



2012 Global GHG Emissions

Developing a consistent set of national and global estimates

Michael Delgado and Kate Larsen

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Methodology

The Rhodium Group has developed an internally consistent set of national greenhouse gas (GHG) emissions estimates for all countries in 2012. To do so we draw from several sources: national GHG inventory data submitted to the UN Framework Convention on Climate Change (UNFCCC), the Emissions Database for Global Atmospheric Research (EDGAR), the UN Food and Agriculture Organization (FAO), the US Environmental Protection Agency (EPA), and Rhodium Group analysis.

In developing the dataset, we have sought to reflect the most up-to-date nationally-reported information wherever possible. This nationally-derived data is the basis for national decision-making and tracking progress toward emission reduction goals under the UNFCCC. Recent nationally-reported data is not available from all countries, however. While GHG emissions data for 2012 is available for all Annex I Parties to the UNFCCC, aside from the Republic of Korea and Kazakhstan, no non-Annex I Parties have submitted 2012 data to date. For the majority of non-Annex I Parties, the most recent available GHG data is 10-20 years old. Nationally-reported data therefor provide an incomplete picture of global GHG emissions for 2012. This dataset attempts to fill those gaps by extrapolating from the most recently reported GHG emissions data for non-Annex I countries using growth rates from external sources (see more detail below).

The Rhodium Group GHG dataset also provides, for the first time, national and global GHG emission estimates using a range of different global warming potential (GWP) values. Scientific understanding of the GWP of non-CO₂ gases has evolved significantly over the past two decades. Reporting of GHG emissions under the UNFCCC, however, has not kept pace. Until this year, most countries reported GHG emissions using the Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report (1995), hereafter referred to as SAR. Subsequent IPCC reports – the Third Assessment Report (TAR), Fourth Assessment Report (AR4), and Fifth Assessment Report (AR5) – have updated the GWP values for most gases, changing the relative weight of gases in comparison to CO₂. Starting in 2015, Annex I Parties are required to report using AR4 GWP values, though non-Annex I Parties may continue to use outdated GWP values in their future reports.

Inconsistencies in the GWP values used to estimate and report GHG emissions across countries make it difficult

to compare emissions across countries and sum up to an internally consistent global total. The Rhodium Group GHG dataset provides national and global GHG emissions in 2012 for the full range of GWP vintages (SAR, TAR, AR4 and AR5), as well as results based on 100-year and 20-year lifetime GWP values for each.

Below we provide a detailed description of our methodology. Although we have sought to reflect the most up-to-date nationally-reported information whenever possible, manipulations of this data, described below, represent an attempt to resolve inconsistent, insufficient, or missing data from national GHG inventories submitted to the UNFCCC.

EMISSIONS ESTIMATION BY GAS AND SECTOR

The gases and sectors covered in this dataset are those covered by the UNFCCC as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Specifically, this includes carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and 21 F-gases, including sulfur hexafluoride (SF₆) and hydrofluorocarbons (HFCs). Because countries have reported data to the UNFCCC using GWP estimates from the SAR, only gases listed in the SAR have been reported to the UNFCCC as of 2014. This set of gases is somewhat more limited than the number of gases covered in AR4 and AR5, and GHG inventory data submitted using AR4 or AR5 methods will include a broader set of gases.

This dataset provides emissions by gas, and in some cases, by sector. We used sector resolution when available to disaggregate emissions from land use/land use change and forestry (LULUCF), and where additional sectoral resolution would increase the accuracy of the estimate. Sector definitions used here follow the IPCC's Common Reporting Framework (CRF) defined in the IPCC Guidelines for National Greenhouse Gas Inventories (2006). All estimates are presented in CO₂-equivalent masses. The global warming potential values used in this dataset are given in tables A1 – A4.

For all sectors and gasses described in the following sections, 2012 emissions data reported to the UNFCCC (UNFCCC, 2015) were used preferentially. When this data is not available for the year, gas, or sector required, we extrapolated from the most recently available UNFCCC data using secondary sources. When a country has never reported to the UNFCCC, we use secondary

Table 1. Primary and secondary data sources by gas and sector

2012 UNFCCC data used where possible; extrapolated or replaced with secondary sources elsewhere

Gas/Sector	Primary Source	Secondary Source
Carbon Dioxide (CO₂)		
Non-LULUCF	UNFCCC (All without LULUCF)	EDGAR (EU Commission, 2014b)
LULUCF	UNFCCC (All with LULUCF - All without LULUCF)	FAO (2013)
Methane (CH₄)		
Oil and Gas Methane	UNFCCC (1B2)	Rhodium Group (Larsen <i>et al.</i> , 2015)
Other CH ₄ (non-LULUCF)	UNFCCC (1A, 1B1, 2, 3, 4, 6, 7)	EPA (2012)
LULUCF	UNFCCC (All with LULUCF - All without LULUCF)	FAO (2013)
Nitrous Oxide (N₂O)		
Non-LULUCF	UNFCCC (1B2)	EPA (2012)
LULUCF	UNFCCC (1A, 1B1, 2, 3, 4, 6, 7)	FAO (2013)
F-gases		
Industrial Processes	UNFCCC (All F-gases)	EPA (2012)

sources emissions estimates. Table 1 outlines the primary secondary sources, which are described in more detail below.

We use the following four secondary sources when data reported to the UNFCCC is not available: the EDGAR (EU Commission, 2014b) estimates of CO₂ emissions (excluding LULUCF), Rhodium Group estimates of oil and gas methane emissions (Larsen *et al.* 2015), EPA (2012) estimates of other non-CO₂ GHG emissions (excluding LULUCF), and FAO (2013) estimates of LULUCF emissions. With the exception of EPA, all secondary sources provide emissions estimates for every year from 1990 – 2012. EPA data is available in 5-year increments from 1990 – 2030. For intervening years (including 2012), we extrapolate between EPA estimates by sector and gas by assuming a constant annually-compounding growth rate.

CO₂ Emissions (Excluding LULUCF)

All countries generally report GHG inventory data to the UNFCCC aggregated by total (all-sector) emissions with and without LULUCF, as well as aggregated by gas. We used nationally-reported estimates of total CO₂ emissions excluding LULUCF whenever available.

2012 data is available only for Annex I countries, Kazakhstan and the Republic of Korea. For all other countries, we estimate non-LULUCF CO₂ emissions by extrapolating from the most recent reported year and 2012 using EDGAR's (EU Commission, 2014b) implied CO₂ growth rate estimates (excluding LULUCF). Specifically,

$$e_{2012} = e_{year} * \frac{EDGAR_{2012}}{EDGAR_{year}}$$

where e_{year} are the CO₂ emissions (excluding LULUCF) reported to the UNFCCC for a given year and $EDGAR_{year}$ is the EDGAR estimate of emissions in that year.

For countries or regions that have never reported data to the UNFCCC, we use EDGAR estimates for 2012 total CO₂ emissions (excluding LULUCF).

CH₄ Emissions from Oil and Gas Systems

When UNFCCC data for 2012 was not available, we used estimates for methane emissions from oil and natural gas systems from Rhodium Group's [Untapped Potential](#) report (Larsen *et al.*, 2015). The method for developing 2012 estimates is described in the appendix of that report.

Other CH₄ Emissions (Excluding LULUCF)

For methane emissions, we used nationally-reported estimates of total 2012 CH₄ emissions (excluding LULUCF) reported to the UNFCCC wherever available (i.e. for Annex I Parties, Republic of Korea, and Kazakhstan). For all other countries, we extrapolated from the latest reported value using the implied growth rate of EPA CH₄ emissions estimates for that sector between the last reported year and 2012. Specifically,

$$e_{2012} = e_{year} * \frac{EPA_{2012}}{EPA_{year}}$$

where e_{year} are the CH₄ emissions (excluding LULUCF) reported to the UNFCCC for a given year and EPA_{year} is the EPA estimate of emissions in that year. If data was never reported to the UNFCCC, we use estimated 2012 emissions from EPA. Sectors were aggregated according to the sector mapping shown in Table 2.

N₂O Emissions (Excluding LULUCF)

For N₂O emissions, we use nationally-reported estimates of total 2012 N₂O emissions (excluding LULUCF) wherever available (i.e. Annex I Parties, Korea and Kazakhstan). For all other countries, we extrapolated from the latest reported value using the implied EPA (2012) growth rate of total N₂O emissions (excluding LULUCF) between the last reported year and 2012. Specifically,

$$e_{2012} = e_{year} * \frac{EPA_{2012}}{EPA_{year}}$$

where e_{year} are the N₂O emissions (excluding LULUCF) reported to the UNFCCC for a given year and EPA_{year} is the extrapolated estimate of EPA emissions data for that year. For countries or regions that have never reported data to the UNFCCC, we use estimates of 2012 N₂O emissions (excluding LULUCF) from EPA (2012).

High Global Warming Potential Gases

For high GWP gases (i.e. F-gases), we use nationally-reported 2012 all-sector F-gas emissions wherever available (i.e. all Annex I Parties, the Republic of Korea and Kazakhstan). For all other countries, we extrapolated from the last reported value using the implied EPA (2012) growth rate for total “Hi-GWP” emissions between the last reported year and 2012.

Because EPA uses GWP values from the SAR to estimate F-gas emissions and does not disaggregate by gas, our

ability to convert to alternate GWP values is constrained. To do so, we assume the growth in F-gas emissions is equal to the growth in EPA’s aggregated F-gas emissions over that period (using SAR GWP values). While this is the only available method for calculating alternate GWP values, this approach neglects potential changes in the relative composition of F-gases. Until there is more detailed national reporting of individual F-gases, it will be difficult to estimate alternate GWP values for these gases.

Table 2. Sector mapping for EPA Non-CO₂ sectors

Used to construct secondary source data when UNFCCC data unavailable

Global GHGs Sector	EPA Sectors
Methane (CH₄)	
Energy Combustion	BiomassCH4, StatMobCH4
Coal Fugitives	coal
Oil and Gas Fugitives	NGO, OtherEnergyCH4
Industrial Processes	OtherIPCH4
Agriculture	enteric, MMCH4, rice, OtherAgCH4
Waste	landfill, wastewater, OtherWasteCH4
Nitrous Oxide (N₂O)	
All N ₂ O (except LULUCF)	N2O

For countries that have never submitted GHG inventory data to the UNFCCC, we extrapolate 2012 HiGWP values from EPA (2012). Because EPA reports aggregated F-gas emissions weighted using SAR GWP values, the GWP values for these estimates cannot be updated. Furthermore, many countries report some portion of their total F-gas emissions as aggregated HFCs and PFCs, again eliminating our ability to update these emissions with alternate GWP values. Table C1 gives the share of F-gas emissions that cannot be updated with new GWP values by country. These emissions represent only 0.35% of global GHGs. Because this value is so small, we believe that our estimate of total GHGs is robust even under a range of different GWP assumptions. However, care should be taken when using these estimates with GWP values other than 100-year SAR estimates for countries with a high share of aggregated F-gas emissions.

Land Use/Land Use Change and Forestry

While not all national GHG inventories provide sector-level data, all submissions to the UNFCCC contain estimates of total emissions with and without LULUCF by

gas. We used the difference between these two values to estimate total LULUCF emissions and removals. We use reported 2012 LULUCF emissions and removals for all countries reporting data for this year (all Annex I Parties, the Republic of Korea, and Kazakhstan).

For all other countries, we extrapolated from the latest reported value using the implied FAO (2013) growth rate of LULUCF emissions and removals from the latest reported year to 2012. Specifically,

$$e_{2012,gas} = e_{year,gas} * \frac{FAO_{2012,gas}}{FAO_{year,gas}}$$

where $e_{year,gas}$ are the LULUCF emissions and removals reported to the UNFCCC for a given year and gas and $FAO_{year,gas}$ is the FAO estimate of emissions in that year for that gas. The FAO data used was the 'Land use total' estimate from FAO's Emissions - Land Use bulk download tool (FAO, 2014).

For countries or regions that have never reported data to the UNFCCC, FAO (2013) estimates of 2012 total LULUCF emissions and removals by gas were used.

COUNTRIES REQUIRING SPECIAL TREATMENT

Aruba

Aruba does not report data to the UNFCCC; therefore, secondary sources are used to estimate their emissions. EDGAR (EU Commission, 2014b) and FAO (2013) report data for Aruba. These data are used as direct estimates of 2012 emissions. EPA (2012) does not report data for Aruba, and we assume that non-CO₂ GHG emissions (excluding LULUCF) are zero.

Chile

In its Biannual Report (Chile, 2014), Chile reports emissions by detailed sector and gas. We believe some of these gas-specific totals were reported inconsistently. Tables 6 and 7 of that report give emissions by gas for all F-gases, labeled in gigagrams (Gg). It is unclear if this is meant to convey Gg of each gas or of their CO₂ equivalents. Converting these gases into their CO₂ equivalents make F-gases disproportionately large, a value greater than the country's total reported GHG emissions. Conversely, assuming that these are in CO₂-equivalents significantly underestimates non-CO₂ emissions. The only way to arrive at the reported GHG totals provided in Chile's national report is to assume that F-gas emissions reported in Table 7 are given in Gg CO₂ equivalents and that CO₂, CH₄, and N₂O emissions

reported in Table 6 are in Gg of those gases and not their CO₂ equivalents. We made these modifications here, assuming these reporting errors will be corrected on the UNFCCC website.

Gambia

Gambia's Second National Communication (Gambia, 2012), which provides data for the year 2000, reports only SF₆ and aggregated HFCs. The value given for aggregated HFCs is 16.3 Mt, a value that would make it the 7th largest HFC emitter in the world in 2000. Upon inspection of Gambia's GHG inventory, we believe aggregated HFC emissions were incorrectly multiplied by a GWP of 11,700, the Second Assessment Report's 100-year GWP for HFC-23. They should not be multiplied by any GWP, as aggregated HFC emissions have presumably already been weighted by the GWPs of the gases making up the total.

To correct this error, we assume that the value corresponding to total industrial HFC emissions (Gg) of 1.392 Gg, reported above in Gambia's Second National Communication Table 3, is in fact the correctly weighted HFC emissions in Gg CO₂e. This change positions Gambia as the world's 66th largest emitter among the 73 countries reporting data for the year 2000.

Guinea-Bissau

In the data made available on the UNFCCC website, total 1994 CO₂ emissions excluding LULUCF in 1994 were 0.179 Mt CO₂, while net 1994 CO₂ emissions including LULUCF are -11,288 Mt. This would imply that Guinea-Bissau absorbed approximately 53% of total global CO₂ emissions for that year. We assume that this value is an error, but have no way of checking it against the intended value as the land use total is not provided in Guinea-Bissau's latest national communication (Republic of Guinea-Bissau, 2011). To correct this apparent error, we have excluded Guinea-Bissau's reported LULUCF data and instead rely on FAO estimates for this country.

Hong Kong and Macao

In their second national communication (NC₂) to the UNFCCC (People's Republic of China, 2008), China states that the data submitted to the UNFCCC covers mainland China only, and excludes the Special Administrative Regions Hong Kong and Macao as well as Taiwan (Province of China). Hong Kong and Macao do not separately report to the UNFCCC. However, in its NC₂, China provides separate inventories for Macao and Hong Kong. This dataset makes use of the data in these inventories and incorporates them in the same manner as other UNFCCC-reported data.

The latest data reported in China's NC2 corresponds to 2005 emissions estimates, and therefore secondary data sources are required to extrapolate these estimates from 2005 to 2012. While mainland China, Hong Kong, and Macao are treated separately in EDGAR (EU Commission, 2014b), FAO (2013), and Rhodium Group (Larsen *et al.*, 2015) estimates, EPA (2012) provides estimates for all of China, Hong Kong, Macao, and Taiwan as a single aggregated region. We assume that the emissions from sectors and gases using EPA data in this dataset for all of these regions grow at the same rate as the EPA China region from 2005 to 2012. Specifically, this covers CH₄ emissions from energy combustion, coal fugitives, industrial processes, agriculture, and waste, N₂O emissions from all sectors including LULUCF, and F-gas emissions from the industrial processes sector.

Taiwan

Taiwan has submitted two national inventories to the UNFCCC. For reasons discussed further in Appendix B, the UNFCCC does not incorporate these inventories into their database. We make use of these inventories in order to better characterize the emissions in this region.

In its first national communication to the UNFCCC (Taiwan, 2002), Taiwan provides a complete inventory of 2000 GHG emissions by greenhouse gas and sector. However, only the executive summary of Taiwan's second national communication (Taiwan, 2011) is available online. It provides 2008 total GHG emissions by gas, but does not break these emissions down further. In order to disaggregate Taiwan's most recently reported data for use in the RHG dataset, we distribute Taiwan's 2008 emissions by gas using the distribution of sectors from the 2000 data for each gas. In this way, total 2008 emissions by gas are consistent with the reported 2008 inventory data, and the sector breakdown within this is consistent with Taiwan's emissions profile as of the year 2000.

We extrapolate from this constructed 2008 inventory to 2012 using the methods described above, relying on EDGAR (EU Commission, 2014b) growth rates for CO₂ (excluding LULUCF), Rhodium Group (Larsen *et al.*, 2015) estimates for fugitive oil and gas CH₄ emissions, EPA (2012) growth rates for other CH₄ emissions (excluding LULUCF) and F-gas emissions, and FAO (2013) growth rates for LULUCF emissions and removals.

Tokelau

Tokelau does not report data to the UNFCCC; therefore, secondary sources are used to estimate their emissions. Both EDGAR (EU Commission, 2014b) and FAO (2013)

estimate emissions for 2012. These data are used as direct estimates of 2012 emissions. Non-CO₂ GHG emissions (excluding LULUCF) are not included in EPA's global non-CO₂ GHG estimates (EPA, 2012). We assume these emissions are zero.

United Republic of Tanzania

In its first national communication to the UNFCCC (Tanzania, 2003), Tanzania reported inventory data for 1990 and 1994. Data on LULUCF emissions and removals are inconsistently reported and differs significantly from other international sources (by an order of magnitude). Because of the inconsistency of data provided in Tanzania's national communication, the data reported in the UNFCCC's database, and secondary sources, we exclude Tanzania's reported LULUCF emissions and removals and instead use FAO (2013) estimates for 2012.

Serbia and Montenegro

Both Serbia and Montenegro have reported data to the UNFCCC; their latest submissions were for the years 1998 and 2003, respectively. Because neither country reported emissions for 2012, supplementary data from EDGAR (EU Commission, 2014b), FAO (2013), EPA (2012), and Rhodium Group (Larsen *et al.*, 2015) were required to extrapolate reported data to 2012. The EDGAR dataset aggregates these countries into the combined region Serbia and Montenegro.

We aggregate Serbia and Montenegro in order to maintain consistency with the reported EDGAR data. To do this, we linearly interpolated between Montenegro's 1990 and 2003 reported UNFCCC data to arrive at a 1998 estimate, which we combined with Serbia's 1998 reported data. This was used as a 1998 reported value for the Serbia and Montenegro region. Extrapolation to 2012 by sector and gas was conducted in the same manner as other reporting countries.

International Shipping and Aviation (Bunkers)

In accordance with the IPCC and UNFCCC reporting guidelines, we report CO₂ emissions from international shipping and aviation fuel combustion as a global total and do not attribute those emissions to individual countries. Countries do submit bunker emissions as part of their national inventories to the UNFCCC. However, not all countries submit data in each year, and therefore it is impossible to know what share of global bunker emissions are represented by the emissions in the UNFCCC database. Therefore, we use estimates of emissions from global bunkers by GHG from EDGAR (EU Commission, 2014a).

Western Sahara

Western Sahara does not report data to the UNFCCC; therefore, we use secondary sources to estimate their emissions. We use EDGAR (EU Commission, 2014b) and FAO (2013) emissions estimates for 2012. Non-CO₂ GHG

emissions (except from LULUCF) are not included in EPA's global non-CO₂ GHG estimates (EPA, 2012). We assume these emissions are zero.

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Appendix A: Global Warming Potentials

Table A1: Second Assessment Report Global Warming Potentials

GWP values for gases used in this dataset

Species	Chemical Formula	Lifetime	Global Warming Potential		
			20 years	100 years	500 years
Carbon Dioxide	CO ₂		1	1	1
Methane	CH ₄	12.2±3	56	21	6.5
Nitrous oxide	N ₂ O	120	280	310	170
Hydrofluorocarbons (HFCs)					
HFC-23	CHF ₃	264	9,100	11,700	9,800
HFC-32	CH ₂ F ₂	5.6	2,100	650	200
HFC-41	CH ₃ F	3.7	490	150	45
HFC-43-10mee	C ₅ H ₂ F ₁₀	17.1	3,000	1,300	400
HFC-125	C ₂ H ₂ F ₅	32.6	4,600	2,800	920
HFC-134	C ₂ H ₂ F ₄	10.6	2,900	1,000	310
HFC-134a	CH ₂ FCF ₃	14.6	3,400	1,300	420
HFC-143	C ₂ H ₃ F ₃	3.8	1,000	300	94
HFC-143a	C ₂ H ₃ F ₃	48.3	5,000	3,800	1,400
HFC-152a	C ₂ H ₄ F ₂	1.5	460	140	42
HFC-227ea	C ₃ H ₂ F ₇	36.5	4,300	2,900	950
HFC-236fa	C ₃ H ₂ F ₆	209	5,100	6,300	4,700
HFC-245ca	C ₃ H ₃ F ₅	6.6	1,800	560	170
Perfluorinated Compounds (PFCs)					
Perfluoromethane	CF ₄	50,000	4,400	6,500	10,000
Perfluoroethane	C ₂ F ₆	10,000	6,200	9,200	14,000
Perfluoropropane	C ₃ F ₈	2,600	4,800	7,000	10,100
Perfluorobutane	C ₄ F ₁₀	2,600	4,800	7,000	10,100
Perfluoropentane	C ₅ F ₁₂	4,100	5,100	7,500	11,000
Perfluorohexane	C ₆ F ₁₄	3,200	5,000	7,400	10,700
Perfluorocyclobutane	c-C ₄ F ₈	3,200	6,000	8,700	12,700
Other F-Gases					
Sulphur hexafluoride	SF ₆	3,200	16,300	23,900	34,900

Note: Gases covered by the Montreal protocol but not shown in this table were not covered in the SAR and/or had no data in the UNFCCC Flexible Query database (UNFCCC, 2015) and were not included in this dataset.

Source: IPCC (1995)

Table A2: Third Assessment Report Global Warming Potentials

GWP values for gases used in this dataset

Species	Chemical Formula	Lifetime	Global Warming Potential		
			20 years	100 years	500 years
Carbon Dioxide	CO ₂		1	1	1
Methane	CH ₄	12	62	23	7
Nitrous oxide	N ₂ O	114	275	296	156
Hydrofluorocarbons (HFCs)					
HFC-23	CHF ₃	260	9,400	12,000	10,000
HFC-32	CH ₂ F ₂	5	1,800	550	170
HFC-41	CH ₃ F	2.6	330	97	30
HFC-43-10mee	C ₅ H ₂ F ₁₀	15	3,700	1,500	470
HFC-125	C ₂ H ₂ F ₅	29	5,900	3,400	1,100
HFC-134	C ₂ H ₂ F ₄	9.6	3,200	1,100	330
HFC-134a	CH ₂ FCF ₃	13.8	3,300	1,300	400
HFC-143	C ₂ H ₃ F ₃	3.4	1,100	330	100
HFC-143a	C ₂ H ₃ F ₃	52	5,500	4,300	1,600
HFC-152a	C ₂ H ₄ F ₂	1.4	410	120	37
HFC-227ea	C ₃ HF ₇	33	5,600	3,500	1,100
HFC-236fa	C ₃ H ₂ F ₆	220	7,500	9,400	7,100
HFC-245ca	C ₃ H ₃ F ₅	5.9	2,100	640	200
Perfluorinated Compounds (PFCs)					
Perfluoromethane	CF ₄	50,000	3,900	5,700	8,900
Perfluoroethane	C ₂ F ₆	10,000	8,000	11,900	18,000
Perfluoropropane	C ₃ F ₈	2,600	5,900	8,600	12,400
Perfluorobutane	C ₄ F ₁₀	2,600	5,900	8,600	12,400
Perfluoropentane	C ₅ F ₁₂	4,100	6,000	8,900	13,200
Perfluorohexane	C ₆ F ₁₄	3,200	6,100	9,000	13,200
Perfluorocyclobutane	c-C ₄ F ₈	3,200	6,800	10,000	14,500
Other F-Gases					
Sulphur hexafluoride	SF ₆	3,200	15,100	22,200	32,400

Note: Gases covered by the Montreal protocol but not shown in this table were not covered in the TAR and/or had no data in the UNFCCC Flexible Query database (UNFCCC, 2015) and were not included in this dataset.

Source: IPCC (2001)

Table A3: Fourth Assessment Report Global Warming Potentials

GWP values for gases used in this dataset

Species	Chemical Formula	Lifetime	Global Warming Potential		
			20 years	100 years	500 years
Carbon Dioxide	CO ₂		1	1	1
Methane	CH ₄	12	72	25	7.6
Nitrous oxide	N ₂ O	114	289	298	153
Hydrofluorocarbons (HFCs)					
HFC-23	CHF ₃	270	12,000	14,800	12,200
HFC-32	CH ₂ F ₂	4.9	2,330	675	205
HFC-41*	CH ₃ F				
HFC-43-10mee	C ₅ H ₂ F ₁₀	15.9	4,140	1,640	500
HFC-125	C ₂ H ₂ F ₅	29	6,350	3,500	1,100
HFC-134*	C ₂ H ₂ F ₄				
HFC-134a	CH ₂ FCF ₃	14	3,830	1,430	435
HFC-143*	C ₂ H ₃ F ₃				
HFC-143a	C ₂ H ₃ F ₃	52	5,890	4,470	1,590
HFC-152a	C ₂ H ₄ F ₂	1.4	437	124	38
HFC-227ea	C ₃ H ₂ F ₇	34.2	5,310	3,220	1,040
HFC-236fa	C ₃ H ₂ F ₆	240	8,100	9,810	7,660
HFC-245ca*	C ₃ H ₃ F ₅				
Perfluorinated Compounds (PFCs)					
Perfluoromethane	CF ₄	50,000	5,210	7,390	11,200
Perfluoroethane	C ₂ F ₆	10,000	8,630	12,200	18,200
Perfluoropropane	C ₃ F ₈	2,600	6,310	8,830	12,500
Perfluorobutane	C ₄ F ₁₀	2,600	6,330	8,860	12,500
Perfluoropentane	C ₅ F ₁₂	4,100	6,510	9,160	13,300
Perfluorohexane	C ₆ F ₁₄	3,200	6,600	9,300	13,300
Perfluorocyclobutane	c-C ₄ F ₈	3,200	7,310	10,300	14,700
Other F-Gases					
Sulphur hexafluoride	SF ₆	3,200	16,300	22,800	32,600

*Values for HFC-41, HFC-134, HFC-143, and HFC-245ca are not provided in AR4. For these gases, this dataset used SAR GWP values.

Note: Gases covered by the Montreal protocol but not shown in this table were not covered in AR4 and/or had no data in the UNFCCC Flexible Query database (UNFCCC, 2015) and were not included in this dataset.

Source: IPCC (2007)

Table A4: Fifth Assessment Report Global Warming Potentials

GWP values for gases used in this dataset

Species	Chemical Formula	Lifetime	Global Warming Potential		
			20 years	100 years	500 years*
Carbon Dioxide	CO ₂		1	1	
Methane	CH ₄	12.4	84	28	
Nitrous oxide	N ₂ O	121	264	265	
Hydrofluorocarbons (HFCs)					
HFC-23	CHF ₃	222	10,800	12,400	
HFC-32	CH ₂ F ₂	5.2	2,430	677	
HFC-41	CH ₃ F	2.8	427	116	
HFC-43-10mee	C ₅ H ₂ F ₁₀	16.1	4,310	1,650	
HFC-125	C ₂ H ₂ F ₅	28.2	6,090	3,170	
HFC-134	C ₂ H ₂ F ₄	9.7	3,580	1,120	
HFC-134a	CH ₂ FCF ₃	13.4	3,710	1,300	
HFC-143	C ₂ H ₃ F ₃	3.5	1,200	328	
HFC-143a	C ₂ H ₃ F ₃	47.1	6,940	4,800	
HFC-152a	C ₂ H ₄ F ₂	0.4	506	138	
HFC-227ea	C ₃ HF ₇	38.9	5,360	3,350	
HFC-236fa	C ₃ H ₂ F ₆	242	6,940	8,060	
HFC-245ca	C ₃ H ₃ F ₅	6.5	2,510	716	
Perfluorinated Compounds (PFCs)					
Perfluoromethane	CF ₄	50,000	4,880	6,630	
Perfluoroethane	C ₂ F ₆	10,000	8,210	11,100	
Perfluoropropane	C ₃ F ₈	2,600	6,640	8,900	
Perfluorobutane	C ₄ F ₁₀	2,600	6,870	9,200	
Perfluoropentane	C ₅ F ₁₂	4,100	6,350	8,550	
Perfluorohexane	C ₆ F ₁₄	3,100	5,890	7,910	
Perfluorocyclobutane	c-C ₄ F ₈	3,200	7,110	9,540	
Other F-Gases					
Sulphur hexafluoride	SF ₆	3,200	17,500	23,500	

*AR5 does not provide 500-year global warming potentials.

Note: Gases covered by the Montreal protocol but not shown in this table were not covered in AR5 and/or had no data in the UNFCCC Flexible Query database (UNFCCC, 2015) and were not included in this dataset.

Source: IPCC (2013)

Appendix B: Region Definitions

Where possible, this dataset uses the ISO 3166-1 standard for country and territory definitions. This is largely compatible with the reporting parties to the UNFCCC. Some UNFCCC parties report data for multiple territories – these are noted below. The People’s Republic of China (China) poses a unique challenge as several data sources used in this dataset handle Chinese territories differently – the method used in handling these exceptions is covered in the methodology section ‘countries requiring special treatment’ above. Finally, limitations in the historical data for some countries, specifically Serbia, Montenegro, Sudan, and South Sudan, have forced us to group these countries into the combined regions “Serbia and Montenegro” and “Sudan and South Sudan.”

PARTIES AND OBSERVERS TO THE UNFCCC

Afghanistan, Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Plurinational State of Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Cook Islands, Costa Rica, Côte d’Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Democratic People’s Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, European Union (28), Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Islamic Republic of Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Lao People’s Democratic Republic, Latvia, Lebanon, Lesotho, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Mexico, Federated States of Micronesia, Monaco, Mongolia, Serbia and Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Niue, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Rwanda, Saint Kitts and Nevis, Saint

Lucia, Saint Vincent and the Grenadines, Samoa, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia and Montenegro, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, Sudan and South Sudan, Spain, Sri Lanka, Sudan and South Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, the former Yugoslav Republic of Macedonia, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, United States of America, Uruguay, Uzbekistan, Vanuatu, Bolivarian Republic of Venezuela, Viet Nam, Yemen, Zambia, and Zimbabwe

ISO REGIONS NOT RECOGNIZED BY THE UNFCCC

Aruba – Aruba is a former member of the Netherlands Antilles that seceded in 1986 and is now a member country of the Kingdom of the Netherlands (see discussion on Netherlands Antilles below). Aruba is not a party to the UNFCCC, but estimates of CO₂ and non-CO₂ emissions from LULUCF are available from secondary sources.

Hong Kong – Hong Kong is a Special Administrative Region of the People’s Republic of China (China). China does not include Hong Kong as part of China’s total emissions in its submissions to the UNFCCC, and so is estimated separately in this dataset.

Macao – Macao is a Special Administrative Region of the People’s Republic of China (China). China does not include Macao as part of China’s total emissions in its submissions to the UNFCCC, and so is estimated separately in this dataset.

Taiwan, Province of China – As of this writing, China is recognized as the representative of Taiwan at the UN as per UN General Assembly Resolution 2758. Taiwan, which uses the formal name Republic of China (Taiwan), is identified in the ISO-3166 standard as “Taiwan, Province of China” (henceforth referred to as Taiwan). Except where data availability prevents it, this dataset uses the current ISO-3166 country designations and therefore uses the name “Taiwan, Province of China” to represent the region.

In its filings to the UNFCCC, the People's Republic of China does not present emissions estimates covering Taiwan, Province of China. In 2009, Taiwan officially announced its intention to seek participation in the UNFCCC (Shen, 2009), but has not yet been granted recognition. Taiwan's environment agency, the Republic of China (Taiwan) Environmental Protection Administration (Taiwan EPA) has reported emissions estimates, including a first (Taiwan, 2002) and second (Taiwan, 2011) formal national communication to the UNFCCC. However, because the UN does not recognize the sovereignty of Taiwan, the data from this submission has not been incorporated into the UNFCCC Flexible Query data system.

This dataset makes use of the data presented in Taiwan EPA's first and second national communications, and includes Taiwan as a separate region in order to transparently incorporate this data.

Tokelau – Tokelau is not a party to the UNFCCC, but estimates of CO₂ and non-CO₂ emissions from LULUCF are available from secondary sources.

Western Sahara – Western Sahara is not a party to the UNFCCC, but estimates of CO₂ and non-CO₂ emissions from LULUCF are available from secondary sources.

NON-ISO REGIONS IN THIS DATASET

Netherlands Antilles – The Netherlands Antilles was a country in the Caribbean within the Kingdom of the Netherlands that includes the European nation of the Netherlands. The former state is made up of the islands Aruba, Bonaire, Curaçao, Sint Eustatius, Saba, and Sint Maarten. In 1986, Aruba seceded from the Netherlands Antilles and became an independent country within the Kingdom of the Netherlands. In 2010, the Netherlands Antilles, also referred to as the Dutch Antilles, was dissolved. Bonaire, Sint Eustatius, and Saba became special municipalities within the Netherlands, while Curaçao and Sint Maarten joined Aruba as constituent countries within the Kingdom of the Netherlands.

The European country of the Netherlands (within the Kingdom of the Netherlands) is a member of the European Union and is an Annex I party to the UNFCCC, but the rest of the Kingdom of the Netherlands is not. Because of this, submissions to the UNFCCC do not include emissions estimates for the former Netherlands Antilles. Additionally, the source used for CO₂ emissions (not including LULUCF) in this dataset, EDGAR (EU Commission, 2014b), reports

emissions estimates for Aruba and the pre-2010 members of the Netherlands Antilles but neither for the constituent islands nor for the modern members of the Kingdom of the Netherlands.

For these reasons, we report emissions estimates for Aruba, the Netherlands (consisting of the portion of the country on the European mainland only), and the Netherlands Antilles (consisting of Bonaire, Curaçao, Sint Eustatius, Saba, and Sint Maarten) separately. This is consistent with the regional groupings used in EDGAR, and is an aggregation of regions in the FAO (2013) and EPA (2012) data.

UNFCCC REGIONS AGGREGATED IN THIS DATASET

Serbia and Montenegro – The countries Serbia and Montenegro were aggregated in this dataset into the combined region “Serbia and Montenegro” to maintain consistency with the EDGAR dataset (EU Commission, 2014b), which also aggregates these countries. The method used to aggregate the data reported to the UNFCCC by these countries is detailed in the ‘countries requiring special treatment’ section above.

Sudan and South Sudan – The countries Sudan and South Sudan were aggregated in this dataset into the combined region “Sudan and South Sudan” because insufficient historical data exists to separate these countries. The method used to aggregate these countries is detailed in the ‘countries requiring special treatment’ section above.

OTHER EMISSIONS

International bunkers (aviation and shipping) – The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) specifies that countries not include international aviation and shipping emissions in their inventories, but should present these as separate lines in their inventories. These emissions are presented in this dataset as a separate region.

REGIONS NOT INCLUDED IN THIS DATASET

Antarctica – Emissions in Antarctica are not included in UNFCCC (2015), EDGAR (EU Commission, 2014b), FAO (2013), EPA (2012), or Rhodium Group (Larsen *et al.*, 2015) datasets, and are excluded from this dataset.

Appendix C: Unspecified F-gas Emissions

Table C1: Unspecified F-Gas Emissions by Country

F-gas emissions for which countries do not disaggregate F-gas totals into specific F-gases, based on SAR 100-year GWPs

Country	HFCs		PFCs		SF6	F-Gas Total		Unspecified F-gases as a share of country's total F-gases	
	Unspecified	Total	Unspecified	Total		Unspecified	Total	total F-gases	total GHGs
Bolivia (Plurinational State of)	-	39.45	-	-	-	39.45	39.45	100%	24.6%
Japan	15.17	35.70	2.75	2.76	1.16	17.91	39.62	45%	1.3%
Mexico	-	-	-	-	0.59	11.71	12.30	95%	0.9%
South Africa	-	-	-	-	-	11.63	11.63	100%	2.0%
Israel	-	-	-	-	-	8.84	8.84	100%	8.1%
United States of America	8.19	368.71	-	4.39	6.14	8.19	379.23	2%	0.1%
Venezuela (Bolivarian Republic of)	-	-	-	-	-	6.15	6.15	100%	1.5%
Thailand	-	-	-	-	-	5.06	5.06	100%	0.9%
Saudi Arabia	-	-	-	-	-	4.82	4.82	100%	0.8%
Argentina	-	-	-	-	0.13	4.62	4.75	97%	0.8%
Philippines	-	-	-	-	-	3.86	3.86	100%	2.1%
Zambia	-	-	-	-	0.01	3.74	3.75	100%	3.5%
Indonesia	-	-	-	-	-	2.06	2.06	100%	0.1%
Kuwait	-	-	-	-	-	2.04	2.04	100%	2.5%
Egypt	-	0.09	-	1.88	-	1.97	1.97	100%	0.5%
Syrian Arab Republic	-	-	-	-	-	1.66	1.66	100%	1.4%
Korea (Democratic People's Republic of)	-	-	-	-	-	1.34	1.34	100%	1.1%
Cuba	-	-	-	-	-	1.33	1.33	100%	1.8%
Taiwan, Province of China	-	-	-	-	2.51	1.21	3.71	32%	0.4%
Pakistan	-	-	-	-	-	1.20	1.20	100%	0.2%
Mongolia	-	1.08	-	-	-	1.08	1.08	100%	2.3%
Viet Nam	-	-	-	-	-	0.82	0.82	100%	0.2%
Peru	-	-	-	-	-	0.71	0.71	100%	0.4%
Tunisia	-	-	-	-	-	0.66	0.66	100%	1.1%
Netherlands	0.52	3.95	0.11	0.14	0.14	0.63	4.24	15%	0.3%
Oman	-	-	-	-	-	0.62	0.62	100%	1.0%
Bangladesh	-	-	-	-	-	0.60	0.60	100%	0.2%
Mali	-	0.57	-	-	-	0.57	0.57	100%	-8.4%
Zimbabwe	-	-	-	-	-	0.54	0.54	100%	39.6%
France	0.49	39.96	-	0.32	0.49	0.49	40.77	1%	0.1%
Ecuador	-	-	-	-	-	0.44	0.44	100%	0.1%
Guatemala	-	-	-	-	-	0.44	0.44	100%	1.9%
Libya	-	-	-	-	-	0.43	0.43	100%	0.1%
El Salvador	-	-	-	-	-	0.42	0.42	100%	1.6%
Trinidad and Tobago	-	-	-	-	-	0.37	0.37	100%	0.8%
Macedonia (the former Yugoslav Republic of)	-	-	-	-	0.05	0.37	0.41	89%	2.2%
Costa Rica	-	-	-	-	-	0.36	0.36	100%	1.5%
Armenia	-	-	-	-	-	0.35	0.35	100%	2.4%
Sri Lanka	-	-	-	-	-	0.32	0.32	100%	0.8%

Country	HFCs		PFCs		SF6	F-Gas Total		Unspecified F-gases as a share of country's total F-gases	
	Unspecified	Total	Unspecified	Total		Unspecified	Total	total F-gases	total GHGs
Azerbaijan	-	-	-	-	-	0.31	0.31	100%	0.2%
Dominican Republic	-	-	-	-	-	0.31	0.31	100%	1.0%
Nigeria	-	-	-	-	-	0.30	0.30	100%	0.0%
Qatar	-	-	-	-	-	0.30	0.30	100%	0.3%
Morocco	-	-	-	-	-	0.27	0.27	100%	0.2%
Afghanistan	-	-	-	-	-	0.27	0.27	100%	0.4%
Tajikistan	-	-	-	-	-	0.27	0.27	100%	1.6%
Italy	0.25	20.32	-	0.99	0.26	0.25	21.57	1%	0.0%
Yemen	-	-	-	-	-	0.25	0.25	100%	0.5%
Panama	-	-	-	-	-	0.24	0.24	100%	1.5%
Kenya	-	-	-	-	-	0.23	0.23	100%	0.4%
Mauritius	-	0.22	-	0.00	-	0.22	0.22	100%	2.2%
Germany	0.21	23.53	-	0.17	2.42	0.21	26.12	1%	0.0%
Bosnia and Herzegovina	-	-	-	-	-	0.14	0.14	100%	0.5%
Cambodia	-	-	-	-	-	0.12	0.12	100%	0.3%
Angola	-	-	-	-	-	0.12	0.12	100%	0.0%
Iraq	-	-	-	-	-	0.11	0.11	100%	0.0%
Honduras	-	-	-	-	-	0.11	0.11	100%	0.4%
Nicaragua	-	-	-	-	-	0.10	0.10	100%	0.1%
Brunei Darussalam	-	-	-	-	-	0.09	0.09	100%	0.2%
Cameroon	-	-	-	-	-	0.08	0.08	100%	0.0%
Ukraine	0.06	1.81	-	-	0.01	0.06	1.82	3%	0.0%
Norway	0.05	2.27	-	0.13	0.04	0.05	2.45	2%	0.1%
Nepal	-	-	-	-	-	0.04	0.04	100%	0.0%
Suriname	-	-	-	-	-	0.04	0.04	100%	0.3%
Austria	0.00	3.44	0.04	0.04	0.24	0.04	3.72	1%	0.0%
Congo (Democratic Republic of the)	-	-	-	-	-	0.03	0.03	100%	-0.8%
Albania	-	-	-	-	-	0.02	0.02	100%	0.1%
Jamaica	-	0.02	-	-	-	0.02	0.02	100%	0.1%
Kyrgyzstan	-	0.02	-	-	-	0.02	0.02	100%	0.1%
Finland	0.01	2.12	0.00	0.00	0.03	0.01	2.15	1%	0.0%
Lao People's Democratic Republic	-	-	-	-	-	0.01	0.01	100%	0.0%
Gambia	-	-	-	-	3.96	0.01	3.97	0%	0.1%
United Kingdom	0.00	35.31	0.00	0.18	0.40	0.00	35.88	0%	0.0%
Malta	0.00	0.39	0.00	0.00	0.00	0.00	0.39	1%	0.1%
Bhutan	-	-	-	-	-	0.00	0.00	100%	-0.1%
Hong Kong	-	-	-	-	0.12	0.00	2.76	0%	0.0%
Cyprus	0.00	0.66	-	-	0.00	0.00	0.66	0%	0.0%
Denmark	0.00	1.62	0.00	0.01	0.09	0.00	1.71	0%	0.0%
Sweden	0.00	2.10	0.00	0.05	0.04	0.00	2.19	0%	0.0%
Kazakhstan	0.00	3.37	0.00	1.03	0.00	0.00	4.40	0%	0.0%
Greece	0.00	9.49	0.00	0.09	0.00	0.00	9.59	0%	0.0%
Latvia	0.00	0.22	-	-	0.01	0.00	0.23	0%	0.0%
Iceland	0.00	0.30	0.00	0.06	0.00	0.00	0.37	0%	0.0%
Slovakia	0.00	1.07	-	0.02	0.02	0.00	1.11	0%	0.0%
Portugal	0.00	4.25	-	-	0.03	0.00	4.28	0%	0.0%

Country	HFCs		PFCs		SF6	F-Gas Total		Unspecified F-gases as a share of country's total F-gases and total GHGs	
	Unspecified	Total	Unspecified	Total		Unspecified	Total	total F-gases	total GHGs
Luxembourg	0.00	0.16	0.00	0.00	0.01	0.00	0.17	0%	0.0%
Switzerland	0.00	3.08	-	0.03	0.16	0.00	3.27	0%	0.0%
Cabo Verde	-	-	-	-	-	0.00	0.01	0%	0.0%
Uzbekistan	-	-	-	-	-	0.00	0.05	0%	0.0%
Croatia	-	1.28	0.00	0.00	0.01	0.00	1.28	0%	0.0%
Belgium	0.00	5.15	-	0.21	0.09	0.00	5.44	0%	0.0%
Uruguay	-	-	-	-	0.00	0.00	0.16	0%	0.0%
Monaco	0.00	0.02	-	-	0.00	0.00	0.02	0%	0.0%
Dominica	-	0.00	-	-	-	0.00	0.00	100%	0.0%
Hungary	0.00	2.41	-	0.00	0.11	0.00	2.52	0%	0.0%
Jordan	-	-	-	-	-	0.00	0.00	100%	0.0%
Moldova (Republic of)	-	-	-	-	0.00	0.00	0.32	0%	0.0%
European Union (28)	2	205	0	2	5	2	212	1%	0.03%
World	25	765	3	18	43	154	1298	12%	0.24%

Notes:

Countries with negative F-gas shares of total GHGs have negative net GHG emissions due to LULUCF sinks

Unspecified F-gas emissions cannot be updated with new GWP values - see methodology for a discussion of this issue

Columns may not sum to totals due to independent rounding

EU member states do not sum to European Union total due to member state accounting of non-EU overseas territories

Source: Rhodium Group estimates, based on UNFCCC, EDGAR, EPA, FAO, and Rhodium Group analysis