Department for
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& Industrial Strategy

2019 Government greenhouse gas conversion factors for company reporting

Methodology paper for emission factors
Final report

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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 2019 UK Government Greenhouse Gas Conversion Factors for Company Reporting[1] (hereafter the 2019 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 2019 GHG Conversion Factors.

1.4. Values for the non-carbon dioxide (CO_2) GHGs, methane (CH_4) and nitrous oxide (N_2O), are presented as CO_2 equivalents (CO_2e), using Global Warming Potential (GWP) factors from the Intergovernmental Panel on Climate Change (IPCC)'s fourth assessment report (GWP for CH_4 = 25, GWP for N_2O = 298), consistent with reporting under the United Nations Framework Convention on Climate Change (UNFCCC). 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 2019 GHG Conversion Factors are therefore consistent with this.

1.5. The GHGI for 2017, on which these 2019 GHG Conversion Factors are based on, is available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1905151122_ukghgi-90-17_Main_Issue_2_final.pdf.

1.6. The 2019 GHG Conversion Factors are for one year, from the end of May 2019, 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: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting.

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 2019 GHG Conversion Factors. The report aims to expand and compliment the information already provided in the data tables themselves. However, it is not intended to be an exhaustively detailed explanation of every calculation performed (this is not practical/possible), nor is it intended to provide guidance on the practicalities of reporting for organisations. Rather, the intention is to provide an

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

overview with key information so that the basis of the emission factors provided can be better understood and assessed.

1.9. Further information about the 2019 GHG Conversion Factors together with previous methodology papers is available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting.

Overview of changes since the previous update

1.10. Major changes and updates in terms of methodological approach from the 2018 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 2018 update):

a) The methodology for calculating emissions from vans/LGVs has been improved this year to use a more recent, detailed (and annually updatable) dataset to calculate, (i) the relative differences in CO_2 emission factors between different van size categories, (ii) the average van payload capacity (in tonnes) for different van size categories. This has resulted in some significant changes in the emission factors per vehicle-km and per tonne-km in the 2019 update, compared to the previous year.

b) The “natural gas” emission factor, part of the Fuels factors, has been updated this year to account for the limited biogas content contained in the natural gas received through the gas mains grid network in the UK. In addition, a "natural gas (100% mineral blend)" factor is now included in the list of gaseous fuels emission factors, which does not contain any biogas content. Furthermore, improvements have been made to the assumptions of the composition of natural gas to utilise operator-provided data, where possible, which led to a reduction in the corresponding factors (when expressed on a mass or volume basis).

1.11. Detailed guidance on how the emission factors provided should be used is contained in the introduction to the 2019 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.

1.12. 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. Fuel Emission Factors

Section summary

2.1. Fuels conversion factors should be used for primary fuel sources combusted at a site or in an asset owned or controlled by the reporting organisation. Well-to-tank (WTT) factors should be used to account for the upstream Scope 3 emissions associated with extraction, refining and transportation of the raw fuel sources to an organisation's site (or asset), prior to their combustion. The fuel properties can be used to determine the typical calorific values / densities of most common fuels. The conversion values should be utilised to change units of energy, mass, volume, etc. into alternative units; this is particularly useful where an organisation is collecting data in units of measure that do not have a conversion factor that can be directly used to determine a carbon emission total.

2.2.

2.3. Table 1 shows where the related worksheets to fuel emission factors are available in the online sets of the factors.

Table 1: Related worksheets to fuel emission factors

Worksheet name	Full set	Condensed set
Fuels	Y	Y
WTT – fuels	Y	N
Fuel properties	Y	Y
Conversions	Y	Y

Summary of changes since the previous update

2.4. In the 2019 update, improvements have been made to the assumptions of the composition of natural gas to utilise operator-provided data where possible. The natural gas composition is now based on a nationally-weighted average. The new assumptions imply a reduced methane content and higher proportions of other constituents, including ethane, propane, and nitrogen. This has therefore had an impact on the physical and emissions characteristics of natural gas, and other related products included CNG (compressed natural gas) and LNG (liquefied natural gas). Overall, when expressed on a mass or volume basis, emission factors for all pollutants have reduced by 8% because of this change. Emission factors expressed in energy terms are unchanged by this recalculation.

2.5. Factors relating to the UK's natural gas network now account for the injection of biogas. Fossil carbon factors are therefore reduced by a minor amount for natural gas and CNG. Factors for LNG, however, are unchanged by this improvement as the UK's LNG supply is largely imported and it is not believed to contain any biogenic material. In addition to UK-specific natural gas factors, a mineral blend factor is included in the outputs for the first time.

2.6. Changes to the underlying assumptions on the airport taxi times (i.e. moving to/from the runway) for aircrafts have meant large increases in the CH_4 factors for aviation spirit (+9%) and aviation turbine fuel (+13-15%). These changes are due to recalculations within the UK's Greenhouse Gas Emissions Inventory (GHGI), from which these factors are derived.

2.7. Continued fleet turnover in road transport and off-road machinery of engines meeting more recent emissions standards has caused significant changes to the CH_4 and N_2O emission factors for diesel consumption in the 2019 submission of these factors. Whilst CH_4 emission factors have reduced by between 25% and 29%, N_2O emission factors for road transport vehicles alone have increased due to new after-treatment technology applied to reduce nitrogen oxide emissions to meet more stringent air pollution standards. However, a recalculation within the UK GHG emissions inventory for N_2O emission factors from off-road machinery has meant that the overall N_2O factors have reduced by 8% for diesel.

2.8. Significant recalculations in the N_2O emission factors for gas oil and processed distillates have caused an 87% decline in this factor between the 2018 and 2019 submissions and is a result of underlying changes to the UK GHG emissions inventory.

Direct Emissions

2.9. All the fuel conversion factors for direct emissions presented in the 2019 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2017 (managed by Ricardo Energy & Environment) (Ricardo Energy & Environment, 2019).

2.10. The CO_2 emissions factors are based on the same ones used in the UK GHGI and are essentially independent of application as they assume that all fuel is fully oxidised and combusted. However, emissions of CH_4 and N_2O can vary to some degree for the same fuel depending on the 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 2019 GHG Conversion Factors are based on an activity-weighted average of all the different CH_4 and N_2O emission factors from the GHGI.

2.11. The majority of emission factors from the GHGI have been converted into different energy and volume units using information on Gross and Net Calorific Values (CV) (see definition of Gross CV and Net CV in the footnote below[2]) from BEIS's Digest of UK Energy Statistics (DUKES) (BEIS, 2018).

[2] 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).

2.12. There are three tables in the 2019 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.

2.13. 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 kilowatt hours (kWh) by suppliers in the UK are generally calculated (from the volume of gas used) on a Gross CV basis (National Grid, 2019). 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

2.14. 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.

2.15. For the upstream emission factors relating to diesel, petrol, kerosene, natural gas, CNG, and LNG, data are taken from a study by Exergia (Exergia et al., 2014). However, since this report does not estimate upstream emissions for coal, naphtha, and LPG, the JRC Well-To-Wheels (JEC WTW, 2014) study is used for these fuels (being the most recent update to this source).

2.16. 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.

2.17. WTT emissions for petrol, diesel and kerosene in the Exergia study (Exergia et al., 2014), used within the 2019 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.

2.18. 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 (3.50% by unit volume, 3.23% by unit energy – see Table 2). These estimates have been made based on the Department for Business, Energy and Industrial Strategy's (BEIS) Quarterly Energy Statistics for Renewables (BEIS, 2018b).

2.19. 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 (4.60% by unit volume, 3.03% by unit energy – see Table 2). These estimates have also been made based on BEIS's Quarterly Energy Statistics for Renewables (BEIS, 2018b).

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

	Total Sales, millions of litres		Biofuel % Total Sales		
	Biofuel	Conventional Fuel	per unit mass	per unit volume	per unit energy
Diesel/Biodiesel	1,065	29,352	3.71%	3.50%	3.23%
Petrol/Bioethanol	760	15,757	4.96%	4.60%	3.03%

Source: Department for Transport, Table RTFO 01. Data used here is from December 2018 (BEIS, 2018b)

2.20. Emissions for natural gas, LNG and CNG, used within the 2019 GHG Conversion Factors, are based on (Exergia et al., 2014):

a) 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.

b) The pattern of gas supply for each Member State (based on IEA data for natural gas supply in 2012).

c) 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.

2.21. A similar methodology was developed for use in the 2019 GHG Conversion Factors, to allow the value calculated for gas supply in the UK to be updated annually (Exergia et al., 2014). This allows changes in the sources of imported gas, particularly LNG, to be reflected in the emissions value.

2.22. Information on quantities and source of imported gas are available annually from DUKES[3] (BEIS, 2018a) and can be used to calculate the proportion of gas in UK supply coming from each source. These can then be combined with the emissions factors for gas from each source from the EU study (Exergia et al., 2014), to calculate a weighted emissions factor for UK supply.

2.23. 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.

[3] From Table 4.1 Commodity balances for natural gas and Table 4.5 Natural gas imports and exports, DUKES 2018

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

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	34.1%	41.3%	19.1%
2011	46.0%	43.7%	29.5%
2012	27.1%	49.2%	17.5%
2013	19.1%	51.7%	12.1%
2014	26.0%	46.3%	15.9%
2015	30.2%	43.4%	18.8%
2016	22.2%	48.4%	13.2%
2017	14.6%	47.1%	8.7%

Source: DUKES 2018, (1) Table 4.1 - Commodity balances and (2) Table 4.5 - Natural gas imports and exports; (BEIS, 2018).

2.24. The final combined emission factors measured in kilograms of carbon dioxide equivalents per gigajoule on a net calorific value basis ($kgCO_2e/GJ$, Net CV basis) are presented in Table 4. These include WTT emissions of CO_2, N_2O and CH_4 and were converted into other units of energy (e.g. kWh, Therms) and to units of volume and mass using the default Fuel Properties and Unit Conversion factors also provided in the 2019 GHG Conversion Factors alongside the emission factor data tables.

Table 4: Basis of the indirect/WTT emissions factors for different fuels

Fuel	Indirect/WTT EF ($kgCO_2e/GJ$, 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 et al., 2014)	Emission factor for kerosene
Burning oil[1]	15.00	Estimate	Same as Kerosene, as above
CNG[2]	10.89	(Exergia et al., 2014)	CNG from natural gas EU mix. Factors in UK % share LNG imports
Coal (domestic)	14.55	(JEC WTW, 2014)	Emission factor for coal

Fuel	Indirect/WTT EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Coal (electricity generation)	14.55	(JEC WTW, 2014)	Emission factor for coal
Coal (industrial)	14.55	(JEC WTW, 2014)	Emission factor for coal
Coal (electricity generation - home produced coal only)	14.55	(JEC WTW, 2014)	Emission factor for coal
Coking coal	14.55	Estimate	Assume same as factor for coal
Diesel (100% mineral diesel)	17.40	(Exergia et al., 2014)	
Fuel oil[4]	15.00	Estimate	Assume same as factor for kerosene
Gas oil[5]	17.40	Estimate	Assume same as factor for diesel
LPG	8.04	(JEC WTW, 2014)	
LNG[6]	19.60	(Exergia et al., 2014)	
Lubricants	9.12	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	7.38	(Exergia et al., 2014)	Natural gas EU mix. Factors in UK % share LNG imports
Other petroleum gas	6.85	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Petrol (100% mineral petrol)	18.20	(Exergia et al., 2014)	
Petroleum coke	12.20	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	9.65	Estimate	Based on LPG figure, scaled relative to direct emissions ratio

Fuel	Indirect/WTT EF ($kgCO_2e/GJ$, Net CV basis)	Source of Indirect/WTT Emission Factor	Assumptions
Refinery miscellaneous	8.80	Estimate	Based on LPG figure, scaled relative to direct emissions ratio
Waste oils	9.55	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.

3. UK Electricity, Heat and Steam Emission Factors

Section summary

3.1. UK electricity conversion factors should be used to report on electricity used by an organisation at sites owned or controlled by them. This is reported as a Scope 2 (indirect) emission. The conversion factors for electricity are for the electricity supplied to the grid that organisations purchase – i.e. not including the emissions associated with the transmission and distribution of electricity. Conversion factors for transmission and distribution losses (the energy loss that occurs in getting the electricity from the power plant to the organisations that purchase it) are available separately and should be used to report the Scope 3 emissions associated with grid losses. WTT conversion factors for UK and overseas electricity should be used to report the Scope 3 emissions of extraction, refining and transportation of primary fuels before their use in the generation of electricity.

3.2. Heat and steam conversion factors should be used to report emissions within organisations that purchase heat or steam energy for heating purposes or for use in specific industrial processes. District heat and steam factors are also available. WTT heat and steam conversion factors should be used to report emissions from the extraction, refinement and transportation of primary fuels that generate the heat and steam organisations purchase.

3.3. Table 5 shows where the related worksheets to the UK electricity and heat & steam emission factors are available in the online sets of the factors.

Table 5: Related worksheets to UK electricity and heat & steam emission factors

Worksheet name	Full set	Condensed set
UK electricity	Y	Y
Transmission and distribution	Y	Y
WTT – UK & overseas Electricity	Y	N
Heat and steam	Y	N
WTT – heat and steam	Y	N

Summary of changes since the previous update

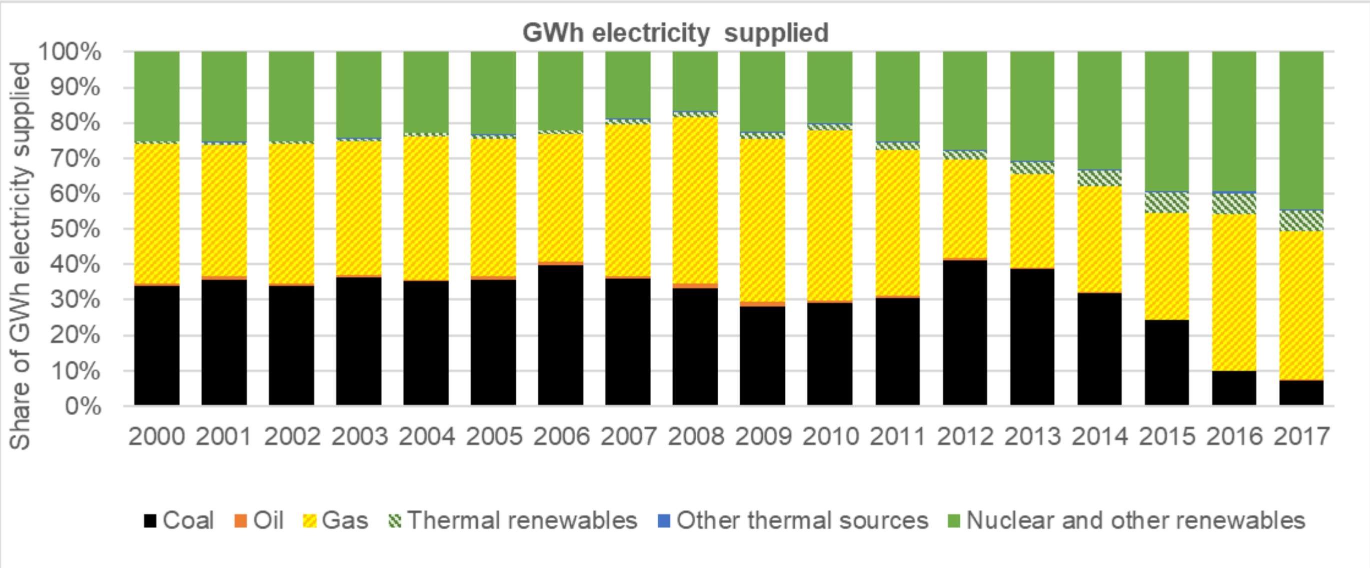
3.4. In 2019 update, like 2018, there have been changes to the data that the CHP methodologies depend upon. These comprise changes to DUKES CHP fuel mix, and assumptions about the CH_4 and N_2O emissions for certain fuels due to changes in the underlying data within NAEI; for changes in the fuel emission factors, see the Fuels section of this report.

Direct Emissions from UK Grid Electricity

3.5. The electricity conversion factors given represent the average CO_2 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 CO_2, CH_4 and N_2O emissions at UK power stations and from autogenerators (the latter added for the first time in the 2013 GHG Conversion Factors), plus those from the proportion of imported electricity. They do not include emissions resulting from production and delivery of fuel to these power stations (i.e. from gas rigs, refineries and collieries, etc.).

3.6. 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.

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



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 behind, i.e. the 2019 emission factors are based on 2017 data.

3.7. The UK electricity emission factors provided in the 2019 GHG Conversion Factors are based on emissions from sector 1A1ai (power stations) and 1A2b (autogenerators) in the UK Greenhouse Gas Inventory (GHGI) for 2017 (Ricardo Energy & Environment, 2019) according to the amount of CO_2, CH_4 and N_2O

emitted per unit of electricity consumed (BEIS, 2018). These emissions from the GHGI only include autogeneration from coal and natural gas fuels, and do not include emissions for electricity generated and supplied by autogenerators using oil or other thermal non-renewable fuels[4]. 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 (~9.4% for the 2017 data year), which varies significantly from year-to-year.

3.8. The UK is a net importer of electricity from the interconnectors with France, Netherlands and Ireland according to DUKES (2018). For the 2019 GHG Conversion Factors the total net electricity imports were calculated from DUKES (2018) Table 5.1.2 (Electricity supply, availability and consumption 1970 to 2017). The net shares of imported electricity over the interconnectors are calculated from data from DUKES (2018) Table 5A (Net Imports via interconnectors, GWh).

3.9. An average imported electricity emission factor is calculated from the individual factors for the relevant countries (CBS, 2017), (RTE, 2019), (SEAI, 2019) weighted by their respective share of net imports. This average electricity emission factor – including losses – is used to account for the net import of electricity, as it will also have gone through the relevant countries' distribution systems. Note that this year this method effectively increases the UK's electricity emission factors as the resulting average net imported electricity emission factor is higher than that for the UK. This is largely due to the lower emissions from the generation of electricity in the UK.

3.10. The source data and calculated emissions factors are summarised in the following Table 6, Table 7 and Table 8. Time series source data and emission factors are fixed/locked from the 2018 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 6 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 2019 GHG Conversion Factors is based on a data year of 2017.

3.11. A full-time series of data using the most recently available GHGI and DUKES datasets for all years is also provided in Appendix 2 of this report. This is provided for purposes other than company reporting, where a fully consistent data time series is desirable, e.g. for policy impact analysis. This dataset also reflects the changes in the methodological approach implemented for the 2016 update, and is applied across the whole-time series.

[4] Other thermal non-renewable fuels include the following (with ~2017 update % share): blast furnace gas (~35%), chemical waste (~15%), coke oven gas (~7%) and municipal solid waste (MSW, ~43%)

Table 6: Base electricity generation emissions data

Data Year	Applied to Reporting Year*	Electricity Generation [1] GWh	Total Grid Losses [2] %	UK electricity generation emissions [3], ktonne		
				CO_2	CH_4	N_2O
1990	1992	290,666	8.08%	204,614	2.671	5.409
1991	1993	293,743	8.27%	201,213	2.499	5.342
1992	1994	291,692	7.55%	189,327	2.426	5.024
1993	1995	294,935	7.17%	172,927	2.496	4.265
1994	1996	299,889	9.57%	168,551	2.658	4.061
1995	1997	310,333	9.07%	165,700	2.781	3.902
1996	1998	324,724	8.40%	164,875	2.812	3.612
1997	1999	324,412	7.79%	152,439	2.754	3.103
1998	2000	335,035	8.40%	157,171	2.978	3.199
1999	2001	340,218	8.25%	149,036	3.037	2.772
2000	2002	349,263	8.38%	160,927	3.254	3.108
2001	2003	358,185	8.56%	171,470	3.504	3.422
2002	2004	360,496	8.26%	166,751	3.490	3.223
2003	2005	370,639	8.47%	177,044	3.686	3.536
2004	2006	367,883	8.71%	175,963	3.654	3.414
2005	2007	370,977	7.25%	175,086	3.904	3.550
2006	2008	368,314	7.21%	184,517	4.003	3.893
2007	2009	365,252	7.34%	181,256	4.150	3.614
2008	2010	356,887	7.45%	176,418	4.444	3.380
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
2017	2019	294,086	7.83%	74,386	7.588	1.353

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 (~10% in 2017).

(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, 2019) for the 2017 data year.

Table 7: Base electricity generation emission factors (excluding imported electricity)

Data Year	Emission Factor, kgCO_{2}e / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
1990	0.70395	0.00019	0.00577	0.70991	0.05061	0.00001	0.00042	0.05104	0.7658	0.00021	0.00628	0.77229	**3.85%**
1991	0.685	0.00018	0.00564	0.69081	0.04318	0.00001	0.00033	0.04352	0.74675	0.00019	0.00615	0.75309	**5.18%**
1992	0.64907	0.00017	0.00534	0.65458	0.05678	0.00002	0.00042	0.05722	0.70205	0.00019	0.00578	0.70801	**5.29%**
1993	0.58632	0.00018	0.00448	0.59098	0.05101	0.00002	0.00037	0.0514	0.6316	0.00019	0.00483	0.63662	**5.25%**
1994	0.56204	0.00019	0.0042	0.56643	0.04471	0.00002	0.0003	0.04502	0.62154	0.00021	0.00464	0.62639	**5.22%**
1995	0.53394	0.00019	0.0039	0.53803	0.03813	0.00001	0.00024	0.03839	0.58721	0.00021	0.00429	0.5917	**4.97%**
1996	0.50774	0.00018	0.00345	0.51137	0.04182	0.00002	0.00026	0.0421	0.55432	0.0002	0.00376	0.55828	**4.80%**
1997	0.46989	0.00018	0.00297	0.47304	0.03816	0.00002	0.00022	0.0384	0.50961	0.00019	0.00322	0.51302	**4.76%**
1998	0.46912	0.00019	0.00296	0.47226	0.04084	0.00002	0.00024	0.04111	0.51211	0.0002	0.00323	0.51555	**3.51%**
1999	0.43806	0.00019	0.00253	0.44077	0.04375	0.00002	0.00027	0.04404	0.47745	0.00020	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%**

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
2009	0.45211	0.00027	0.00263	0.45501	0.03783	0.00002	0.00024	0.03809	0.49074	0.0003	0.00285	0.49389	**0.80%**
2010	0.4598	0.00028	0.00269	0.46277	0.05061	0.00001	0.00042	0.05104	0.49613	0.0003	0.0029	0.49933	**0.73%**
2011	0.44877	0.00029	0.00285	0.45192	0.04318	0.00001	0.00033	0.04352	0.48715	0.00032	0.0031	0.49056	**1.76%**
2012	0.5052	0.00034	0.00381	0.50935	0.04418	0.00003	0.00033	0.04454	0.54938	0.00037	0.00414	0.55389	**3.40%**
2013	0.4753	0.0004	0.0035	0.4791	0.0392	0.0000	0.0003	0.0396	0.5146	0.0004	0.0038	0.5187	**4.10%**
2014	0.42417	0.00040	0.00217	0.42673	0.03837	0.00004	0.00020	0.03860	0.46254	0.00044	0.00236	0.46534	**6.44%**
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%**
2017	0.25294	0.00065	0.00137	0.25496	0.02148	0.00005	0.00012	0.02165	0.27442	0.00070	0.00149	0.27660	**4.78%**

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 2019 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 8: Base electricity generation emissions factors (including imported electricity)

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Elec Imports
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
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%**

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Elec Imports
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
2010	0.45706	0.00028	0.00267	0.46002	0.03611	0.00002	0.00021	0.03634	0.49317	0.0003	0.00289	0.49636	**0.73%**
2011	0.44238	0.00029	0.00281	0.44548	0.03783	0.00002	0.00024	0.03809	0.4802	0.00031	0.00305	0.48357	**1.76%**
2012	0.49023	0.00033	0.00369	0.49426	0.04287	0.00003	0.00032	0.04322	0.5331	0.00036	0.00402	0.53748	**3.40%**
2013	0.4585	0.00035	0.00334	0.46219	0.03786	0.00003	0.00028	0.03816	0.49636	0.00038	0.00362	0.50035	**4.10%**
2014	0.40957	0.00039	0.00209	0.41205	0.03705	0.00003	0.00019	0.03727	0.44662	0.00042	0.00228	0.44932	**6.44%**
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%**
2017	0.25358	0.00065	0.00137	0.2556	0.02153	0.00005	0.00012	0.0217	0.27511	0.0007	0.00149	0.2773	**4.78%**

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 2019 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)

Indirect/WTT Emissions from UK Grid Electricity

3.12. 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.

3.13. 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 2018 (BEIS, 2018). The data used in these calculations are presented in Table 9, Table 10 and Table 11, 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 2016 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 2018).

Table 9: Fuel Consumed in electricity generation (GWh), by year

Data Year	Fuel Consumed in Electricity Generation, GWh					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Total
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

Data Year	Fuel Consumed in Electricity Generation, GWh					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Total
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
2016	87,669	6,790	298,077	25,319	325,774	743,630
2017	64,597	6,324	286,031	24,882	339,012	720,846

Source: For the latest 2017 data year, Table 5.6, Digest of UK Energy Statistics (DUKES) 2018 (BEIS, 2018) is used. 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. No data is available from DUKES on fuel consumed prior to 1996, so it is assumed the shares prior to this were the same as 1996.

Table 10: Fuel consumed in electricity generation as a % of the Total, by year

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

Data Year	Fuel Consumed in Electricity Generation, % Total					
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Total
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%
2017	8.96%	0.88%	39.68%	3.45%	47.03%	100.00%

Notes: Calculated from figures in Table 9

Table 11: Indirect/WTT emissions share for fuels used for electricity generation and the calculated average indirect/WTT emission factor, by year

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

Data Year	Indirect/WTT Emissions as % Direct CO_2 Emissions, by fuel							
	Coal	Fuel Oil	Natural Gas	Other thermal (excl. renewables)	Other generation	Weighted Average	Direct CO_2 ((kg CO_2/ kWh)	Calc Indirect /WTT (kg CO_2e/ kWh
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
2017	16.38%	19.02%	13.55%	12.59%	14.06%	**14.06%**	0.25358	0.03565

Notes: Indirect/WTT emissions as % direct CO_2 emissions is based on information for specific fuels. Weighted average is calculated from the figures for fuels from both Table 10 and Table 11.

Emission Factors for the Supply of Purchased Heat or Steam

3.14. Updated emission factors for the supply of purchased heat or steam have been provided for the 2019 GHG Conversion Factors. These conversion factors represent the average emission from the heat and steam supplied by the UK Combined Heat and Power Quality Assurance (CHPQA) scheme (CHPQA, 2018) 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 (Combined Heat and Power) operations.

3.15. CHP 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. Only this method is described below.

3.16. 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 Method 1 used in the GHG CF is described below.

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

3.17. Under the UK's Climate Change Agreements (CCAs)[5] (Environment Agency, 2019), 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%.

3.18. 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.

3.19. 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.

Calculation of CO_2 Emissions Factor for CHP Fuel Input, FuelMixCO_2factor

3.20. The value FuelMixCO_2factor 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 FuelMixCO_2factor is determined using the following expression:

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

[5] 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).

Where:

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

3.21. Fuel inputs and emissions factors are evaluated on a Gross Calorific Value (Higher Heating Value) basis. The following Table 12 provides the individual fuel types considered under the CHPQA scheme and their associated emissions factors, consistent with other reporting.

Table 12: Fuel types and associated emissions factors used in determination of FuelMixCO_2factor

Fuel	CO_2 Emissions Factor ($kgCO_2/kWh_{th}$)
Biodiesel, bioethanol etc	0
Biomass (such as woodchips, chicken litter etc)	0
Blast furnace gas	0.99
Butane	0.21
Coal and lignite	0.33
Coke oven gas	0.14
Coke, and semi-coke	0.34
Domestic refuse (raw)	0.16
Ethane	0.19
Fuel oil	0.27
Gas oil	0.25
Hydrogen	0
Landfill gas	0
Methane	0.18
Mixed refinery gases	0.25
Natural gas	0.18
Other	0.18
Other Biogas (e.g. gasified woodchips)	0
Other gaseous waste	0.18
Other liquid waste (non-renewable)	0.21
Other liquid waste (renewable)	0
Other oils	0.26
Other solid waste	0.25

Fuel	CO_2 Emissions Factor ($kgCO_2/kWh_{th}$)
Petroleum coke	0.34
Petroleum gas	0.21
Propane	0.21

Sources: GHG Conversion Factors for Company Reporting (2019 update) and National Atmospheric Emissions Inventory (NAEI) (Ricardo Energy & Environment, 2019).

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.

3.22. 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 2019 GHG Conversion Factors. This is shown in Table 13. 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 2019 GHG Conversion Factors is based on the data year of 2017 in the table.

3.23. While not used in the 2019 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 CO_2/kWh heat (Boiler displacement), 0.19233 CO_2/kWh heat (Power station displacement), 0.37236 CO_2/kWh power (DUKES method), 0.30401 CO_2/kWh power (Boiler displacement), 0.35997 CO_2/kWh power (power station displacement).

Table 13: Heat/Steam CO_2 emission factor for DUKES 1/3 2/3 method.

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
2009	0.22196
2010	0.21859
2011	0.21518
2012	0.20539

Data Year	$KgCO_2$/kWh supplied heat/steam
	Method 1 (DUKES: 2/3rd - 1/3rd)
2013	0.20763
2014	0.20245
2015	0.19564
2016	0.18618
2017	**0.17447**

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

3.24. CH_4 and N_2O emissions have been estimated relative to the CO_2 emissions, based upon activity weighted average values for each CHP fuel used (using relevant average fuel emission factors from the NAEI). 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 2019 update, although the overall impacts are not significant.

3.25. Indirect/WTT GHG emission factors have been estimated relative to the CO_2 emissions, based upon activity weighted average indirect/WTT GHG emission factor values for each CHP fuel used (see Indirect/WTT Emissions from Fuels section for more information). Where fuels are not included in the set of indirect/WTT GHG emission factors provided in the 2019 GHG Conversion Factors, the value for the closest/most similar alternative fuel was utilised instead.

3.26. The complete final emission factors for supplied heat or steam utilised are presented in the 'Heat and Steam' tables of the 2019 GHG Conversion Factors, and are counted as Scope 2 emissions under the GHG Protocol.

3.27. 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

Section summary

4.1. Refrigerant and process conversion factors should be used for reporting leakage from air-conditioning and refrigeration units or the release to the atmosphere of other gases that have a global warming potential.

4.2. This section of the methodology paper relates to the worksheet "refrigerant & other," available in both the full and condensed set of factors.

Summary of changes since the previous update

4.3. There are no major changes for the refrigerant factors in the 2019 update.

Global Warming Potentials of Greenhouse Gases

4.4. 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

4.5. 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% HFC125[6], 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

4.6. CFCs and HCFCs[7]: 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.

[6] HFC: Hydrofluorocarbon

[7] CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons

5. Passenger Land Transport Emission Factors

Section summary

5.1. Conversion factors for passenger land transport are included in this section of the methodology paper. This includes vehicles owned by the reporting organisation (Scope 1), business travel in other vehicles (e.g. employee own car for business use, hire car, public transport) (Scope 3), and electric vehicles (EVs) (Scope 2). Other Scope 3 conversion factors included here are for transmission and distribution losses for electricity used for electric vehicles, WTT for passenger transport (vehicles owned by reporting organisation) and other business travel.

5.2. Table 14 shows where the related worksheets to passenger land transport emission factors are available in the online sets of the factors.

Table 14: Related worksheets to passenger land transport emission factors

Worksheet name	Full set	Condensed set
Passenger vehicles	Y	Y
UK Electricity for Electric Vehicles (EVs)	Y	Y
UK Electricity T&D for EVs	Y	Y
Business travel – land*	Y	Y
WTT – pass vehicles & travel – land*	Y	N

* cars and motorbikes only

Summary of changes since the previous update

5.3. Whilst there have been no methodological changes to the calculation of emission factors relating to car and motorcycle use, the continued penetration of vehicles meeting more stringent EURO exhaust standards has contributed to reductions in emissions of CH_4.

5.4. Emission factors for CH_4 for LPG consumption have reduced by 29%, as a result of an update to EMEP/EEA Guidebook 2016 source data.

5.5. Test data from the Society of Motor Manufacturers & Traders indicates an improvement in the fuel efficiency of hybrid vehicles, and therefore a reduction of 18% to CO_2e factors for this vehicle type.

5.6. Rail passenger-km emission factors have decline significantly for international travel in particular (>50% for CO_2e) as a result of revisions to data received from Eurostar to inform emissions estimates in this sector.

5.7. As with cars and motorcycles, increased penetration of buses satisfying the latest EURO standards causes a decline in CH_4 emission factors in particular, although this is somewhat offset by lower occupancy rates for London-specific services.

Direct Emissions from Passenger Cars

Emission Factors for Petrol and Diesel Passenger Cars by Engine Size

5.8. The methodology for calculating average emissions factors for passenger cars is based upon a combination of datasets on the average new vehicle regulatory emissions for vehicles registered in the UK, and an uplift to account for differences between these and real-world driving performance. The regulatory test cycle/procedures are currently under transition from the previous NEDC[8] to the new WLTP (Worldwide Harmonised Light Vehicle Test Procedure) (ACEA, 2019). The key objective of the change is to bring the results of tests under regulatory testing conditions closer to those observed in the real-world. From 2019, all new light duty vehicles (cars and vans) registered in the EU will have WLTP-based regulatory CO2 emissions values. An adjustment in the methodology used for the GHG Conversion Factors will be needed from the 2020 update onwards to reflect these changes. It has NOT been necessary to make a change for the 2019 update.

5.9. SMMT (Society for Motor Manufacturers and Traders)[9] provides numbers of registrations and averages of the NEDC gCO2/km figures for new vehicles registered from 1997 to 2017[10]. The dataset represents a good indication of the relative NEDC gCO2/km by size category. Table 15 presents the 2002-2018 average CO2 emission factors and number of vehicle registrations.

[8] NEDC = New European Driving Cycle, which has been the standard cycle used in the type approval of all new passenger cars and vans up to September 2018.

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

[10] The SMMT gCO_2/km dataset for 1997 represented around 70% of total registrations, which rose to about 99% by 2000 and essentially all vehicles thereafter.

Table 15: Average CO_2 emission factors and total registrations by engine size for 2002 to 2018 (based on data sourced from SMMT)

Vehicle Type	Engine size	Size label	NEDC gCO_2 per km	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	125.5	13,122,822	57%
	1.4 - 2.0 l	Medium	163.8	8,529,052	37%
	> 2.0 l	Large	247.7	1,337,365	6%
Average petrol car		**All**	**151.8**	**22,989,239**	**100%**
Diesel car	<1.7 l	Small	110.6	5,544,235	34%
	1.7 - 2.0 l	Medium	138.3	7,357,193	45%
	> 2.0 l	Large	169.2	3,468,567	21%
Average diesel car		**All**	**139.0**	**16,369,995**	**100%**

5.10. For the 2019 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. Although ANPR data was received for 2017, it did not provide sufficient disaggregation and so couldn't be used in the calculations.

5.11. 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 2019 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.

5.12. 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 2019 GHG Conversion Factors' emission factors for petrol and diesel passenger cars were subsequently calculated based upon the equation below:

$$\text{2019 update gCO}_2/\text{km} = \Sigma\left(\text{gCO}_2/\text{km}_{\text{yr reg}} \times \frac{\text{ANPR}_{\text{yr reg}}}{\text{ANPR}_{\text{total 2015}}}\right)$$

5.13. A limitation of the NEDC (New European Driving Cycle – previously used in vehicle type approval, but now being superseded by WLTP, as discussed earlier) 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.

5.14. An uplift factor over NEDC based gCO_2/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); this study used data on almost 1.1 million vehicles from fourteen data sources and eight countries, covering the fuel consumption/CO_2 from actual real-world use and the corresponding type-approval values. The values used are based on average data from the two UK-based sources analysed in the ICCT study, as summarised in Table 16 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. The methodology will need to be further revised for future updates, when WLTP-based datasets will become the norm for all new light duty vehicles (i.e. cars and vans).

Table 16: Average GCF 'real-world' uplift for the UK, applied to the NEDC-based gCO_2/km data

Data year	2002	2003	2004	2005	2006	2007	2008	2009
RW uplift %	8.60%	9.70%	10.80%	11.90%	13.00%	15.65%	18.30%	20.95%
Data year	2010	2011	2012	2013	2014	2015	2016	2017
RW uplift %	23.60%	26.25%	27.63%	29.00%	33.33%	41.50%	38.00%	31.50%

5.15. The above uplifts have been applied to the ANPR weighted SMMT gCO_2/km to give the new 'Real-World' 2019 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 22.9% on top of NEDC gCO_2/km.

Figure 2: Updated GCF 'Real world' uplift values for the UK based on (ICCT, 2017)

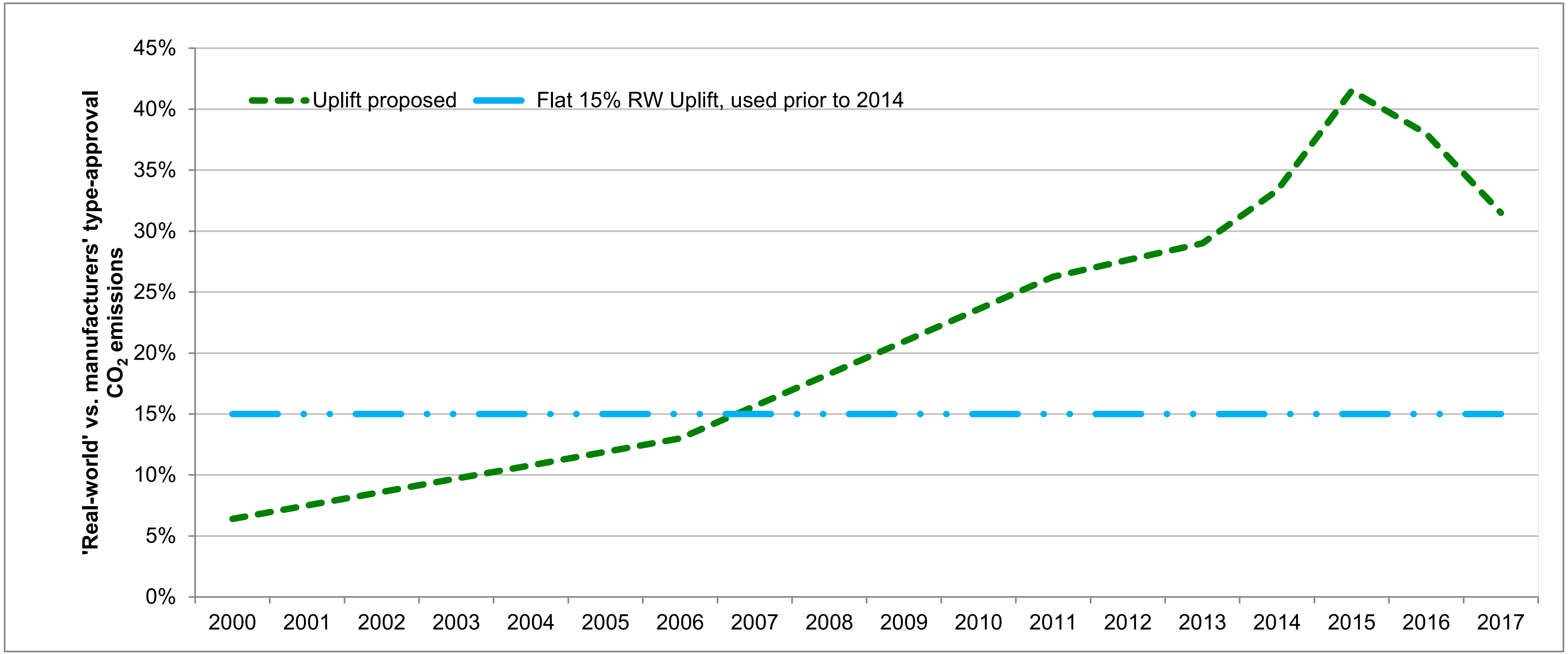
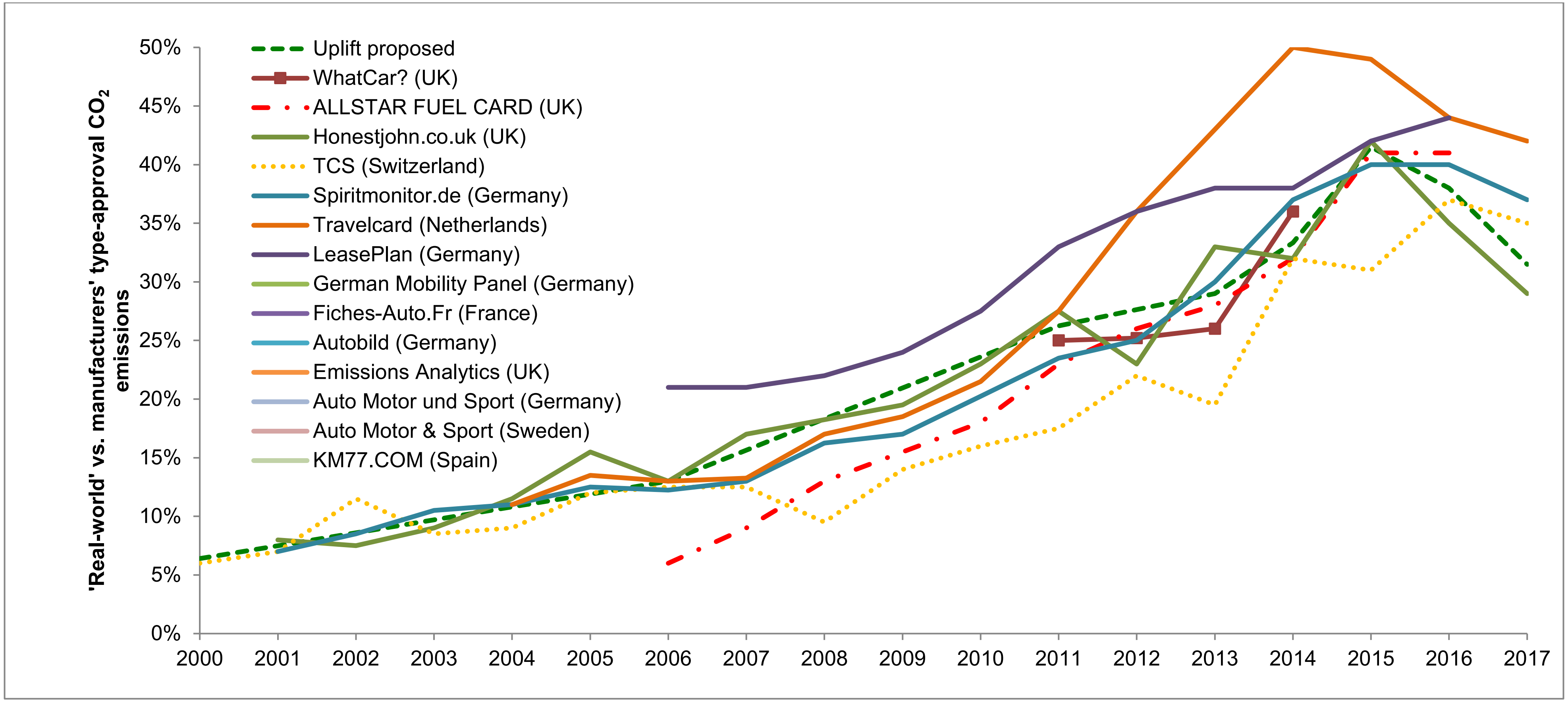


Figure 3: Comparison of 'Real world' uplift values from various sources (ICCT, 2017)



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

5.16. 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 49.98% petrol and 50.02% diesel, and can be compared to the respective total registrations of the different vehicle types for 2002-2018, which were 58.4% petrol and 41.6% diesel.

5.17. Emission factors for CH_4 and N_2O have been updated for all vehicle classes and are based on the emission factors from the NAEI. The emission factors used in the NAEI are based on COPERT 4 version 11 (EMISIA, 2019).

5.18. The final 2019 emission factors for petrol and diesel passenger cars by engine size are presented in the ‘Passenger vehicles’ and ‘business travel- land’ tables of the 2019 GHG Conversion Factors.

Hybrid, LPG and CNG Passenger Cars

5.19. The methodology used in the 2019 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 gCO_2/km figures from SMMT for new hybrid vehicles registered between 2012 and 2018. In previous years, the SMMT source dataset used in the derivation of passenger car emission factors included plug-in hybrid cars within the hybrid category. (As for petrol and diesel cars, data in future years will be based on the new regulatory test cycle protocol – WLTP).

5.20. 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 2019 GHG Conversion Factors, CO_2 emission factors for CNG and LPG medium and large cars are derived by multiplying the equivalent petrol EF by the ratio of CNG (and LPG) to petrol emission factors on a unit energy (Net CV) basis. For example, for a Medium car run on CNG:

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

5.21. For the 2019 GHG Conversion Factors, the emission factors for CH_4 and N_2O were updated, but the methodology remains unchanged. These are based on the emission factors from the NAEI (produced by Ricardo Energy & Environment) and are presented together with an overall total emission factors in the ‘Passenger vehicles’ and ‘business travel- land’ tables of the 2019 GHG Conversion Factors.

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

5.22. Since the number of electric vehicles (xEVs[11]) in the UK fleet is rapidly increasing (and will continue to increase in the future), at least for passenger cars and vans, 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.

5.23. 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 17, 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.

5.24. Table 17 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.

Table 17: Summary of emissions reporting and tables for new electric vehicle emission 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- passenger vehicles & travel- land • WTT- delivery vehicles & freight	Yes	Yes

[11] 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).

Emission component	Emissions Scope and Reporting Worksheet	Plug-in hybrid electric vehicles (PHEVs)	Battery electric vehicles (BEVs)
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 Greenhouse Gas Protocol Corporate Standard.

Data inputs, sources and key assumptions

5.25. 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 18, 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.

5.26. The calculation of UK fleet average emission factors for electric vehicles is based upon data obtained from the EEA CO_2 monitoring databases for cars and vans, which are publicly available (EEA, 2019), (EEA, 2019a). 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 CO_2 emissions (gCO_2/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 18. 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.

Table 18: xEV car models and their allocation to different market segments

Make	Model	Segment	Segment Name	BEV	PHEV
AUDI	A3	C	Lower Medium	-	Yes
AUDI	Q7	H	Dual Purpose	-	Yes
BMW	I3	B	Supermini	Yes	-
BMW	I3 REEV	B	Supermini	Yes	Yes

Make	Model	Segment	Segment Name	BEV	PHEV
BMW	I8	G	Specialist Sports	-	Yes
BMW	SERIES 2	C	Lower Medium	-	Yes
BMW	SERIES 3	D	Upper Medium	-	Yes
BMW	SERIES 5	E	Executive	-	Yes
BMW	SERIES 7	F	Luxury Saloon	-	Yes
BMW	X5	H	Dual Purpose	-	Yes
BYD	E6Y	C	Lower Medium	Yes	-
CHEVROLET	VOLT	C	Lower Medium	-	Yes
CITROEN	C-ZERO	A	Mini	Yes	-
FORD	FOCUS	C	Lower Medium	Yes	-
FORD	MONDEO	D	Upper Medium	-	Yes
HYUNDAI	IONIQ	C	Lower Medium	Yes	Yes
KIA	OPTIMA	D	Upper Medium	-	Yes
KIA	NIRO	C	Lower Medium	-	Yes
KIA	SOUL	C	Lower Medium	Yes	-
MAHINDRA	E20PLUS	C	Lower Medium	Yes	-
MCLAREN	P1	G	Specialist Sports	-	Yes
MERCEDES BENZ	B CLASS	C	Lower Medium	Yes	-
MERCEDES BENZ	C CLASS	D	Upper Medium	-	Yes
MERCEDES BENZ	E CLASS	E	Executive	-	Yes
MERCEDES BENZ	GL	H	Dual Purpose	-	Yes
MERCEDES BENZ	S CLASS	F	Luxury Saloon	-	Yes
MIA	MIA	A	Mini	Yes	-
Mini	COUNTRYMAN	B	Supermini	-	Yes
MITSUBISHI	I-MIEV	A	Mini	Yes	-
MITSUBISHI	OUTLANDER	H	Dual Purpose	-	Yes
NISSAN	E-NV200	I	Multi Purpose Vehicle	Yes	-
NISSAN	LEAF	C	Lower Medium	Yes	-
OPEL	AMPERA	D	Upper Medium	-	Yes
PEUGEOT	ION	A	Mini	Yes	-
PORSCHE	918	G	Specialist Sports	-	Yes
PORSCHE	CAYENNE	H	Dual Purpose	-	Yes
PORSCHE	PANAMERA	F	Luxury Saloon	-	Yes
RENAULT	FLUENCE Z.E.	D	Upper Medium	Yes	-
RENAULT	KANGOO	I	Multi Purpose Vehicle	Yes	-
RENAULT	ZOE	C	Lower Medium	Yes	-
SMART	FORFOUR	B	Supermini	Yes	-
SMART	FORTWO	A	Mini	Yes	-
TESLA	MODEL S	F	Luxury Saloon	Yes	-
TESLA	MODEL X	H	Dual Purpose	Yes	-
TESLA	ROADSTER	G	Specialist Sports	Yes	-
THINK	THINKCITY	A	Mini	Yes	-

Make	Model	Segment	Segment Name	BEV	PHEV
TOYOTA	PRIUS	C	Lower Medium	-	Yes
VOLKSWAGEN	E-GOLF	C	Lower Medium	Yes	-
VOLKSWAGEN	E-UP	A	Mini	Yes	-
VOLKSWAGEN	GOLF	C	Lower Medium	Yes	Yes
VOLKSWAGEN	PASSAT	D	Upper Medium	-	Yes
VOLVO	V60	D	Upper Medium	-	Yes
VOLVO	S90	E	Executive	-	Yes
VOLVO	V90	E	Executive	-	Yes
VOLVO	XC90	H	Dual Purpose	-	Yes
VOLVO	XC60	H	Dual Purpose	-	Yes

Notes: Only includes models with registrations in the UK fleet up to the end of 2017.

5.27. During the course of the derivation of the emission factors, a number of discrepancies were found in the EEA CO_2 monitoring database for the gCO_2/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 Guide (Green Car Guide, 2018).

5.28. Consistent with the approach used for the calculation of emission factors for conventionally fuelled passenger cars, the gCO_2/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 methodology (VDA, 2014)). 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.

5.29. 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 gCO_2/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.

5.30. The key assumptions used in the calculation of adjusted Real-World gCO_2/km and Wh/km figures are summarised in Table 19. 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 19).

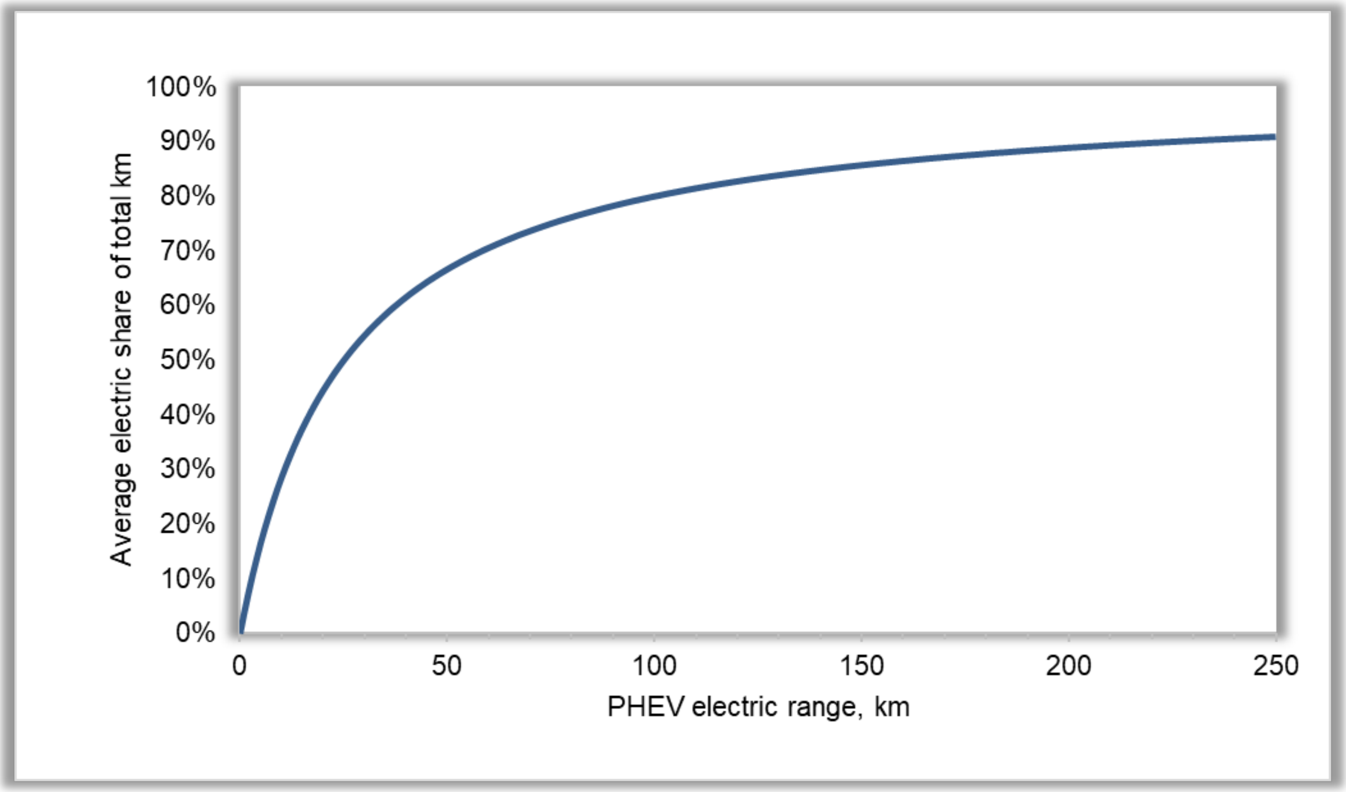
Table 19: Summary of key data elements, sources and key assumptions used in the calculation of GHG conversion factors for electric cars and vans

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 CO_2 monitoring databases: • Data for 2010-2017 for cars • Data for 2012-2017 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
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

Data type	Raw data source / assumption	Other notes
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.
GHG emission factors for electricity consumption	UK electricity emission factors ($kgCO_2e$ / 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_2O and WTT CO_2e 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_2O or WTT CO_2e component for petrol/diesel.

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

Figure 4: 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

5.31. For the 2019 GHG Conversion Factors, the market classification split (according to SMMT classifications) was derived using detailed SMMT data on new car registrations between 2011 and 2018 split by fuel, presented in Table 20, 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 2019 GHG Conversion Factors.

5.32. Emission factors for CH_4 and N_2O were also updated for all car classes. These figures are based on the emission factors from the UK GHG Inventory. The emission factors used in the NAEI are now based on COPERT 4 version 11 (EMISIA, 2019). The factors are presented together with the overall total emission factors in the tables of the 2019 GHG Conversion Factors.

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

Table 20: Average car CO_2 emission factors and total registrations by market segment for 2001 to 2018 (based on data sourced from SMMT)

Fuel Type	Market Segment	Example Model	2001 to 2018		
			gCO_2/km	# registrations	% Total
Diesel	A. Mini	Smart ForTwo	90.5	8,058	0.0%
	B. Super Mini	Renault Clio	106.2	1,888,112	11.53%
	C. Lower Medium	VW Golf	117.2	4,837,373	29.55%
	D. Upper Medium	Ford Mondeo	135.4	3,580,521	21.87%
	E. Executive	BMW 5 Series	140.5	1,393,339	8.51%
	F. Luxury Saloon	Mercedes S-Class	172.0	81,556	0.50%
	G. Specialist Sports	Porsche Panamera	136.1	118,085	0.72%
	H. Dual Purpose	Land Rover Discovery	160.0	3,137,023	19.16%
	I. Multi Purpose	Renault Espace	146.1	1,325,929	8.10%
	All	**Total**	**139.0**	**16,369,996**	**100%**
Petrol	A. Mini	Smart ForTwo	112.3	869,084	3.77%
	B. Super Mini	Renault Clio	128.0	11,455,760	49.70%
	C. Lower Medium	VW Golf	151.0	6,096,466	26.45%
	D. Upper Medium	Ford Mondeo	181.6	1,723,290	7.48%
	E. Executive	BMW 5 Series	207.2	472,871	2.05%
	F. Luxury Saloon	Mercedes S-Class	290.6	85,298	0.37%
	G. Specialist Sports	Porsche Panamera	211.0	760,191	3.30%
	H. Dual Purpose	Land Rover Discovery	201.1	850,744	3.69%
	I. Multi Purpose	Renault Espace	167.8	734,128	3.19%
	All	**Total**	**151.8**	**23,047,832**	**100%**
Unknown Fuel (Diesel + Petrol)	A. Mini	Smart ForTwo	111.1	877,142	2.23%
	B. Super Mini	Renault Clio	123.5	13,343,872	33.85%
	C. Lower Medium	VW Golf	134.8	10,933,839	27.74%
	D. Upper Medium	Ford Mondeo	148.3	5,303,811	13.46%
	E. Executive	BMW 5 Series	153.7	1,866,210	4.73%
	F. Luxury Saloon	Mercedes S-Class	221.4	166,854	0.42%
	G. Specialist Sports	Porsche Panamera	193.5	878,276	2.23%

Fuel Type	Market Segment	Example Model	2001 to 2018		
			gCO_2/km	# registrations	% Total
	H. Dual Purpose	Land Rover Discovery	166.2	3,987,767	10.12%
	I. Multi Purpose	Renault Espace	153.5	2,060,057	5.23%
	All	**Total**	**145.0**	**39,417,828**	**100%**

Direct Emissions from Taxis

5.34. The emission factors for black cabs are based on data provided by Transport for London (TfL)[12] 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).

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

5.36. Emission factors per passenger km for taxis and black cabs are presented in the 'business travel- land' tables of the 2019 GHG Conversion Factors. The base emission factors per vehicle km are also presented in the 'business travel- land' tables of the 2019 GHG Conversion Factors.

5.37. Emission factors for CH_4 and N_2O have been updated for all taxis for the 2019 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 2019 GHG Conversion Factors.

5.38. 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.

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

Direct Emissions from Vans/Light Goods Vehicles (LGVs)

5.39. Average emission factors by fuel, for vans/light good vehicles (LGVs: N1 vehicles, vans up to 3.5 tonnes gross vehicle weight - GVW) and by size (Class I, II or III) are presented in Table 19 and in the "delivery vehicles" section of the 2019 GHG Conversion Factors. The methodology for calculating the CO2 emissions factors for different LGV size classes (from the average LGV values based on NAEI datasets) has been amended for this year's update, also for consistency with changes made to the dataset on payload capacity (see later section of this report on the freight emissions factors for vans/LGVs). In previous years (up to the 2018 update) older data from the NAEI (now no longer available) was used to estimate the relative performance of vans of different size classes.

5.40. Emission factors for petrol and diesel vans/LGVs are based upon emission factors and vehicle km for average sized LGVs from the NAEI for 2017. CO_2 emissions factors for different size classes are estimated relative to quantitative analysis of (EEA, 2019a) datasets, as outlined below in more detail. 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.

5.41. The dataset used to allocate different vehicles to each van class is based on reference weight (approximately equivalent to kerb weight plus 60kg). Previously (up to the 2018 update) this was based on an extraction for a single year from the SMMT MVRIS (Motor Vehicle Registration Information System) database. The new dataset used from this 2019 update has now been updated to be based on data from the monitoring of European new vehicle CO2 emissions (EEA, 2019a) from 2012 (the first year for which data was available) to the most recent year available (currently 2017). The assumed split of petrol and diesel van stock between size classes uses the split of registrations from this dataset. The relative CO_2 emissions performance of different petrol/diesel van size categories is based on a registrations-weighted average from this dataset. This change in dataset/methodology has resulted in significant changes in the absolute CO_2 emissions, and relative differences, by van size class. However, the new data are based on a more recent and extensive dataset, so should be much more representative of the current UK fleet. Importantly, this dataset is consistent with the new data used to calculate the average van loading capacity from 2019 (see later section on van freight emission factors), and will be updatable in future years as new data becomes available from the EEA CO_2 monitoring databases.

5.42. In the 2019 GHG Conversion Factors, CO_2 emission factors for CNG and LPG vans are calculated from the emission factors for conventionally fuelled vans using the same methodology as for passenger cars. The average van emission factor is calculated on the basis of the relative NAEI vehicle km for petrol and diesel vans for 2017, as presented in Table 21.

5.43. Emission factors for CH_4 and N_2O were also updated for all van classes, based on the emission factors from the UK GHG Inventory.

5.44. As a final additional step, an accounting for biofuel use has been included in the calculation of the final vans/LGVs emission factors.

Table 21: New emission factors for vans for the 2019 GHG Conversion Factors

Van fuel	Van size	Direct gCO_2e per km				vkm	Payload Capacity
		CO_2	CH_4	N_2O	Total	% split	Tonnes
Petrol (Class I)	Up to 1.305 tonne	243.8	0.25	0.71	244.8	23.2%	0.53
Petrol (Class II)	1.305 to 1.740 tonne	234.5	0.25	0.71	235.4	73.0%	0.82
Petrol (Class III)	Over 1.740 tonne	395.6	0.25	0.71	396.6	3.8%	1.09
Petrol (average)	**Up to 3.5 tonne**	**242.8**	**0.25**	**0.71**	**243.8**	**100.0%**	**0.76**
Diesel (Class I)	Up to 1.305 tonne	152.6	0.01	1.84	154.5	4.7%	0.49
Diesel (Class II)	1.305 to 1.740 tonne	199.1	0.01	1.84	201.0	23.7%	0.85
Diesel (Class III)	Over 1.740 tonne	285.1	0.01	1.84	287.0	71.7%	1.10
Diesel (average)	**Up to 3.5 tonne**	**258.6**	**0.01**	**1.84**	**260.5**	**100.0%**	**1.01**
LPG	Up to 3.5 tonne	271.6	0.04	0.84	272.4	**100.0%**	1.01
CNG	Up to 3.5 tonne	245.7	1.27	0.84	247.8	**100.0%**	1.01
Average		**258.1**	**0.0**	**1.8**	**259.9**	**100.0%**	**1.01**

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

5.45. As outlined earlier for cars, since the number of electric cars and vans (xEVs[13]) 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.

5.46. 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.

[13] 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).

5.47. It should be noted that only models with registrations in the UK fleet up to the end of 2016 are included in the model.

5.48. Table 22 provides a summary of the vans models registered into the UK market by the end of 2017 (the most recent data year for the source EEA CO_2 monitoring database at the time of the development of the 2019 GHG Conversion Factors). At this point there are only battery electric vehicle (BEV) models available in the vans marketplace.

Table 22: xEV van models and their allocation to different size categories

Make	Model	Van Segment	BEV	PHEV
CITROEN	BERLINGO	Class II	Yes	-
FORD	TRANSIT CONNECT	Class III	Yes	-
GOUPIL	G4	Class I	Yes	-
IVECO	DAILY	Class III	Yes	-
MERCEDES	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 2017

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

Direct Emissions from Buses

5.50. The 2015 and earlier updates used data from DfT from the Bus Service Operators Grant (BSOG) in combination with DfT bus activity statistics (vehicle km, passenger km, average passenger occupancy) to estimate emission factors for local buses. DfT holds very accurate data on the total amount of money provided to bus service operators under the scheme, which provides a fixed amount of financial support per unit of fuel consumed. Therefore, the total amount of fuel consumed (and hence CO_2 emissions) could be calculated from this, which when combined with DfT statistics on total vehicle km, bus occupancy and passenger km allows the calculation of emission factors[14].

5.51. 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:

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

b) 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.

5.52. In the 2018 update, an additional calculation was also added to the emission factors for buses to account for additional direct CO_2 emissions resulting from the use of a technology developed to enable manufacturers to meet recent diesel engine emissions standards for NO_x, known as selective catalytic reduction (SCR). This technology uses a urea solution (also known as 'AdBlue') to effectively remove NO_x and NO_2 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 NO_x 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 are included in the estimates for overall CO_2 emission factors for buses. A summary of the key assumptions used in the calculation of emissions from urea is provided in the following Table 23. These are based on assumptions in the EMEP/EEA Emissions Inventory Guidebook.

[14] 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.

Table 23: Key assumptions used in the calculation of CO_2 emissions from Urea (aka 'AdBlue') use

	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%
Euro VI	0.238	100%	3.5%

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

5.53. 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
d) Average bus emission factor = Average fuel consumption x Fuel Emission Factor ($kgCO_2e$/litre) + Average Emission Factor from Urea Use

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

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

5.56. Emission factors for CH_4 and N_2O are based on the emission factors from the UK GHG Inventory. These factors are also presented together with an overall total factor in Table 24.

5.57. Table 24 gives a summary of the 2019 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.

Table 24: Emission factors for buses for the 2019 GHG Conversion Factors

Bus type	Average passenger occupancy	gCO2e per passenger km			
		CO_2	CH_4	N_2O	Total
Local bus (not London)	9.57	119.74	0.03	0.99	120.76
Local London bus	20.15	81.63	0.01	0.44	82.08
Average local bus	**12.24**	**103.91**	**0.03**	**0.77**	**104.71**
Coach*	17.56	27.28	0.02	0.49	27.79

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.

Direct Emissions from Motorcycles

5.58. Data from type approval is not currently readily available for motorbikes and CO_2 emission measurements were only mandatory in motorcycle type approval from 2005.

5.59. For the practical purposes of the GHG Conversion Factors, emission factors for motorcycles are split into 3 categories:

a) Small motorbikes (mopeds/scooters up to 125cc);
b) Medium motorbikes (125-500cc); and
c) Large motorbikes (over 500cc).

5.60. Since the 2009 update the emission factors have been calculated based on a large dataset kindly provided by (Clear, 2008)[15], based on a mix of magazine road test reports and user reported data. A summary is presented in Table 25, with the corresponding complete emission factors developed for motorcycles presented in the 'Passenger vehicles' tables of the 2019 GHG Conversion Factors. The total average has been calculated weighted by the relative number of registrations of each category according to DfT licencing statistics for 2018 (DVLA, 2019).

5.61. 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 ACEM[16] (+9%) is smaller than the corresponding differential previously used to uplift cars and vans test cycle data to real-world equivalents (+15%).

5.62. Emission factors for CH_4 and N_2O were updated for the 2019 GHG Conversion Factors based on the emission factors from the 2017 UK GHG Inventory (Ricardo

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

[16] The European Motorcycle Manufacturers Association

Energy & Environment, 2019). These factors are also presented together with overall total emission factors in the tables of the 2019 GHG Conversion Factors.

Table 25: Summary dataset on CO_2 emissions from motorcycles based on detailed data provided by Clear (2008)

CC Range	Model Count	Number	Av. gCO_2/km	Av. MPG*
Up to 125cc	24	58	85.0	76.5
125cc to 200cc	3	13	77.8	83.5
200cc to 300cc	16	57	93.1	69.8
300cc to 400cc	8	22	112.5	57.8
400cc to 500cc	9	37	122.0	53.3
500cc to 600cc	24	105	139.2	46.7
600cc to 700cc	19	72	125.9	51.6
700cc to 800cc	21	86	133.4	48.8
800cc to 900cc	21	83	127.1	51.1
900cc to 1000cc	35	138	154.1	42.2
1000cc to 1100cc	14	57	135.6	48.0
1100cc to 1200cc	23	96	136.9	47.5
1200cc to 1300cc	9	32	136.6	47.6
1300cc to 1400cc	3	13	128.7	50.5
1400cc to 1500cc	61	256	132.2	49.2
1500cc to 1600cc	4	13	170.7	38.1
1600cc to 1700cc	5	21	145.7	44.6
1700cc to 1800cc	3	15	161.0	40.4
1800cc to 1900cc	0	0		0.0
1900cc to 2000cc	0	0		0.0
2000cc to 2100cc	1	5	140.9	46.2
<125cc	**24**	**58**	**85.0**	**76.5**
126-500cc	**3**	**13**	**77.8**	**83.5**
>500cc	**16**	**57**	**93.1**	**69.8**
Total	303	1179	116.7	55.7

Note: Summary data based on data provided by Clear (www.clear-offset.com) from a mix of magazine road test reports and user reported data. * MPG has been calculated from the supplied gCO_2/km dataset, using the fuel properties for petrol from the latest conversion factors dataset.

Direct Emissions from Passenger Rail

5.63. Emission factors for passenger rail services have been updated and provided in the “Business travel – land” section of the 2019 GHG Conversion Factors. These include updates to the national rail, international rail (Eurostar), light rail schemes and the London Underground. Emission factors for CH_4 and N_2O emissions were also updated in the 2019 GHG Conversion Factors. These factors are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

5.64. The international rail factor is based on a passenger-km weighted average of the emission factors for the following Eurostar routes: London-Brussels, London-Paris, London-Marne Le Vallee (Disney), London-Avignon and the ski train from London-Bourg St Maurice[17]. The emission factors were provided by Eurostar for the 2019 update, together with information on the basis of the electricity figures used in their calculation.

5.65. The methodology applied in calculating the Eurostar emission factors currently uses 3 key pieces of information:

a) Total electricity use by Eurostar trains on the UK and France/Belgium track sections;

b) Total passenger numbers (and therefore calculated passenger km) on all Eurostar services;

c) Emission factors for electricity (in $kgCO_2$ per kWh) for the UK and France/Belgium journey sections. These are based on the UK grid average electricity from the GHG Conversion Factors and the France/Belgium grid averages from the last freely available version of the IEA CO_2 Emissions from Fuel Combustion highlights dataset (from 2013).

5.66. The new figure from Eurostar is 5.922 gCO_2/pkm.

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

National Rail

5.68. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2017-18. The factor is sourced from information from the Office of the Rail Regulator's National rail trends for 2017-18 (ORR, 2019). This has been calculated based on total electricity and diesel consumed by the railways for the year sourced from the Association of Train Operating Companies (ATOC), and the total number of passenger kilometres (from National Rail Trends).

5.69. CH_4 and N_2O emission factors have been estimated from the corresponding emissions factors for electricity generation and diesel rail (from the UK GHG Inventory), proportional to the CO_2 emission factors. The emission factors were calculated based on the relative passenger km proportions of diesel and electric rail provided by DfT for 2006-2007 (since no newer datasets are available from DfT).

Light Rail

5.70. 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 26.

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

5.71. Figures for the London Overground and Croydon Tramlink for 2017/18 are based on figures kindly provided by TfL, adjusted to the new 2019 grid electricity CO_2 emission factor.

5.72. 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 statistics (DfT, 2019a) and the new 2019 grid electricity CO_2 emission factor.

5.73. The factor for the Glasgow Underground was calculated based on the annual passenger km data from DfT's Glasgow Underground statistics, and the new 2019 grid electricity CO_2 emission factor.

5.74. 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 26).

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

Table 26: GHG emission factors, electricity consumption and passenger km for different tram and light rail services

	Type	Electricity use	gCO₂e per passenger km				Million pkm
		kWh/pkm	CO_2	CH_4	N_2O	Total	
DLR (Docklands Light Rail)	Light Rail	0.113	31.16	0.08	0.17	31.41	**643.60**
Glasgow Underground	Light Rail	0.164	45.20	0.12	0.24	45.56	**40.44**
Midland Metro	Light Rail	0.135	37.22	0.09	0.20	37.52	**59.90**
Tyne and Wear Metro	Light Rail	0.389	107.00	0.27	0.58	107.85	**317.10**
London Overground	Light Rail	0.078	21.57	0.05	0.12	21.74	**1,480.22**
London Tramlink	Tram	0.108	29.82	0.08	0.16	30.06	**153.56**
Manchester Metrolink	Tram	0.078	21.58	0.05	0.12	21.75	**430.90**
Sheffield Supertram	Tram	0.350	96.29	0.25	0.52	97.06	**79.90**
Average* or Total		**0.126**	**34.80**	**0.09**	**0.19**	**35.07**	**3,206**

Notes: * Weighted by relative passenger km

London Underground

5.76. The London Underground rail factor was provided from DfT, which was based on the 2019 UK electricity emission factor, so was therefore adjusted to be consistent with the 2019 grid electricity CO_2 emission factor.

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

Indirect/WTT Emissions from Passenger Land Transport

Cars, Vans, Motorcycles, Taxis, Buses and Ferries

5.78. 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 CO_2 emission factors and the indirect/WTT emission factors for the relevant fuels from the “Fuels” section and the corresponding direct CO_2 emission factors for vehicle types using these fuels in the “Passenger vehicles”, “Business travel – land” and “Business travel – air” sections in the 2019 GHG Conversion Factors.

Rail

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

5.80. 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

Section summary

6.1. This section describes the calculation of the conversion factors for transport of freight on land (road and rail). Scope 1 factors included are for delivery vehicles owned or controlled by the reporting organisation. Scope 3 factors are described for freighting goods over land through a third-party company, including factors for both the whole vehicle's worth of goods or per tonne of goods shipped. WTT factors for both delivery vehicles owned by the reporting organisation and for freighting goods via a third party. Factors for managed assets (vans/LGVs, HGVs) are also detailed in this section.

6.2. Table 27 shows where the related worksheets to the freight land transport emission factors are available in the online sets of the factors.

Table 27 Related worksheets to freight land transport emission factors

Worksheet name	Full set	Condensed set
Delivery vehicles	Y	N
Freighting goods*	Y	Y
WTT – delivery vehicles & freight*	Y	N
Managed assets – vehicles**	Y	Y

Notes: * vans, HGVs and rail only; ** vans and HGVs only

Summary of changes since the previous update

6.3. The assumptions for the average capacities and payloads for LGVs have been replaced with new data, which is more up to date and representative of the UK fleet, and will be more straightforward to update for future years. This is described in paragraph 1.108.

Direct Emissions from Heavy Goods Vehicles (HGVs)

6.4. The HGV factors are based on road freight statistics from the Department for Transport (DfT, 2019c) for Great Britain (GB), from a survey on different sizes of rigid and articulated HGVs in the fleet in 2018. The statistics on fuel consumption figures (in miles per gallon) have been estimated by DfT from the survey data. For the 2019 GHG Conversion Factors, these are combined with test data from the

European ARTEMIS project showing how fuel efficiency, and therefore the CO_2 emissions, varies with vehicle load.

6.5. The miles per gallon (MPG) figures in Table RFS0141 of DfT (2019) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the 2019 GHG Conversion Factors tables. Table RFS0125 of DfT (2019) shows the percent loading factors are on average between 31-64% 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 28 showing the change in CO_2 emissions for a vehicle completely empty (0% load) or fully laden (100% load) on a weight basis compared with the emissions at half-load (50% load). The data show the effect of load is symmetrical and largely independent of the HGVs Euro emission classification and type of drive cycle. So, for example, a >17t rigid HGV emits 18% more CO_2 per kilometre when fully laden and 18% less CO_2 per kilometre when empty relative to emissions at half-load.

6.6. The 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 an 18% uplift applied. This is based on average data for different sizes of refrigerated HGV from (Tassou, S.A., et al., 2009). This accounts for the typical additional energy needed to power refrigeration equipment in such vehicles over similar non-refrigerated alternatives (AEA/Ricardo, 2011).

Table 28: Change in CO_2 emissions caused by +/- 50% change in load from average loading factor of 50%

	Gross Vehicle Weight (GVW)	% change in CO_2 emissions
Rigid	<7.5t	± 8%
	7.5-17t	± 12.5%
	>17 t	± 18%
Articulated	<33t	± 20%
	>33t	± 25%

Source: EU-ARTEMIS project

6.7. Using these loading factors, the CO_2 factors derived from the DfT survey's MPG data, each corresponding to different average states of HGV loading, were corrected to derive the 50% laden CO_2 factor shown for each class of HGV. These are shown in the final factors presented in sections "Delivery vehicles" and "Freighting goods" of the 2019 GHG Conversion Factors.

6.8. The loading factors in Table 28 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in the above sections. Because the effect of vehicle loading on CO_2 emissions is linear with load (according to the ARTEMIS data), then these factors can be linearly interpolated if a more precise figure on vehicle load is known. For example, an HGV running at 75% load would have a CO_2 factor halfway between the values for 50% and 100% laden factors.

6.9. It might be surprising to see that the CO_2 factor for a >17t rigid HGV is greater than for a >33t articulated HGV. However, these factors merely reflect the estimated MPG figures from DfT statistics that consistently show worse MPG fuel efficiency, on average, for large rigid HGVs than large articulated HGVs once the relative degree of loading is accounted for. This is likely to be a result of the usage pattern for different types of HGVs where large rigid HGVs may spend more time travelling at lower, more congested urban speeds, operating at lower fuel efficiency than articulated HGVs which spend more time travelling under higher speed, free-flowing traffic conditions on motorways where fuel efficiency is closer to optimum. Under the drive cycle conditions more typically experienced by large articulated HGVs, the CO_2 factors for large rigid HGVs may be lower than indicated in “Delivery vehicles” and “Freighting goods” of the 2019 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.

6.10. UK average factors for all rigid and articulated HGVs are also provided in sections “Delivery vehicles” and “Freighting goods” of the 2019 GHG Conversion Factors if the user requires aggregate factors for these main classes of HGVs, perhaps because the weight class of the HGV is not known. Again, these factors represent averages for the GB HGV fleet in 2017. These are derived directly from the mpg values for rigid and articulated HGVs in Table RFS0141of DfT (2018).

6.11. 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 CO_2 emissions in, for example, inter-modal freight transport comparisons.

6.12. The conversion factors included in “Delivery vehicles” in the 2019 GHG Conversion Factors are provided in distance units to enable CO_2 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.

6.13. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO_2 factors in tonne km (tkm) units. The “Freighting goods” section of the 2019 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 gCO_2 per vehicle km factors in “Delivery vehicles”. The average tonne freight lifted figures are derived from the tkm and vehicle km (vkm) figures given for each class of HGV in Tables RFS0113 and RFS0110, 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 45%. The 2019 GHG Conversion Factors, include factors in tonne km (tkm) for all loads (0%, 50%, 100% and average).

6.14. 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 CO_2 emissions are calculated from these factors by multiplying the number of tkm the user has for the distance and weight of the goods being moved by the CO_2 conversion factor in “Freighting goods” of the 2019 GHG Conversion Factors for the relevant HGV class.

6.15. Emission factors for CH_4 and N_2O have been updated for all HGV classes. These are based on the emission factors from the 2017 UK GHG Inventory. CH_4 and N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for HGVs. These factors are presented with an overall total factor in sections “Delivery vehicles” and “Freighting goods” of the 2019 GHG Conversion Factors.

6.16. Emissions from the consumption of urea to control NO_x exhaust emissions (in SCR systems) in HGVs are included in the estimates for overall CO_2 emission factors. The method for this is the same as for buses, as described in the section “Direct emissions from Buses”.

Direct Emissions from Vans/Light Goods Vehicles (LGVs)

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

6.18. The typical / average capacities and average payloads that are used in the calculation of van emission factors per tonne km are presented in Table 29. There was a methodology update from 2019, with a revision to the dataset used to calculate the average payload capacities. Previously the payload capacity was calculated based on a (now quite old) extract from the SMMT MVRIS database (see also the earlier passenger transport chapter on van emission factors). From 2019, the average payload capacity values are based on quantitative (registrations-weighted) assessment of the EEA new van CO_2 monitoring databases for 2012-2017 registrations in the UK (EEA, 2019a). These databases provide information on the number of registrations for different vehicle makes and models with specifications including also the unloaded (reference) mass of the vehicle and maximum permitted weight rating (i.e. Gross Vehicle Weight, GVW). The change in dataset/methodology has resulted in a significant reduction (of between 13%-25%) in the average payload capacities for different van size classes. However, the new average payload capacities are based on a much larger, more recent and extensive dataset, so should be much more representative of the current UK fleet. In addition, these factors will be updatable in future years as new data becomes available from the EEA CO_2 monitoring databases.

Table 29: Typical van freight capacities and estimated average payload

Van fuel	Van size, Gross Vehicle Weight	Vkm % split	Av. Payload Capacity, tonnes	Av. Payload, tonnes
Petrol (Class I)	Up to 1.305 tonne	23.20%	0.53	0.20
Petrol (Class II)	1.305 to 1.740 tonne	72.96%	0.82	0.30
Petrol (Class III)	Over 1.740 tonne	3.85%	1.09	0.45
Petrol (average)	**Up to 3.5 tonne**		**0.76**	**0.31**
Diesel (Class I)	Up to 1.305 tonne	4.65%	0.49	0.18

Van fuel	Van size, Gross Vehicle Weight	Vkm % split	Av. Payload Capacity, tonnes	Av. Payload, tonnes
Diesel (Class II)	1.305 to 1.740 tonne	23.65%	0.85	0.31
Diesel (Class III)	Over 1.740 tonne	71.70%	1.10	0.45
Diesel (average)	**Up to 3.5 tonne**		**1.01**	**0.41**
LPG (average)	Up to 3.5 tonne		1.01	0.41
CNG (average)	Up to 3.5 tonne		1.01	0.41
Average (unknown fuel)			**1.01**	**0.41**

6.19. The average load factors assumed for different vehicle types used to calculate the average payloads in Table 29 are summarised in Table 30, on the basis of DfT statistics from a survey of company owned vans. No new/more recent datasets have been identified for the average % loading of vans/LGVs for the 2019 update.

Table 30: Utilisation of vehicle capacity by company-owned LGVs: annual average 2003 – 2005 (proportion of total vehicle kilometres travelled)

Average van loading	Utilisation of vehicle volume capacity				
	0-25%	**26-50%**	**51-75%**	**76-100%**	**Total**
Mid-point for van loading ranges	12.5%	37.5%	62.5%	87.5%	
Proportion of vehicles in the loading range					
Up to 1.8 tonnes	45%	25%	18%	12%	**100%**
1.8 – 3.5 tonnes	36%	28%	21%	15%	**100%**
All LGVs	38%	27%	21%	14%	**100%**
Estimated weighted average % loading					
Up to 1.8 tonnes					**36.8%**
1.8 – 3.5 tonnes					**41.3%**
All LGVs					**40.3%**

Notes: Based on information from Table 24, (Allen, J. and Browne, M., 2008)

6.20. Emission factors for CH_4 and N_2O have been updated for all van classes in the 2019 GHG Conversion Factors. These are based on the emission factors from the UK GHG Inventory. N_2O emissions are assumed to scale relative to vehicle class/CO_2 emissions for diesel vans.

6.21. Emission factors per tonne km are calculated from the average load factors for the different weight classes in combination with the average freight capacities of the different vans in Table 29 and the earlier emission factors per vehicle-km in the “Delivery vehicles” and “Freighting goods” sections of the 2019 GHG Conversion Factors.

Direct Emissions from Rail Freight

6.22. The data, used to update the rail freight emission factors for the 2019 GHG Conversion Factors, was provided by the Office of the Rail Regulator's (ORR, 2019a). This factor is presented in "Freighting goods" in the 2019 GHG Conversion Factors.

6.23. The factor can be expected to vary with rail traffic route, speed and train weight. Freight trains are hauled by electric and diesel locomotives, but the vast majority of freight is carried by diesel rail and correspondingly CO_2 emissions from diesel rail freight are over 96% of the total CO_2 from rail freight for 2017-18 (ORR, 2019a).

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

6.25. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for diesel rail from the UK GHG Inventory, proportional to the CO_2 emissions. The emission factors were calculated based on the relative passenger km proportions of diesel and electric rail provided by DfT for 2006-7 in the absence of more suitable tonne km data for freight.

Indirect/WTT Emissions from Freight Land Transport

Vans and HGVs

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

Rail

6.27. 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 CO_2 emissions from traction energy for diesel and electric freight rail provided from ORR in "Table 2.100 Estimates of passenger and freight energy consumption and CO_2e emissions" (ORR, 2019a).

7. Sea Transport Emission Factors

Section summary

7.1. This section contains Scope 3 factors only, relating to direct emissions from transport by sea, and WTT emissions for business travel by sea, and for freighting goods by sea. The business travel factors should be used for passenger ferries used for business trips. The WTT factors relate to emissions from the upstream extraction, refining and transport of fuels before they are used to power the ships.

7.2. Table 31 shows where the related worksheets to the sea transport emission factors are available in the online sets of the factors.

Table 31: Related worksheets to sea transport emission factors

Worksheet name	Full set	Condensed set
Business travel – sea	Y	Y
WTT – business travel – sea	Y	N
Freighting goods*	Y	Y
WTT – delivery vehicles & freight*	Y	N

Notes: * sea tankers and cargo ships only

Summary of changes since the previous update

7.3. There were no major methodological changes in the 2019 submission. Improvements in ferry engine efficiencies have led to a decline in methane emission factors in the passenger-km factors for business travel at sea on the order of 12%.

Direct Emissions from RoPax Ferry Passenger Transport and freight

7.4. 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). No new methodology or updated dataset has been identified for the 2019 GHG Conversion Factors.

7.5. 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.

7.6. From the information provided by the operators, figures for passenger-km, tonne-km and CO_2 emissions were calculated. CO_2 emissions from ferry fuels were allocated between passengers and freight on the basis of tonnages transported, taking into account freight, vehicles and passengers. Some of the assumptions included in the analysis are presented in the following table.

Table 32: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	(MCA, 2017)
Average weight of passenger + luggage, total	0.100	(MCA, 2017)
Average Freight Unit*, total	22.173	(BFF, 2007)[18]
Average Freight Load (per freight unit)*, tonnes	13.624	(DfT, 2006)

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

7.7. CO_2 emissions are allocated to passengers based on the weight of passengers + luggage + cars relative to the total weight of freight including freight vehicles/containers. For the data supplied by the 11 (out of 17) PSA operators this equated to just under 12% of the total emissions of the ferry operations. The emission factor for passengers was calculated from this figure and the total number of passenger-km, and is presented in the “Business travel – sea” section of the 2019 GHG Conversion Factors. A further split has been provided between foot-only passengers and passengers with cars in the 2019 GHG Conversion Factors, again on a weight allocation basis.

7.8. CO_2 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 2019 GHG Conversion Factors tables.

7.9. 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).

7.10. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the 2017 UK GHG Inventory, proportional to the CO_2 emissions.

[18] 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.

Direct Emissions from Other Marine Freight Transport

7.11. CO_2 emission factors for the other representative ships (apart from RoPax ferries discussed above) are now based on information from Table 9-1 of the (IMO, 2009) report on GHG emissions from ships. The figures in “Freighting goods” of the 2019 GHG Conversion Factors represent international average data (i.e. including vessel characteristics and typical loading factors), as UK-specific datasets are not available.

7.12. CH_4 and N_2O emission factors have been estimated from the corresponding emissions for shipping from the 2017 UK GHG Inventory, proportional to the CO_2 emissions.

Indirect/WTT Emissions from Sea Transport

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

8. Air Transport Emission Factors

Section summary

8.1. This section contains Scope 3 factors only, related to direct emissions from and WTT emissions for business travel and freight transport by air. Air transport conversion factors should be used to report Scope 3 emissions for individuals flying for work purposes, and the related WTT factors account for the upstream emissions associated with the extraction, refining and transport of the aviation fuels prior to take-off. For freighting goods, emission factors are provided per tonne.km of goods transported.

8.2. Table 33 shows where the related worksheets to the air transport emission factors are available in the online sets of the factors.

Table 33: Related worksheets to air transport emission factors

Worksheet name	Full set	Condensed set
Business travel – air	Y	Y
WTT – business travel – air	Y	N
Freighting goods*	Y	Y
WTT – delivery vehicles & freight*	Y	N

Notes: * freight flights only

Summary of changes since the previous update

8.3. There are no major changes for the aviation factors in the 2019 update.

Passenger Air Transport Direct CO_2 Emission Factors

8.4. 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 emitter’s tool.

8.5. The 2019 update of the average factors (presented at the end of this section) uses the same updated data source first introduced in 2015. The EUROCONTROL small emitters tool was used as the basis for calculating the CO_2 emissions factors resulting from fuel burn over average flights for different aircraft. The principal advantages of the source are:

a) The tool is based on a methodology designed to estimate the fuel burn for an entire flight, 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.

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

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

8.6. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 34. Key features of the calculation methodology, data and assumptions include:

a) A wide variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights;

b) Average seating capacities, load factors and proportions of passenger km by the different aircraft types (subsequently aggregated to totals for domestic, short- and long-haul flights) have all been calculated from detailed UK Civil Aviation Authority (CAA, 2018) statistics for UK registered airlines for the year 2017 (the most recent complete dataset available at the time of calculation), split by aircraft and route type (Domestic, European Economic Area, other International)[19];

c) Freight transported on passenger services has also been taken into account (with the approach taken summarised in the following section). Accounting for freight makes a significant difference to long-haul factors.

Table 34: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights for 2019

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	Emissions Factor, $kgCO_2$/vkm	Av. flight length, km
Domestic Flights					
AIRBUS A319	152	82%	33%	14.9	445
AIRBUS A320-100/200	175	80%	26%	15.0	476
AIRBUS A321	198	72%	4%	17.6	480
ATR72 200/500/600	70	64%	2%	6.1	226
BOEING 737-800	190	84%	6%	15.1	501
BOEING 767-300ER/F	259	71%	2%	25.8	536
BOMBARDIER DASH 8 Q400	78	71%	19%	7.1	393
EMB ERJ170 (170-100)	83	70%	1%	10.6	419
EMBRAER ERJ190	106	69%	5%	12.5	445

[19] 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
SAAB 2000	35	74%	2%	6.7	371
SAAB FAIRCHILD 340	23	76%	1%	3.8	308
Average	***142***	***78%***	***100%*(total)***	***11.1***	***407***
Short-haul Flights					
AIRBUS A319	153	82%	12%	11.4	1,033
AIRBUS A320-100/200	180	80%	26%	11.3	1,355
AIRBUS A321	215	82%	12%	12.6	1,840
AIRBUS A330-200	352	85%	0%	22.4	2,390
AIRBUS A330-300	298	71%	0%	23.1	2,453
AIRBUS A350-900	298	82%	0%	27.1	1,851
ATR72 200/500/600	71	68%	0%	5.2	383
AVROLINER RJ85	94	71%	0%	13.6	523
BOEING 737-300	152	87%	1%	11.6	1,614
BOEING 737-400	85	77%	0%	11.9	1,776
BOEING 737-700	135	79%	1%	11.2	990
BOEING 737-800	189	87%	37%	11.5	1,522
BOEING 737-900	176	85%	0%	12.9	1,017
BOEING 757-200	177	89%	4%	14.7	2,345
BOEING 757-300	277	90%	1%	16.3	2,704
BOEING 767-300ER/F	220	78%	1%	20.6	1,806
BOEING 777-200	223	74%	0%	28.2	1,949
BOEING 777-300	357	75%	1%	30.5	2,840
BOEING 787-800 DREAMLINER	293	93%	0%	19.6	2,655
BOMBARDIER DASH 8 Q400	78	71%	0%	6.5	540
EMB ERJ170 (170-100)	85	74%	0%	8.9	722
EMBRAER ERJ190	105	72%	1%	10.2	879
Average	***185***	***84%***	***100%*(total)***	***11.8***	***1,335***
Long-haul Flights					
AIRBUS A310	246	82%	0%	18.5	5,488
AIRBUS A320-100/200	171	81%	1%	10.5	2,450
AIRBUS A321	158	81%	0%	11.8	3,592
AIRBUS A330-200	281	80%	5%	20.9	6,590
AIRBUS A330-300	278	78%	4%	21.7	6,294
AIRBUS A340-300	267	79%	1%	24.9	9,990
AIRBUS A340-600	307	81%	1%	31.7	6,021
AIRBUS A350-900	291	76%	2%	23.6	7,564
AIRBUS A380-800	499	82%	17%	47.0	6,968
BOEING 737-800	164	70%	0%	10.3	4,203
BOEING 747-400	344	81%	12%	38.1	6,928

	Av. No. Seats	Av. Load Factor	Proportion of passenger km	Emissions Factor, $kgCO_2/vkm$	Av. flight length, km
BOEING 757-200	170	74%	1%	14.4	5,487
BOEING 767-300ER/F	201	76%	4%	19.1	6,050
BOEING 777-200	246	80%	13%	25.6	6,738
BOEING 777-300	340	81%	16%	28.7	7,393
BOEING 777-300ER	300	83%	3%	30.6	8,546
BOEING 787-800 DREAMLINER	254	82%	9%	18.4	6,833
BOEING 787-900 DREAMLINER	263	82%	10%	19.8	7,517
Weighted average	***322***	***81%***	***100%*(total)***	***26.9***	***6,723***

Notes: Figures on seats, load factors, % tkm and av. flight length have been calculated from 2018 CAA statistics for UK registered airlines for the different aircraft types. Figures of $kgCO_2/vkm$ were calculated using the average flight lengths in the EUROCONTROL small emitters tool. * 100% denotes the pkm share of the aircraft included in the assessment - as listed in the table. The aircraft listed in the table above account for 93% of domestic pkm, 100% of short-haul pkm and 100% of long-haul pkm.

Allocating flights into short- and long-haul:

8.7. 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.

8.8. The current preferred definition is to assume that all fights to 'Europe' (or those of similar distance, up to a 3,700km maximum) are short-haul, and those that are to non-European destinations (or for flights over 3,700km) should be counted as long-haul. Some examples of such 'long-haul' flights have been provided in the following Table 35, 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.

Table 35: Illustrative short- and long- haul flight distances from the UK

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**

Area	Destination Airport	Distance, km
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

8.9. Aviation factors are also included for international flights between non-UK destinations. 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 factors[20].

Taking Account of Freight

8.10. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers and their luggage, as well as freight. The CAA data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights. In fact, the quantity of freight carried on scheduled long-haul passenger flights is nearly 8 times higher than the quantity of freight carried on scheduled long-haul cargo services.

8.11. The CAA data provides a split of tonne km for freight and passengers (plus luggage) by airline for both passenger and cargo services. This data may be used as a basis for an allocation methodology. There are essentially three options, with the resulting emission factors presented in Table 36:

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 CO_2 **between passengers and freight**. However, in this case, the derived emission factors for freight are significantly higher than those derived for dedicated cargo services using similar aircraft.

[20] 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.

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.

Table 36: CO_2 emission factors for alternative freight allocation options for passenger flights based on 2019 GHG Conversion Factors

Freight Weighting:	None		Option 1: Direct		Option 2: Equivalent	
Mode	Passenger tkm % of total	gCO_2 /pkm	Passenger tkm % of total	gCO_2 /pkm	Passenger tkm % of total	gCO_2 /pkm
Domestic flights	100.00%	123.9	99.76%	123.6	99.76%	123.6
Short-haul flights	100.00%	78.9	97.77%	76.8	97.77%	76.8
Long-haul flights	100.00%	111.5	34.48%	41.6	85.65%	94.9

8.12. The basis of the freight weighting **Option 2** is to take account of the supplementary equipment (such as seating, galley) and other weight for passenger aircraft compared to dedicated cargo aircraft in the allocation. 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 2019 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 36.

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

8.14. **Option 2** is the preferred methodology to allocate emissions between passengers and freight, **Option 1** is included for information only.

8.15. Validation checks using the derived emission factors calculated using the EUROCONTROL small emitters tool and CAA flights data have shown a very close comparison in derived CO_2 emissions with those from the UK GHG Inventory (which is scaled using actual fuel supplied).

8.16. The final average emission factors for aviation are presented in Table 37. The figures in Table 37 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 2019 GHG Conversion Factor data tables.

Table 37: Final average CO_2 emission factors for passenger flights for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Mode	Factors for 2019	
	Load Factor%	gCO_2/pkm
Domestic flights	77.7%	123.6
Short-haul flights	83.5%	76.8
Long-haul flights	80.6%	94.9

Notes: Load factors based on data provided by DfT that contains detailed analysis of CAA statistics for the year 2017

Taking Account of Seating Class Factors

8.17. The efficiency of aviation per passenger km is influenced not only by the technical performance of the aircraft fleet, but also by the occupancy/load factor of the flight. Different airlines provide different seating configurations that change the total number of seats available on similar aircraft. Premium priced seating, such as in First and Business class, takes up considerably more room in the aircraft than economy seating and therefore reduces the total number of passengers that can be carried. This in turn raises the average CO_2 emissions per passenger km.

8.18. There is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, 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 38, together with additional information obtained either directly from airline websites or from other specialist websites that had already collated such information for most of the major airlines.

8.19. For long-haul flights, the relative space taken up by premium seats can vary by a significant degree between airlines and aircraft types. The variation is at its most extreme for First class seats, which can account for from 3 to over 6 times[21] the space taken up by the basic economy seating. Table 38 shows the seating class-based emission factors, together with the assumptions made in their calculation. An indication is also provided of the typical proportion of the total seats that the different classes represent in short- and long-haul flights. The effect of the scaling is to lower the economy seating emission factor in relation to the average, and increase the business and first class factors.

8.20. The relative share in the number of seats by class for short-haul and long-haul flights was updated/revised in 2015 using data provided by DfT's aviation team,

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

following checks conducted by them on the validity of the current assumptions based on more recent data.

Table 38: CO_2 emission factors by seating class for passenger flights for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Flight type	Cabin Seating Class	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Weighted average**	**77.7%**	**123.6**	**1.00**	**100.0%**	**100.0%**
Short-haul	**Weighted average**	**83.5%**	**76.8**	**1.02**	**100.0%**	**100.0%**
	Economy class	83.5%	75.5	1.00	98.4%	96.7%
	First/Business class	83.5%	113.3	1.50	147.5%	3.3%
Long-haul	**Weighted average**	**80.6%**	**94.9**	**1.31**	**100.0%**	**100.0%**
	Economy class	80.6%	72.6	1.00	76.6%	83.0%
	Economy+ class	80.6%	116.2	1.60	122.5%	3.0%
	Business class	80.6%	210.7	2.90	222.1%	11.9%
	First class	80.6%	290.6	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 2017

Freight Air Transport Direct CO_2 Emission Factors

8.21. 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.

8.22. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2019). These data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts approximately for 82% of all long-haul air freight transport. How this freight carried on long-haul passenger services is treated has a significant effect on the average emission factor for all freight services.

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

Emission Factors for Dedicated Air Cargo Services

8.24. Table 39 presents average emission factors for dedicated air cargo. 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 2019 GHG Conversion Factor data tables.

Table 39: Revised average CO_2 emission factors for dedicated cargo flights for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Mode	Factors for 2019	
	Load Factor%	$kgCO_2$/tkm
Domestic flights	52.5%	2.5
Short-haul flights	74.3%	1.0
Long-haul flights	73.9%	0.6

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)

8.25. The updated factors have been calculated in the same basic methodology as for the passenger flights, which was updated in 2015 to use the aircraft specific fuel consumption/emission factors calculated using the EUROCONTROL small emitters tool (EUROCONTROL, 2019). A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 40. 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 2017 (the latest available complete dataset) (CAA, 2019).

Table 40: Assumptions used in the calculation of average CO_2 emission factors for dedicated cargo flights for the 2019 GHG Conversion Factors

	Average Cargo Capacity, tonnes	Av. Load Factor	Proportion of tonne km	EF, $kgCO_2$ /vkm	Av. flight length, km
Domestic Flights					
BAE ATP	8.0	47%	0.0%	0.00	153
BAE 146-200/QT	10.0	34%	0.0%	0.00	153
BOEING 737-300	15.2	45%	32.9%	26.20	156
BOEING 757-200	23.2	56%	64.6%	23.72	149
BOEING 747-8 (FREIGHTER)	126.9	19%	0.0%	0.00	153
BOEING 767-300ER/F	58.0	53%	2.5%	26.63	484
Average	***21.4***	***53%***	***100%***	***24.95***	***379***
Short-haul Flights					
BAE ATP	8.0	43%	0.0%	0.00	734

	Average Cargo Capacity, tonnes	Av. Load Factor	Proportion of tonne km	EF, $kgCO_2$ /vkm	Av. flight length, km
BOEING 737-400	15.0	45%	5.6%	14.63	581
BOEING 757-200	22.0	77%	80.8%	16.12	718
BOEING 747-8 (FREIGHTER)	124.3	33%	0.8%	54.52	630
Average	***23.5***	***74%***	***100%***	***16.44***	***1,432***
Long-haul Flights					
BAE ATP	8.0	16%	0.0%	0.00	3500
BOEING 737-400	21.6	79%	7.1%	15.28	1242
BOEING 757-200	129.4	73%	48.6%	37.75	4731
BOEING 747-8 (FREIGHTER)	29.6	74%	44.3%	19.25	4824
Average	***77.6***	***74%***	***100%***	***21.89***	***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 2017. Figures of $kgCO_2$/vkm were calculated using the average flight lengths in the EUROCONTROL small emitters tool (EUROCONTROL, 2019).

Emission Factors for Freight on Passenger Services

8.26. The CAA data provides a similar breakdown for freight on passenger services as it does for cargo services. As already discussed earlier, the statistics give tonne-km data for passengers and for freight. This information has been used in combination with the assumptions for the earlier calculation of passenger emission factors to calculate the respective total emission factor for freight carried on passenger services. These emission factors are presented in Table 41 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 2019 GHG Conversion Factor data tables (discussed later).

Table 41: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Freight Weighting: Mode	% Total Freight tkm		Option 1: Direct		Option 2: Equivalent	
	Passenger Services (PS)	Cargo Services	PS Freight tkm, % total	Overall $kgCO_2$ /tkm	PS Freight tkm, % total	Overall $kgCO_2$ /tkm
Domestic flights	4.7%	95.3%	0.2%	2.4	0.2%	2.4
Short-haul flights	22.8%	77.2%	2.2%	1.2	2.2%	1.2
Long-haul flights	81.7%	18.3%	65.5%	2.0	14.3%	0.5

8.27. 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.

8.28. **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 2019.

Average Emission Factors for All Air Freight Services

8.29. Table 42 presents the final average air freight emission factors for all air freight for the 2019 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 2019 GHG Conversion Factor data tables (discussed later).

Table 42: Final average CO_2 emission factors for all air freight for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Mode	% Total Air Freight tkm		All Air Freight $kgCO_2/tkm$
	Passenger Services	Cargo Services	
Domestic flights	4.7%	95.3%	2.4
Short-haul flights	22.8%	77.2%	1.2
Long-haul flights	81.7%	18.3%	0.5

Notes: % Total Air Freight tkm based on CAA statistics for 2017 (T0.1.6 All Services)

Air Transport Direct Emission Factors for CH_4 and N_2O

Emissions of CH_4

8.30. Total emissions of CO_2, CH_4 and N_2O are calculated in detail and reported at an aggregate level for aviation as a whole are reported from the UK GHG inventory. Therefore, the relative proportions of total CO_2 and CH_4 emissions from the UK GHG inventory for 2017 (see Table 43) were used to calculate the specific CH_4 emission factors per passenger km or tonne-km relative to the corresponding CO_2 emission factors. The resulting air transport emission factors for the 2019 GHG Conversion Factors are presented in Table 44 for passengers and Table 45 for freight.

Table 43: Total emissions of CO_2, CH_4 and N_2O for domestic and international aircraft from the UK GHG inventory for 2017

	CO_2		CH_4		N_2O	
	Mt CO_2e	% Total CO_2e	Mt CO_2e	% Total CO_2e	Mt CO_2e	% Total CO_2e
Aircraft - domestic	1.61	98.97%	0.0014	0.09%	0.015	0.94%
Aircraft - international	34.45	99.06%	0.0025	0.01%	0.326	0.94%

Emissions of N_2O

8.31. Similar to those for CH_4, emission factors for N_2O per passenger-km or tonne-km were calculated on the basis of the relative proportions of total CO_2 and N_2O emissions from the UK GHG inventory for 2017 (see Table 43), and the corresponding CO_2 emission factors. The resulting air transport emission factors for the 2019 GHG Conversion Factors are presented in Table 44 for passengers and Table 45 for freight. The factors presented here do not include the distance or radiative forcing uplifts applied to the emission factors provided in the 2019 GHG Conversion Factor data tables (discussed later).

Table 44: Final average CO_2, CH_4 and N_2O emission factors for all air passenger transport for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Air Passenger Mode	Seating Class	CO_2 gCO_2/pkm	CH_4 gCO_2e/pkm	N_2O gCO_2e/pkm	Total GHG gCO_2e/pkm
Domestic flights	**Average**	**123.6**	**0.1**	**1.2**	**124.8**
Short-haul flights	**Average**	**76.8**	**0.0**	**0.7**	**77.5**
	Economy	75.5	0.0	0.7	76.2
	First/Business	113.3	0.0	1.1	114.4
Long-haul flights	**Average**	**94.9**	**0.0**	**0.9**	**95.8**
	Economy	72.6	0.0	0.7	73.3
	Economy+	116.2	0.0	1.1	117.3
	Business	210.7	0.0	2.0	212.7
	First	290.6	0.0	2.7	293.3
International flights (non-UK)	**Average**	**87.7**	**0.0**	**0.8**	**88.5**
	Economy	67.1	0.0	0.6	67.8
	Economy+	107.4	0.0	1.0	108.4
	Business	194.7	0.0	1.8	196.5
	First	268.5	0.0	2.5	271.1

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

Table 45: Final average CO_2, CH_4 and N_2O emission factors for air freight transport for 2019 GHG Conversion Factors (excluding distance and RF uplifts)

Air Freight Mode	CO_2 $kgCO_2/tkm$	CH_4 $kgCO_2e/tkm$	N_2O $kgCO_2e/tkm$	Total GHG $kgCO_2e/tkm$
Passenger Freight				
Domestic flights	1.83	0.0016	0.0173	1.85
Short-haul flights	1.61	0.0001	0.0152	1.63
Long-haul flights	0.53	0.0000	0.0050	0.53
Dedicated Cargo				
Domestic flights	2.45	0.0022	0.0232	2.48
Short-haul flights	1.02	0.0001	0.0096	1.03
Long-haul flights	0.65	0.0000	0.0061	0.65
All Air Freight				
Domestic flights	2.42	0.0022	0.0229	2.45
Short-haul flights	1.15	0.0001	0.0109	1.16
Long-haul flights	0.55	0.0000	0.0052	0.55

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

Indirect/WTT Emission Factors from Air Transport

8.32. Indirect/WTT emissions factors for air passenger and air freight services include only emissions resulting from the fuel lifecycle (i.e. production and distribution of the relevant transport fuel). These indirect/WTT emission factors were derived using simple ratios of the direct CO_2 emission factors and the indirect/WTT emission factors for aviation turbine fuel (kerosene) and the corresponding direct CO_2 emission factors for air passenger and air freight transport in sections “Business travel – air” and “Freighting goods”.

Other Factors for the Calculation of GHG Emissions

Great Circle Flight Distances

8.33. We wish to see standardisation in the way that emissions from flights are calculated in terms of the distance travelled and any uplift factors applied to account for circling and delay. However, we acknowledge that a number of methods are currently used.

8.34. An 8% uplift factor is used in the UK Greenhouse Gas Inventory to scale up Great Circle distances (GCD) for flights between airports to take into account indirect flight paths and delays, etc. This is lower than the 9-10% suggested by IPCC Aviation and the global atmosphere, and has been agreed with DfT based on recent analysis as more appropriate for flights arriving and departing from the UK. This factor has been used since the 2014 update of both the GHGI, and the GHG Conversion Factors.

8.35. It is not practical to provide a database of origin and destination airports to calculate flight distances in the GHG Conversion Factors. However, the principal of adding a factor of 8% to distances calculated on a Great Circle is recommended (for consistency with the existing approach) to take 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 2019 GHG Conversion Factors tables.

Non-CO_2 impacts and Radiative Forcing

8.36. The emission factors provided in the 2019 GHG Conversion Factors sections "Business travel – air" and "Freighting goods" refer to aviation's direct CO_2, CH_4 and N_2O emissions only. There is currently uncertainty over the other non-CO_2 climate change effects of aviation (including water vapour, contrails, NO_X, etc.) which have been indicatively accounted for by applying a multiplier in some cases.

8.37. Currently there is no suitable climate metric to express the relationship between emissions and climate warming effects from aviation, but this is an active area of research. Nonetheless, it is clear that aviation imposes other effects on the climate which are greater than that implied from simply considering its CO_2 emissions alone.

8.38. The application of a 'multiplier' to take account of non-CO_2 effects is a possible way of illustratively taking account of the full climate impact of aviation. A multiplier is not a straight forward instrument. In particular, it implies that other emissions and effects are directly linked to production of CO_2, which is not the case. Nor does it reflect accurately the different relative contribution of emissions to climate change over time, or reflect the potential trade-offs between the warming and cooling effects of different emissions.

On the other hand, consideration of the non-CO_2 climate change effects of aviation can be important in some cases, and there is currently no better way of taking these effects into account. A multiplier of 1.9 is recommended as a central estimate, based on the best available scientific evidence, as summarised in

8.39. Table 46 and the GWP_{100} figure (consistent with UNFCCC reporting convention) from the ATTICA research presented in Table 47 below (Sausen , et al., 2005) and in analysis by Lee et al (2009) reported on by (CCC, 2009).

> *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 47 shows the 20-year and 100-year GWPs, plus 100-year GTPs, for each forcing agent from aviation. Based on estimates of fuel usage and emission indices for 2005, the emission equivalent of each agent for these metrics is given on the right, and on the bottom right is the overall ratio of total CO_2-equivalent emissions to CO_2 emissions for aviation in 2005."*

8.40. It is important to note that **the value of this 1.9 multiplier is subject to significant uncertainty** and should only be applied to the CO_2 component of direct emissions (i.e. not also to the CH_4 and N_2O emissions components). The 2019 GHG Conversion Factors provide separate emission factors including this radiative forcing uplift in separate tables in sections “Business travel – air” and “Freighting goods”.

Table 46: Impacts of radiative forcing according to (Sausen, et al., 2005)

		RF [mW/m^2]							
Year	**Study**	**CO_2**	**O_3**	**CH_4**	**H_2O**	**Direct Sulphate**	**Direct Soot**	**Contrails**	**Total (w/o) Cirrus**
1992	IPCC (1999)	18.0	23.0	-14.0	1.5	-3.0	3.0	20.0	48.5
2000	IPCC (1999) scaled to 2000	25.0	28.9	-18.5	2.0	-4.0	4.0	33.9	71.3
2000	TRADEOFF	25.3	21.9	-10.4	2.0	-3.5	2.5	10.0	47.8

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

Table 47: Findings of ATTICA project

	Metric values			**CO_2e 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_2e/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 NO_x reflecting the wide uncertainties in current estimates. The ratios on the bottom right are presented both including and excluding aviation induced cloudiness (AIC) because of uncertainties both in estimates of the magnitude of this effect and in the future incidence of AIC due to air traffic. The different time horizons illustrate how a unit emission of CO_2 increases in importance relative to shorter-lived effects as longer timescales are considered.

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

9. Bioenergy and Water

Section summary

9.1. Bioenergy conversion factors should be used for the combustion of fuels produced from recently living sources (such as trees) at a site or in an asset under the direct control of the reporting organisation. This section of the report describes both the direct (Scope 1) emissions and the indirect (Scope 3) emissions associated with bioenergy sources.

9.2. The section also includes factors for emissions associated with water supply, to account for water delivered through the mains supply network, and water treatment, which are used for water returned to the sewage system through mains drains. These are classified as Scope 3 emissions.

9.3. Table 48 shows where the related worksheets to the bioenergy and water emission factors are available in the online sets of the factors.

Table 48: Related worksheets for bioenergy and water emission factors

Worksheet name	Full set	Condensed set
Bioenergy	Y	Y
WTT – bioenergy	Y	N
Water supply	Y	Y
Water treatment	Y	Y

Summary of changes since the previous update

9.4. In the UK GHGI, there has been an improvement to the accounting of net calorific values for a number of fuels, to align more closely to the Digest of UK Energy Statistics (DUKES) (BEIS, 2018). Previously, for less important fuel such as peat and straw, generic assumptions were made about the moisture content. The closer alignment has meant a revision in these assumptions, and as a result, grass and straw CO_2e emission factors have declined by around 30% compared to the 2018 submission.

9.5. A marked increase in the proportion of biodiesel sold on petrol station forecourts has led to a respective increase in the bio-carbon emissions from consumption of diesel bought on forecourts.

General Methodology

9.6. The 2019 GHG Conversion Factors provide tables of emission factors for: water supply and treatment; biofuels; and biomass and biogas.

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

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

Water

9.9. The emission factors for water supply and treatment in sections “Water supply” and “Water treatment” of the 2019 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.

9.10. 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

9.11. Biofuels are defined as “net carbon zero” or “carbon neutral” as any CO_2 expelled during the burning of the fuel is cancelled out by the CO_2 absorbed by the feedstock used to produce the fuel during growth[22]. Therefore, all direct emissions from biofuels provided in the GHG Conversion Factors dataset are only made up of CH_4 and N_2O emissions.

9.12. Unlike the direct emissions of CO_2, the CH_4 and N_2O emissions aren’t 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.

9.13. The indirect/WTT/fuel lifecycle emission factors for biofuels were based on UK average factors from the Quarterly Report (2017/18)[23] on the Renewable Transport Fuel Obligation (RTFO). These average factors and the direct CH_4 and N_2O factors are presented in Table 49.

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

[23] These cover the period from April 2017 - April 2018 and were the most recent figures available at the time of production of the 2019 GHG Conversion Factors. The report is available from the GOV. website at: https://www.gov.uk/government/collections/biofuels-statistics

Table 49: Fuel lifecycle GHG Conversion Factors for biofuels

Biofuel	Emissions Factor, gCO_2e/MJ				
	RTFO Lifecycle (1)	Direct CH_4 (2)	Direct N_2O (2)	Total Lifecycle	Direct CO_2 Emissions (Out of Scope (3))
Biodiesel	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 CO_2 emitted by the biofuel when combusted. This will be counter-balanced by /equivalent to the CO_2 absorbed in the growth of the biomass feedstock used to produce the biofuel. These factors are based on data from Forest Research, the Forestry Commission's research agency (previously BEC), (2016)

9.14. 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.

9.15. In addition to the direct and indirect/WTT emission factors provided in Table 49, emission factors for the out of Scope CO_2 emissions have also been provided in the 2019 GHG Conversion Factors (see table and the table footnote), based on data sourced from Forest Research, the Forestry Commission's research agency (previously BEC) (Forest Research, 2016).

Other biomass and biogas

9.16. A number of different bioenergy/biomass types can be used in dedicated biomass heating systems, including wood logs, chips and pellets, as well as grasses/straw or biogas. Emission factors produced for these bioenergy sources are presented in the "Bioenergy" section of the 2019 GHG Conversion Factors.

9.17. All indirect/WTT/fuel lifecycle emission factors here, except for wood logs, are sourced from the Ofgem carbon calculators (Ofgem, 2012), (Ofgem, 2015). These calculators have been developed to support operators determining the GHG emissions associated with the cultivation, processing and transportation of their biomass fuels.

9.18. 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 ($BEAT_2$) (Forest Research, 2016a), provided by Defra.

9.19. The direct CH_4 and N_2O emission factors presented in the 2019 GHG Conversion Factors are based on the emission factors used in the UK GHG Inventory (GHGI) for 2017 (managed by Ricardo Energy & Environment).

9.20. 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 50.

9.21. In addition to the direct and indirect/WTT emission factors provided, emission factors for the out of Scope CO_2 emissions are also provided in the 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) (Forest Research, 2016a) [24].

Table 50: Fuel sources and properties used in the calculation of biomass and biogas emission factors

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	16.9	DUKES
Grass/Straw	10% moisture	13.4	DUKES
Biogas	Based on 65% CH_4	20	Swedish Gas Technology Centre
Landfill gas	Based on 40% CH_4	12.3	Swedish Gas Technology Centre

[24] Carbon emissions of different fuels; available at: https://www.forestry.gov.uk/fr/beeh-absIby

10. Overseas Electricity Emission Factors

Section summary

10.1. This section describes the calculation of the Scope 3 upstream well-to-tank emission factors for electricity generated overseas, as well as for transmission and distribution losses. These should be used for sites owned or controlled by the reporting organisation in another country. The Scope 2 indirect factors are not included here as these are now published by the IEA.

10.2. The related worksheet for this section is “WTT – UK & overseas elec”, available only in the full set of factors.

Summary of changes since the previous update

10.3. 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 IEA[25].

10.4. The conversion factors supplied by the IEA for electricity supplied to the grid can be purchased by organisations. Since last 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.

10.5. 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 2019 GHG Conversion Factors.

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

10.6. 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.

10.7. 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 CO_2 emission factors per kWh GENERATED (Scope 2), and corresponding emission factors for losses in Transmission and Distribution (T&D) (Scope 3). As stated, these can be purchased from the IEA website.

[25] Available here: http://data.iea.org/

Indirect/WTT Emissions from Overseas Electricity Generation

10.8. In addition to the GHG emissions resulting directly from the generation of electricity, there are also indirect/WTT emissions resulting from the production, transport and distribution of the fuels used in electricity generation (i.e. indirect/WTT / fuel lifecycle emissions as included in the “Fuel” section). The average fuel lifecycle emissions per unit of electricity generated will be a result of the mix of different sources of fuel/primary energy used in electricity generation.

10.9. Average indirect/WTT emission factors for UK electricity were calculated and included in “UK electricity” by using the “Fuels” sections indirect/WTT emission factors and data on the total fuel consumption by type of generation for the UK. This information was not available for the overseas emission factors. As an approximation therefore, the indirect/WTT (Scope 3) emission factors for different countries are estimated as being roughly a similar ratio of the direct CO_2 emission factors as for the UK (which is 14.9%).

11. Hotel Stay

Section summary

11.1. This section describes the calculation of conversion factors for Hotel Stays, which should be used to report the Scope 3 emissions associated with overnight hotel stays for business travel.

11.2. These factors appear in the “Hotel Stay” worksheet, available in the full set of factors only.

Summary of changes since the previous update

11.3. A number of factors have been added to the 2019 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 2018 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

11.4. All the hotel stay emission factors presented in the 2019 GHG Conversion Factors are in CO_2e. These are taken directly from the Cornell Hotel Sustainability Benchmarking Index (CHSB) Tool, produced by the International Tourism Partnership (ITP) and Greenview (ITP/Greenview, 2019).

11.5. The factors use annual data from more than 10,400 hotel companies comprising several international hotel organisations, such as: Club Med Resorts, Hilton Worldwide, Host Hotels & Resorts, Hyatt Hotels Corporation, InterContinental Hotels Group, Mandarin Oriental Hotel Group, Marriott International, MGM Resorts International, Park Hotel Group, Saunders Hotel Group, Six Senses Hotels Resorts Spas and Wyndham Worldwide.

11.6. For the 2019 GHG Conversion Factors the mean benchmark for each country, for all hotel classes included within the tool, was used.

11.7. The following five steps were carried out in the CHSB study to arrive at the emission factors included within the 2019 GHG Conversion Factors:

a) **Harmonising.** The data received was converted into the same units and then converting to kg CO_2e.

b) **Validity tests** were carried out to remove outliers 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.

11.8. 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. Hotels in the lower tier segments are not as strongly represented in these data.

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 CH_4 and N_2O emissions, plus there are also no indirect/ WTT factors.

11.9. For more information about how the factors have been derived, please see (ITP/Greenview, 2019), where more granular data is also available by city and segment.

12. Material Consumption/Use and Waste Disposal

Section summary

12.1. This section describes conversion factors for material use and waste disposal. Material use conversion factors should be used to report on consumption of procured materials based on their origin (that is, comprised of primary material or recycled materials). For primary materials, these factors cover the extraction, primary processing, manufacture and transportation of materials to the point of sale, not the materials in use. For secondary materials, the factors cover sorting, processing, manufacture and transportation to the point of sale, not the materials in use. These factors are useful for reporting efficiencies gained through reduced procurement of material or the benefit of procuring items that are the product of a previous recycling process. Waste-disposal figures should be used for end-of-life disposal of different materials using a variety of different disposal methods.

12.2. These factors appear in the “Material use” and “Waste disposal” worksheets, available in both the full and condensed sets of workbooks.

Summary of changes since the previous update

12.3. There have been no significant methodological updates to this section since the 2017 update. Three minor changes have been made:

a) *Paper and board closed-loop source:* Corrected a discrepancy where emissions for domestic recycling transport had been included in the closed loop source emissions and were thus being double counted (transport emissions are accounted for under disposal).

b) *Landfill disposal of WEEE:* This was brought into line with other landfill factors by applying a common landfill-transport figure. The previous WEEE figure had been sourced from WRATE data that was dated (2005) and not compatible with the revised approach to landfill based on MELMod.

c) *Composting and anaerobic digestion:* Transport factors were reviewed for consistency and some changes made where composting factors had not previously been updated (e.g. books). Anaerobic digestion transport assumptions were changed from those applied to landfill to those used for composting.

Emissions from Material Use and Waste Disposal

12.4. 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’)[26].

[26] http://www.ghgprotocol.org/standards/Scope-3-standard

This sets down rules on accounting for emissions associated with material consumption and waste management.

12.5. 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.

12.6. 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).

12.7. All figures expressed are kilograms of carbon dioxide equivalent (CO_2e) per tonne of material. This includes the Kyoto protocol basket of greenhouse gases. Please note that biogenic[27] CO_2 has also been excluded from these figures.

12.8. 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.

12.9. 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.

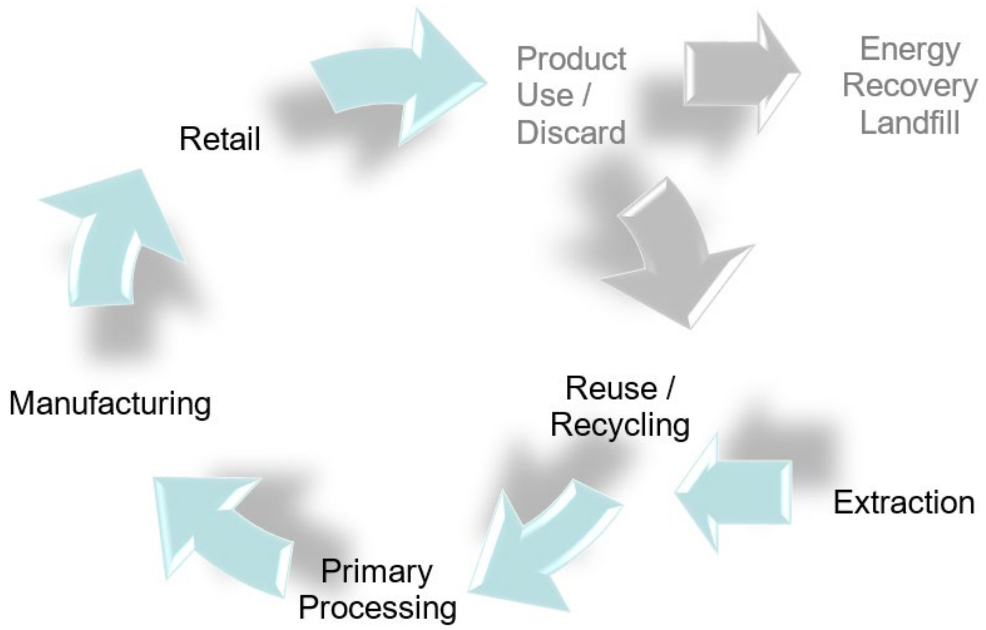
12.10. The following subsections provide a summary of the methodology, key data sources and assumptions used to define the emission factors.

Material Consumption/Use

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

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

Figure 5: Boundary of material consumption data sets



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

12.12. The factors presented for material consumption cover all greenhouse gas emissions from the point of raw material extraction through to the point at which a finished good is manufactured and provided for sale. Commercial enterprises may therefore use these figures to estimate the impact of goods they procure. Organisations involved in manufacture of goods using these materials should note that if they separately report emissions associated with their energy use in forming products with these materials, there is potential for double counting. As many of the data sources used in preparing the tables are confidential we are unable to publish a more detailed breakdown. However, the standard assumptions made are described below.

12.13. 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.

12.14. 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.

12.15. 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.

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

12.17. Table 51 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.

Table 51: Distances and transportation types used in EF calculations

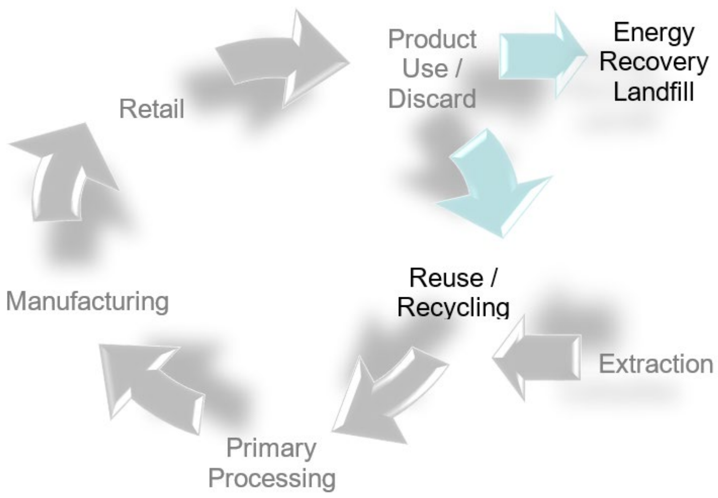
Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Transport of raw materials to factory	122km	Average, all HGVs	(DfT, 2010) Based on average haulage distance for all commodities, not specific to the materials in the first column.
Distribution to Retail Distribution Centre & to retailer	96km		(McKinnon, 2007), (IGD, 2018)

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

Waste Disposal

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

Figure 5: Boundary of waste disposal data sets



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

12.20. 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.

12.21. 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.

12.22. 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.

12.23. Figures for Refuse Collection Vehicles have been taken from the Environment Agency’s Waste and Resource Assessment Tool for the Environment (WRATE) (Environment Agency, 2010).

12.24. Transport distances for waste were estimated using a range of sources, principally data supplied by the Environment Agency for use in the WRATE (2005) tool (Environment Agency, 2010). The distances adopted are shown in Table 52.

Table 52: Distances used in calculation of emission factors

Destination / Intermediate Destination	One Way Distance	Mode of transport	Source
Household, commercial and industrial landfill	25km by Road	26 Tonne GVW Refuse Collection Vehicle, maximum waste capacity 12 tonnes	WRATE (2005)
Inert landfill	10km by Road		WRATE (2005)
Transfer station / CA site	10km by Road		
MRF	25km by Road		
MSW incinerator	50km by Road		
Cement kiln	50km by Road		
Recyclate	50km by Road	Average, all HGVs	WRATE (2005)
Inert recycling	10km by Road		WRATE (2005)

12.25. 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.

13. Fuel Properties

Section summary

13.1. The fuel properties can be used to determine the typical calorific values / densities of most common fuels.

13.2. These factors appear in the "Fuel properties" worksheet, available in both the full and condensed sets of workbooks.

Summary of changes since the previous update

13.3. No significant changes were made this year.

General Methodology

13.4. 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, kWh/kg and kWh/litre;

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

c) Density in units of litres/tonne and kg/m^3.

13.5. 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 (BEIS, 2018).

13.6. 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) (JEC WTW, 2014). The exception is for methyl-ester based biodiesels and bioethanol, where values for NCV and GCV are taken from DUKES 2018.

13.7. Fuel properties, both density and CV, for wood chips (25% moisture content) come from the Forest Research (previously Biomass Energy Centre (BEC)[28]. 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 Research[29].

[28] Available at: https://www.forestry.gov.uk/fr/beeh-9ukqcn

[29] Available at: https://www.forestry.gov.uk/fr/beeh-absg5h

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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.

Table 1.1: Data Quality Indications for the waste management GHG factors

Data Quality Indicator	Requirement	Comments
Time-related coverage	Data less than 5 years' old	Ideally, data should 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.

Data Quality Indicator	Requirement	Comments
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.	
Reproducibility	An independent practitioner should be able to follow the method and arrive at the same results.	
Sources of data	Data will be derived from credible sources and databases	Where possible data in public domain will be used. All data sources referenced.
Uncertainty of the information		Many data sources come from single sources. Uncertainty will arise from assumptions made and the setting of the system boundaries.

1.2 Data Sources

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 the section on "Material Consumption/Use and Waste Disposal". Data on waste management options has been modelled using SimaPro 8.2.3.[30] 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

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

available. The justification for inclusion of each dataset is explained. The most common data quality issues encountered concerned data age and availability.

Wood and Paper data

Published data on wood products is sparse, an issue highlighted by the Waste and Resources Action Programme (WRAP) in 2006 and 2010[31]. Data used in this report for material consumption is based on studies from the USA, where production processes may not be representative of activity in the UK (e.g. different fuel mix to generate electricity). This data should therefore be viewed with caution. Data on different types of wood has been used in combination with information on the composition of wood waste in the UK[32] 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 draft[33] 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.

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[31] 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

[32] 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

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

Oil Data

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

Mineral oil will be included in the waste management 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.

Table 1.2 Data Sources

Material	Reference	
	Material Consumption	Waste Disposal
Aluminium cans and foil	European Aluminium Association (2013) Environmental Profile Report for the European Aluminium Industry CE Delft (2007) Environmental Indices for the Dutch Packaging Tax 2019 GHG Conversion Factors Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0 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	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009

Material	Reference	
	Material Consumption	Waste Disposal
Steel Cans	World Steel Association (2017) Lifecycle Inventory Data for Steel Products 2019 GHG Conversion Factors Swiss Packaging Institute (1997) BUWAL ERM (2008) Waste and Resources Assessment Tool for the Environment (WRATE) Version 1	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
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	
Wood	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 ERM (2008) Single trip pallet no biogenic CO_2 Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0 2019 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	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009

Material	Reference	
	Material Consumption	**Waste Disposal**
Aggregates	WRAP (2008) Lifecycle Assessment of Aggregates	
Paper and board	2019 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_201612 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" "Wang & Mao (2012) Risk Analysis and Carbon Footprint Assessments of the Paper Industry in China" Swiss Centre for Life Cycle Inventories (2007) Ecoinvent v2 CEPI (2008) Key Statistics 2007 European Pulp and Paper Industry Oakdene Hollins (2008) CO_2 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	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009

Material	Reference	
	Material Consumption	**Waste Disposal**
	Chen, C., Gan, J., Qui, R., (2017) Energy Use and CO_2 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) 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	
Scrap Metal	British Metals Recycling Association (website[34]) Swiss Centre for Life Cycle Inventories (2014) Ecoinvent v3.0 Giurco, D., Stewart, M., Suljada, T., and Petrie, J., (2006) Copper Recycling Alternatives: An Environmental Analysis	ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
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)
Food and Drink Waste	2019 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	AFOR (2009) Market survey of the UK organics recycling industry - 2007/08; WRAP, Banbury (Substitution rates for compost) Williams AG, Audsley E and Sandars DL (2006) Determining the Environmental Burdens and

[34] http://www.recyclemetals.org/about_metal_recycling. No longer online.

Material	Reference	
	Material Consumption	**Waste Disposal**
	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 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 AIC (2009) Fertiliser Statistics 2009 Report Greenhouse Gas Inventory Data - Detailed data by Party Davis, J. and Haglund, C. (1999) Life Cycle Inventory (LCI) of Fertiliser Production Brook Lyndhurst (2009) London's Food Sector GHG Emissions - Final Report 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.; Stockle, C.O. (2010) Biomass assessment for potential bio-	Resource Uses in the Production of Agricultural and Horticultural Commodities. Main Report. IS0205, DEFRA (avoided fertiliser impacts) Kranert, M. & Gottschall (2007) Grünabfälle – besser kompostieren oder energetisch verwerten? Eddie (information on peat) DEFRA (unpublished) (information on composting impacts) ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009

Material	Reference	
	Material Consumption	Waste Disposal
	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	2019 GHG Conversion Factors DEFRA (2013) Family food and expenditure survey	

Material	Reference	
	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	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
PS (excel forming)	Plastics Europe (2015) Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polystyrene (High Impact) (HIPS). Plastics Europe, Brussels	PWC (2002) Life Cycle Assessment of Expanded Polystyrene Packaging, Umps

Material	Reference	
	Material Consumption	**Waste Disposal**
PET (excel forming)	Plastics Europe (2010) Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polyethylene Terephthalate (PET). Plastics Europe, Brussels	WRAP (2010) LCA of Example Milk Packaging Systems; WRAP, Banbury
Average plastic film (inch bags)	Based on split in AMA Research (2009) Plastics Recycling Market UK 2009-2013, UK; Cheltenham	WRAP (2008) LCA of Mixed Waste Plastic Management Options; WRAP, Banbury
Average plastic rigid (inch bottles)		
Clothing	BIO IS (2009) Environmental Improvement Potentials of Textiles (IMPRO-Textiles), EU Joint Research Commission	Farrant (2008) Environmental Benefit from Reusing Clothes, ELCD data sets, http://lca.jrc.ec.europa.eu. (c) European Commission 1995-2009
Footwear	Albers, K., Canapé, P., Miller, J. (2008) Analysing the Environmental Impacts of Simple Shoes, University of Santa Barbara, California	
Furniture	WRAP (2015) Benefits of Reuse	
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 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	

Greenhouse Gas Conversion Factors

Industrial Designation or Common Name	Chemical Formula	Lifetime (years)	Radiative Efficiency (Wm^{-2} ppb^{-1})	Global Warming Potential with 100 year time horizon (previous estimates for 1st IPCC assessment report)	Possible source of emissions
Carbon dioxide	CO_2	Variable	1.4×10^{-5}	1	Combustion of fossil fuels
Methane	CH_4	12	3.7×10^{-4}	25 (23)	Decomposition of biodegradable material, enteric emissions.
Nitrous Oxide	N_2O	114	3.03×10^{-3}	298 (296)	N_2O arises from Stationary Sources, mobile sources, manure, soil management and agricultural residue burning, sewage, combustion and bunker fuels
Sulphur hexafluoride	SF_6	3200	0.52	22,800 (22,200)	Leakage from electricity substations, magnesium smelters, some consumer goods
HFC 134a (R134a refrigerant)	CH_2FCF_3	14	0.16	1,430 (1,300)	Substitution of ozone depleting substances, refrigerant manufacture / leaks, aerosols, transmission and distribution of electricity.
Dichlorodifluoro-methane CFC 12 (R12 refrigerant)	CCl_2F_2	100	0.32	10,900	
Difluoromono-chloromethane HCFC 22 (R22 refrigerant)	$CHClF_2$	12	0.2	1,810	

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

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (eds.) (2007) Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom Table 2.14. Lifetimes, radiative efficiencies and direct (except for CH_4) global warming potentials (GWP) relative to CO_2. Available at: https://www.ipcc.ch/site/assets/uploads/2018/05/ar4_wg1_full_report-1.pdf

Appendix 2. Updated full time series – Electricity and Heat and Steam Factors

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

Table 53: Base electricity generation emissions data – most recent datasets for time series

Data Year	Electricity Generation [1]	Total Grid Losses [2]	UK electricity generation emissions [3], ktonne		
	GWh	%	CO_2	CH_4	N_2O
1990	280,234	**8.08%**	205,810	2.864	3.631
1991	283,201	**8.27%**	202,393	2.700	3.601
1992	281,223	**7.55%**	190,391	2.559	3.381
1993	284,350	**7.17%**	173,969	2.523	2.884
1994	289,126	**9.57%**	169,559	2.651	2.736
1995	299,196	**9.07%**	166,699	2.729	2.686
1996	313,070	**8.40%**	166,598	2.752	2.507
1997	311,220	**7.79%**	154,222	2.653	2.173
1998	320,740	**8.40%**	159,045	2.835	2.253
1999	323,872	**8.25%**	151,229	2.836	1.970
2000	331,553	**8.38%**	163,419	2.997	2.206
2001	342,686	**8.56%**	173,781	3.291	2.460
2002	342,338	**8.26%**	168,403	3.234	2.318
2003	354,225	**8.47%**	180,642	3.464	2.554
2004	349,312	**8.71%**	178,654	3.433	2.466
2005	350,778	**7.25%**	176,921	4.048	2.603
2006	349,211	**7.21%**	185,821	4.133	2.817
2007	352,778	**7.34%**	183,600	4.113	2.620
2008	348,876	**7.43%**	178,942	4.376	2.466
2009	338,983	**7.86%**	157,602	4.245	2.123
2010	344,127	**7.38%**	162,529	4.444	2.198
2011	329,792	**7.91%**	149,735	4.411	2.240
2012	324,823	**8.00%**	163,853	4.838	2.848
2013	318,753	**7.57%**	151,378	5.268	2.723
2014	298,064	**8.11%**	127,387	5.979	2.341

Data Year	Electricity Generation [1]	Total Grid Losses [2]	UK electricity generation emissions [3], ktonne		
	GWh	%	CO_2	CH_4	N_2O
2015	297,520	**8.43%**	107,207	7.287	2.152
2016	297,083	**7.88%**	85,007	7.550	1.485
2017	294,086	**7.83%**	74,386	7.588	1.353

Notes:

(1) Based upon calculated **total** for **all** electricity generation (GWh supplied) from DUKES (2018) 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 (~10% in 2017).

(2) Based upon calculated net grid losses from data in DUKES (2018) 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 2017 (Ricardo-AEA, 2019), with data from the GHGI for 2017 (Ricardo Energy & Environment, 2019) 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 54: Base electricity generation emission factors (excluding imported electricity) – fully consistent time series dataset

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
1990	0.73442	0.00026	0.00386	0.73854	0.06453	0.00002	0.00034	0.06489	0.79895	0.00028	0.00420	0.80343	**4.08%**
1991	0.71466	0.00024	0.00379	0.71869	0.06443	0.00002	0.00034	0.06479	0.77909	0.00026	0.00413	0.78348	**5.48%**
1992	0.67701	0.00023	0.00358	0.68082	0.05526	0.00002	0.00029	0.05557	0.73227	0.00025	0.00388	0.73639	**5.60%**
1993	0.61181	0.00022	0.00302	0.61506	0.04725	0.00002	0.00023	0.04750	0.65906	0.00024	0.00326	0.66256	**5.55%**
1994	0.58645	0.00023	0.00282	0.58950	0.06208	0.00002	0.00030	0.06241	0.64854	0.00025	0.00312	0.65191	**5.52%**
1995	0.55716	0.00023	0.00268	0.56006	0.05558	0.00002	0.00027	0.05587	0.61274	0.00025	0.00294	0.61594	**5.26%**
1996	0.53214	0.00022	0.00239	0.53475	0.04882	0.00002	0.00022	0.04906	0.58096	0.00024	0.00261	0.58381	**5.08%**
1997	0.49554	0.00021	0.00208	0.49783	0.04189	0.00002	0.00018	0.04208	0.53743	0.00023	0.00226	0.53991	**5.06%**
1998	0.49587	0.00022	0.00209	0.49818	0.04545	0.00002	0.00019	0.04566	0.54132	0.00024	0.00228	0.54384	**3.74%**
1999	0.46694	0.00022	0.00181	0.46897	0.04199	0.00002	0.00016	0.04218	0.50893	0.00024	0.00198	0.51115	**4.21%**
2000	0.49289	0.00023	0.00198	0.49510	0.04511	0.00002	0.00018	0.04531	0.53800	0.00025	0.00216	0.54041	**4.10%**
2001	0.50712	0.00024	0.00214	0.50949	0.04748	0.00002	0.00020	0.04770	0.55460	0.00026	0.00234	0.55720	**2.95%**
2002	0.49192	0.00024	0.00202	0.49417	0.04426	0.00002	0.00018	0.04447	0.53618	0.00026	0.00220	0.53864	**2.40%**
2003	0.50996	0.00024	0.00215	0.51236	0.04718	0.00002	0.00020	0.04740	0.55715	0.00027	0.00235	0.55976	**0.61%**
2004	0.51145	0.00025	0.00210	0.51380	0.04880	0.00002	0.00020	0.04902	0.56024	0.00027	0.00230	0.56282	**2.10%**
2005	0.50437	0.00029	0.00221	0.50687	0.03940	0.00002	0.00017	0.03959	0.54377	0.00031	0.00238	0.54646	**2.32%**
2006	0.53212	0.00030	0.00240	0.53482	0.04138	0.00002	0.00019	0.04159	0.57349	0.00032	0.00259	0.57640	**2.11%**
2007	0.52044	0.00029	0.00221	0.52295	0.04121	0.00002	0.00018	0.04141	0.56165	0.00031	0.00239	0.56436	**1.46%**
2008	0.51291	0.00031	0.00211	0.51533	0.04117	0.00003	0.00017	0.04137	0.55408	0.00034	0.00228	0.55670	**3.06%**
2009	0.46493	0.00031	0.00187	0.46711	0.03965	0.00003	0.00016	0.03984	0.50458	0.00034	0.00203	0.50694	**0.84%**
2010	0.47229	0.00032	0.00190	0.47452	0.03762	0.00003	0.00015	0.03780	0.50991	0.00035	0.00205	0.51232	**0.77%**
2011	0.45403	0.00033	0.00202	0.45639	0.03899	0.00003	0.00017	0.03920	0.49302	0.00036	0.00220	0.49558	**1.85%**

Data Year	Emission Factor, kgCO2e / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
2012	0.50444	0.00037	0.00261	0.50742	0.04385	0.00003	0.00023	0.04411	0.54829	0.00040	0.00284	0.55153	**3.52%**
2013	0.47491	0.00041	0.00255	0.47786	0.03887	0.00003	0.00021	0.03911	0.51378	0.00045	0.00275	0.51698	**4.33%**
2014	0.42738	0.00050	0.00234	0.43022	0.03774	0.00004	0.00021	0.03799	0.46512	0.00055	0.00255	0.46822	**6.44%**
2015	0.36033	0.00061	0.00216	0.36310	0.03318	0.00006	0.00020	0.03344	0.39352	0.00067	0.00235	0.39654	**6.62%**
2016	0.28614	0.00064	0.00149	0.28827	0.02448	0.00005	0.00013	0.02466	0.31062	0.00069	0.00162	0.31293	**5.64%**
2017	0.25294	0.00065	0.00137	0.25496	0.02148	0.00005	0.00012	0.02165	0.27442	0.00070	0.00149	0.27660	**4.78%**

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)

⇒ Emission Factor (Electricity CONSUMED) = Emission Factor (Electricity GENERATED) + Emission Factor (Electricity LOSSES)[35],

[35] 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.

Table 55: Base electricity generation emissions factors (including imported electricity) – fully consistent time series dataset

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
1990	0.70909	0.00025	0.00373	0.71307	0.0623	0.00002	0.00033	0.06265	0.77139	0.00027	0.00406	0.77572	**4.08%**
1991	0.68252	0.00023	0.00362	0.68637	0.06153	0.00002	0.00033	0.06188	0.74405	0.00025	0.00395	0.74825	**5.48%**
1992	0.64474	0.00022	0.00341	0.64837	0.05263	0.00002	0.00028	0.05293	0.69737	0.00024	0.00369	0.70130	**5.60%**
1993	0.58163	0.00021	0.00287	0.58471	0.04492	0.00002	0.00022	0.04516	0.62655	0.00023	0.00309	0.62987	**5.55%**
1994	0.55789	0.00022	0.00268	0.56079	0.05906	0.00002	0.00028	0.05936	0.61695	0.00024	0.00296	0.62015	**5.52%**
1995	0.53197	0.00022	0.00255	0.53474	0.05307	0.00002	0.00025	0.05334	0.58504	0.00024	0.00280	0.58808	**5.26%**
1996	0.50928	0.00021	0.00228	0.51177	0.04672	0.00002	0.00021	0.04695	0.55600	0.00023	0.00249	0.55872	**5.08%**
1997	0.4743	0.0002	0.00199	0.47649	0.04009	0.00002	0.00017	0.04028	0.51439	0.00022	0.00216	0.51677	**5.06%**
1998	0.48124	0.00021	0.00203	0.48348	0.04411	0.00002	0.00019	0.04432	0.52535	0.00023	0.00222	0.52780	**3.74%**
1999	0.45108	0.00021	0.00175	0.45304	0.04057	0.00002	0.00016	0.04075	0.49165	0.00023	0.00191	0.49379	**4.21%**
2000	0.47601	0.00022	0.00192	0.47815	0.04356	0.00002	0.00018	0.04376	0.51957	0.00024	0.00210	0.52191	**4.10%**
2001	0.49417	0.00023	0.00208	0.49648	0.04627	0.00002	0.0002	0.04649	0.54044	0.00025	0.00228	0.54297	**2.95%**
2002	0.48183	0.00023	0.00198	0.48404	0.04335	0.00002	0.00018	0.04355	0.52518	0.00025	0.00216	0.52759	**2.40%**
2003	0.50738	0.00024	0.00214	0.50976	0.04694	0.00002	0.0002	0.04716	0.55432	0.00026	0.00234	0.55692	**0.61%**
2004	0.50223	0.00024	0.00207	0.50454	0.04792	0.00002	0.0002	0.04814	0.55015	0.00026	0.00227	0.55268	**2.10%**
2005	0.49465	0.00028	0.00217	0.4971	0.03864	0.00002	0.00017	0.03883	0.53329	0.00030	0.00234	0.53593	**2.32%**
2006	0.52254	0.00029	0.00236	0.52519	0.04063	0.00002	0.00018	0.04083	0.56317	0.00031	0.00254	0.56602	**2.11%**
2007	0.51404	0.00029	0.00219	0.51652	0.04071	0.00002	0.00017	0.0409	0.55475	0.00031	0.00236	0.55742	**1.46%**
2008	0.49959	0.00031	0.00205	0.50195	0.0401	0.00002	0.00016	0.04028	0.53969	0.00033	0.00221	0.54223	**3.06%**
2009	0.46174	0.00031	0.00185	0.4639	0.03938	0.00003	0.00016	0.03957	0.50112	0.00034	0.00201	0.50347	**0.84%**
2010	0.46932	0.00032	0.00189	0.47153	0.03739	0.00003	0.00015	0.03757	0.50671	0.00035	0.00204	0.50910	**0.77%**
2011	0.44876	0.00033	0.002	0.45109	0.03854	0.00003	0.00017	0.03874	0.48730	0.00036	0.00217	0.48983	**1.85%**
2012	0.49574	0.00037	0.00257	0.49868	0.0431	0.00003	0.00022	0.04335	0.53884	0.00040	0.00279	0.54203	**3.52%**

Data Year	Emission Factor, $kgCO_2e$ / kWh												% Net Electricity Imports
	For electricity GENERATED (supplied to the grid, plus imports)				Due to grid transmission /distribution LOSSES				For electricity CONSUMED (includes grid losses)				
	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	TOTAL
2013	0.46405	0.0004	0.00249	0.46694	0.03798	0.00003	0.0002	0.03821	0.50203	0.00043	0.00269	0.50515	**4.33%**
2014	0.41283	0.00048	0.00226	0.41557	0.03646	0.00004	0.0002	0.0367	0.44929	0.00052	0.00246	0.45227	**6.44%**
2015	0.35130	0.0006	0.0021	0.354	0.03235	0.00005	0.00019	0.03259	0.38365	0.00065	0.00229	0.38659	**6.62%**
2016	0.28425	0.00063	0.00148	0.28636	0.02432	0.00005	0.00013	0.0245	0.30857	0.00068	0.00161	0.31086	**5.64%**
2017	0.25358	0.00065	0.00137	0.2556	0.02153	0.00005	0.00012	0.0217	0.27511	0.00070	0.00149	0.27730	**4.78%**

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

Data Year	$kgCO_2/kWh$ supplied heat/steam	$kgCO_2/kWh$ supplied power
	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
2017	0174	0.349

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