Department for
Energy Security
& Net Zero

2023 Government Greenhouse Gas Conversion Factors for Company Reporting

Methodology Paper for Conversion Factors Final Report

June 2023

conversion factors for aviation turbine fuel (kerosene) and the corresponding direct CO_2 conversion factors for air passenger and air freight transport in the "Business travel – air" and "Freighting goods" worksheets.

Other Factors for the Calculation of GHG Emissions

Great Circle Flight Distances

8.37. 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.

8.38. 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 set.

8.39. 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 conversion factors presented in the 2023 GHG Conversion factors set.

Non-CO_2 impacts and Radiative Forcing

8.40. The conversion factors provided in the 2023 GHG Conversion factors "Business travel – air" and "Freighting goods" worksheets refer to aviation's direct CO_2, CH_4 and N_2O emissions only. There is currently uncertainty over the magnitude of the other non-CO_2 radiative forcing effects of aviation (including water vapour, contrails, NO_X, etc.) which have been indicatively accounted for by applying a multiplier to account for CO_2 equivalent emissions in some cases.

8.41. The use of CO_2 equivalent emissions metrics such as the Global Warming Potential or the Global Temperature change Potential requires definition of a time horizon – the period over which the metric is calculated for. Such a choice is not a scientific one but a policy one. In the UNFCCC, the Global Warming Potential for 100 years is used (GWP100). The application of GWPs to short-lived climate forcers, such as the non-CO_2 effects of aviation has particular problems, but this is an active area of research. Nonetheless, aviation imposes other effects on the climate which are greater than that implied from simply considering its CO_2 emissions alone.

8.42. The application of an aggregate 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 straightforward CO_2 equivalence metric, In particular, it implies that all other emissions and effects are directly linked to production of CO_2, which is not necessarily the case. Nor does it reflect accurately the different relative contribution of emissions to climate change over time, or reflect the potential trade-offs between the warming and cooling effects of different emissions.

8.43. 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 than applying an aggregate multiplier. A multiplier of 1.7 is recommended as a central estimate, based on the best available scientific evidence, as summarised in Table 43 and the GWP_{100} figure (consistent with UNFCCC reporting convention) in Table 44 below and in analysis by Lee et al. (2021).

8.44. It is important to note that **the value of this 1.7 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 2023 GHG Conversion factors provide separate conversion factors including this radiative forcing uplift in separate tables in the "Business travel – air" and "Freighting goods" worksheets. The 1.7 multiplier is equally applicable to the CO_2 component of the scope 1 litres based emission factors for aviation turbine fuel.

8.45. The non-CO_2 effects are likely to be more pronounced at higher altitudes. However, the current scientific evidence relates to aviation emissions in their entirety, and it provides no means of distinguishing the affects at different altitudes or during different phases of the flight. The multiplier is therefore recommended to be applied equally to all flights irrespective of distance or altitude and to equally to all phases of the flight, albeit accepting the approximations involved in this approach. Similarly, due to the flight altitudes, the non-CO_2 effects are likely to be less pronounced for turboprops than for commercial jet aircraft, but again the scientific evidence does not provide a mechanism to treat them differently, so the recommendation remains to apply the multiplier equally to all flights.

Table 46: Impacts of radiative forcing according to Lee et al., (2021)

ERF ($mW\ m^{-2}$)	2018 [a]	2011 [a]	2005 [a]	Sensitivity to emissions	ERF/RF
Contrail cirrus	57.4 (17, 98)	44.1 (13, 75)	34.8 (10, 59)	9.36×10^{-10} $mW\ m^{-2}\ km^{-1}$	0.42
CO_2	34.3 (28, 40)	29.0 (24, 34)	25.0 (21, 29)		1.0
Short-term O_3 increase	49.3 (32, 76)	37.3 (24, 58)	33.0 (21, 51)	34.4 ± 9.9 $mW\ m^{-2}$ $(Tg\ (N)\ yr^{-1})^{-1}$	1.37
Long-term O_3 decrease	-10.6 (-20, -7.4)	-7.9 (-15, -5.5)	-6.7 (-13, -4.7)	-9.3 ± 3.4 $mW\ m^{-2}$ $(Tg\ (N)\ yr^{-1})^{-1}$	1.18

ERF (mW m^{-2})	2018 [a]	2011 [a]	2005 [a]	Sensitivity to emissions	ERF/RF
CH_4 decrease	-21.2 (-40, -15)	-15.8 (-30, -11)	-13.4 (-25, -9.4)	-18.7 ± 6.9 mW m^{-2} (Tg (N) yr^{-1})$^{-1}$	1.18
Stratospheric water vapor decrease	-3.2 (-6.0 -2.2)	-2.4 (-4.4, -1.7)	-2.0 (-3.8, -1.4)	-2.8 ± 1.0 mW m^{-2} (Tg (N) yr^{-1})$^{-1}$	1.18
Net NO_x	17.5 (0.6, 29)	13.6 (0.9, 22)	12.9 (1.9, 20)	5.5 ± 8.1 mW m^{-2} (Tg (N) yr^{-1})$^{-1}$	
Stratospheric H_2O increase	2.0 (0.8, 3.2)	1.5 (0.6, 2.4)	1.4 (0.6, 2.3)	0.0052 ± 0.0026 mW m^{-2} (Tg (H_2O) yr^{-1})$^{-1}$	---
Soot (aerosol-radiation)	0.94 (0.1, 4.0)	0.71 (0.1, 3.0)	0.67 (0.1, 2.8)	100.7 ± 165.5 mW m^{-2} (Tg (BC) yr^{-1})$^{-1}$	---
Sulfate (aerosol-radiation)	-7.4 (-19, -2.6)	-5.6 (-14, -1.9)	-5.3 (-13, -1.8)	-19.9 ± 16.0 mW m^{-2} (Tg (SO_2) yr^{-1})$^{-1}$	---
Sulfate and soot (aerosol-cloud)	----	----	----	----	---
Net ERF (only non-CO_2 terms)	66.6 (21, 111)	51.4 (16, 85)	41.9 (14, 69)	----	---
Net aviation ERF	100.9 (55, 145)	80.4 (45, 114)	66.9 (38, 95)	----	---
Net anthropogenic ERF in 2011	----	2290 (1130, 3330) [b]	----	----	---

[a] The uncertainty distributions for all forcing terms are lognormal except for CO_2 and contrail cirrus (normal) and Net NO_x (discrete pdf).

[b] Boucher et al., 2013. IPCC also separately estimated the contrail cirrus term for 2011 as 50 (20, 150) mW m^{-2}

Table 47: Aviation non-CO_2 emissions equivalence metrics for GWP, GTP and GWP* taken from Lee et al. (2021)

Metrics

ERF term	GWP_{20}	GWP_{50}	GWP_{100}	GTP_{20}	GTP_{50}	GTP_{100}
CO_2	1	1	1	1	1	1

ERF term	GWP_{20}	GWP_{50}	GWP_{100}	GTP_{20}	GTP_{50}	GTP_{100}
Contrail cirrus ($Tg\ CO_2$ basis)	2.32	1.09	0.63	0.67	0.11	0.09
Contrail cirrus (km basis)	39	18	11	11	1.8	1.5
Net NO_x	619	205	114	-222	-69	13
Aerosol-radiation						
Soot emissions	4288	2018	1166	1245	195	161
SO_2 emissions	-832	-392	-226	-241	-38	-31
Water vapor emissions	0.22	0.10	0.06	0.07	0.01	0.008

CO_2-eq emissions ($Tg\ CO_2\ yr^{-1}$) for 2018

ERF term	GWP_{20}	GWP_{50}	GWP_{100}	GTP_{20}	GTP_{50}	GTP_{100}	GWP^*_{100} (E^*_{CO2e})
CO_2	1034	1034	1034	1034	1034	1034	1034
Contrail cirrus ($Tg\ CO_2$ basis)	2399	1129	652	695	109	90	1834
Contrail cirrus (km basis)	2395	1127	651	694	109	90	1834
Net NO_x	887	293	163	-318	-99	19	339
Aerosol-radiation							
Soot emissions	40	19	11	12	2	2	20
SO_2 emissions	-310	-146	-84	-90	-14	-12	-158
Water vapor emissions	83	39	23	27	4	3	42
Total CO_2-eq (using km basis)	4128	2366	1797	1358	1035	1135	3111

ERF term	GWP_{20}	GWP_{50}	GWP_{100}	GTP_{20}	GTP_{50}	GTP_{100}	GWP^*_{100} (E^*_{CO2e})
Total CO_2-eq / CO_2	4.0	2.3	1.7	1.3	1.0	1.1	3.0

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