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Annex III: Tables of Historical and Projected Well-mixed Greenhouse Gas Mixing Ratios and Effective Radiative Forcing of All Climate Forcers

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This annex should be cited as:

IPCC, 2021: Annex III: Tables of historical and projected well-mixed greenhouse gas mixing ratios and effective radiative forcing of all climate forcers [Dentener F.J., B. Hall, C. Smith (eds.)]. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2139–2152, doi:[10.1017/9781009157896.017](https://doi.org/10.1017/9781009157896.017).

AIII.1 Introduction

Annex III presents, in tabulated form, data related to historical and projected changes in greenhouse gas (GHG) mixing ratios and effective radiative forcing (ERF) of all climate forcers as assessed and used throughout Chapters 1–7. Where available 90% confidence level uncertainties on observed GHG mixing ratios are given. For each species, the abundance is given as dry air mole fraction: ppm = micromoles per mole (10^{-6}); ppb = nanomoles per mole (10^{-9}); and ppt = picomoles per mole (10^{-12}). ERF is given in $W m^{-2}$ for CO_2 , N_2O , and CH_4 and in $10^{-3} W m^{-2}$ ($mW m^{-2}$) for other components.

Pre-instrumental mixing ratios are estimated from ice-core and firn air records that are described in Machida et al. (1995); Flückiger et al. (1999); Sowers (2001); Siegenthaler et al. (2005); Ahn et al. (2012); Mitchell et al. (2013); Bauska et al. (2015); Meinshausen et al. (2017); Rubino et al. (2020); Ryu et al. (2020).

Observed (instrumental) mixing ratios are described in Masarie and Tans (1995); Trudinger et al. (2004); Worton et al. (2006);

Montzka et al. (2009); Dlugokencky et al. (2011); Hall et al. (2011); Rigby et al. (2014); Laube et al. (2016); Simmonds et al. (2017); Adcock et al. (2018); Prinn et al. (2018); Leedham Elvidge et al. (2018); Mühle et al. (2019); Naus et al. (2019); Droste et al. (2020).

Projected concentrations for the five core scenarios discussed in the report (Section 1.6.1) are from Gidden et al. (2019), Meinshausen et al. (2017, 2020) and Velders et al. (2015). These scenarios span a wide range of plausible societal and climatic futures from potentially below 1.5°C best-estimate warming to over 4°C warming by 2100 (Section 4.3.4). Computational methods and assumptions to calculate historical and projected ERF are described in Chapter 7 and detailed information can be found in Chapter 7 Supplementary Material 7.SM.1.3 and 7.SM.1.4.

Extended datasets and further auxiliary data are made available via <https://doi.org/10.5281/zenodo.5705391> (Smith et al., 2021).

Tables AIII.1a–f provide historical abundances (mixing ratios) and effective radiative forcing (ERF) values for greenhouse gases assessed in this report.

Chemical Abbreviations and Symbols of Components Regulated Under the Kyoto¹ and Montreal Protocols.

| | | |
|-------------|---|-----------------|
| CO_2 | carbon dioxide | Kyoto |
| CH_4 | methane | Kyoto |
| N_2O | nitrous oxide | Kyoto |
| HFC | hydrofluorocarbon (a class of compounds: HFC-32, HFC-134a ...) | Kyoto, Montreal |
| PFC | perfluorocarbon (a class of compounds: CF_4 , C_2F_6 , C_4F_{10} ...) | Kyoto |
| SF_6 | sulphur hexafluoride | Kyoto |
| NF_3 | nitrogen trifluoride | Kyoto |
| CFC | chlorofluorocarbon (a class of compounds: $CFCl_3$, CF_2Cl_2 ...) | Montreal |
| HCFC | hydrochlorofluorocarbon (a class of compounds: HCFC-22, HCFC-141b ...) | Montreal |
| CCl_4 | carbon tetrachloride | Montreal |
| CH_3CCl_3 | methyl chloroform | Montreal |
| CH_3Br | Methyl bromide | Montreal |
| Halons | bromo(chloro)fluorocarbon (a class of compounds: CF_2ClBr – 'Halon-1211'; $CBrF_3$ – 'Halon-1301'; $C_2Br_2F_4$ – 'Halon-2402') | Montreal |

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¹ The Kyoto protocol (1 December 1997–31 December 2020) regulated a basket of seven GHGs. The term Kyoto gases is widely used in the scientific literature.

Table AIII.1a | Historical abundances and ERF ($W m^{-2}$) for CO₂ (ppm), CH₄ (ppb) and N₂O (ppb).

| Year | CO ₂ | CH ₄ | N ₂ O | Year | CO ₂ | CH ₄ | N ₂ O | Year | CO ₂ | CH ₄ | N ₂ O | |
|-------------------|-----------------|-----------------|------------------|------|--------------------|-------------------|--------------------|------|------------------------|-----------------|------------------|-------------|
| 1750 ^a | 278.3 | 729 | 270.1 | 1968 | 322.5 | 1372 | 295.2 | 1994 | 358.2 | 1743 | 310.8 | |
| 1850 ^a | 285.5 | 808 | 272.1 | 1969 | 323.4 | 1389 | 295.6 | 1995 | 360.0 | 1748 | 311.4 | |
| 1860 ^b | 286.8 | 822 | 273.2 | 1970 | 324.9 | 1411 | 296.0 | 1996 | 361.8 | 1750 | 312.3 | |
| 1870 | 288.4 | 852 | 274.9 | 1971 | 325.5 | 1431 | 296.5 | 1997 | 362.5 | 1754 | 313.1 | |
| 1880 | 290.4 | 868 | 276.6 | 1972 | 327.4 | 1449 | 296.9 | 1998 | 365.5 | 1764 | 313.9 | |
| 1890 | 293.3 | 896 | 277.6 | 1973 | 330.0 | 1463 | 297.3 | 1999 | 367.6 | 1772 | 314.9 | |
| 1900 | 296.4 | 925 | 278.9 | 1974 | 330.8 | 1476 | 297.8 | 2000 | 368.8 | 1773 | 315.9 | |
| 1905 | 298.0 | 947 | 280.2 | 1975 | 330.9 | 1492 | 298.3 | 2001 | 370.4 | 1772 | 316.6 | |
| 1910 | 300.0 | 974 | 281.8 | 1976 | 331.6 | 1509 | 298.8 | 2002 | 372.4 | 1773 | 317.3 | |
| 1915 | 302.5 | 991 | 283.6 | 1977 | 333.4 | 1528 | 299.3 | 2003 | 375.0 | 1777 | 318.0 | |
| 1920 | 304.8 | 1025 | 284.5 | 1978 | 335.0 | 1547 | 299.8 | 2004 | 376.8 | 1776 | 318.6 | |
| 1925 | 306.3 | 1052 | 285.3 | 1979 | 336.6 | 1566 | 300.4 | 2005 | 378.8 | 1774 | 319.3 | |
| 1930 | 307.1 | 1072 | 285.6 | 1980 | 338.8 ^c | 1585 | 301.1 ^c | 2006 | 381.0 | 1774 | 320.2 | |
| 1935 | 308.6 | 1097 | 286.3 | 1981 | 340.0 | 1603 | 301.9 | 2007 | 382.7 | 1781 | 320.9 | |
| 1940 | 311.7 | 1120 | 287.3 | 1982 | 340.8 | 1619 | 303.1 | 2008 | 384.8 | 1788 | 321.8 | |
| 1945 | 312.7 | 1139 | 289.0 | 1983 | 342.4 | 1633 | 303.7 | 2009 | 386.3 | 1793 | 322.6 | |
| 1950 | 313.1 | 1164 | 289.5 | 1984 | 344.0 | 1645 ^c | 304.3 | 2010 | 388.6 | 1798 | 323.4 | |
| 1955 | 314.6 | 1207 | 290.7 | 1985 | 345.5 | 1657 | 304.9 | 2011 | 390.5 | 1803 | 324.4 | |
| 1960 | 316.8 | 1264 | 292.1 | 1986 | 346.9 | 1670 | 305.8 | 2012 | 392.5 | 1808 | 325.3 | |
| 1961 | 317.5 | 1269 | 292.5 | 1987 | 348.6 | 1680 | 306.0 | 2013 | 395.2 | 1814 | 326.2 | |
| 1962 | 318.2 | 1282 | 292.8 | 1988 | 351.2 | 1693 | 306.7 | 2014 | 397.1 | 1823 | 327.4 | |
| 1963 | 318.8 | 1301 | 293.2 | 1989 | 352.8 | 1707 | 307.8 | 2015 | 399.4 | 1834 | 328.3 | |
| 1964 | 319.5 | 1317 | 293.6 | 1990 | 354.0 | 1714 | 308.7 | 2016 | 402.9 | 1842 | 329.1 | |
| 1965 | 320.0 | 1331 | 293.9 | 1991 | 355.3 | 1728 | 309.4 | 2017 | 405.0 | 1849 | 330.0 | |
| 1966 | 321.0 | 1342 | 294.4 | 1992 | 356.0 | 1735 | 309.9 | 2018 | 407.4 | 1858 | 331.2 | |
| 1967 | 321.6 | 1354 | 294.8 | 1993 | 356.7 | 1737 | 310.3 | 2019 | 409.9 | 1866 | 332.1 | |
| | | | | | | | | | ERF^d | 2.16 | 0.54 | 0.21 |

Notes: ^a 1750/1850 CO₂, CH₄ and N₂O from multiple ice cores assessed in Chapter 2. Uncertainties (90% CI) for 1750 are 2.9 ppm, 9.4 ppb and 6.0 ppb for CO₂, CH₄ and N₂O, respectively. Uncertainties for 1850 are 2.1 ppm, 13.8 ppb and 5.7 ppb, based on variations of ice cores.

^b Mixing ratios from 1851–1980/1984 are updated from the CMIP6 (Meinshausen et al., 2017) dataset, using a linear time-dependent offset correction function.

^c CO₂ from NOAA network; CH₄ and N₂O from merged NOAA and AGAGE networks. Uncertainties (90% CI) in 2019, derived from multiple global networks, are 0.36 ppm, 3.3 ppb and 0.4 ppb for CO₂, CH₄ and N₂O, respectively, and do not include estimates of analytical accuracy. Uncertainties for other years may differ.

^d ERF (2019–1750) from Chapter 7.

Table AIII.1b | Historical abundances (ppt) and ERF ($mW m^{-2}$) of NF₃, SF₆, SO₂F₂, and perfluorocarbons (PFCs).

| Year | NF ₃ | SF ₆ | SO ₂ F ₂ | CF ₄ | C ₂ F ₆ | C ₃ F ₈ | c-C ₄ F ₈ | n-C ₄ F ₁₀ | n-C ₅ F ₁₂ | n-C ₆ F ₁₄ | i-C ₆ F ₁₄ | C ₇ F ₁₆ | C ₈ F ₁₈ |
|------|-----------------|-----------------|--------------------------------|-----------------|-------------------------------|-------------------------------|---------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------------|--------------------------------|
| 1750 | 0.00 | 0.00 | 0.00 | 34.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1850 | 0.00 | 0.00 | 0.00 | 34.1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1900 | 0.00 | 0.00 | 0.00 | 34.1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1910 | 0.00 | 0.00 | 0.00 | 34.1 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1920 | 0.00 | 0.00 | 0.00 | 34.4 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1930 | 0.00 | 0.00 | 0.00 | 34.9 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1940 | 0.00 | 0.00 | 0.00 | 35.8 | 0.19 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1950 | 0.00 | 0.00 | 0.00 | 38.0 | 0.40 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1960 | 0.00 | 0.09 | 0.00 | 40.1 | 0.51 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1970 | 0.00 | 0.32 | 0.01 | 43.4 | 0.62 | 0.03 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.00 | 0.86 | 0.35 | 53.5 | 1.22 | 0.05 | 0.38 | 0.02 | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 |
| 1990 | 0.01 | 2.35 | 0.68 | 63.8 | 2.07 | 0.12 | 0.76 | 0.07 | 0.05 | 0.03 | 0.015 | 0.03 | 0.02 |



| Year | NF ₃ | SF ₆ | SO ₂ F ₂ | CF ₄ | C ₂ F ₆ | C ₃ F ₈ | c-C ₄ F ₈ | n-C ₄ F ₁₀ | n-C ₅ F ₁₂ | n-C ₆ F ₁₄ | i-C ₆ F ₁₄ | C ₇ F ₁₆ | C ₈ F ₁₈ |
|------|-----------------|-----------------|--------------------------------|-----------------|-------------------------------|-------------------------------|---------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------------|--------------------------------|
| 2000 | 0.17 | 4.56 | 1.07 | 71.5 | 3.11 | 0.28 | 0.98 | 0.13 | 0.10 | 0.14 | 0.038 | 0.07 | 0.06 |
| 2010 | 0.73 | 7.01 | 1.63 | 78.3 | 4.09 | 0.54 | 1.26 | 0.17 | 0.12 | 0.21 | 0.055 | 0.10 | 0.09 |
| 2015 | 1.30 | 8.57 | 2.11 | 81.9 | 4.49 | 0.62 | 1.50 | 0.19 | 0.14 | 0.22 | 0.062 | 0.11 | n.a. |
| 2019 | 2.05 | 9.95 | 2.50 | 85.5 | 4.85 | 0.68 | 1.75 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Unc. | 0.03 | 0.03 | 0.05 | 0.2 | 0.05 | 0.01 | 0.01 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| ERF | 0.4 | 5.6 | 0.5 | 5.1 | 1.3 | 0.2 | 0.5 | 0.1 | 0.1 | 0.1 | 0.0 ^a | 0.1 | 0.1 |

Notes: Data merged from AR5 (1750; 1850); CMIP6 compilation by Meinshausen et al. (2017) until about 1995, and data directly taken from merged AGAGE and NOAA networks, depending on date of availability. Perfluorocarbons from CMIP6 dataset (Meinshausen et al., 2017) or estimated from Droste et al. (2020), with CMIP6 n-C₆F₁₄ and C₇F₁₆ scaled to account for calibration changes in Droste et al. (2020). Uncertainties pertain to 2019, derived from observations made by global networks and literature, and do not include estimates of analytical accuracy. Uncertainties are not available for n-C₄F₁₀, n-C₅F₁₂, n-C₆F₁₄, i-C₆F₁₄, C₇F₁₆ or C₈F₁₈. ERF (2019–1750) from Chapter 7, except for n-C₄F₁₀, n-C₅F₁₂, n-C₆F₁₄, i-C₆F₁₄ and C₇F₁₆, uses 2015 abundances and C₈F₁₈ which uses 2010 abundance.

^a Below <0.5 m Wm⁻². n.a. Not available.

Table AIII.1c | Historical abundances (ppt) and ERF (mW m⁻²) of hydrofluorocarbons (HFCs).

| Year | HFC-134a | HFC-23 | HFC-32 | HFC-125 | HFC-143a | HFC-152a | HFC-227ea | HFC-236fa | HFC-245fa | HFC-365mfc | HFC-43-10mee |
|------|----------|--------|--------|---------|----------|----------|-----------|-----------|-----------|------------|--------------|
| 1750 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1850 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1900 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1910 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1920 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1930 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1940 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1950 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1960 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1970 | 0.0 | 1.8 | 0.0 | 0. | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.2 | 3.9 | 0.0 | 0.1 | 0.1 | 0.0 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1990 | 0.5 | 8.3 | 0.1 | 0.1 | 0.5 | 0.2 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| 2000 | 14.2 | 15.2 | 0.2 | 1.5 | 2.5 | 1.6 | 0.11 | 0.02 | 0.02 | 0.01 | 0.03 |
| 2010 | 57.5 | 23.3 | 3.8 | 8.8 | 10.8 | 6.2 | 0.66 | 0.09 | 1.34 | 0.55 | 0.20 |
| 2015 | 83.4 | 28.0 | 10.0 | 18.1 | 17.6 | 6.6 | 1.10 | 0.14 | 2.23 | 0.86 | 0.25 |
| 2019 | 107.6 | 32.4 | 20.0 | 29.4 | 24.0 | 7.1 | 1.59 | 0.19 | 3.06 | 1.09 | 0.29 |
| Unc. | 0.5 | 0.1 | 1.4 | 0.6 | 0.4 | 0.4 | 0.06 | n.a. | 0.06 | 0.14 | n.a. |
| ERF | 18.0 | 6.2 | 2.2 | 6.9 | 4.0 | 0.7 | 0.4 | 0.0 | 0.7 | 0.2 | 0.1 |

Notes: Data merged from AR5 (1750; 1850); CMIP6 compilation by Meinshausen et al. (2017) until about 1995, and data directly taken from merged AGAGE and NOAA networks, depending on the date of availability for various components. Uncertainties pertain to 2019, derived from observations made by global networks, and do not include estimates of analytical accuracy. n.a.: not available. ERF (2019–1750) from Chapter 7.

Table AIII.1d | Historical abundances (ppt) and ERF (mW m⁻²) of hydrochlorofluorocarbons (HCFCs).

| Year | HCFC-22 | HCFC-141b | HCFC-142b | HCFC-133a | HCFC-31 | HCFC-124 |
|------|---------|-----------|-----------|-----------|---------|----------|
| 1750 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1850 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1900 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1910 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1920 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1930 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1940 | 0.3 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1950 | 0.9 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1960 | 2.3 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |

| Year | HCFC-22 | HCFC-141b | HCFC-142b | HCFC-133a | HCFC-31 | HCFC-124 |
|------|---------|-----------|-----------|-----------|---------|----------|
| 1970 | 13.1 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 |
| 1980 | 44.6 | 0.0 | 0.4 | 0.01 | 0.00 | 0.00 |
| 1990 | 89.6 | 0.3 | 1.5 | 0.05 | 0.00 | 0.00 |
| 2000 | 141.8 | 12.7 | 11.4 | 0.11 | 0.027 | 0.00 |
| 2010 | 206.3 | 20.5 | 20.4 | 0.31 | 0.084 | 1.10 |
| 2015 | 233.3 | 24.2 | 22.2 | 0.40 | 0.084 | 1.02 |
| 2019 | 246.8 | 24.4 | 22.3 | n.a. | n.a. | n.a. |
| Unc. | 0.6 | 0.3 | 0.4 | n.a. | n.a. | n.a. |
| ERF | 52.8 | 3.9 | 4.3 | 0.1 | 0.0 | 0.2 |

Notes: 1750/1850 from AR5; 1900–1970 from CMIP6 dataset in Meinshausen et al. (2017). 1980–1995 AGAGE, or data directly taken from merged AGAGE and NOAA networks, depending on the date of availability for various components; HCFC-31 from Schoenenberger et al. (2015), HCFC-124 from Simmonds et al. (2017). Uncertainties pertain to 2019, derived from observations made by global networks, and do not include estimates of analytical accuracy. For HCFC-133a, HCFC-31 and HCFC-124 abundancies in 2019 and uncertainties are not available. ERF (2019–1750) from Chapter 7, except HCFC-133a, HCFC-31 and HCFC-124 which are for 2015.

Table AIII.1e | Historical abundances (ppt) and ERF (mW m⁻²) of chlorofluorocarbon (CFCs).

| Year | CFC-12 | CFC-11 | CFC-113 | CFC-114 | CFC-115 | CFC-13 | CFC-112 | CFC-112a | CFC-113a | CFC-114a |
|------|--------|--------|---------|---------|---------|--------|---------|----------|----------|----------|
| 1750 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1850 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1900 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1910 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1920 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1930 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1940 | 0.0 | 0.0 | 0.5 | 0.0 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1950 | 6.4 | 0.9 | 1.0 | 1.5 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1960 | 31.6 | 10.2 | 2.0 | 3.9 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1970 | 121.7 | 57.0 | 5.9 | 6.7 | 0.20 | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 304.0 | 166.8 | 20.8 | 10.1 | 1.75 | 1.20 | 0.11 | 0.00 | 0.06 | 0.44 |
| 1990 | 483.1 | 258.1 | 70.6 | 15.6 | 5.46 | 2.42 | 0.31 | 0.00 | 0.16 | 0.91 |
| 2000 | 542.3 | 259.2 | 82.1 | 16.4 | 8.16 | 2.83 | 0.49 | 0.07 | 0.28 | 1.03 |
| 2010 | 530.9 | 239.4 | 75.2 | 16.3 | 8.38 | 3.04 | 0.45 | 0.07 | 0.41 | 1.06 |
| 2015 | 516.6 | 231.0 | 72.0 | 16.0 | 8.46 | 3.16 | 0.42 | 0.07 | 0.62 | 1.05 |
| 2019 | 503.1 | 226.2 | 69.8 | 16.0 | 8.67 | 3.28 | n.a. | n.a. | n.a. | n.a. |
| Unc. | 3.2 | 1.1 | 0.3 | 0.1 | 0.02 | 0.02 | n.a. | n.a. | n.a. | n.a. |
| ERF | 180.3 | 66.3 | 21.0 | 5.0 | 2.1 | 0.9 | 0.1 | 0.0 | 0.2 | 0.3 |

Notes: 1750/1850 from AR5; 1900–1970 from CMIP6 dataset in Meinshausen et al. (2017). 1980–1995 AGAGE, or data directly taken from merged AGAGE and NOAA networks, depending on the date of availability for various components; CFC-13 from Vollmer et al. (2018) until 2015, then AGAGE; CFC-114 and CFC-114a from AGAGE and Laube et al. (2016). CFC-112 and CFC-112a from Laube et al. (2014) and Engel et al. (2018); CFC-113a from Adcock et al. (2018). Uncertainties pertain to 2019, derived from observations made by global networks, and do not include estimates of analytical accuracy. For CFC-112, CFC-112a, CFC-113a and CFC-114a abundancies and uncertainties for 2019 are not available. ERF (2019–1750) from Chapter 7, except for CFC-112, CFC-112a, CFC-113a and CFC-114a for 2015.

Table AIII.1f | Historical abundances (ppt) and ERF (mW m⁻²) of CH₃CCl₃, CCl₄, CH₂Cl₂, CH₃Br, CHCl₃, CHCl₃ and halons.

| Year | CH ₃ CCl ₃ | CCl ₄ | CH ₂ Cl ₂ | CH ₃ Br | CH ₂ Cl ₂ | CHCl ₃ | Halon-1211 | Halon-1301 | Halon-2402 |
|------|----------------------------------|------------------|---------------------------------|--------------------|---------------------------------|-------------------|------------|------------|------------|
| 1750 | 0.00 | 0.03 | 457 | 5.30 | 7 | 4.8 | 0.00 | 0.00 | 0.00 |
| 1850 | 0.00 | 0.03 | 457 | 5.30 | 7 | 4.8 | 0.00 | 0.00 | 0.00 |
| 1900 | 0.00 | 0.03 | 457 | 5.30 | 7 | 4.8 | 0.00 | 0.00 | 0.00 |
| 1910 | 0.00 | 0.03 | 457 | 5.30 | 7 | 4.8 | 0.00 | 0.00 | 0.00 |
| 1920 | 0.00 | 1.2 | 457 | 5.30 | 7 | 4.8 | 0.00 | 0.00 | 0.00 |
| 1930 | 0.00 | 4.1 | 457 | 5.30 | 7 | 5.0 | 0.00 | 0.00 | 0.00 |



| Year | CH ₂ Cl ₂ | CCl ₄ | CH ₃ Cl | CH ₃ Br | CH ₂ Cl ₂ | CHCl ₃ | Halon-1211 | Halon-1301 | Halon-2402 |
|------|---------------------------------|------------------|--------------------|--------------------|---------------------------------|-------------------|------------|------------|------------|
| 1940 | 0.00 | 14.1 | 457 | 5.66 | 7 | 5.3 | 0.00 | 0.00 | 0.00 |
| 1950 | 0.00 | 35.5 | 478 | 6.06 | 8 | 5.7 | 0.03 | 0.00 | 0.00 |
| 1960 | 1.70 | 53.2 | 512 | 6.50 | 11 | 6.4 | 0.02 | 0.00 | 0.00 |
| 1970 | 17.7 | 77.0 | 540 | 7.06 | 14 | 7.5 | 0.04 | 0.00 | 0.02 |
| 1980 | 85.9 | 93.8 | 549 | 7.77 | 18 | 8.8 | 0.71 | 0.38 | 0.15 |
| 1990 | 129.3 | 106.2 | 550 | 8.69 | 20 | 10.3 | 2.44 | 1.85 | 0.37 |
| 2000 | 45.4 | 98.1 | 547 | 9.09 | 20 | 7.5 | 4.12 | 2.82 | 0.48 |
| 2010 | 7.6 | 87.3 | 538 | 7.14 | 29 | 7.3 | 4.12 | 3.21 | 0.46 |
| 2015 | 3.1 | 81.6 | 547 | 6.68 | 35 | 8.6 | 3.66 | 3.31 | 0.42 |
| 2019 | 1.6 | 77.9 | 551 | 6.49 | 41 | 8.8 | 3.28 | 3.32 | 0.40 |
| Unc. | 0.1 | 0.7 | 5 | 0.07 | 6 | 0.3 | 0.05 | 0.07 | 0.03 |
| ERF | 0.1 | 12.9 | 0.4 | 0.0 | 1.0 | 0.3 | 1.0 | 1.0 | 0.1 |

Notes: 1750 from AR5; 1850–1970 from CMIP6 dataset in Meinshausen et al. (2017). 1980–2019 AGAGE or merged AGAGE and NOAA networks, depending on the date of availability. ERF (2019–1750) from Chapter 7.

Table AIII.2 | Future abundances of CO₂, CH₄ and N₂O for selected SSP scenarios (2020–2500).

| Year/ Scenario | CO ₂ (ppm) | | | | | CH ₄ (ppb) | | | | | N ₂ O (ppb) | | | | |
|-------------------|-----------------------|----------|----------|----------|----------|-----------------------|----------|----------|----------|----------|------------------------|----------|----------|----------|----------|
| | SSP1-1.9 | SSP1-2.6 | SSP2-4.5 | SSP3-7.0 | SSP5-8.5 | SSP1-1.9 | SSP1-2.6 | SSP2-4.5 | SSP3-7.0 | SSP5-8.5 | SSP1-1.9 | SSP1-2.6 | SSP2-4.5 | SSP3-7.0 | SSP5-8.5 |
| 2019 ^a | 410 | | | | | 1866 | | | | | 332 | | | | |
| 2020 | 414 | 414 | 414 | 415 | 415 | 1894 | 1888 | 1911 | 1921 | 1907 | 332 | 332 | 332 | 332 | 332 |
| 2030 | 434 | 440 | 444 | 451 | 452 | 1796 | 1810 | 2002 | 2099 | 2018 | 337 | 337 | 340 | 341 | 341 |
| 2040 | 440 | 458 | 475 | 493 | 500 | 1593 | 1663 | 2045 | 2289 | 2209 | 341 | 341 | 348 | 351 | 350 |
| 2050 | 438 | 469 | 507 | 541 | 563 | 1428 | 1519 | 2020 | 2472 | 2446 | 344 | 344 | 356 | 362 | 358 |
| 2060 | 431 | 474 | 537 | 593 | 643 | 1305 | 1402 | 1942 | 2655 | 2613 | 346 | 346 | 363 | 373 | 366 |
| 2070 | 424 | 473 | 564 | 652 | 744 | 1220 | 1299 | 1854 | 2840 | 2670 | 348 | 348 | 369 | 385 | 374 |
| 2080 | 415 | 467 | 585 | 716 | 864 | 1150 | 1197 | 1779 | 3028 | 2652 | 350 | 349 | 373 | 397 | 380 |
| 2090 | 405 | 457 | 598 | 787 | 998 | 1088 | 1112 | 1719 | 3208 | 2549 | 352 | 352 | 376 | 409 | 387 |
| 2100 | 394 | 446 | 603 | 867 | 1135 | 1036 | 1056 | 1683 | 3372 | 2415 | 354 | 354 | 377 | 422 | 392 |
| 2200 | 343 | 403 | 643 | 1457 | 2108 | 929 | 928 | 1255 | 2572 | 1516 | 364 | 363 | 376 | 497 | 414 |
| 2300 | 342 | 396 | 621 | 1483 | 2162 | 872 | 864 | 1001 | 1988 | 1068 | 361 | 360 | 367 | 511 | 411 |
| 2400 | 339 | 389 | 598 | 1424 | 2080 | 871 | 864 | 999 | 1959 | 1038 | 358 | 358 | 362 | 514 | 408 |
| 2500 | 337 | 384 | 579 | 1371 | 2010 | 871 | 864 | 997 | 1938 | 1019 | 357 | 356 | 360 | 516 | 407 |

Note:^aObserved from Table AIII.1a. SSP GHG concentrations (Meinshausen et al., 2017, 2020) available at greenhousegases.science.unimelb.edu.au. Concentrations of halogenated compounds in electronic supplement. Major scenarios used in this report are selected.

Table AIII.3 | Effective radiative forcing (W m⁻²) time series of all climate forcers from 1750–2019.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land Use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 1750 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.10 | 0.00 | 0.30 | 0.30 |
| 1850 | 0.14 | 0.05 | 0.01 | 0.00 | 0.03 | 0.00 | 0.00 | -0.01 | -0.07 | 0.01 | -0.03 | 0.19 | 0.01 | 0.13 | 0.20 | 0.33 |
| 1900 | 0.35 | 0.12 | 0.03 | 0.00 | 0.08 | 0.01 | 0.00 | -0.06 | -0.29 | 0.02 | -0.08 | 0.20 | -0.04 | 0.18 | 0.16 | 0.34 |
| 1910 | 0.41 | 0.15 | 0.04 | 0.00 | 0.09 | 0.01 | 0.00 | -0.10 | -0.42 | 0.03 | -0.10 | 0.20 | -0.02 | 0.12 | 0.18 | 0.30 |

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land Use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 1920 | 0.50 | 0.17 | 0.05 | 0.00 | 0.10 | 0.02 | 0.00 | -0.10 | -0.43 | 0.03 | -0.11 | 0.19 | 0.01 | 0.23 | 0.20 | 0.43 |
| 1930 | 0.54 | 0.20 | 0.06 | 0.00 | 0.12 | 0.02 | 0.00 | -0.11 | -0.46 | 0.03 | -0.13 | 0.19 | 0.02 | 0.26 | 0.21 | 0.48 |
| 1940 | 0.62 | 0.22 | 0.06 | 0.00 | 0.14 | 0.02 | 0.00 | -0.15 | -0.52 | 0.03 | -0.14 | 0.19 | 0.04 | 0.29 | 0.23 | 0.52 |
| 1950 | 0.65 | 0.24 | 0.07 | 0.01 | 0.17 | 0.02 | 0.00 | -0.15 | -0.55 | 0.03 | -0.14 | 0.18 | 0.06 | 0.35 | 0.24 | 0.59 |
| 1960 | 0.71 | 0.29 | 0.08 | 0.03 | 0.22 | 0.03 | 0.01 | -0.25 | -0.73 | 0.04 | -0.17 | 0.18 | 0.09 | 0.26 | 0.27 | 0.54 |
| 1970 | 0.85 | 0.36 | 0.09 | 0.08 | 0.28 | 0.03 | 0.02 | -0.38 | -0.92 | 0.05 | -0.18 | 0.05 | 0.08 | 0.29 | 0.13 | 0.42 |
| 1980 | 1.09 | 0.43 | 0.11 | 0.20 | 0.33 | 0.04 | 0.02 | -0.41 | -1.04 | 0.06 | -0.18 | 0.09 | 0.11 | 0.66 | 0.19 | 0.86 |
| 1990 | 1.33 | 0.49 | 0.13 | 0.33 | 0.36 | 0.04 | 0.03 | -0.38 | -1.05 | 0.07 | -0.19 | 0.14 | 0.11 | 1.17 | 0.24 | 1.42 |
| 2000 | 1.56 | 0.51 | 0.16 | 0.37 | 0.40 | 0.05 | 0.04 | -0.30 | -0.92 | 0.07 | -0.19 | 0.18 | 0.11 | 1.74 | 0.29 | 2.02 |
| 2010 | 1.85 | 0.52 | 0.18 | 0.39 | 0.44 | 0.05 | 0.04 | -0.27 | -0.99 | 0.08 | -0.20 | 0.14 | -0.01 | 2.10 | 0.13 | 2.23 |
| 2015 | 2.01 | 0.53 | 0.20 | 0.40 | 0.47 | 0.05 | 0.05 | -0.23 | -0.89 | 0.08 | -0.20 | 0.11 | 0.03 | 2.47 | 0.14 | 2.61 |
| 2019 | 2.16 | 0.54 | 0.21 | 0.41 | 0.47 | 0.05 | 0.06 | -0.22 | -0.84 | 0.08 | -0.20 | 0.14 | -0.02 | 2.72 | 0.12 | 2.84 |

Notes: O₃ includes tropospheric and stratospheric O₃, dominated by tropospheric O₃. Stratospheric water vapour from methane oxidation is a linear function of the methane ERF (Section 7.3.2.6). Contrail forcing is a linear scaling of aviation NO_x emissions, scaled to ERF in 2018 (Lee et al., 2021). Present-day aerosol forcing is assessed in Section 7.3.3 as -0.3 [-0.6 to 0.0] W m⁻² for aerosol-radiation interactions and -1.0 [-1.7 to -0.3] W m⁻² for aerosol-cloud interactions for the 2005–2014 mean relative to 1750. Land-use change considers albedo and irrigation effects (Section 7.3.4.1). BC on snow forcing is linear with emissions of BC (Section 7.3.4.3). Volcanic forcing is positive in years without large volcanic eruptions, such that the long-term pre-industrial (500 BCE to 1749 CE) mean volcanic forcing is zero. Solar forcing is derived from the ¹⁴C reconstruction of total solar irradiance in the combined PMIP4/CMIP6 dataset (Jungclauss et al., 2017; Matthes et al., 2017). Present-day solar forcing is assessed in Section 7.3.4.4 as +0.01 [-0.06 to +0.08] W m⁻², based on the mean total solar irradiance from solar cycle 24 (2009–2019) compared a long pre-industrial baseline period (6754 BCE to 1744 CE); the 2019 ERF value differs from this as it represents a single year near the solar minimum. Natural is the sum of volcanic and solar forcing, while anthropogenic includes all others. Further details on methods for computing ERF are in Chapter 7 Supplementary Material 7.SM.1.3.

Table AIII.4a | Effective radiative forcing (W m⁻²) time series of all climate forcers for SSP1-1.9.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 2020 | 2.22 | 0.55 | 0.21 | 0.40 | 0.42 | 0.05 | 0.05 | -0.20 | -0.81 | 0.08 | -0.20 | 0.06 | -0.02 | 2.77 | 0.04 | 2.81 |
| 2030 | 2.49 | 0.52 | 0.23 | 0.38 | 0.25 | 0.05 | 0.03 | -0.16 | -0.39 | 0.03 | -0.21 | 0.00 | -0.02 | 3.22 | -0.02 | 3.20 |
| 2040 | 2.56 | 0.44 | 0.24 | 0.32 | 0.19 | 0.04 | 0.02 | -0.16 | -0.28 | 0.02 | -0.21 | 0.00 | -0.01 | 3.18 | -0.01 | 3.18 |
| 2050 | 2.53 | 0.37 | 0.25 | 0.27 | 0.14 | 0.03 | 0.02 | -0.17 | -0.20 | 0.01 | -0.21 | 0.00 | 0.01 | 3.04 | 0.01 | 3.05 |
| 2060 | 2.45 | 0.31 | 0.26 | 0.23 | 0.12 | 0.03 | 0.01 | -0.17 | -0.16 | 0.01 | -0.21 | 0.00 | 0.01 | 2.87 | 0.01 | 2.88 |
| 2070 | 2.35 | 0.27 | 0.26 | 0.21 | 0.11 | 0.02 | 0.01 | -0.16 | -0.13 | 0.00 | -0.20 | 0.00 | 0.02 | 2.74 | 0.02 | 2.76 |
| 2080 | 2.23 | 0.24 | 0.27 | 0.19 | 0.09 | 0.02 | 0.01 | -0.15 | -0.09 | 0.00 | -0.19 | 0.00 | 0.02 | 2.62 | 0.02 | 2.64 |
| 2090 | 2.09 | 0.21 | 0.28 | 0.17 | 0.09 | 0.02 | 0.01 | -0.14 | -0.05 | 0.00 | -0.19 | 0.00 | 0.01 | 2.48 | 0.01 | 2.48 |
| 2100 | 1.92 | 0.18 | 0.28 | 0.15 | 0.08 | 0.02 | 0.01 | -0.13 | -0.01 | 0.00 | -0.18 | 0.00 | 0.00 | 2.33 | 0.00 | 2.33 |
| 2200 | 1.16 | 0.12 | 0.32 | 0.07 | 0.06 | 0.01 | 0.00 | -0.10 | 0.08 | -0.01 | -0.17 | 0.00 | 0.03 | 1.55 | 0.03 | 1.58 |
| 2300 | 1.14 | 0.09 | 0.31 | 0.04 | 0.03 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.17 | 0.00 | 0.00 | 1.49 | 0.00 | 1.49 |
| 2400 | 1.09 | 0.09 | 0.30 | 0.03 | 0.03 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.17 | 0.00 | 0.00 | 1.42 | 0.00 | 1.42 |
| 2500 | 1.05 | 0.09 | 0.30 | 0.02 | 0.03 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.17 | 0.00 | 0.00 | 1.38 | 0.00 | 1.38 |

Notes: ERF based on future abundancies of well-mixed greenhouse gases (WMGHGs) listed in AIII.2. See notes of AIII.3. Future ozone forcing uses projected emissions of carbon monoxide, volatile organic carbon, nitrogen oxides, and concentrations of methane, nitrous oxide and halogenated compounds with relationships to forcing derived from Thornhill et al. (2021a, b). Future contrail forcing is a linear scaling of future NO_x emissions (Smith et al., 2018) and scaled to year-2018 ERF (Lee et al., 2021). Future aerosol forcing is based on emissions of black carbon, organic carbon, sulphur dioxide and ammonia using a method described in Smith et al. (2018). Land-use forcing scales with cumulative emissions of future land-use CO₂ (Smith et al., 2018). Future volcanic forcing set to zero from a 10-year linear transition from the end of the historical period following Eyring et al. (2016). Solar forcing is set to zero from 2300 CE. Further details on methods for computing SSP-projection ERF are in Chapter 7 Supplementary Material 7.SM.1.4.



Table AIII.4b | Effective radiative forcing ($W m^{-2}$) time series of all climate forcers for SSP1-2.6.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 2020 | 2.22 | 0.55 | 0.21 | 0.40 | 0.42 | 0.05 | 0.05 | -0.20 | -0.81 | 0.08 | -0.20 | 0.06 | -0.02 | 2.76 | 0.04 | 2.80 |
| 2030 | 2.56 | 0.52 | 0.22 | 0.39 | 0.30 | 0.05 | 0.04 | -0.19 | -0.51 | 0.04 | -0.21 | 0.00 | -0.02 | 3.23 | -0.02 | 3.21 |
| 2040 | 2.79 | 0.46 | 0.24 | 0.34 | 0.26 | 0.04 | 0.04 | -0.16 | -0.36 | 0.03 | -0.20 | 0.00 | -0.01 | 3.49 | -0.01 | 3.48 |
| 2050 | 2.93 | 0.41 | 0.25 | 0.28 | 0.21 | 0.04 | 0.04 | -0.15 | -0.26 | 0.02 | -0.20 | 0.00 | 0.01 | 3.56 | 0.01 | 3.58 |
| 2060 | 2.99 | 0.35 | 0.25 | 0.24 | 0.18 | 0.03 | 0.04 | -0.13 | -0.20 | 0.02 | -0.20 | 0.00 | 0.01 | 3.58 | 0.01 | 3.58 |
| 2070 | 2.98 | 0.31 | 0.26 | 0.21 | 0.15 | 0.03 | 0.04 | -0.13 | -0.16 | 0.02 | -0.19 | 0.00 | 0.02 | 3.52 | 0.02 | 3.54 |
| 2080 | 2.91 | 0.26 | 0.27 | 0.19 | 0.12 | 0.02 | 0.04 | -0.13 | -0.10 | 0.01 | -0.18 | 0.00 | 0.02 | 3.40 | 0.02 | 3.42 |
| 2090 | 2.78 | 0.22 | 0.28 | 0.17 | 0.10 | 0.02 | 0.03 | -0.13 | -0.06 | 0.01 | -0.17 | 0.00 | 0.01 | 3.24 | 0.01 | 3.25 |
| 2100 | 2.63 | 0.19 | 0.28 | 0.16 | 0.08 | 0.02 | 0.03 | -0.12 | -0.01 | 0.00 | -0.17 | 0.00 | 0.00 | 3.10 | 0.00 | 3.10 |
| 2200 | 2.06 | 0.12 | 0.32 | 0.07 | 0.04 | 0.01 | 0.01 | -0.10 | 0.08 | -0.01 | -0.15 | 0.00 | 0.03 | 2.47 | 0.03 | 2.50 |
| 2300 | 1.96 | 0.08 | 0.31 | 0.04 | 0.01 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.15 | 0.00 | 0.00 | 2.30 | 0.00 | 2.30 |
| 2400 | 1.87 | 0.08 | 0.30 | 0.03 | 0.01 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.15 | 0.00 | 0.00 | 2.19 | 0.00 | 2.19 |
| 2500 | 1.79 | 0.08 | 0.29 | 0.02 | 0.01 | 0.01 | 0.00 | -0.09 | 0.14 | -0.01 | -0.15 | 0.00 | 0.00 | 2.11 | 0.00 | 2.11 |

Notes: See Table AIII.3 and Table AIII.4a.

Table AIII.4c | Effective radiative forcing ($W m^{-2}$) time series of all climate forcers for SSP2-4.5.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 2020 | 2.22 | 0.56 | 0.21 | 0.40 | 0.45 | 0.05 | 0.05 | -0.18 | -0.88 | 0.10 | -0.20 | 0.06 | -0.02 | 2.79 | 0.04 | 2.83 |
| 2030 | 2.62 | 0.59 | 0.23 | 0.40 | 0.47 | 0.05 | 0.07 | -0.21 | -0.84 | 0.09 | -0.21 | 0.00 | -0.02 | 3.25 | -0.02 | 3.24 |
| 2040 | 3.01 | 0.61 | 0.26 | 0.37 | 0.45 | 0.06 | 0.09 | -0.20 | -0.74 | 0.07 | -0.22 | 0.00 | -0.01 | 3.76 | -0.01 | 3.75 |
| 2050 | 3.38 | 0.60 | 0.28 | 0.34 | 0.43 | 0.06 | 0.09 | -0.18 | -0.61 | 0.06 | -0.22 | 0.00 | 0.01 | 4.23 | 0.01 | 4.24 |
| 2060 | 3.72 | 0.57 | 0.30 | 0.32 | 0.39 | 0.05 | 0.10 | -0.18 | -0.51 | 0.05 | -0.22 | 0.00 | 0.01 | 4.59 | 0.01 | 4.60 |
| 2070 | 4.01 | 0.54 | 0.32 | 0.30 | 0.35 | 0.05 | 0.12 | -0.19 | -0.43 | 0.04 | -0.21 | 0.00 | 0.02 | 4.89 | 0.02 | 4.91 |
| 2080 | 4.23 | 0.51 | 0.33 | 0.29 | 0.31 | 0.05 | 0.15 | -0.19 | -0.34 | 0.02 | -0.20 | 0.00 | 0.02 | 5.15 | 0.02 | 5.16 |
| 2090 | 4.35 | 0.49 | 0.34 | 0.28 | 0.28 | 0.04 | 0.16 | -0.19 | -0.25 | 0.01 | -0.19 | 0.00 | 0.01 | 5.32 | 0.01 | 5.33 |
| 2100 | 4.40 | 0.47 | 0.35 | 0.27 | 0.25 | 0.04 | 0.18 | -0.19 | -0.21 | 0.01 | -0.18 | 0.00 | 0.00 | 5.40 | 0.00 | 5.40 |
| 2200 | 4.79 | 0.29 | 0.35 | 0.14 | 0.08 | 0.03 | 0.06 | -0.13 | -0.01 | -0.01 | -0.15 | 0.00 | 0.03 | 5.43 | 0.03 | 5.46 |
| 2300 | 4.59 | 0.16 | 0.32 | 0.05 | -0.02 | 0.01 | 0.00 | -0.11 | 0.09 | -0.01 | -0.15 | 0.00 | 0.00 | 4.94 | 0.00 | 4.94 |
| 2400 | 4.35 | 0.16 | 0.31 | 0.03 | -0.02 | 0.01 | 0.00 | -0.11 | 0.09 | -0.01 | -0.15 | 0.00 | 0.00 | 4.67 | 0.00 | 4.67 |
| 2500 | 4.17 | 0.16 | 0.30 | 0.03 | -0.02 | 0.01 | 0.00 | -0.11 | 0.09 | -0.01 | -0.15 | 0.00 | 0.00 | 4.47 | 0.00 | 4.47 |

Notes: See Table AIII.3 and Table AIII.4a.

Table AIII.4d | Effective radiative forcing ($W m^{-2}$) time series of all climate forcers for SSP3-7.0.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land Use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 2020 | 2.23 | 0.56 | 0.21 | 0.40 | 0.51 | 0.05 | 0.05 | -0.19 | -1.02 | 0.12 | -0.20 | 0.06 | -0.02 | 2.72 | 0.04 | 2.76 |
| 2030 | 2.71 | 0.63 | 0.23 | 0.39 | 0.57 | 0.06 | 0.07 | -0.19 | -1.04 | 0.12 | -0.21 | 0.00 | -0.02 | 3.33 | -0.02 | 3.31 |
| 2040 | 3.22 | 0.69 | 0.26 | 0.37 | 0.62 | 0.06 | 0.08 | -0.19 | -1.06 | 0.13 | -0.22 | 0.00 | -0.01 | 3.97 | -0.01 | 3.96 |
| 2050 | 3.76 | 0.75 | 0.29 | 0.36 | 0.66 | 0.07 | 0.09 | -0.20 | -1.06 | 0.13 | -0.23 | 0.00 | 0.01 | 4.61 | 0.01 | 4.63 |
| 2060 | 4.31 | 0.80 | 0.33 | 0.35 | 0.69 | 0.07 | 0.09 | -0.20 | -1.03 | 0.12 | -0.24 | 0.00 | 0.01 | 5.30 | 0.01 | 5.30 |
| 2070 | 4.87 | 0.86 | 0.36 | 0.35 | 0.71 | 0.08 | 0.10 | -0.20 | -0.99 | 0.12 | -0.25 | 0.00 | 0.02 | 6.00 | 0.02 | 6.02 |
| 2080 | 5.45 | 0.91 | 0.39 | 0.35 | 0.73 | 0.08 | 0.10 | -0.20 | -0.95 | 0.11 | -0.26 | 0.00 | 0.02 | 6.71 | 0.02 | 6.72 |
| 2090 | 6.04 | 0.96 | 0.42 | 0.35 | 0.75 | 0.09 | 0.10 | -0.21 | -0.92 | 0.11 | -0.26 | 0.00 | 0.01 | 7.43 | 0.01 | 7.44 |
| 2100 | 6.64 | 1.00 | 0.45 | 0.36 | 0.77 | 0.09 | 0.11 | -0.20 | -0.87 | 0.10 | -0.27 | 0.00 | 0.00 | 8.18 | 0.00 | 8.18 |
| 2200 | 10.00 | 0.77 | 0.64 | 0.22 | 0.38 | 0.07 | 0.04 | -0.16 | -0.32 | 0.03 | -0.29 | 0.00 | 0.03 | 11.37 | 0.03 | 11.40 |
| 2300 | 10.11 | 0.58 | 0.68 | 0.08 | 0.15 | 0.05 | 0.00 | -0.14 | 0.02 | -0.01 | -0.29 | 0.00 | 0.00 | 11.24 | 0.00 | 11.24 |
| 2400 | 9.84 | 0.57 | 0.69 | 0.06 | 0.14 | 0.05 | 0.00 | -0.14 | 0.02 | -0.01 | -0.29 | 0.00 | 0.00 | 10.94 | 0.00 | 10.94 |
| 2500 | 9.60 | 0.56 | 0.70 | 0.06 | 0.13 | 0.05 | 0.00 | -0.14 | 0.02 | -0.01 | -0.29 | 0.00 | 0.00 | 10.68 | 0.00 | 10.68 |

Note: See Table AIII.3 and Table AIII.4a.

Table AIII.4e | Effective radiative forcing ($W m^{-2}$) time series of all climate forcers for SSP5-8.5.

| Year | CO ₂ | CH ₄ | N ₂ O | Halogenated Compounds | O ₃ | Stratospheric Water Vapour | Contrail-cirrus | Aerosol-radiation Interactions | Aerosol-cloud Interactions | Black Carbon on Snow | Land Use | Volcanic | Solar | Total Anthropogenic | Total Natural | Total |
|------|-----------------|-----------------|------------------|-----------------------|----------------|----------------------------|-----------------|--------------------------------|----------------------------|----------------------|----------|----------|-------|---------------------|---------------|-------|
| 2020 | 2.23 | 0.56 | 0.21 | 0.40 | 0.48 | 0.05 | 0.06 | -0.14 | -0.86 | 0.11 | -0.20 | 0.06 | -0.02 | 2.90 | 0.04 | 2.94 |
| 2030 | 2.71 | 0.60 | 0.23 | 0.41 | 0.49 | 0.06 | 0.08 | -0.13 | -0.71 | 0.09 | -0.21 | 0.00 | -0.02 | 3.61 | -0.02 | 3.59 |
| 2040 | 3.30 | 0.66 | 0.26 | 0.41 | 0.54 | 0.06 | 0.09 | -0.14 | -0.67 | 0.09 | -0.23 | 0.00 | -0.01 | 4.37 | -0.01 | 4.37 |
| 2050 | 4.00 | 0.74 | 0.28 | 0.42 | 0.56 | 0.07 | 0.10 | -0.15 | -0.57 | 0.07 | -0.23 | 0.00 | 0.01 | 5.29 | 0.01 | 5.30 |
| 2060 | 4.79 | 0.79 | 0.30 | 0.45 | 0.60 | 0.07 | 0.12 | -0.18 | -0.58 | 0.06 | -0.24 | 0.00 | 0.01 | 6.21 | 0.01 | 6.22 |
| 2070 | 5.68 | 0.81 | 0.32 | 0.50 | 0.60 | 0.07 | 0.14 | -0.20 | -0.55 | 0.06 | -0.24 | 0.00 | 0.02 | 7.19 | 0.02 | 7.21 |
| 2080 | 6.62 | 0.80 | 0.34 | 0.55 | 0.56 | 0.07 | 0.15 | -0.20 | -0.48 | 0.05 | -0.23 | 0.00 | 0.02 | 8.24 | 0.02 | 8.25 |
| 2090 | 7.54 | 0.77 | 0.36 | 0.58 | 0.49 | 0.07 | 0.15 | -0.21 | -0.38 | 0.03 | -0.23 | 0.00 | 0.01 | 9.18 | 0.01 | 9.19 |
| 2100 | 8.38 | 0.73 | 0.37 | 0.60 | 0.40 | 0.07 | 0.15 | -0.21 | -0.27 | 0.02 | -0.23 | 0.00 | 0.00 | 10.01 | 0.00 | 10.00 |
| 2200 | 12.30 | 0.40 | 0.42 | 0.32 | 0.06 | 0.04 | 0.05 | -0.16 | -0.07 | 0.00 | -0.22 | 0.00 | 0.03 | 13.14 | 0.03 | 13.17 |
| 2300 | 12.46 | 0.19 | 0.42 | 0.08 | -0.11 | 0.02 | 0.00 | -0.14 | 0.03 | -0.01 | -0.22 | 0.00 | 0.00 | 12.72 | 0.00 | 12.72 |
| 2400 | 12.22 | 0.18 | 0.42 | 0.06 | -0.13 | 0.02 | 0.00 | -0.14 | 0.03 | -0.01 | -0.22 | 0.00 | 0.00 | 12.43 | 0.00 | 12.43 |
| 2500 | 12.01 | 0.17 | 0.41 | 0.06 | -0.14 | 0.02 | 0.00 | -0.14 | 0.03 | -0.01 | -0.22 | 0.00 | 0.00 | 12.19 | 0.00 | 12.19 |

Note: See Table AIII.3 and Table AIII.4a.



Table AIII.4f | Effective radiative forcing (mW m^{-2}) time series of halogenated compounds for selected scenarios and Kyoto and Montreal gases.

| Year | SSP1-1.9 | | | | | | SSP3-7.0 | | | | | | SSP5-8.5 | | | | | |
|------------|----------|--|-------------|--|-------------|----------------|----------|--|-------------|--|-------------|----------------|----------|--|-------------|--|-------------|----------------|
| | HFCs | NF ₃ , SF ₆ , PFCs | CFCs, HCFCs | CH ₃ CCl ₃ , CCl ₄ , CH ₃ Br, halons | Kyoto gases | Montreal gases | HFCs | NF ₃ , SF ₆ , PFCs | CFCs, HCFCs | CH ₃ CCl ₃ , CCl ₄ , CH ₃ Br, halons | Kyoto gases | Montreal gases | HFCs | NF ₃ , SF ₆ , PFCs | CFCs, HCFCs | CH ₃ CCl ₃ , CCl ₄ , CH ₃ Br, halons | Kyoto gases | Montreal gases |
| 2019 (obs) | 40 | 13 | 338 | 17 | 53 | 392 | 40 | 13 | 338 | 17 | 53 | 392 | 40 | 13 | 338 | 17 | 53 | 392 |
| 2020 | 43 | 13 | 330 | 15 | 56 | 388 | 42 | 14 | 330 | 15 | 56 | 387 | 43 | 14 | 330 | 15 | 57 | 388 |
| 2030 | 53 | 16 | 296 | 12 | 69 | 361 | 68 | 17 | 295 | 12 | 85 | 375 | 83 | 17 | 294 | 12 | 100 | 389 |
| 2040 | 41 | 17 | 249 | 9 | 58 | 299 | 92 | 20 | 248 | 9 | 113 | 349 | 130 | 20 | 246 | 9 | 150 | 385 |
| 2050 | 33 | 18 | 209 | 7 | 51 | 249 | 116 | 23 | 208 | 7 | 139 | 330 | 180 | 24 | 207 | 6 | 204 | 393 |
| 2060 | 28 | 18 | 180 | 5 | 47 | 213 | 138 | 26 | 178 | 5 | 164 | 321 | 238 | 27 | 177 | 5 | 265 | 420 |
| 2070 | 25 | 19 | 157 | 4 | 44 | 186 | 157 | 29 | 155 | 3 | 186 | 316 | 304 | 31 | 154 | 3 | 335 | 462 |
| 2080 | 24 | 19 | 139 | 3 | 43 | 165 | 176 | 31 | 136 | 2 | 208 | 315 | 370 | 34 | 135 | 2 | 405 | 507 |
| 2090 | 23 | 20 | 123 | 2 | 43 | 148 | 195 | 34 | 119 | 2 | 229 | 316 | 420 | 37 | 118 | 2 | 458 | 540 |
| 2100 | 22 | 20 | 110 | 1 | 43 | 134 | 212 | 37 | 105 | 1 | 249 | 319 | 447 | 41 | 104 | 1 | 488 | 552 |
| 2200 | 12 | 22 | 38 | 0 | 34 | 50 | 132 | 55 | 31 | 0 | 187 | 162 | 225 | 60 | 29 | 0 | 286 | 254 |

Notes: ERF for 2019 was calculated using the concentrations list in Table AIII.1; 2020 and onward are scenario projections. ERF was calculated using concentrations of individual halogenated compounds. Updated from Meinshausen et al. (2017, 2020) available at greenhousegases.science.unimelb.edu.au. Minor halogenated compounds SO₂F₂, CH₃Cl, CH₂Cl₂, CHCl₃ and Kyoto gases CO₂, CH₄, and N₂O are not included in this table.

Table AIII.5 | Total anthropogenic and natural effective radiative forcing relative to 1750 assessed in AR5 (RCP scenarios) and AR6 (SSP scenarios).

| | | 2030 | | | 2050 | | | 2090 | | |
|-----|---|---------------|---------|---------------------|---------------|---------|---------------------|---------------|---------|---------------------|
| | | Anthropogenic | Natural | Total | Anthropogenic | Natural | Total | Anthropogenic | Natural | Total |
| AR5 | RCP2.6 ^a | 2.52 | | 2.50 ± 0.51 | 2.64 | | 2.65 ± 0.47 | 2.35 | | 2.44 ± 0.49 |
| | RCP4.5 ^a | 2.67 | | 2.61 ± 0.54 | 3.42 | | 3.25 ± 0.56 | 3.91 | | 3.78 ± 0.58 |
| | RCP6.0 ^a | 2.52 | | 2.41 ± 0.60 | 3.20 | | 3.07 ± 0.61 | 4.93 | | 4.64 ± 0.71 |
| | RCP8.5 ^a | 2.91 | | 2.92 ± 0.57 | 4.37 | | 4.21 ± 0.63 | 7.32 | | 7.13 ± 0.89 |
| AR6 | RCP2.6 ^b | 2.85 | -0.02 | 2.83 (1.93–3.61) | 3.11 | 0.01 | 3.12 (2.33–3.76) | 2.70 | 0.01 | 2.71 (2.04–3.22) |
| | RCP4.5 ^b | 3.01 | -0.02 | 2.99 (2.12–3.84) | 3.90 | 0.01 | 3.91 (3.07–4.68) | 4.48 | 0.01 | 4.49 (3.75–5.15) |
| | RCP6.0 ^b | 2.84 | -0.02 | 2.82 (1.88–3.69) | 3.56 | 0.01 | 3.58 (2.59–4.47) | 5.51 | 0.01 | 5.52 (4.50–6.38) |
| | RCP8.5 ^b | 3.36 | -0.02 | 3.34 (2.40–4.23) | 5.01 | 0.01 | 5.03 (4.06–5.92) | 8.46 | 0.01 | 8.46 (7.23–9.61) |
| | SSP1-1.9 ^c | 3.22 | -0.02 | 3.20 (2.62–3.75) | 3.04 | 0.01 | 3.05 (2.58–3.50) | 2.48 | 0.01 | 2.48 (2.12–2.83) |
| | SSP1-2.6 ^c | 3.23 | -0.02 | 3.21 (2.57–3.84) | 3.56 | 0.01 | 3.58 (3.02–4.11) | 3.24 | 0.01 | 3.25 (2.81–3.67) |
| | SSP2-4.5 ^c | 3.25 | -0.02 | 3.24 (2.40–4.08) | 4.23 | 0.01 | 4.24 (3.46–5.02) | 5.32 | 0.01 | 5.33 (4.56–6.05) |
| | SSP3-7.0 ^c | 3.33 | -0.02 | 3.31 (2.30–4.31) | 4.61 | 0.01 | 4.63 (3.51–5.73) | 7.43 | 0.01 | 7.44 (6.17–8.70) |
| | SSP3-7.0-low NTCF ^d | 3.40 | -0.02 | 3.48 (2.53–4.24) | 4.91 | 0.01 | 4.92 (4.13–5.70) | 7.73 | 0.01 | 7.74 (6.70–8.76) |
| | SSP3-7.0-low NTCFCH ₄ ^e | 3.26 | -0.02 | 3.24 (2.40–4.09) | 4.28 | 0.01 | 4.29 (3.56–5.01) | 6.67 | 0.01 | 6.67 (5.75–7.57) |

| | | 2030 | | | 2050 | | | 2090 | | |
|-----|----------------------------|---------------|---------|---------------------|---------------|---------|---------------------|---------------|---------|----------------------|
| | | Anthropogenic | Natural | Total | Anthropogenic | Natural | Total | Anthropogenic | Natural | Total |
| AR6 | SSP4-3.4 ^c | 3.26 | -0.02 | 3.24 (2.33-4.11) | 3.90 | 0.01 | 3.91 (3.06-4.68) | 4.18 | 0.01 | 4.19 (3.49-4.83) |
| | SSP4-6.0 ^c | 3.31 | -0.02 | 3.30 (2.35-4.23) | 4.44 | 0.01 | 4.46 (3.49-5.42) | 6.12 | 0.01 | 6.13 (5.21-7.02) |
| | SSP5-3.4-over ^c | 3.62 | -0.02 | 3.60 (2.82-4.40) | 5.04 | 0.01 | 5.05 (4.29-5.79) | 3.93 | 0.01 | 3.93 (3.40-4.45) |
| | SSP5-8.5 ^c | 3.61 | -0.02 | 3.59 (2.80-4.38) | 5.29 | 0.01 | 5.30 (4.44-6.17) | 9.18 | 0.01 | 9.19 (7.96-10.40) |

Notes: ^a Tables AII.6.8 and 6.10 in Annex II of the IPCC AR5 WG1 report (IPCC, 2013), for which total ERF is derived from CMIP5 models and anthropogenic ERF from a simple climate model emulator. ^b RCPs calculated for ERF as described in Chapter 7 Supplementary Material 7.SM.1.4. Similar to AR5, an emulator was used in AR6 to derive anthropogenic ERF (Cross-Chapter Box 7.1 and Chapter 7 Supplementary Material 7.SM.1.4). Further discussion on the difference between AR5 and AR6 radiative forcing is in Section 4.6.2. ^c ScenarioMIP (O'Neill et al., 2016), ^d AerChemMIP (Collins et al., 2017), ^e Allen et al. (2021).



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