **Harmonising.** The data received was converted into the same units and then converting to kg CO₂e.
 - b. Validity tests were carried out to remove outliners or errors from the data sets received.
 - c. **Geographic segmentation**. The data sets were grouped by location; either on a city, country or regional basis.
 - d. **Market segmentation**. Hotels were grouped by market segment, applying a revenue-based approach and a standardised industry methodology.
 - e. **Minimum output thresholds**. A minimum threshold of eight hotels per geographical region was required before it was populated within the tool. If there were less than eight hotels, these were excluded from the final outputs.
- 11.6. It should be noted that there are certain limitations with the CHSB tool used to derive the 2018 GHG Conversion Factors. The main limitations are detailed below:
 - a. The factors are skewed toward large, more upmarket hotels and to branded chains. This is because it was mainly large owners or operators of hotels who submitted the aggregated data sets. The tool contains only 83 hotels within the economy or midscale segment.

- b. The data sets used to derive the factors have not been verified and therefore it cannot be concluded to be 100% accurate.
- c. The factors do not distinguish a property's amenities with the exception of outsourced laundry services, which are taken into consideration. The factors are an aggregation of all types of hotels within the revenue-based segmentation and geographic location. Which means it is very difficult to compare two hotels since some may contain distinct attributes, (such as restaurants, fitness centres, swimming pool and spa) while others do not.
- d. The provision of conversion factors is limited by the availability of data in different parts of the world. The datasets used are updated each year, therefore it is expected that a wider range of countries will be covered in the future.
- e. At present there is no breakdown of CH₄ and N₂O emissions, plus there are also no indirect/ WTT factors.
- 11.7. For more information about how the factors have been derived, please visit <u>https://www.hotelfootprints.org,</u> where you will also find more granular data available by city and segment.

12.Material Consumption/Use and Waste Disposal

Summary of changes since the previous update

- 12.1. There have been three methodological updates to this section since last year's (2017) update:
 - a. Steel closed loop source: The impacts for closed loop steel recycling have been updated using new Lifecycle Assessment data from the World Steel Association and the methodology has been improved. The new data directly provides Lifecycle Inventory emissions factors per kg of steel recycled, whereas these were previously derived based on emissions for different grades of recycled steel.
 - b. Construction and demolition metals closed loop source: The updated metals recycling factors for construction and demolition have been standardised using the updated closed loop steel recycling factor. The methodology has changed, and is now based directly on emissions from metals recycling (see above); previously this had been based on published estimated savings from recycling metals.
 - c. *Glass landfill / green and mixed organics composting:* These factors had previously been taken directly from published studies that used a methodology different from that used for the other waste factors. The approach has now been standardised, with these factors using MELMod (landfill emissions model) factors for the landfill emissions and BEIS transport factors for associated transport emissions (see below for discussion of transport distance assumptions).

Emissions from Material Use and Waste Disposal

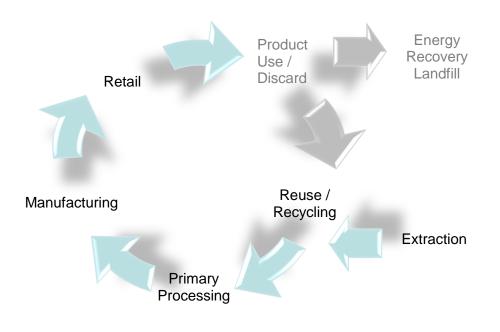
- 12.2. Since 2012 the greenhouse gas emission factors for material consumption / use and waste disposal have been aligned with the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard ('the Scope 3 Standard')⁶⁷. This sets down rules on accounting for emissions associated with material consumption and waste management.
- 12.3. 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.
- 12.4. 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).

⁶⁷ http://www.ghgprotocol.org/standards/scope-3-standard

- 12.5. All figures expressed are kilograms of carbon dioxide equivalent (CO₂e) per tonne of material. This includes the Kyoto protocol basket of greenhouse gases. Please note that biogenic⁶⁸ CO₂ has also been excluded from these figures.
- 12.6. 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.
- 12.7. 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.
- 12.8. The following subsections provide a summary of the methodology, key data sources and assumptions used to define the emission factors.

Material Consumption/Use

12.9. Figure 4 shows the boundary of greenhouse gas emissions summarised in the material consumption table.



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

Figure 4: Boundary of material consumption data sets

12.10. 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

⁶⁸ Biogenic CO₂ is the CO₂ 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.

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

- 12.11. 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.
- 12.12. 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.
- 12.13. 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.
- 12.14. Emission factors provided include emissions associated with product forming.
- 12.15. Table 45 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	122km	Average, all HGVs	Department for Transport (2010) ⁶⁹ Based on average haulage distance for all commodities, not specific to the materials in the first column.
Distribution to Retail Distribution Centre & to retailer	96km		McKinnon (2007) ⁷⁰ IGD (2008) ⁷¹

Table 45: Distances and transportation types used in EF calculations

⁶⁹ 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

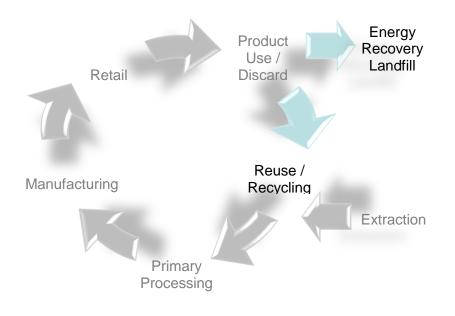
⁷⁰ McKinnon, A.C. (2007) Synchronised Auditing of Truck Utilisation and Energy Efficiency: A Review of the British Government's Transport KPI Programme. Available at: <u>http://www.greenlogistics.org/SiteResources/77a765d8-</u>b458-4e5f-b9e0-1827e34f2f1f_Review%20of%20Transport%20KPI%20programme%20(WCTR%202007).pdf

⁷¹ IGD (2008) UK Food & Grocery Retail Logistics Overview Date Published: 15/01/2008. Available at: <u>http://www.igd.com/our-expertise/Supply-chain/Logistics/3457/UK-Food--Grocery-Retail-Logistics-Overview/</u>

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

Waste Disposal

12.17. Figure 5 shows the boundary of greenhouse gas emissions summarised in the waste disposal table.



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

Figure 5: Boundary of waste disposal data sets

- 12.18. 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.
- 12.19. 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.
- 12.20. Landfill emissions remain within the accounting scope of the organisation producing waste materials. Factors for landfill are provided within the waste disposal sheet in the 2018 GHG Conversion Factors. As noted above, these factors are now drawn directly from MELMod, which contains information on landfill waste composition and material properties, with the addition of collection and transport emissions.

- 12.21. Figures for Refuse Collection Vehicles have been taken from the Environment Agency's Waste and Resource Assessment Tool for the Environment (WRATE)⁷².
- 12.22. 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 46.

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Household, commercial and industrial landfill	25km by Road	Refuse Collection	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 46: Distances used in calculation of emission factors

12.23. Road vehicles are volume limited rather than weight limited. For all HGVs, an average loading factor (including return journeys) is used based on the HGV factors provided in the 2017 Conversion Factors. 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.

⁷² Environment Agency (2010), Waste and Resource Assessment Tool for the Environment. Available at: <u>www.environment-agency.gov.uk/research/commercial/102922.aspx</u>

13. Fuel Properties

Summary of changes since the previous update

13.1. No significant changes were made this year.

General Methodology

- 13.2. 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.
- 13.3. The standard emission factors from the UK GHG Inventory 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) 2017⁷³.
- 13.4. 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)⁷⁴. The exception is for methyl-ester based biodiesels and bioethanol, where values for NCV and GCV are taken from DUKES 2017.
- 13.5. Fuel properties, both density and CV, for wood chips (25% moisture content) come from the Forest Research (previously Biomass Energy Centre (BEC)⁷⁵. The density of wood logs (20% moister content), wood chips (25% moister content) and grasses/straw (25% water content) are also sourced from the Forest Research⁷⁶.

⁷³Available at: <u>https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes</u>

⁷⁴ Available at: http://iet.jrc.ec.europa.eu/about-jec/

⁷⁵ Available at: https://www.forestry.gov.uk/fr/beeh-9ukqcn

⁷⁶ Available at: <u>https://www.forestry.gov.uk/fr/beeh-absg5h</u>

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 2018 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, so far as is possible, 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 be less than five years old. However, the secondary data in material eco-profiles is only periodically updated. In cases where no reliable data is available from within the five-year period, the most recent data available have been used.
		In cases where use of data over five years old creates specific issues, these are discussed below under "Use of data below the set quality standard". All data over five years old has been marked in the references with an asterisk within the 2.0 Data Sources section.
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 12. Data on waste management options has been modelled using SimaPro 8.2.3.⁷⁷ 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 2010⁷⁸. Data used in this report for material consumption is based on studies from the USA, where production processes may not be representative of activity in the UK (e.g. different fuel mix to generate electricity). This data should therefore be viewed with caution. Data on different types of wood has been used in combination with

⁷⁷ SimaPro (2015). Life Cycle Assessment Software. Available at: <u>http://www.lifecycles.com.au/#!simapro/c1il2</u>

⁷⁸ 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

information on the composition of wood waste in the UK⁷⁹ 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.

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 draft⁸⁰ is the most relevant data source to calculate the carbon factors for textiles even though the report is not 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 2018 GHG Conversion 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.

⁷⁹ 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
- 80 Bio IS (2009) *Environmental Improvement Potentials of Textiles (IMPRO-Textiles)* <u>http://susproc.jrc.ec.europa.eu/textiles/docs/120423%20IMPRO%20Textiles_Publication%20draft%20v1.pdf</u>

2.0 Data Sources

Motorial	Reference		
Material	Material Consumption	Waste Disposal	
	European Aluminium Association (2013) Environmental Profile Report for the European Aluminium Industry		
	*CE Delft (2007) Environmental Indices for the Dutch Packaging Tax		
	2018 GHG Conversion Factors	*ELCD data sets,	
Aluminium cans and foil	Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0	http://lca.jrc.ec.europa.eu. (c)	
	*Environment Agency (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1		
	*Wilmshurst, N. Anderson, P. and Wright, D. (2006) WRT142 Final Report Evaluating the Costs of 'Waste to Value' Management		
	World Steel Association (2017) Lifecycle Inventory Data for Steel Products		
	2018 GHG Conversion Factors	*ELCD data sets,	
Steel Cans	*Swiss Packaging Institute (1997) BUWAL	http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009	
	*ERM (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1	2009	
Mixed Cans	Estimate based on aluminium and steel data, combined with data returns from Courtauld Commitment retailers (confidential, unpublished)	*ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009	
Glass	*Enviros (2003 (a)) Glass Recycling - Life Cycle Carbon Dioxide Emissions		
	*Enviros (2003 (b)) Glass Recycling - Life Cycle Carbon Dioxide Emissions		

Material	Reference	
Material	Material Consumption	Waste Disposal
	* Pöyry Forest Industry Consulting Ltd and Oxford Economics Ltd (2009) Wood Waste Market in UK	
	* Merrild H, and Christensen T. H. (2009) Recycling of wood for particle board production: accounting of greenhouse gases and global warming contributions	
	CORRIM (2013) Particleboard: A Life-Cycle Inventory of Manufacturing Panels from Resource through Product	*ELCD data sets,
Wood	*ERM (2008) Single trip pallet no biogenic CO ₂	http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009
	Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0	
	2018 GHG Conversion Factors	
	*Gnosys (2009) Life Cycle Assessment of Closed Loop MDF Recycling	
	* ERM (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1	
Aggregates	*WRAP (2008) Lifecycle Assessm	ent of Aggregates

	2018 GHG Conversion Factors	
	Procarton (2013) Carbon footprint for cartons	
	FEFCO (2012) European database for Corrugated Board Life Cycle Studies	
	DEFRA (2012) Streamlined LCA of Paper Supply Systems	
	CPI (2016) Filename: CPI_WRAP_Papermaking_2016 12	
	Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0	
	Wencong Yue, Yanpeng Cai, Qiangqiang Rong, Lei Cao and Xumei Wang (2014) A hybrid MCDA-LCA approach for assessing carbon foot-prints and environmental impacts of China's paper producing industry and printing services"	
Paper and board	"Wang & Mao (2012) Risk Analysis and Carbon Footprint Assessments of the Paper Industry in China"	*ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-
	* Swiss Centre for Life Cycle Inventories (2007) Ecoinvent v2	2009
	*CEPI (2008) Key Statistics 2007 European Pulp and Paper Industry	
	* Oakdene Hollins (2008) CO2 impacts of transporting the UK's recovered paper and plastic bottles to China	
	*ERM (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1	
	* ERM (2010) LCA of Example Milk Packaging Containers	
	*European Commission (2010) European Life Cycle Database 3	
	*Chen, C., Gan, J., Qui, R., (2017) Energy Use and CO2 Emissions in China's Pulp and Paper Industry: Supply Chain Approach	
	*Chen, S., Ren, L., Liu, Z., Zhou, C., Yue, W., and Zhang, J (2011)	

Meteriel	Reference	
Material	Material Consumption	Waste Disposal
	Life cycle assessment and type III environmental declarations for newsprint in China. Acta Scientiae Circumstantiae, 31, (6) 1331–1337.	
	* WRAP (2010) Realising the value of recovered paper: An Update	
Books	Estimate based on paper	
	*British Metals Recycling Association (website ⁸¹)	
Scrap Metal	Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0 *Giurco, D., Stewart, M., Suljada, T., and Petrie, J., (2006) Copper	*ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009
	Recycling Alternatives: An Environmental Analysis	
WEEE - Large, small, mixed, fridges and freezers	 * Huisman, J., et al (2008) Review of Directive 2002/96 on Waste Electrical and Electronic Equipment * ISIS (2008) Preparatory Studies for Eco-design Requirements of EuPs (Tender TREN/D1/40- 2005) LOT 13: Domestic Refrigerators & Freezers * The Environment Agency (2005) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1 	*ISIS (2008) Preparatory Studies for Eco-design Requirements of EuPs (Tender TREN/D1/40- 2005) LOT 13: Domestic Refrigerators & Freezers *WRATE (2005)

⁸¹ http://www.recyclemetals.org/about_metal_recycling. No longer online.

	2018 GHG Conversion Factors	
	*Bingemer, HG and Crutzen, PJ (1987) The Production of Methane from Solid Waste	
	*DEFRA (2011) Greenhouse Gas Impacts of Biowaste Management - WR0210	
	*Cranfield University (Unpublished) Greenhouse Gas Impacts of Biowaste Management	
	*Kranert, M. & Gottschall, R. Entsorgergemeinschaft der Deutschen Entsorgungswirtschaft e.V. (2007) Grünabfälle – besser kompostieren oder energetisch verwerten? EdDE- Dokumentation Nr. 11	*AFOR (2009) Market survey of the UK organics recycling industry - 2007/08; WRAP, Banbury (Substitution rates for compost) *Williams AG, Audsley E and
Food and Drink Waste	* Williams AG, Audsley E and Sandars DL (2006) Determining the Environmental Burdens and Resource Uses in the Production of Agricultural and Horticultural Commodities. Main Report. Defra Research Project IS0205	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)
	*AIC (2009) Fertiliser Statistics 2009 Report	*Kranert, M. & Gottschall (2007) Grünabfälle – besser kompostieren oder energetisch
	*Greenhouse Gas Inventory Data - Detailed data by Party	verwerten? Eddie (information on peat)
	* Davis, J. and Haglund, C. (1999) Life Cycle Inventory (LCI) of Fertiliser Production	* DEFRA (unpublished) (information on composting impacts)
	* Brook Lyndhurst (2009) London's Food Sector GHG Emissions - Final Report	*ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009
	*AEA Technology (2005) Food transport: The Validity of Food Miles as an Indicator of Sustainable Development	
	*Tassou, S, Hadawey, A, Ge, Y and Marriot, D (2008) FO405 Greenhouse Gas Impacts of Food Retailing	
	"Wood, S and Cowie A (2004) A Review of Greenhouse Gas Emission Factors	
	for Fertiliser Production."	
	*Zaher, U, Khachatryan, H, Ewing, T.; Johnson, R.; Chen, S.;	

Meterial	Reference		
Material	Material Consumption	Waste Disposal	
	Stockle, C.O. (2010) Biomass assessment for potential bio- fuels production: Simple methodology and case study		
	*Mitaftsi, O and Smith, S R (2006) Quantifying Household Waste Diversion from Landfill Disposal by Home Composting and Kerbside Collection		
	*Enviros Consulting (2006) Production of Guidelines for Using Compost in Crop Production - A Brief Literature Review		
	*Prasad, M (2009) EPA STRIVE Programme 2007-2013 A Literature Review on the Availability of Nitrogen from Compost in Relation to the Nitrate Regulations SI 378 of 2006 Small Scale Study Report		
	*US EPA (2005) Landfill Gas Emissions Model (LandGEM) V3.02		
	* Environment Agency (2005) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1		
	*DEFRA and ONS (2009) Family food and expenditure survey		
	*DECC and DEFRA (2011) Anaerobic Digestion Strategy and Action Plan		
	*WRC (2010) National Food Waste Programme (Work Package 1.1) Comparison of the Sustainability of Food Waste Disposal Options		
	*WRAP (2011) The Water and Carbon Footprint of UK Household Food Waste		
Garden Waste	2018 GHG Conversion Factors DEFRA (2013) Family food and expenditure survey		

Meterial	Reference		
Material	Material Consumption	Waste Disposal	
Plastics:	*WRAP (2008) LCA of Mixed Waste Plastic Recovery Options * WRAP (2006) A review of supplies for recycling, global market demand, future trends and associated risks *PriceWaterhouseCoopers & Ecobilan (2002) Life Cycle Assessment of Expanded Polystyrene Packaging. Case Study: Packaging system for TV sets Plastics Europe (2014) Ecoprofiles DEFRA / BEIS (2017) Company GHG Reporting Guidelines *The Environment Agency (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1 Ecoinvent (2013) Plastics Processing options		
HDPE, LDPE and LLDPE	Plastics Europe (2014) Eco- profiles and Environmental Product Declarations of the European Plastics Manufacturers High-density Polyethylene (HDPE), Low-density Polyethylene (LDPE), Linear Low-density Polyethylene (LLDPE) Plastics Europe, Brussels	*WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury	
PP (excel forming)	Plastics Europe (2014) Eco- profiles and Environmental Product Declarations of the European Plastics Manufacturers Polypropylene (PP). Plastics Europe, Brussels	*WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury	
PVC (excel forming)	*Boustead (2006) Eco-profiles of the European Plastics Industry Polyvinyl Chloride (PVC) (Suspension). Plastics Europe, Brussels		
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	

Meterial	Reference	
Material	Material Consumption	Waste Disposal
PET (excel forming)	Plastics Europe (2010) Eco- profiles and Environmental Product Declarations of the European Plastics Manufacturers Polyethylene Terephthalate (PET). Plastics Europe, Brussels	*WRAP (2010) LCA of Example Milk Packaging Systems; WRAP, Banbury
Average plastic film (inch bags)	*Based on split in AMA Research	*WRAP (2008) LCA of Mixed
Average plastic rigid (inch bottles)	(2009) Plastics Recycling Market UK 2009-2013, UK; Cheltenham	Waste Plastic Management Options; WRAP, Banbury
Clothing	*BIO IS (2009) Environmental Improvement Potentials of Textiles (IMPRO-Textiles), EU Joint Research Commission	*Farrant (2008) Environmental Benefit from Reusing Clothes, ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995- 2009
Footwear	*Albers, K., Canapé, P., Miller, J. (2008) Analysing the Environmental Impacts of Simple Shoes, University of Santa Barbara, California	
Furniture	WRAP (2015) Benefits of Reuse	
Batteries (Post Consumer Non- Automotive)		*DEFRA (2006) Battery Waste Management Life Cycle Assessment, prepared by ERM; WRAP, Banbury
Paint	*Althaus et al (2007) Life Cycle Inventories of Chemicals, Final report ecoinvent data v2.2 *CBI (2009) CBI Market Survey The paints and other coatings market in the United Kingdom and CBI, The Netherlands 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	
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 *WRAP (2008) LCA of Aggregates	

Material	Reference		
Material	Material Consumption	Waste Disposal	
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 Mineral Products Association (2011) Sustainable Development Report		
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		

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 1 st IPCC assessment report)	Possible source of emissions
Carbon dioxide	CO ₂	Variable	1.4 x10 ⁻⁵	1	Combustion of fossil fuels
Methane	CH ₄	12	3.7 x 10 ⁻⁴	25 (23)	Decomposition of biodegradable material, enteric emissions.
Nitrous Oxide	N ₂ O	114	3.03 x 10⁻³	298 (296)	N ₂ O 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 ₂ FCF 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 ₂ F ₂	100	0.32	10900	
Difluoromono- chloromethane HCFC 22 (R22 refrigerant)	CHCIF ₂	12	0.2	1810	

Greenhouse Gas Conversion Factors

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 CH₄) global warming potentials (GWP) relative to CO₂. Available at: <u>http://www.ipcc.ch/ipccreports/assessments-reports.htm</u>

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 <u>OTHER</u> than for company reporting (e.g. policy analysis).

Data Year	Electricity Generation ⁽¹⁾	Total Grid Losses ⁽²⁾	UK electricity gene	eration emissions ⁽³⁾ ,	ktonne
	GWh	%	CO ₂	CH ₄	N ₂ O
1990	280,234	8.08%	205,804	2.856	3.628
1991	283,201	8.27%	202,390	2.697	3.599
1992	281,223	7.55%	190,393	2.559	3.380
1993	284,350	7.17%	173,966	2.527	2.884
1994	289,126	9.57%	169,592	2.657	2.735
1995	299,196	9.07%	166,590	2.735	2.686
1996	313,070	8.40%	166,524	2.759	2.507
1997	311,220	7.79%	154,069	2.660	2.173
1998	320,740	8.40%	158,723	2.844	2.253
1999	323,872	8.25%	150,921	2.855	1.972
2000	331,553	8.38%	163,027	3.026	2.210
2001	342,686	8.56%	173,424	3.286	2.449
2002	342,338	8.26%	168,088	3.239	2.323
2003	354,225	8.47%	180,433	3.420	2.559
2004	349,312	8.71%	178,534	3.419	2.470
2005	350,778	7.25%	176,880	4.038	2.607
2006	349,211	7.21%	185,915	4.133	2.820
2007	352,778	7.34%	183,729	4.099	2.622
2008	348,876	7.43%	179,103	4.381	2.470
2009	338,983	7.86%	157,790	4.247	2.128
2010	343,841	7.42%	162,530	4.457	2.201
2011	329,253	7.89%	149,602	4.405	2.246
2012	324,823	8.00%	163,594	4.830	2.854
2013	318,753	7.57%	151,074	5.301	2.729
2014	298,064	8.11%	126,937	5.991	2.345
2015	297,575	8.40%	106,519	7.418	2.173
2016	297,203	7.85%	84,007	7.856	1.532

Notes:

- (1) Based upon calculated total for all electricity generation (GWh supplied) from DUKES (2016) 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 (~16% in 2015).
- (2) Based upon calculated net grid losses from data in DUKES (2016) 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 2015 (Ricardo Energy & Environment, 2017) for the 2015 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 47: Base electricity generation emissions data - most recent datasets for time series

Data	Emission Fa	ctor, kgCO ₂ e	/ kWh										% Net
Year	For electricition (supplied to	ty GENERAT the grid)	ED		Due to grid	transmissio	n /distributio	n LOSSES	For electrici (includes gr	ity CONSUM id losses)	ED		Electricity Imports
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL
1990	0.73440	0.00025	0.00386	0.73851	0.06453	0.00002	0.00034	0.06489	0.79893	0.00028	0.00420	0.80340	4.08%
1991	0.71465	0.00024	0.00379	0.71868	0.06443	0.00002	0.00034	0.06479	0.77908	0.00026	0.00413	0.78347	5.48%
1992	0.67702	0.00023	0.00358	0.68083	0.05526	0.00002	0.00029	0.05557	0.73228	0.00025	0.00387	0.73640	5.60%
1993	0.61180	0.00022	0.00302	0.61505	0.04725	0.00002	0.00023	0.04750	0.65905	0.00024	0.00326	0.66255	5.55%
1994	0.58657	0.00023	0.00282	0.58962	0.06210	0.00002	0.00030	0.06242	0.64867	0.00025	0.00312	0.65204	5.52%
1995	0.55679	0.00023	0.00268	0.55970	0.05555	0.00002	0.00027	0.05584	0.61234	0.00025	0.00294	0.61553	5.26%
1996	0.53191	0.00022	0.00239	0.53451	0.04880	0.00002	0.00022	0.04904	0.58070	0.00024	0.00261	0.58355	5.08%
1997	0.49505	0.00021	0.00208	0.49734	0.04184	0.00002	0.00018	0.04204	0.53689	0.00023	0.00226	0.53938	5.06%
1998	0.49486	0.00022	0.00209	0.49718	0.04535	0.00002	0.00019	0.04557	0.54022	0.00024	0.00229	0.54275	3.74%
1999	0.46599	0.00022	0.00181	0.46802	0.04191	0.00002	0.00016	0.04209	0.50790	0.00024	0.00198	0.51011	4.21%
2000	0.49171	0.00023	0.00199	0.49392	0.04500	0.00002	0.00018	0.04520	0.53671	0.00025	0.00217	0.53913	4.10%
2001	0.50607	0.00024	0.00213	0.50844	0.04738	0.00002	0.00020	0.04761	0.55346	0.00026	0.00233	0.55605	2.95%
2002	0.49100	0.00024	0.00202	0.49326	0.04418	0.00002	0.00018	0.04438	0.53518	0.00026	0.00220	0.53764	2.40%
2003	0.50938	0.00024	0.00215	0.51177	0.04713	0.00002	0.00020	0.04735	0.55650	0.00026	0.00235	0.55912	0.61%
2004	0.51110	0.00024	0.00211	0.51345	0.04876	0.00002	0.00020	0.04899	0.55986	0.00027	0.00231	0.56244	2.10%
2005	0.50425	0.00029	0.00221	0.50675	0.03939	0.00002	0.00017	0.03958	0.54364	0.00031	0.00239	0.54634	2.32%
2006	0.53238	0.00030	0.00241	0.53509	0.04140	0.00002	0.00019	0.04161	0.57378	0.00032	0.00259	0.57669	2.11%
2007	0.52081	0.00029	0.00222	0.52331	0.04124	0.00002	0.00018	0.04144	0.56205	0.00031	0.00239	0.56475	1.46%
2008	0.51337	0.00031	0.00211	0.51579	0.04121	0.00003	0.00017	0.04140	0.55458	0.00034	0.00228	0.55720	3.06%
2009	0.46548	0.00031	0.00187	0.46766	0.03970	0.00003	0.00016	0.03989	0.50518	0.00034	0.00203	0.50755	0.84%
2010	0.47269	0.00032	0.00191	0.47492	0.03791	0.00003	0.00015	0.03809	0.51060	0.00035	0.00206	0.51301	0.77%
2011	0.45437	0.00033	0.00203	0.45674	0.03892	0.00003	0.00017	0.03912	0.49329	0.00036	0.00221	0.49586	1.85%
2012	0.50364	0.00037	0.00262	0.50663	0.04378	0.00003	0.00023	0.04404	0.54742	0.00040	0.00285	0.55067	3.52%
2013	0.47395	0.00042	0.00255	0.47692	0.03879	0.00003	0.00021	0.03903	0.51274	0.00045	0.00276	0.51595	4.33%
2014	0.42587	0.00050	0.00234	0.42872	0.03761	0.00004	0.00021	0.03786	0.46348	0.00055	0.00255	0.46658	6.44%
2015	0.35796	0.00062	0.00218	0.36076	0.03282	0.00006	0.00020	0.03307	0.39077	0.00068	0.00238	0.39383	6.57%

Year	Emission Fa	actor, kgCO ₂ e	e / kWh										% Net
	For electrici (supplied to		ED		e			SSES For electricity CONSLIMED				Electricity Imports	
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL
2016	0.28266	0.00066	0.00154	0.28486	0.02409	0.00006	0.00013	0.02428	0.30675	0.00072	0.00167	0.30913	5.57%

Notes: * The 2017 update 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 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 48: Base electricity generation emission factors (excluding imported electricity) – fully consistent time series dataset

Data	Emission Fa	actor, kgCO ₂	Emission Factor, kgCO ₂ e / kWh													
Year	For electric	ity GENERAT s)	ED (supplied	d to the grid,	Due to grid transmission /distribution LOSSES			For electricity CONSUMED (includes grid losses)				Electricity Imports				
	CO ₂	CH₄	N ₂ O	CO ₂	CH₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL				
1990	0.70907	0.00025	0.00372	0.71304	0.0623	0.00002	0.00033	0.06265	0.77137	0.00027	0.00405	0.77569	4.08%			
1991	0.68251	0.00023	0.00362	0.68636	0.06153	0.00002	0.00033	0.06188	0.74404	0.00025	0.00395	0.74824	5.48%			
1992	0.64475	0.00022	0.00341	0.64838	0.05263	0.00002	0.00028	0.05293	0.69738	0.00024	0.00369	0.70131	5.60%			
1993	0.58162	0.00021	0.00287	0.5847	0.04492	0.00002	0.00022	0.04516	0.62654	0.00023	0.00309	0.62986	5.55%			
1994	0.558	0.00022	0.00268	0.5609	0.05907	0.00002	0.00028	0.05937	0.61707	0.00024	0.00296	0.62027	5.52%			
1995	0.53163	0.00022	0.00255	0.5344	0.05304	0.00002	0.00025	0.05331	0.58467	0.00024	0.00280	0.58771	5.26%			
1996	0.50906	0.00021	0.00228	0.51155	0.0467	0.00002	0.00021	0.04693	0.55576	0.00023	0.00249	0.55848	5.08%			
1997	0.47383	0.0002	0.00199	0.47602	0.04005	0.00002	0.00017	0.04024	0.51388	0.00022	0.00216	0.51626	5.06%			
1998	0.48028	0.00022	0.00203	0.48253	0.04402	0.00002	0.00019	0.04423	0.52430	0.00024	0.00222	0.52676	3.74%			
1999	0.45017	0.00021	0.00175	0.45213	0.04048	0.00002	0.00016	0.04066	0.49065	0.00023	0.00191	0.49279	4.21%			

⁸² 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	Emission Fa	actor, kgCO ₂ e	e / kWh										% Net
Year	For electrici plus imports	ty GENERAT s)	ED (supplied	d to the grid,	Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				Electricity Imports
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	TOTAL
2000	0.47488	0.00022	0.00192	0.47702	0.04346	0.00002	0.00018	0.04366	0.51834	0.00024	0.00210	0.52068	4.10%
2001	0.49315	0.00023	0.00208	0.49546	0.04617	0.00002	0.00019	0.04638	0.53932	0.00025	0.00227	0.54184	2.95%
2002	0.48093	0.00023	0.00198	0.48314	0.04327	0.00002	0.00018	0.04347	0.52420	0.00025	0.00216	0.52661	2.40%
2003	0.5068	0.00024	0.00214	0.50918	0.04689	0.00002	0.0002	0.04711	0.55369	0.00026	0.00234	0.55629	0.61%
2004	0.50189	0.00024	0.00207	0.5042	0.04789	0.00002	0.0002	0.04811	0.54978	0.00026	0.00227	0.55231	2.10%
2005	0.49453	0.00028	0.00217	0.49698	0.03863	0.00002	0.00017	0.03882	0.53316	0.00030	0.00234	0.53580	2.32%
2006	0.5228	0.00029	0.00236	0.52545	0.04065	0.00002	0.00018	0.04085	0.56345	0.00031	0.00254	0.56630	2.11%
2007	0.5144	0.00029	0.00219	0.51688	0.04073	0.00002	0.00017	0.04092	0.55513	0.00031	0.00236	0.55780	1.46%
2008	0.50003	0.00031	0.00206	0.5024	0.04014	0.00002	0.00016	0.04032	0.54017	0.00033	0.00222	0.54272	3.06%
2009	0.46229	0.00031	0.00186	0.46446	0.03943	0.00003	0.00016	0.03962	0.50172	0.00034	0.00202	0.50408	0.84%
2010	0.46971	0.00032	0.0019	0.47193	0.03767	0.00003	0.00015	0.03785	0.50738	0.00035	0.00205	0.50978	0.77%
2011	0.44909	0.00033	0.00201	0.45143	0.03847	0.00003	0.00017	0.03867	0.48756	0.00036	0.00218	0.49010	1.85%
2012	0.49497	0.00037	0.00257	0.49791	0.04303	0.00003	0.00022	0.04328	0.53800	0.00040	0.00279	0.54119	3.52%
2013	0.46314	0.00041	0.00249	0.46604	0.03791	0.00003	0.0002	0.03814	0.50105	0.00044	0.00269	0.50418	4.33%
2014	0.41142	0.00049	0.00227	0.41418	0.03633	0.00004	0.0002	0.03657	0.44775	0.00053	0.00247	0.45075	6.44%
2015	0.34915	0.00061	0.00212	0.35188	0.03201	0.00006	0.00019	0.03226	0.38116	0.00067	0.00231	0.38414	6.57%
2016	0.28088	0.00066	0.00153	0.28307	0.02394	0.00006	0.00013	0.02413	0.30482	0.00072	0.00166	0.30720	5.57%

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

Data	kgCO ₂ /kWh supplied heat/steam	kgCO ₂ /kWh supplied power
Year	Method 1 (DUKES: 2/3rd - 1/3rd)	Method 1 (DUKES: 2/3rd - 1/3rd)
2001	0.233	0.466
2002	0.225	0.45
2003	0.228	0.457
2004	0.221	0.443
2005	0.214	0.428
2006	0.223	0.445
2007	0.223	0.447
2008	0.218	0.435
2009	0.214	0.428
2010	0.21	0.421
2011	0.24	0.48
2012	0.194	0.388
2013	0.197	0.393
2014	0.193	0.386
2015	0.192	0.384
2016	0.186	0.372

 Table 50: Fully consistent time series for the heat/steam and supplied power carbon factors as calculated using DUKES method

Appendix 3. Major Changes to the Conversion Factors

The following table provides a summary of major changes in emission factors for the 2018 GHG Conversion Factors, compared to the equivalent factors provided in the 2017 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 Scope 1 and 2 emission sources most fuels and electricity and greater than 10% for Scope 3 most other emission sources.

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
Fuels						
1	CNG	CH₄	All	-8%	Lower weighted EF due to change in distribution of emissions between natural gas users and due to gas power stations now having a greater share.	Section 2
2	LNG	CH ₄	All	-8%	As above	Section 2
3	LPG	CH₄	All	-6%	Dominated by road transport trend - improved emissions standards/fleet turnover.	Section 2
4	Natural gas	CH ₄	All	-8%	See CNG and LNG above	Section 2
5	Aviation spirit	CH4	All	222%	The NAEI methodology has changed to revert to default Guidebook values in place of local proxy data.	Section 2

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
6	Diesel (average biofuel blend)	CH ₄	All	-19%	Dominated by road transport trend - improved emissions standards/fleet turnover.	Section 2
7	Diesel (100% mineral diesel)	CH4	All	-19%	As above	Section 2
8	Marine gas oil	CH ₄	All	-35%	Output from new BEIS shipping study - method change in NAEI.	Section 2
9	Coal (domestic)	CH₄	All	12%	Change to calculation from default EF to NAEI units, now using year specific CV to domestic coal in place of long term average across multiple users.	Section 2
10	Coking coal	CH ₄	All	-81%	No domestic use of coke in 2016 so weighted average is for industrial sources only.	Section 2
11	LPG	N ₂ O	All	-15%	Dominated by road transport trend - improved emissions standards/fleet turnover.	Section 2
12	Fuel oil	N ₂ O	All	6%	Impact of inclusion of fishing vessels (new source in NAEI16).	Section 2
13	Petrol (average biofuel blend)	N ₂ O	All	81%	Correction to calculation for N ₂ O to take out cold start "fuel consumption".	Section 2
14	Petrol (100% mineral petrol)	N ₂ O	All	81%	As above	Section 2
15	Processed fuel oils - residual oil	N ₂ O	All	6%	Impact of inclusion of fishing vessels (new source in NAEI16).	Section 2

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
16	Waste oils	N2O	All	5%	Due to a method change: now uses CV for gas oil (annual) in place of a long term average for fuel oil. Now fully consistent with energy conversions used for the inventory fuel use, and for other pollutants.	Section 2
17	Marine gas oil	N ₂ O	All	78%	Output from new BEIS shipping study - method change in NAEI.	Section 2
18	Marine fuel oil	N ₂ O	All	85%	As above	Section 2
19	Coal (industrial)	N₂O	All	9%	Method change to use year specific CV for conversions from energy to mass units, change to distribution of sources impacts weighted average.	Section 2
20	Coking coal	N ₂ O	All	-21%	No domestic use of coke in 2016 so weighted average is for industrial sources only.	Section 2
Bioenerg	ЗУ					
21	Wood pellets	CO ₂ e	Tonnes	19%	Revisions to CV.	Section 9
22	Grass/straw	CO ₂ e	All	-37%	Higher proportion from power stations compared to agriculture - stationary combustion.	Section 9
23	Bioethanol	All	All	27%	Correction to calculation for N ₂ O emissions for conventional fuel in the Fuels workbook to take out cold start "fuel consumption". Results in a big increase in a small number.	Section 9
24	Biodiesel (from UCO)	All	All	73%	As above	Section 9

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
25	Biodiesel (from Tallow)	All	All	73%	As above	Section 9
Refrigera	ants and other					
No chang	jes					Section 4
Passeng	er Vehicles					
26	Cars by market segment- Dual Purpose cars, Unknown fuel	CH4	km and miles	-13%	Continued uptake of Euro 6 vehicles causes reduction in EFs for petrol and diesel cars.	Section 5
27	Cars by size: Large car, Hybrid	CO ₂	km and miles	24%	Increase in gCO ₂ /km from 2016 (21) to 2017 (163) and changes in the registrations of hybrid cars.	Section 5
28	Cars by size: Large car, Hybrid	CO ₂ e	km and miles	24%	As above	Section 5
29	Cars by size: Medium car, LPG	CH₄	km and miles	-13%	Continued uptake of Euro 6 vehicles causes reduction in EFs for petrol and diesel cars.	Section 5
30	Cars by size: Large car, LPG	CH ₄	km and miles	-13%	As above	Section 5
31	Cars by size: Average car, LPG	CH₄	km and miles	-13%	As above	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:	
32	Upper medium cars- PHEV	CO ₂	km and miles	26%	Spike in the new petrol PHEVs registered in 2016 mean that the fuel split of petrol/diesel has altered significantly, affecting the balance of fuel EFs which feed this calculation. Also affects CO ₂ emissions as petrol cars use fuel more quickly and so increases emissions factors.	Section 5	
33	Upper medium cars- PHEV	CH₄	km and miles	38%	As above	Section 5	
34	Upper medium cars- PHEV	CO ₂ e	km and miles	26%	As above	Section 5	
35	Cars by market segment PHEV	N2O	km and miles	71.4% to 100%	Change to kg per kWh (net CV) for diesel and petrol factors causes recalculations for N ₂ O emissions.	Section 5	
36	Cars by size- PHEV	N ₂ O	km and miles	75% to 84.6%	As above	Section 5	
37	All Motorcycles	CH ₄	km and miles	-9.2% to - 5.4%	Fleet turnover to vehicles with lower emissions.	Section 5	
Delivery vehicles							
38	Petrol Vans- All classes	CH4	km and miles	-48%	Large reduction due partly to a correction in the NAEI for catalyst repair rates of petrol LGVs but also due to fleet turnover with new vehicles satisfying more stringent EURO standard requirements.	Section 6	

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
39	Petrol Vans- All classes	N ₂ O	km and miles	-29%	As above	Section 6
40	CNG Vans- Average class	CH₄	km and miles	-47%	As above	Section 6
41	CNG Vans- Average class	N ₂ O	km and miles	-29%	As above	Section 6
42	LPG Vans- Average class	CH₄	km and miles	-51%	As above	Section 6
43	LPG Vans- Average class	N ₂ O	km and miles	-29%	As above	Section 6
44	Unknown fuel- All Vans	CH4	km and miles	-36%	This is due to the petrol and diesel changes seen above.	Section 6
45	HGVs (all diesel)- Rigid (>3.5 - 7.5 tonnes)	CH4	km and miles	-28.6%	The change in CH ₄ emissions is due to changes in emission factors to COPERT 4v11.	Section 6
46	HGVs (all diesel)- Rigid (>7.5 tonnes-17 tonnes)	CH4	km and miles	-27.6%	As above	Section 6
47	HGVs (all diesel)- Rigid (>17 tonnes) and All rigids	CH₄	km and miles	-20.5%	As above	Section 6

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
48	HGVs (all diesel)- Articulated (>3.5 - 33t)	CH4	km and miles	-28%	As above	Section 6
49	HGVs (all diesel)- Articulated (>33t)	CH₄	km and miles	-19.3%	As above	Section 6
50	HGVs (all diesel)- All artics	CH₄	km and miles	-18.3%	As above	Section 6
51	HGVs (all diesel)- All HGVs	CH4	km and miles	-21.5%	As above	Section 6
52	HGVs refrigerated (all diesel)		Same n	nagnitude of c	changes as for HGVs (all diesel)	Section 6
UK Elect	ricity		_			
53	UK Electricity	CO ₂	kWh	-19%	There was a significant decrease in coal generation and a significant increase in mainly gas generation since the previous year.	Section 3
54	UK Electricity	CH ₄	kWh	6%	Higher CH ₄ emissions from power generation from NAEI data.	Section 3
55	UK Electricity	N ₂ O	kWh	-27%	There was a significant decrease in coal generation and an increase in gas generation since the previous year.	Section 3

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
56	UK Electricity	CO ₂ e	kWh	-19%	As above	Section 3
UK elect	ricity for EVs					
57	Cars by market segment- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-25.8% to - 17.2%	Changes are mainly due to the changes in electricity but also changes in the market of electric vehicles can significantly contribute.	Section 5
58	Cars by market segment- PHEV, BEV	N ₂ O	km and miles	-33.3% to - 17.4%	As above	Section 5
59	Cars by size- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-22.6% to - 12.6%	As above	Section 5
60	Cars by size- PHEV, BEV	N ₂ O	km and miles	-30.8% to - 22.2%	As above	Section 5
61	All Vans- BEV	CO ₂ e and CO ₂	tonne.km	-19.5% to - 12.9%	As above	Section 5
62	All Vans- BEV	N ₂ O	tonne.km	-27.7% to - 20.8%	As above	Section 5
Heat and	l Steam					
63	Onsite and district heating	CH ₄	kWh	-34%	Changes in CHP fuel mix and in assumptions for CH ₄ and N ₂ O emissions for certain fuels.	Section 3
64	Onsite and district heating	N ₂ O	kWh	-20%	As above	Section 3

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
WTT- fue	els					
65	CNG	CO ₂ e	All	-8% to -6%	Reduction in LNG imports as a proportion of total supply compared to 2017 update.	Section 2
66	Natural gas	CO ₂ e	All	-10% to - 8%	As above	Section 2
WTT- bio	benergy					
67	WTT- Bioethanol	CO ₂ e	All	-5%	Changes to DfT data (Table RTFO 05)	Section 9
68	WTT -Biodiesel	CO ₂ e	All	-23%	Changes to DfT data (Table RTFO 05)	Section 9
69	WTT -Biodiesel (from UCO)	CO ₂ e	All	-23%	Changes to DfT data (Table RTFO 05)	Section 9
Transmi	ssion and distribu	ition				
70	UK Electricity T&D Losses	CO ₂	kWh	-27%	The increase in lower GHG electricity generation was enhanced by a decrease in losses from the grid.	Section 3
71	UK Electricity T&D Losses	N ₂ O	kWh	-35.0%	As above	Section 3
72	UK Electricity T&D Losses	CO ₂ e	kWh	-27%	As above	Section 3
UK elect	ricity T&D for EVs	;				
73	Cars by market segment- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-32.4% to - 14.9%	Big change in CO ₂ electricity factor causes most of the change here.	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
74	Cars by market segment- PHEV, BEV	N2O	km and miles	-50% to - 25%	As above	Section 5
75	Cars by size- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-29.4% to - 20.4%	As above	Section 5
76	Cars by size- PHEV, BEV	N ₂ O	km and miles	-50% to - 25%	As above	Section 5
77	All Vans- BEV	CO ₂ e and CO ₂	tonne.km	-26.6%	As above	Section 5
78	All Vans- BEV	N ₂ O	tonne.km	-36.4% to - 28.6%	As above	Section 5
WTT- UK	elec					
79	WTT - UK Electricity	CO ₂ e	kWh	-25%	As for Scope 2 emissions	Section 3
80	WTT - UK Electricity T&D Losses	CO ₂ e	kWh	-32%	As above	Section 3
WTT- ov	erseas electricity	(generati	on)			
81	WTT- overseas electricity (generation) - Electricity: Ireland	CO ₂ e	kWh	-11%	Reflects trend in electricity conversion factor as reported by SEAI (Sustainable Energy Authority of Ireland.	Section 10

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
82	WTT- overseas electricity (generation) - Electricity: France	CO ₂ e	kWh	25%	Reflects trend in electricity conversion factor as reported by RTE (the French transmission system operator).	Section 10
83	WTT- overseas electricity (generation) - Electricity: Netherlands	CO2e	kWh	-6%	Reflects trend in electricity conversion factor as reported by CBS (the Netherlands Central Statistics Bureau).	Section 10
WTT- ove	erseas electricity	(T&D)				
84	WTT T&D losses - Electricity: Australia	CO ₂ e	kWh	19%	Reflects changes in reported losses from the IEA energy balance data set and estimated trends in CO ₂ per unit of electricity.	Section 10
85	WTT T&D losses - Electricity: Canada	CO ₂ e	kWh	12%	As above	Section 10
86	WTT T&D losses - Electricity: Cyprus	CO ₂ e	kWh	21%	As above	Section 10

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
87	WTT T&D losses - Electricity: Estonia	CO ₂ e	kWh	-16%	As above	Section 10
88	WTT T&D losses - Electricity: Finland	CO ₂ e	kWh	-11%	As above	Section 10
89	WTT T&D losses - Electricity: France	CO2e	kWh	23%	As above	Section 10
90	WTT T&D losses - Electricity: Greece	CO ₂ e	kWh	16%	As above	Section 10
91	WTT T&D losses - Electricity: Ireland	CO ₂ e	kWh	-13%	As above	Section 10
92	WTT T&D losses - Electricity: Israel	CO ₂ e	kWh	36%	As above	Section 10

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:	
93	WTT T&D losses - Electricity: Luxembourg	CO2e	kWh	32%	As above	Section 10	
94	WTT T&D losses - Electricity: Malta	CO ₂ e	kWh	64%	As above	Section 10	
95	WTT T&D losses - Electricity: Saudi Arabia	CO2e	kWh	13%	As above	Section 10	
96	WTT T&D losses - Electricity: Singapore	CO ₂ e	kWh	-13%	As above	Section 10	
97	WTT T&D losses - Electricity: Slovak Republic	CO ₂ e	kWh	105%	As above	Section 10	
98	WTT T&D losses - Electricity: Sweden	CO ₂ e	kWh	-17%	As above	Section 10	
	WTT- heat and steam						
N/A							

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
Water su	pply					
No chang	les					Section 9
Water tre	eatment					
No chang	es					Section 9
Business	s travel- air					
99	average passenger, with	CO ₂ e, CO ₂ , N ₂ O;	, passenger.k m	12%	Overall increase (~11.5%) reflects the increased use of small planes, and also shorter average flight distances.	Section 8
		CH ₄			Larger increase in CH ₄ is due to changes in emission factors for CH ₄ used in the UK GHGI.	
100	Long-haul Business class, with and without RF	CO2e, CO2, N2O	passenger.k m	8%	Increase is due to a range of input data changes: decrease in load factors, increase to calculated EFs from EUROCONTROL small emitters tool for key aircraft, changes in shares of different aircraft, and increase in allocation of CO ₂ between passenger and freight for passenger services.	Section 8
WTT- Bu	siness travel- air					
101	WTT - Flights			As for E	Business travel- air	Section 8
Business	s travel- sea					
102	Foot passenger	CH ₄	passenger.k m	-14%	Output from new BEIS shipping model is very different to previous estimates.	Section 7
103	Car passenger	CH ₄	passenger.k m	-17%	As above	Section 7

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
104	Average (all passenger)	CH₄	passenger.k m	-18%	As above	Section 7
105	Foot passenger	N ₂ O	passenger.k m	78%	As above	Section 7
106	Car passenger	N ₂ O	passenger.k m	77%	As above	Section 7
107	Average (all passenger)	N ₂ O	passenger.k m	78%	As above	Section 7
WTT- Bu	siness travel- sea					
No chang	jes					Section 7
Business	s travel- land					
108	Cars by market segment- Dual Purpose cars, Unknown fuel	CH4	km and miles	-13%	Continued uptake of Euro 6 vehicles causes reduction in EFs for petrol and diesel cars.	Section 5
109	Cars by size: Large car, Hybrid	CO ₂	km and miles	24%	There is a massive increase in gCO ₂ /km from 2016 (21) to 2017 (163) and changes in the registrations of hybrid cars.	Section 5
110	Cars by size: Large car, Hybrid	CO ₂ e	km and miles	24%	As above	Section 5
111	Cars by size: Medium car, LPG	CH₄	km and miles	-13%	Continued uptake of Euro 6 vehicles causes reduction in EFs for petrol and diesel cars.	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
112	Cars by size: Large car, LPG	CH4	km and miles	-13%	As above	Section 5
113	Cars by size: Average car, LPG	CH₄	km and miles	-13%	As above	Section 5
114	Motorbike: all sizes	CH ₄	km and miles	-9.2% to - 5.4%	Fleet turnover to vehicles with lower emissions.	Section 5
115	Local bus (not London)	CH4	passenger.k m	-33%	A ~20% reduction in Euro III bus vkm and the removal of all Euro II buses from the fleet cause the majority of CH ₄ reductions. This reason causes a large drop in emissions because there is a large drop in emissions per km from Euro III to Euro IV+ vehicles (Euro IV EFs are roughly 5% of Euro III).	Section 5
116	Local London bus	CH₄	passenger.k m	-33%	As above	Section 5
117	Average local bus	CH ₄	passenger.k m	-40%	As above	Section 5
118	Local bus (not London)	N2O	passenger.k m	13%	The decline in vkm causes a small increase in N ₂ O emissions due to the more efficient conversion of NOx to N ₂ O in later EURO standard models which now contribute a greater % to total bus vkm.	Section 5
119	Local London bus	N ₂ O	passenger.k m	15%	As above	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
120	Average local bus	N ₂ O	passenger.k m	15%	As above	Section 5
121	Cars by market segment- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-24.9% to - 14.9%	Big change in CO ₂ electricity factor causes most of this change.	Section 5
122	Cars by market segment- PHEV, BEV	N ₂ O	km and miles	-31.7% to - 17.9%	As above	Section 5
123	Cars by size- PHEV, BEV	CO ₂ e and CO ₂	km and miles	-23.2% to - 14.9%	As above	Section 5
124	Cars by size- PHEV, BEV	N ₂ O	km and miles	-28.8% to - 11.9%	As above	Section 5
125	National rail	CH4	passenger.k m	33%	Increase in CH ₄ emissions from electricity consumption (this factor is a combination of electric and diesel trains).	Section 5
126	International rail	CH ₄	passenger.k m	50%	Increase in the CH ₄ emissions are due to the change in the CO ₂ electricity factor.	Section 5
127	Light rail and tram	CH ₄	passenger.k m	13%	As above	Section 5
128	Light rail and tram	N ₂ O	passenger.k m	-19%	Decrease in the N ₂ O emissions due to the change in the CO ₂ electricity factor and due to a decrease in ORR data.	Section 5
129	London underground	CO ₂ e	passenger.k m	-20%	Due to change in data published by TfL.	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
130	London underground	CO ₂	passenger.k m	-20%	As above	Section 5
131	London underground	N ₂ O	passenger.k m	-29%	As above	Section 5
Freightin	ig goods					
132	All Vans- BEV	CO ₂ e and CO ₂	tonne.km	-20.1% to - 13.6%	Big change in CO ₂ electricity factor causes most of this change.	Section 6
133	All Vans- BEV	N ₂ O	tonne.km	-28.9% to - 21.5%	As above	Section 6
134	Sea tanker, all types	CH ₄	passenger.k m	up to -50%	Output from new BEIS shipping model is very different to previous estimates.	Section 6
135	Cargo ship, all types	CH ₄	passenger.k m	up to -50%	As above	Section 6
136	Sea tanker, all types	N ₂ O	passenger.k m	up to 86%	As above	Section 6
137	Cargo ship, all types	N ₂ O	passenger.k m	up to 86%	As above	Section 6
138	Freight train			No sig	gnificant changes	Section 6
139	Vans	See de	elivery vehicles a	·	ne.km magnitude of change is the same as the dimites changes)	Section 6

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
140	HGVs (all diesel)- Rigid (>3.5 - 7.5 tonnes)	CH₄	tonne.km	-26.4% to - 21.7%	Lower CH ₄ implied EF is due to an increase in vkm from HGVs and reduced emissions. In addition, changes are due to the uptake of EURO VI HGVs into the fleet which have lower CH ₄ and higher N ₂ O emissions. Finally, the loading factors were revised by DfT in RFS as part of a methodological review which causes significant shifts for lots of HGV categories.	Section 6
141	HGVs (all diesel)- Rigid (>7.5 tonnes-17 tonnes)	CH4	tonne.km	-27.5%	As above	Section 6
142	HGVs (all diesel)- Rigid (>17 tonnes)	CH₄	tonne.km	-32% to - 12%	As above	Section 6
143	HGVs (all diesel)- All rigids	CH₄	tonne.km	-23% to - 15.3%	As above	Section 6
144	HGVs (all diesel)- Articulated (>3.5 - 33t)	CH4	tonne.km	-28% to - 20%	As above	Section 6
145	HGVs (all diesel)- Articulated (>33t) - average	CH₄	tonne.km	-34.9%	As above	Section 6

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:	
146	HGVs (all diesel)- All artics- average	CH4	tonne.km	-36%	As above	Section 6	
147	HGVs (all diesel)- All HGVs	CH4	tonne.km	-23% to - 19.4%	As above	Section 6	
148	HGVs (all diesel)- Rigid (>7.5 tonnes-17 tonnes)- Average	CO ₂ e and CO ₂	tonne.km	16.6%	As above	Section 6	
149	HGVs (all diesel)- Rigid (>7.5 tonnes-17 tonnes)- Average	N ₂ O	tonne.km	24%	As above	Section 6	
150	HGVs (all diesel)- All rigids- Average	N ₂ O	tonne.km	20%	As above	Section 6	
151	HGVs refrigerated (all diesel)		Same r	Same magnitude of changes as for HGVs (all diesel)			
152	HGVs (all diesel)- all categories	CH ₄ and N ₂ O	km and miles	See de	livery vehicles- same magnitude of changes	Section 6	

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
153	Short-haul flights	CO ₂ e, CO ₂ , N ₂ O;	tonne.km	14%	Overall change (increase of ~14%) reflects the demise of the ATP and use of larger aircraft; also larger share of freight carried on passenger services (with higher EF).	Section 6
		CH₄			Larger increase for CH ₄ is due to changes in emission factors for CH ₄ used in the UK GHGI.	
154	Long-haul flights	CO2e, CO2, N2O	tonne.km	-15%	Decrease reflects the reintroduction of B748 with higher freight efficiency, changes to relative allocation of emission between passengers and freight in passenger services, and larger relative share of dedicated freight services (with lower emission factors).	Section 6
WTT pas	senger vehicles 8	busines	s travel- land			
155	WTT - Hybrid Cars by size: Large car	CO ₂ e	km	23%	There is a massive increase in gCO ₂ /km from 2016 (21) to 2017 (163) and changes in the registrations of hybrid cars.	Section 5
156	WTT- cars by market segment- Upper medium- PHEV	CO2e	km and miles	26.6%	Huge spike in the petrol PHEVs registered in 2016 mean that the fuel split of petrol/diesel has altered significantly, affecting the balance of fuel EFs which feed this calculation. Also affects CO ₂ as petrol cars use fuel more quickly and so increases emission factors.	Section 5

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:		
157	WTT- cars by market segment- Executive- PHEV	CO2e	km and miles	13.30%	Small sample size causes big shift in emission factors of executive PHEVs as more are sold in 2016.	Section 5		
158	WTT- Light rail and tram	CO ₂ e	passenger.k m	-17%	WTT emissions are linked to the direct emissions so proportionate decrease.	Section 5		
159	WTT- London Underground	CO ₂ e	passenger.k m	-25%	As above	Section 5		
160	WTT - All Motorcycles		No significant changes					
161	WTT - All buses and coaches		No significant changes					
WTT deli	very vehicles & fr	eighting	goods					
162	WTT- all Vans- BEV	CO ₂ e	tonne.km	-25.7% to - 19.6%	Big change in CO ₂ electricity factor causes most of this change.	Section 6		
163	WTT - Freight train			No sig	gnificant changes	Section 6		
164	WTT- Vans			No sig	gnificant changes	Section 6		
165	WTT- Freight flights		As for Freighting goods					
166	WTT-HGVs (all diesel)- Rigid (>17 tonnes) Average	CO ₂ e	tonne.km	20%	Increase in WTT factors is due to change in source for this data in 2017 update (and increased EFs) and due to new accounting for biofuel component in final results from 2017.	Section 6		

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:		
167	WTT- HGVs (all diesel)- All rigids- Average	CO ₂ e	tonne.km	17%	As above	Section 6		
168	WTT- HGVs (all diesel)- Articulated (>33t) Average	CO ₂ e	tonne.km	17%	As above	Section 6		
169	WTT- HGVs refrigerated (all diesel)	CO ₂ e	tonne.km	Same mag	Same magnitude of changes as for WTT- HGVs (all diesel)			
Hotel Sta	Hotel Stay							
170	Changes due to the data source, see: https://scholarship.sha.cornell.edu/cgi/viewcontent.cgi?article=1255&context=chrpubs							
Managed	l assets- electricit	у						
171	See "UK electricity" (which is identical for managed assets electricity)							
Managed	l assets- vehicles							
172	Managed Cars by size and market segment	by size and Section 5						
173	Managed cars - PHEV, BEV					Section 5		
174	Managed Vans- PHEV, BEV		See freighting goods (the values are identical to these) Sectio					
175	Managed motorbikes	CH ₄	km and miles	-9.2% to - 5.4%	Fleet turnover to vehicles with lower emissions.	Section 5		

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:		
176	Managed Vans	See de	livery vehicles (t		magnitude of change is the same as the km and les changes).	Section 5		
177	Managed HGV refrigerated (all diesel)		See Delivery vehicles for changes in km					
178	Managed HGV (all diesel)							
Outside	of scopes							
179	Diesel (average biofuel blend)	CO ₂	All	-15%	The litres of biodiesel consumed this year has increased by 15% causing the percentage of biodiesel within the diesel blend to be more (11% more) and therefore the emissions associated with the biodiesel are proportionately more.	Section 9		
Waste: N	laterial use							
180	Metals - closed loop source	CO ₂ e	tonne	430%	Complete change of method. Driven by the changes in steel closed loop recycling (updated data). Have also changed method and references (using metal specific factors with recycling data whereas previous approach used an estimate of CO ₂ saved only rather than emitted from recycling).	Section 12		
181	Metal: mixed cans - Closed loop source	CO ₂ e	tonne	21%	Driven by the changes in steel closed loop recycling (updated data).	Section 12		

Ref. number	Emission factor	GHG	Unit (all units are kgCO ₂ e per "unit" of GHG, unless stated)	Magnitude of change vs 2017 update	Reason for change	For more information see:
182	Metal: scrap metal - Closed loop source	CO ₂ e	tonne	43%	As above	Section 12
183	Metal: steel cans - Closed loop source	CO2e	tonne	53%	Old method used data from World Steel (2009) for virgin steel and subtracted a factor derived based on comparing impact of varying steel grades (recycled content %). New version uses data from WSA (2017) which has published direct cradle to gate figure for recycled steel.	Section 12
Waste: V	Vaste disposal	Γ	1	F		
184	Glass - landfill	CO2e	tonne	-65%	New model based on zero landfill gas and standardised landfill transport (collection, transfer station and on site vehicle movements). This replaces a data point taken from a 2003 Enviros report and is more systematic and reproducible.	Section 12
185	Organic: food and drink waste, Organic: garden waste and Organic: mixed food and garden waste - Composting	CO2e	tonne	71%	New factor is general, based on collection from households, transport to site and on-site movements. Previous figures were replaced by using a 2009 study done by ORA, WRAP and MEL.	Section 12

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