

CLIMATE WATCH COUNTRY GREENHOUSE GAS EMISSIONS DATA METHOD NOTE

This document accompanies the Climate Watch GHG emissions/CAIT¹ dataset.

*Please **note** that this is a preliminary document intended as an explanatory note only. The content of the document is subject to change and the document should not be treated as a formal WRI publication.*

*Please also **note** that significant changes have been made to our methodology in this year's update and some of the descriptions below has changed since our last update.*

Availability of high-quality greenhouse gas (GHG) emissions data is essential for countries to understand their emissions profiles, identify mitigation opportunities, and reduce emissions.

Drawing from non-governmental sources, the Climate Watch Country Greenhouse Gas Emissions dataset offers comprehensive and comparable emissions data for 193 countries over the 1990-2019 time period, and provide open access to those data to help inform climate decision-making, and to increase transparency, understanding, and use of GHG emissions data.

This methodology note describes the Climate Watch Country GHG Emissions dataset, detailing the sources and methodologies used to compile GHG inventories at country and global level. Data includes emissions of all GHGs across all sectors (Table 1). The dataset is available for explore and download at <https://www.climatewatchdata.org/ghg-emissions>.

The dataset is updated regularly to reflect the most recent available emissions data.

DATA SOURCES

Climate Watch country historical GHG emissions dataset compiles a number of data sources to create a full gas, all sector inventory, comparable across countries by applying a consistent methodology, not to replace existing sources of GHG emissions data, but to complement them.

Among the various existing data sources available, Climate Watch opt to only use independent resources that have been widely used in their own respective space, with wealth of available documentation explaining the methodology, and follows recognized guideline such as Intergovernmental Panel on Climate Change (IPCC) methodologies.

This section describes the data sources used, and the preprocessing performed for compiling the Climate Watch Country GHG Emissions dataset.

IEA

The International Energy Agency (IEA) publishes GHG Emissions from Fossil Fuel Combustion (IEA 2021) yearly, and is the main source used in Climate Watch. The IEA dataset is used as the highest priority source for CO₂ and non-CO₂ emissions related to the burning of fossil fuel. It is also used for energy subsector emissions estimates for the countries that have data available.

When including IEA data to the Climate Watch dataset, several flows of data are often combined to one Climate Watch category.

The data is **not public**, and all uses of IEA data (as described and clarified in the table above) shall be referenced to IEA following its Terms

Climate Watch historical GHG emissions dataset, or Climate Watch dataset in this document.

¹ CAIT stands for Climate Analysis Indicators Tool. The CAIT acronym has been used for over a decade since this dataset was first introduced. The dataset is referred to as

and Conditions explained on its website <https://www.iea.org/t&c/termsandconditions>.

FAOSTAT

The Statistic Division of the United Nations Food and Agriculture Organization (FAO) publishes emissions estimates for agriculture and land sectors in its FAOSTAT online database (FAO 2021).

FAO data includes CO₂, methane (CH₄) and nitrous oxide (N₂O) emissions. When included into Climate Watch dataset, the non-CO₂ gases are converted into CO₂-equivalent using 100-year Global Warming Potential Values from the 4th Assessment Report of the IPCC.

For the purpose of Climate Watch dataset, sub-sector breakdown for agriculture and land-use emissions are not included.

Any use of the Land-Use Change and Forestry or Agriculture indicator should be cited as FAO 2021, FAOSTAT Emissions Database.

U.S. EPA

The U.S. Environmental Protection Agency (EPA) published technical report on estimated and projected global anthropogenic non-CO₂ gases (EPA 2019). The EPA dataset is used to for non-CO₂ emissions from sectors other than energy, agriculture and forestry, in other words, industrial processes, and waste.

With the report EPA provides yearly emissions estimates from 1990-2050 for 193 countries. Historical estimates are available from 1990-2015, and projected through 2050. Emissions through 2020-2050 are estimates under a 'business-as-usual' (BAU) scenario. Thus, emissions beyond 2015 should be treated with caution.

Global Carbon Project

The Global Carbon Project publishes annual Global Carbon Budget reports estimating anthropogenic CO₂ emissions. The fossil-related CO₂ emissions (Global Carbon Project, 2021) are used to fill gaps of a few countries that are not covered by the IEA database.

In addition, one underlying dataset of GCP is used for CO₂ emissions from cement production. The dataset published by Andrew, R.M. reports global and country level CO₂

emissions from cement production, covering period of 1880-2020 (Andrew, R.M., 2021). The dataset builds on a variety of available data sources, prioritizing official data including those submitted to the UNFCCC. The work builds on the legacy work by Carbon Dioxide Information Analysis Center (CDIAC), which was used in earlier iterations of CW dataset.

EMISSIONS BY SECTOR

To the extent possible, Climate Watch dataset has followed the IPCC Common Reporting Framework used by the UNFCCC. The six sectors included in Climate Watch dataset are: Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, Waste, and International Bunkers. Energy sector also includes six subsectors.

Energy

Energy sector contains emissions generated from use of energy. For countries with data available, the sector is also reported under following subsectors: *Electricity/Heat, Building, Manufacturing/Construction, Transportation, Other Fuel Combustion, and Fugitive Emissions*.

Certain energy sub-sectors could include emissions from fuel combustion that might be reallocated to IPCC source/sink category Industrial Processes and Product Use under the 2006 IPCC Guidelines for GHG Inventories. While IEA also provides estimates of CO₂ emissions reallocated to the IPCC sector, those estimates are not compiled into Climate Watch datasets. No double counting should be expected with this approach as the only CO₂ emissions compiled for the industry sector of Climate Watch is for cement production.

Electricity/Heat

Electricity/heat subsector contains CO₂, CH₄ and N₂O emissions from following activities:

- **Main activity producer of electricity and heat** (electricity plants, combined heat and power plants, heat plants)
- **Unallocated autoproducers**
- **Other energy industry own use**

Please **note** that part of the emissions might be reallocated to industrial processes and product use category under the 2006 IPCC GLs.

Table 1 | Overview of Climate Watch Country GHG Emissions Data: Sectors, Content, Gases, and Sources

CLIMATE WATCH SECTOR	CLIMATE WATCH SECTOR CONTENTS	IPCC SOURCE/SINK CATEGORY	GREENHOUSE GAS	SOURCE
Energy				
Electricity/Heat	Electricity & heat plants (fossil fuels)	1 A 1 a	CO ₂ , CH ₄ , N ₂ O	IEA
	- Public plants (electricity, heat, CHP)			
	- Auto-producers (electricity, heat, CHP)			
	Other Energy Industries (fossil fuels)	1 A 1 b,c	CO ₂ , CH ₄ , N ₂ O	IEA
Manufacturing/ Construction	Manufacturing & Const. (fossil fuels)	1 A 2	CO ₂ , CH ₄ , N ₂ O	IEA
Transportation	Transportation (fossil fuels)	1 A 3	CO ₂ , CH ₄ , N ₂ O	IEA
Building	Residential, Commercial and Public Services	1 A 4 a,b	CO ₂ , CH ₄ , N ₂ O	IEA
Other Fuel Combustion	Agriculture, Fishing, and Other Fuel Use	1 A 4 c, 1 A 5	CO ₂ , CH ₄ , N ₂ O	IEA
Fugitive Emissions	Coal Mining	1 B 1	CH ₄	IEA, U.S. EPA
	Natural Gas and Oil Systems	1 B 2	CO ₂ , CH ₄	IEA
	Other Energy Sources	1 B 1,2, 4 C	N ₂ O	U.S. EPA
Industrial Processes				
	Cement	2 A 1	CO ₂	Andrew R.M.
	Adipic and Nitric Acid Production	2 B 2,3	N ₂ O	U.S. EPA
	Electronics Manufacturing	2 E 1,2,3	Aggregated F-Gases	U.S. EPA
	Electric Power Systems	2 G 1	SF ₆	U.S. EPA
	Metals (Aluminum Production, Magnesium Manufacturing)	2 C 3,4	PFCs, SF ₆	U.S. EPA
	Use of Substitutes for Ozone-depleting Substances (ODS)	2 F 1,2,3,4,5,6	HFCs	U.S. EPA
	HCFC-22 Production	2 B 9 a	HFCs	U.S. EPA
	Other Industrial Processes Sources	2 A,B,C	CH ₄ , N ₂ O	U.S. EPA
Agriculture				
	Enteric Fermentation	3 A 1	CH ₄	FAOSTAT
	Manure Management	3 B 2	CH ₄ , N ₂ O	FAOSTAT
	Rice Cultivation	3 C 7	CH ₄	FAOSTAT
	Agricultural Soils	3 C 4	N ₂ O	FAOSTAT
	Other Agricultural Sources	3 C	CH ₄ , N ₂ O	FAOSTAT
Waste				
	Landfills (Solid Waste)	4 A	CH ₄	EPA
	Wastewater Treatment	4 D	CH ₄ , N ₂ O	EPA
	Other Non-Agricultural Sources (Waste and Other)	4 E	CH ₄ , N ₂ O	EPA
Land-Use Change and Forestry				
	Land Use Total (Forest land, net forest conversion, drained organic soils, and fires)	3 B 1, 3 B 2 b i 3 B 3 b i, 3 C 1	CO ₂ , CH ₄ , N ₂ O	FAOSTAT
Bunker Fuels				
	Aviation Bunkers	1 A 3 a i	CO ₂ , CH ₄ , N ₂ O	IEA
	Marine Bunkers	1 A 3 d i	CO ₂ , CH ₄ , N ₂ O	IEA

Source: Author compiled based on IEA, EPA, GCP, FAOSTAT, etc.

Note: For the purpose of Climate Watch dataset, emissions are reported under major sector and energy sub-sectors only. GCP data is also used in energy sector to fill gaps where IEA data is not available.

Building

Building subsector contains CO₂, CH₄ and N₂O emissions from following activities:

- **Residential**
- **Commercial and public services**

Please **note** that only on-site fuel combustion is covered here. Emissions associated with use of electricity are reported under electricity/heat.

Manufacturing/Construction

Manufacturing/Construction subsector contains CO₂, CH₄ and N₂O emissions from following activities:

- **Mining and quarrying**
- **Construction**
- **Manufacturing**
 - Iron and Steel
 - Chemical and petrochemical
 - Non-ferrous metals
 - Non-metallic minerals
 - Transport equipment
 - Machinery
 - Food and tobacco
 - Paper, pulp and printing
 - Wood and wood products
 - Textile and leather
 - Non-specified industry

Please **note** that part of the emissions might be reallocated to industrial processes and product use category under the 2006 IPCC GLs.

Transportation

Transportation subsector contains CO₂, CH₄ and N₂O emissions from following activities:

- **Road**
- **Rail**
- **Domestic aviation**
- **Pipeline transport**
- **Domestic navigation**
- **Non-specified transport** (all emissions from transport not specified elsewhere)

Please **note** that transport emissions for world total includes international marine bunkers and international aviation bunkers, which are not

included in transportation at a national or regional level.

Other Fuel Combustion

Other fuel combustion subsector contains emissions from following activities:

- **CO₂, CH₄, and N₂O emissions from Agriculture/forestry, fishing, and other fuel consumption**

Other fuel consumption includes emissions from military fuel use.

Fugitive Emissions

Fugitive Emissions subsector contains fugitive CO₂ and CH₄ emissions from following activities:

- **CO₂ from Flaring**
- **CH₄ from Coal mining**
- **CH₄ from Natural gas and oil systems**
 - Production
 - Flaring and venting
 - Transmission and distribution
- **CH₄ and N₂O from Other energy sources** (solid fuels, oil and natural gas, incineration and open burning of waste)

Industry

Industry sector contains emissions from following activities:

- **CO₂ emissions from Cement Manufacture**
- **N₂O emissions from Adipic and Nitric Acid Production**
- **F-Gases from Electronics Manufacturing** (semiconductor, flat panel display (FPD) and photovoltaic (PV))
- **SF₆ from Electric Power Systems**
- **PFCs and SF₆ from Metal Production** (PFCs as by-product of aluminum production, SF₆ from magnesium production)
- **HFCs from Uses of Substitutes for Ozone-Depleting Substances (ODS)**
- **HFCs from HCFC-22 Production**
- **N₂O and CH₄ emissions from Other Industrial activities** (non-agriculture)

Please **note** that for the purpose of Climate Watch dataset, all fluorinated gases are reported as aggregated F-gas.

Agriculture

Agriculture sector contains emissions from following activities:

- **CH₄ emissions from Enteric fermentation** (livestock)
- **CH₄ and N₂O emissions from Manure management** (livestock)
- **CH₄ emissions from Rice cultivation**
- **N₂O emissions from Agriculture soils**
 - Crop residues
 - Drained organic soils
 - Manure applied to soils
 - Manure left on pasture
 - Synthetic fertilizers
- **CH₄ and N₂O emissions from Other agricultural sources** (burning of crop residues and savanna)

Please **note** that emissions associated with agriculture related energy use are reported under Energy sector, and thus not included here.

Land-Use Change and Forestry (LUCF)

Land-Use Change and Forestry sector contains emissions from following activities:

- **CO₂ emissions from Forest land and Net forest conversion** (forestland converted to cropland and grassland)
- **CO₂ emissions from Drained organic soils**
- **CO₂ and CH₄ emissions from Fires in organic soils**
- **CH₄ and N₂O emissions from Forest fires**

Please **note** that the forest land emissions data reflects emissions from changes in forest land area between reported years of Forest Resource Assessment (FRA) submitted by countries. The data is published every 5 years, and emissions values are estimated by interpolating data over those 5-year periods.

Please **note** recent change of FAO's approach for reporting emissions from fires in organic soils (part of the "Burning Biomass"): only values from Southern-east Asia countries are included in country, regional and global aggregates (of burning biomass and subsequently land use total).

Waste

Waste sector contains emissions from following activities:

- **CH₄ from Landfills** (including industrial and municipal solid waste)
- **CH₄ and N₂O from Wastewater treatment** (rural and urban)
- **CH₄ and N₂O from Other waste sources**

Bunker Fuels

Bunker fuels contain **CO₂ emissions from international marine and aviation bunkers**. The split of domestic and international are determined by the departure and landing locations, and not by the nationality of the ship/airline.

Bunker Fuels are shown as a sector, but **excluded from national totals** for Energy (including energy subsector Transport) and Total GHG emissions, in accordance with IPCC Guidelines. In other words, except at World level, Total GHG emissions (and accordingly Energy sector, and Transport sub-sector emissions) do not include bunker fuel emissions.

GREENHOUSE GASES

Climate Watch dataset disaggregates greenhouse gases by carbon dioxide (CO₂) and non-CO₂ gases. Non-CO₂ gases reported are methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃)—with HFCs, PFCs, SF₆ and NF₃ being presented as "F-gas emissions".

Non-CO₂ gases are reported in CO₂-equivalent using 100-year Global Warming Potential (GWP) values from the 4th Assessment Report of the IPCC.

DISCUSSIONS

Uncertainties

Data underpinning the GHG data may have substantial uncertainties. Despite uncertainties, WRI has chosen to err on the side of inclusiveness, by capturing the widest possible range of GHG sources and sinks that contribute to global climate change.

In general, for information about uncertainty, users should refer to documentation from individual data sources described above. These documents provide much more detail and information than can be included here. However, some brief discussion is also warranted.

First, even CO₂ emissions from fossil fuels may have significant errors. Most data sources derive these estimates from national energy use data, which may contain inaccuracies. To promote accuracy, annual revisions of national energy data are common, leading in some cases to significant revisions of recently reported emissions data.

According to the most recent IPCC report (IPCC 2014), estimated uncertainty for global CO₂ emissions from fossil fuels is relatively low, about 8%. For non-CO₂ GHG emissions, CH₄ and F-gases have relatively 'intermediate' uncertainties of around 20%, while N₂O has a higher uncertainty of around 60%. CO₂ emissions from land-use change and forestry have very large uncertainties of 50-75%. In total, when combining these uncertainties, estimates of global total GHG emissions have an uncertainty of around 10%.

The uncertainty of GHG emissions also depends on how recently the data have been compiled, since "in reality, the more recent data is generally more uncertain due to the preliminary nature of much of the information used to calculate estimates. Data for historical periods can also be more uncertain due to less extensive data collection infrastructure and the lack of emissions factor measurements for technologies no longer in use." (IPCC, 2014)

World Total GHG Emissions

It is important to note that the sum of all countries data available in Climate Watch dataset will not be the same as the World total. This is due to two reasons: 1) as explained above, the international bunker fuel related emissions are not included in the country level totals following the IPCC methodology, which account for around 1000 MtCO₂e; 2) in addition, Climate Watch dataset only covers 190+ countries (all of which are parties to the UNFCCC), leaving out a lot of other territories that could also be releasing anthropogenic emissions data.

Differences between Climate Watch and official inventories

Due to the differences in data sources and methodologies used, Climate Watch estimated country GHG emissions are inevitably different than official inventories prepared by countries.

Parties to the UNFCCC are required to "develop, updated periodically, publish and make available to the Conference of the Parties (COP), their national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol." Due to differences in capacity and resources available for Annex I Parties to the Convention and non-Annex I Parties, not all countries have a full time-series GHG data available. With the different reporting requirements and guidelines, not all inventories reported by parties to the UNFCCC are comparable to each other.

Climate Watch Country GHG Emissions dataset is provided to offer a comprehensive and comparable dataset across countries, and as a complement to the official inventories that are available.