WORLD RESOURCES INSTITUTE

CAIT COUNTRY GREENHOUSE GAS EMISSIONS: SOURCES & METHODS

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This document accompanies the CAIT Climate Data Explorer – Historical Emissions – Country GHG Emissions dataset.
http://cait.wri.org/historic

About this Document
This document describes the country greenhouse gas (GHG) emissions data sources, descriptions, and methodologies included in CAIT.

CONTENTS

List of Acronyms

CDIAC	Carbon Dioxide Information Analysis Center (of the U.S. Dept. of Energy)
CH_4	Methane
CO_2	Carbon Dioxide
EIA	Energy Information Administration (of the U.S. Dept. of Energy)
EPA	United States Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LUCF	Land-use Change and Forestry
N_2O	Nitrous Oxide
OECD	Organization for Economic Co-operation and Development
PFC	Perfluorocarbon
SF_6	Sulfur Hexafluoride
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute

1. Introduction

Effectively addressing climate change requires quality data and information. With this need in mind, the World Resources Institute (WRI) developed the Climate Analysis Indicators Tool (CAIT) — a data and analysis tool designed to help inform policy discussions and decisions under the United Nations Framework Convention on Climate Change (UNFCCC) and other forums.

CAIT provides a trusted and reliable online data platform with a streamlined, intuitive, and user-friendly experience. CAIT draws on key climate-relevant data from respected research centers, government agencies, and international bodies. As of June 2015, the platform contains sector-level greenhouse gas (GHG) emissions data for 185 countries and the European Union (EU) for the period 1990-2012, including emissions of the six major GHGs from most major sources and sinks. It also contains historical country-level carbon dioxide (CO_2) emissions data going back to 1850, and energy sub-sector CO_2 emissions data going back to 1971.

With respect to country-level GHG emissions, there are several sources of emissions data widely used by the climate policy and science communities. The data reported directly by countries to the UNFCCC through their national GHG inventories generally include a six-gas inventory. That is, estimates by source and sector of CO_2 and non-CO_2 gases, where applicable. Non-CO_2 gases include methane (CH_4), nitrous oxide (N_2O), and F-gases (hydrofluorocarbons – HFCs; perfluorocarbons – PFCs; and sulfur hexafluoride – SF_6). WRI compiles data from a variety of non-governmental sources (see table, below), not to replace those data reported by countries to the UNFCCC, but to complement them. Our data sources are chosen based on criteria such as completeness and relative accuracy and country datasets are produced by applying a consistent methodology.

This supporting documentation to CAIT describes the sources and methodologies used to compile the country GHG estimates included in CAIT. Other relevant supporting documentation can be found on the CAIT website (http://cait.wri.org).

Emission Source Key:	
CDIAC	Boden, T.A., G. Marland, and R.J. Andres. 2015. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2015 Available online at: http://cdiac.ornl.gov/trends/emis/overview_2011.html.
EIA	U.S. Energy Information Administration (EIA). 2014. *International Energy Statistics* Washington, DC: U.S. Department of Energy. Available online at: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8.
EPA	U.S. Environmental Protection Agency (EPA). 2012. "Global Non-CO_2 GHG Emissions: 1990-2030." Washington, DC: EPA. Available at: http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html.
FAO	Food and Agriculture Organization of the United Nations (FAO). 2014. FAOSTAT. Rome, Italy: FAO. Available at: http://faostat3.fao.org/faostat-gateway/go/to/download/G2/*/E
IEA	International Energy Agency (IEA). 2014. CO_2 Emissions from Fuel Combustion (2014 edition). Paris, France: OECD/IEA. Available online at: http://data.iea.org/ieastore/statslisting.asp. © OECD/IEA, [2014].

1.1. Countries & Regions in CAIT Country GHG Emissions

The CAIT Country GHG Emissions dataset (referred to as CAIT below) includes *country*-level GHG emissions data for 185 countries that are Parties to the UNFCCC[1]. This covers all UNFCCC Parties except Andorra, Liechtenstein, Marshall Islands, Micronesia, Monaco (combined with France), San Marino (combined with Italy), Somalia, Tuvalu, Timor-Leste, South Sudan, and Palestine. For these countries, there are generally inadequate emissions data. The European Union is also included as a "country" in CAIT because the European Community (a unit of the EU) is a Party to the Convention.

A total of 15 regions are also included in CAIT:[2]

1. *6 UN geographic regions:* Africa, Asia, Europe, Oceania, Latin America & the Caribbean, Northern America and *2 other geographic regions*: Middle East and North Africa, Sub-Saharan Africa
2. *6 UNFCCC party groupings:* G-77 and China, Least Developed Countries, Alliance of Small Island States, EU 28, UNFCCC Annex I, UNFCCC Non-Annex I and *1 other grouping*: G7

To the extent possible, CAIT includes emissions from all greenhouse gases and major emission sources for each country. Thus, as described in this document, data sources cover CO_2 emissions from energy, cement manufacture, and land-use changes as well as non-CO_2 gases. For a given country, as many as five GHG data sources may be used (including sector-level data).

[1] See UNFCCC, Parties to the Convention and Observer States, Available online at https://unfccc.int/parties_and_observers/parties/items/2352.php

[2] See http://cait.wri.org for a full listing of regions and their definitions.

2. CO_2 from Fossil Fuels and Cement Manufacture

This section describes the decision criteria, data sources, and methodologies used to compile the CO_2 emissions data in CAIT (excluding CO_2 emissions from land-use change and forestry).

2.1. CO_2 from Fossil Fuels: Data Sources and Selection Criteria

There are several sources of CO_2 emissions from fossil fuels widely used by the climate policy and science communities, including databases provided by the Carbon Dioxide Information Analysis Center (CDIAC)[3], the International Energy Agency (IEA), the UNFCCC, and the Energy Information Administration (EIA). In deciding which database to use for CAIT, we adopted several criteria. Overall, *completeness* is an important overarching feature of CAIT. Accordingly, two important criteria include geographic coverage and temporal coverage of the data. Wide geographic coverage promotes comparability *across countries*, whereas wide temporal coverage enables comparability *over time*. A third criterion used is accuracy of the data.

Table 1. Evaluating Carbon Dioxide Databases
*Scoring: * = Low; **** = High*

Database	Geographic Coverage	Temporal Coverage	Accuracy
CDIAC	**** Almost all countries†	**** (1751 - 2012)	**
IEA	*** 140 countries	*** (1971 - 2012)	***
UNFCCC	** Annex I; many others missing	* (1990 – 2012)	****
EIA	**** Almost all countries†	** (1980 - 2012)	**

Abbreviations. CDIAC (Carbon Dioxide Information Analysis Center); IEA (International Energy Agency); EIA (Energy Information Administration); UNFCCC (United Nations Framework Convention on Climate Change). **Sources**. CDIAC is Boden et al., 2015; IEA, 2014; UNFCCC, 2014; EIA, 2014.
† Even these databases exclude certain Parties to the UNFCCC, namely Liechtenstein, Marshall Islands, Micronesia, Monaco (included with France), San Marino (included with Italy), and Tuvalu. Thus, unfortunately, these Parties have not been included in CAIT.

Of the databases mentioned above, none score high for all criteria. Table 1 shows rough assessments relating to coverage and accuracy for databases that include CO_2 from fossil fuels. In terms of completeness, CDIAC's database scores highest (for both geographic and temporal coverage). IEA's database has the least country coverage, but it still covers more than 130 countries.

With respect to accuracy, UNFCCC data are regarded as the most accurate. These data are found in official submissions by Parties under the Climate Convention. UNFCCC inventories are generally meticulously prepared by national experts according to standardized methodologies and agreed upon criteria. These criteria include *transparency* (clear assumptions and methodologies), *consistency* (across time), *comparability* (across Parties), *completeness* (all sources and sinks, as well as gases) and *accuracy* (no systematic over- or under-estimation) (UNFCCC, 2000). Annex I (industrialized) countries tend to have excellent coverage from 1990 to 2012. For non-Annex I (developing) countries, most countries have reported at least one national communication from which inventory data can be derived. However, for some countries there may be gaps in temporal coverage since national communications are not submitted on an annual basis and/or may be missing source categories.

[3] CDIAC refers to Boden et al. 2013.

The UNFCCC datasets illustrate a clear trade-off between completeness and accuracy. WRI has dealt with this trade-off by excluding UNFCCC data from the country data reported in CAIT. However, we provide a separate data collection within the CAIT platform which has *only* UNFCCC data, so that users may compare "official" country-provided estimates and "unofficial" GHG estimates.

IEA's database also scores relatively high regarding accuracy. This is due to several factors, including the use of recognized Intergovernmental Panel on Climate Change (IPCC) methodologies, the wealth of available documentation explaining methodologies, and the use of both bottom-up (sectoral) and top-down (reference) emission estimates.

The ratings for accuracy are also influenced by WRI's own previous analysis of the datasets. This involved analyzing the degree to which CO_2 estimates from CDIAC,[4] EIA, and IEA (reference approach) differ from one another ("outlier" analysis), as well as analyzing how close these datasets are to UNFCCC inventories of CO_2 emissions from fossil fuels ("closeness" analysis). There are obvious weaknesses and limitations to these kinds of analyses (e.g., an outlying data point may in fact be more accurate than figures in the other datasets which may be clustered around the same value). However, they did reveal cases where one database deviated significantly from others, signaling possible inaccuracies or unexplained inconsistencies. Some results are summarized here:

- IEA has the fewest overall "outliers" (across a range of error parameters).
- IEA data has the closest matches to UNFCCC data (and also explains some discrepancies).
- EIA tends to have the highest CO_2 values, followed by IEA (mid), then CDIAC (lowest).

To maximize the benefits of the different databases, while promoting completeness and accuracy, CAIT compiles data for CO_2 from fossil fuels in the following way:

- **IEA**. For all (34) industrialized (OECD) countries and 101 developing countries, IEA data are used in CAIT for the years 1971 to 2012. Overall, IEA data covers 135 of 186 countries in CAIT. As of 2015, IEA's *sectoral* approach has been used (rather than *reference* approach) to represent *National Totals* in CAIT (See Section 6).
- **CDIAC**. CDIAC data are used from 1850 to 1970 for all countries which have data available. Data prior to 1850, though available from CDIAC for some countries, was excluded due to especially limited geographic coverage (CDIAC covers around 15 CAIT countries in 1850, 35 CAIT countries in 1900, and 153 CAIT countries in 1970). For 50 countries that lack IEA data, CDIAC data is used up to 2011.
- **EIA**. For Lesotho, EIA data are used from 1980 to 2012. ***EIA is also used for the year 2012 in the reported national totals (See Section 6) for 50 countries (including Lesotho) that lack CDIAC and IEA data.***

This approach has advantages and disadvantages. On the one hand, "filling" the gaps from different data sources improves the ability to make cross-country comparisons and related analyses. Yet comparability can be endangered when data points from different sources (using different methodologies) are placed side-by-side. Here, data covering the past two decades is mostly from IEA; however 50 countries are from CDIAC (and one from EIA). Similarly, the time-series data for ALL countries might include a "stitch" between 1970 and 1971 where the source changes from

[4] Cement data was removed from CDIAC for the purposes of this analysis.

CDIAC to IEA, and for the 50 countries (all of which are non-Annex I countries) between 2011 and 2012 where the source changes from CDIAC to EIA.

However, these shortcomings may not be especially problematic. In many cases the difference between data for a "stitch year" is not particularly significant. Also, the 50 countries using EIA data for 2012 are generally small countries (together constituting about 0.2 percent of 2012 global emissions. In any case, users should be aware of "stitch years," particularly when performing a trend analysis.

Box 1. Information on Key CO_2 Data Sources used in CAIT

CDIAC (1751-2012). CDIAC estimates rely on historical records of coal, brown coal, peat, and crude oil production (as well as imports and exports) by country and year. Estimates from more recent years (1950 to present) are derived primarily from energy statistics compiled from questionnaires distributed by the UN Statistical Office and supplemented by official national statistical publications. A more complete description of methodologies and sources is available from the Carbon Dioxide Information Analysis Center. The preliminary 2012 estimates published in 2014 are also included. See Boden et al. (2015) in References.

EIA (1980-2012). The United States Energy Information Administration estimates CO_2 emissions by country and year, based on energy balances. A very limited amount of information on the data, methodology, and sources, as available from EIA (2014), is available in References.

IEA (1971-2012). IEA's Sectoral Approach contains total CO_2 emissions from fuel combustions as calculated using the IPCC Tier 1 Sectoral Approach and corresponds to IPCC Source/Sink Category 1 A. Emissions calculated using a Sectoral Approach include emissions only when the fuel is actually combusted. Also, international marine bunkers and international aviation bunkers (IPCC Source/Sink Category 1A 3 d i; 1 A 3 a i) are not included in Sectoral Approach estimates in the national level. For more information, see IEA (2014) in References.

2.2. CO_2 from Cement Manufacture

Carbon dioxide is a well-known byproduct of cement manufacturing (as cement is calcined to produce calcium oxide). Estimates of CO_2 emitted during cement production, based on data from the U.S. Geological Survey, are available from CDIAC (Boden et al., 2015).[5]

These estimates of CO_2 from cement manufacture, which cover 1928 to the present, are included in CAIT's CO_2 *National Totals* (See Section 6) for 1990-2012, although data for 2012 are considered preliminary and are only available for 66 countries and World total.[6] CO_2 from cement manufacture can also be viewed under the *Industrial Processes* indicator in CAIT (see Section 5.2).

[5] This is an important difference between CDIAC and IEA databases.
[6] For more information, see http://cdiac.ornl.gov/trends/emis/meth_reg.html.

2.3. Methodology for Historical CO_2 Emissions Estimates

Country boundaries have changed significantly over the past century, particularly during the years following World War I and II and the early 1990s. Considering that CAIT uses CO_2 emissions data going back to the 1800s, a method was required to apportion historical carbon emissions in accordance with today's geographic boundaries. In total, WRI has made historical estimates for more than 50 countries whose borders have changed throughout the past 150 years. These include former Soviet Republics, former Yugoslav Republics, Germany (formerly split in two countries), as well as present-day countries that formerly belonged to colonial territories like French Indochina and French West Africa. This section describes the methodology employed and summarizes all estimates made relating to international borders changes (see Table 2). The methodology described below was employed separately for CO_2 from fossil fuels and CO_2 from cement manufacture, the two source categories described in the preceding sections.

For newly formed countries, such as the independent republics of the former Soviet Union, the share of carbon emissions for the years prior to country formation is estimated based on each country's carbon emissions in the five years immediately following its formation (or for the first five years which data are available). Specifically, the four step methodology below is used to make historical emission estimates for newly formed countries:

1. Add the emissions together for the first five years *after* independence or for which data are available (e.g., 1990-94 for Kazakhstan, a former Soviet Republic).
2. Add these five year totals together for all newly formed countries (e.g., sum *all* former Soviet Republics' emissions from 1990-94).
3. Divide the figure obtained in step 1 by the figure obtained in step 2. This yields a percentage "share" of emissions for each newly created country.
4. Apply the share of emissions obtained in step 3 to all pre-independence emissions data.

For example, Kazakhstan's emissions in 1990-94 were about 1,144 million tonnes of carbon dioxide equivalent ($MtCO_2e$) (step 1). Emissions for all former Soviet Republics in 1990-94 were about 15,890 $MtCO_2e$ (step 2). Thus, Kazakhstan's share of Soviet emissions is calculated to be 7.2 percent (step 3). To estimate Kazakhstan's emissions prior to 1990 (when Kazakhstan was part of the Soviet Union), 7.2 percent is multiplied by the Soviet Union's emissions for any given year.

In step 1 above, five years is chosen rather than a single year. This is done to get a smoother average, rather than taking a single year of data, which may not be representative because of economic and social disruption that often accompanies border changes. A longer period was not used, since data many years after independence may poorly reflect that country's relative emissions share prior to independence (of course, this might also be the case even for the five year period used). Generally, there is no precise way to attribute historical emissions to countries when they did not exist. (This is one of several reasons why some governments and observers object to using historical data). Accordingly, the estimates made by WRI (or others) should be considered only rough approximations.

For countries that have *united*—like Germany, Yemen, and Vietnam—the methodology is more straightforward and less subjective: emissions from the former constituent countries are simply added together. For example, the historical emissions of East and West Germany (prior to 1991) are

attributed to present-day Germany. Table 2 below summarizes the estimates made for newly formed countries.

Table 2. Emission Estimates for Newly-Formed Countries

Former country(s)	Newly formed country(s)	Dates estimates made	Emissions data available for new country(s)	Years used to determine shares	Estimated share of former country's emissions	
					Fossil Fuels	Cement
A. Countries Divided						
U.S.S.R						
	Armenia	1850-1989	1990	1990-94	0.4%	0.4%
	Azerbaijan	1850-1989	1990	1990-94	1.4%	0.7%
	Belarus	1850-1989	1990	1990-94	3.1%	2.5%
	Estonia	1850-1989	1990	1990-94	0.8%	0.7%
	Georgia	1850-1989	1990	1990-94	0.7%	0.3%
	Kazakhstan	1850-1989	1990	1990-94	7.2%	4.7%
	Kyrgyzstan	1850-1989	1990	1990-94	0.5%	0.9%
	Latvia	1850-1989	1990	1990-94	0.4%	0.4%
	Lithuania	1850-1989	1990	1990-94	0.7%	1.3%
	Moldova	1850-1989	1990	1990-94	0.7%	0.3%
	Russian Federation	1850-1989	1990	1990-94	61.5%	62.5%
	Tajikistan	1850-1989	1990	1990-94	0.2%	0.3%
	Turkmenistan	1850-1989	1990	1990-94	1.1%	1.1%
	Ukraine	1850-1989	1990	1990-94	17.6%	17.3%
	Uzbekistan	1850-1989	1990	1990-94	3.7%	6.7%
	Note: Cement shares use 1992-96.					
Yugoslavia						
	Bosnia & Herzegovina	1890-1989	1990	1990-94	15.1%	3.6%
	Croatia	1890-1989	1990	1990-94	16.4%	35.4%
	Macedonia	1890-1989	1990	1990-94	8.2%	9.8%
	Serbia & Montenegro[7]	1890-1989	1990	1990-94	47.6%	33.8%
	Slovenia	1890-1985	1986	1990-94	12.7%	17.3%
Note: Due to different data availability, an additional share calculation for 1986-1990 was required; cement shares use 1992-96.						
Pakistan (East and West)	Pakistan	1946-70	1971	1971-75	82.4%	97.0%
	Bangladesh	1946-70	1971	1971-75	17.6%	3.0%
Czechoslovakia						
	Czech Republic	1860-1970	1971	1971-75	78.3%	64.4%
	Slovakia	1860-1970	1971	1971-75	21.7%	35.6%
Note: For cement, estimates were made from 1928 to 1992, using 1993-97 to determine the shares.						
Korea (United)						
	Korea (North)	1905-44	1945	1948-52	31.5%	75.9%
	Korea (South)	1905-44	1945	1948-52	68.5%	24.1%
Rhodesia-Nyasaland						
	Malawi	1950-63	1964	1964-73	3.8%	7.7%
	Zambia	1950-63	1964	1964-73	36.5%	41.5%
	Zimbabwe	1950-63	1964	1964-73	59.8%	50.8%
French Equat'l Africa						
	Central African Republic	1950-58	1959	1959-63	17.5%	n/a
	Chad	1950-58	1959	1959-63	14.3%	n/a
	Congo	1950-58	1959	1959-63	47.9%	n/a
	Gabon	1950-58	1959	1959-63	20.3%	n/a
French West Africa						
	Benin	1949-57	1958	1959-63	6.1%	0.0%
	Burkina Faso	1949-57	1958	1959-63	3.0%	0.0%
	Côte d'Ivoire	1949-57	1958	1959-63	26.0%	0.0%
	Guinea	1949-57	1958	1959-63	23.8%	0.0%

[7] With the independence of Montenegro in 2006, the "Serbia & Montenegro" estimates here are attributed to Serbia only from 1890-1989. The emissions data from Montenegro can be viewed separately in CAIT.

Table 2. Emission Estimates for Newly-Formed Countries

Former country(s)	Newly formed country(s)	Dates estimates made	Emissions data available for new country(s)	Years used to determine shares	Estimated share of former country's emissions	
					Fossil Fuels	Cement
	Mali	1949-57	1959	1959-63	5.6%	0.0%
	Mauritania	1949-57	1959	1959-63	2.5%	0.0%
	Niger	1949-57	1958	1959-63	2.4%	0.0%
	Senegal	1949-57	1958	1959-63	30.6%	100.0%
French Indochina						
	Cambodia	1946-54	1955	1955-59	3.8%	0.0%
	Laos	1928-54	1955	1955-59	1.4%	0.0%
	Vietnam	1928-54	1955	1955-59	94.9%	100.0%
Note: Cement only from 1928 to 1945; cement and fossil fuels from 1946 to 1954.						
Federation of Malaya-Singapore						
	Malaysia	1950-56	1957	1957-60	62.5%	100.0%
	Singapore	1950-56	1957	1957-60	37.5%	0.0%
Rwanda-Urundi						
	Burundi	1950-61	1962	1962-66	43.0%	n/a
	Rwanda	1950-61	1962	1962-66	57.0%	n/a
B. Countries United						
Germany (East and West)	Germany	1945-69	1970	n/a	100%	100%
Note: For IEA data, data before 1970 appear to include only W. Germany; cement estimates are from 1947-1990.						
Vietnam (North and South)	Vietnam	1955-69	1970	n/a	100%	100%
Yemen (North and South)	Yemen	1950-70	1971	n/a	100%	100%
Tanganyika & Zanzibar	Tanzania	1950-69	1970	n/a	100%	100%

3. Emissions from Land Use Change & Forestry (LUCF)

The Statistic Division of the Food and Agriculture Organization of the United Nations (FAO), or FAOSTAT, reports estimates of Land Use emissions for all CAIT countries, as well as a world total, from 1990-2012 (though time series for a few countries are incomplete).

The FAO Emissions-Land Use dataset includes estimates of CO_2 emissions by sources and removal by sinks from forest land, cropland, and grassland, as well as emissions of CO_2 and non-CO_2 from fires of biomass and organic soils. Specifically:

"Land Use Total contains all the emissions and removals produced in the different Land Use sub-domains. GHG emissions and removals from Forestry and Other Land Use (FOLU) sectors consist of CO_2 and non-CO_2 gases (methane, CH_4, and nitrous oxide, N_2O), produced by aerobic and anaerobic processes, e.g. combustion and decay, and by harvesting associated with land management activities. Computed at Tier 1 and Approach 1 of the 2006 IPCC Guidelines for National GHG Inventories.

Land Use Total contains total emissions and removals for each relevant greenhouse gas (CO_2, CH_4, N_2O), expressed in CO_2 equivalents, aggregated for the following sub-domains:

- *Forest Land (CO_2, CH_4, N_2O)*
- *Cropland (CO_2)*
- *Grassland (CO_2)*
- *Burning – Biomass (CO_2, CH_4, N_2O)*

Estimates of carbon stock changes are limited to above and below-ground biomass. Emissions and removals from Wetlands, Settlements and Other, are not estimated yet. "

Consequently, this data is useful as reference only and may not coincide with LUCF emissions reported by countries to the UNFCCC. More generally, users should note that the errors and uncertainties associated with these (and other LUCF) estimates may be significant. Additional methodological information for this dataset is available on the FAOSTAT website: http://faostat3.fao.org/faostat-gateway/go/to/download/G2/*/E.

4. Non-CO_2 Gases

Five non-CO_2 gases are included in CAIT: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—with HFCs, PFCs, and SF_6 being presented in CAIT as "F-gas emissions". Estimates for these gases are drawn from EPA (2012), which reports historic and projected non-CO_2 emissions data from 1990 to 2030 in five year intervals, and FAO (2014), which reports agriculture and land-use emissions data from 1990-2012. ***For CAIT, we have linearly interpolated between reported EPA values to provide estimates of country, gas, and sector totals, where applicable, in the intervening years from 1990 to 2012.*** All non-CO_2 emissions in CAIT are expressed in CO_2 equivalents using 100-year global warming potentials found in the IPCC Second Assessment Report (IPCC, 1996a). Please note that Annex I national inventories reported to the UNFCCC in 2015 start to use global potential warming (GWP) values from IPCC Fourth Assessment Report, which might result in additional differences in our estimates and those provided by national governments.

EPA (2012) provides details regarding emission collection and estimation methodologies, as well as the typically high uncertainties associated with non-CO_2 estimates. The basic approach taken by EPA is to derive emission estimates whenever possible from national sources, including national communications, country studies, inventories submitted to the UNFCCC, or other prepared publications. To improve consistency and comparability, EPA has revised the national estimates to be consistent with the IPCC Guidelines. Any differences between official data submitted to the UNFCCC and data reported by EPA (2012) may be due to the methodologies employed by EPA to improve consistency and/or a result of revisions to national estimates reported to the UNFCCC since the release of EPA's report. As noted, CAIT users should be aware that emissions of non-CO_2 gases have high uncertainty levels.

4.1. Non-CO_2 Emissions from Agriculture

In previous iterations of CAIT, EPA (2012) has been used as the only source for non-CO_2 emissions data. ***As of 2015 update, FAOSTAT estimates of Agriculture Emissions are used to replace EPA as the source for non-CO_2 (CH_4 and N_2O) emissions from agriculture sector***, as marked in section 4.2 below.

The FAO Emissions-Agriculture dataset includes estimates by gases (namely CH_4 and N_2O), and by sectors or subsectors from 1961 to 2012, and projections for 2030 and 2050. Only data from 1990 to 2012 are included in CAIT. ***Please note that time series for a few countries are not complete, for instance newly formed nations such as those from former Soviet Republics, former Yugoslav Republics, Czechoslovakia, etc. Thus Total GHG Emissions might not be available for those countries and years.***

"*Agriculture Total contains all the emissions produced in the different agricultural emissions sub-domains. GHG emissions from agriculture consist of non-CO_2 gases, namely methane (CH_4) and nitrous oxide (N_2O), produced by aerobic and anaerobic decomposition processes in crop and livestock production and management activities. Computed at Tier1 following IPCC Guidelines for National GHG Inventories.*

Agriculture Total contains total GHG emissions, and aggregated GHG emissions for each greenhouse gases (CH_4, N_2O), expressed in CO_2 equivalents. Total agricultural emissions include the following sub-domains:

- *Enteric fermentation (CH_4)*
- *Manure management (CH_4, N_2O)*
- *Rice cultivation (CH_4)*
- Agriculture Soils (N_2O)
    - *Synthetic fertilizers (N_2O)*
    - *Manure applied to soils (N_2O)*
    - *Manure applied to pastures (N_2O)*
    - *Crop residues (N_2O)*
    - *Cultivation of organic soils (N_2O)*
- *Burning-crop residues (CH_4, N_2O)*
- *Burning-savanna (CH_4, N_2O)*
- *Energy Use (CO_2, CH_4, N_2O)* (Not included)

The methodologies followed for the estimations are described under the respective sub-domains."

4.2. CH_4 and N_2O

EPA (2012) and FAO (2014) estimates of CH_4 and N_2O emissions are broken down into sector and sub-sector level detail. The *National Total* CH_4 estimates in CAIT are calculated by summing the following individual sector or subsector estimates in EPA (2012) and FAO (2014):

- Biomass Combustion (EPA)
- Stationary and Mobile Combustion(EPA)
- Natural Gas and Oil Systems(EPA)
- Coal Mining Activities(EPA)
- Other Industrial non-Agricultural Sources(EPA)
- Enteric Fermentation (FAO)
- Manure Management (FAO)
- Rice Cultivation (FAO)
- Other Agricultural Sources (FAO)
- Landfilling of Solid Waste (EPA)
- Wastewater (EPA)
- Other Non-Agricultural Sources (Waste and Other) (EPA)
- Other Energy Sources (Fugitives from Natural Gas & Oil, Fugitives from Solid Fuels) (EPA)

National Total N_2O estimates in CAIT are calculated by summing the following individual sector or subsector estimates in EPA (2012) and FAO (2014):

- Biomass Combustion (EPA)
- Stationary and Mobile Combustion (EPA)
- Adipic Acid and Nitric Acid Production (EPA)
- Other Industrial non-Agricultural Sources (EPA)
- Manure Management (FAO)
- Agricultural Soils (FAO)
- Other Agricultural Sources (FAO)
- Human Sewage (EPA)
- Other Non-Agricultural Sources (Waste and Other) (EPA)
- Other Energy Sources (Fugitives from Natural Gas & Oil, Fugitives from Solid Fuels) (EPA)

As discussed below in Section 5, the above source categories are also compiled in CAIT according to the sector definitions promulgated by the IPCC (1996b). It should be noted that in many cases some countries do not have data available for some of the above source categories. This may affect

National Total estimates in CAIT. In some cases, it is difficult to discern whether a data gap exists, or whether the emissions estimate is zero.

4.3. F-Gases: HFCs, PFCs, and SF_6

EPA (2012) includes estimates of HFCs, PFCs, and SF_6 emissions. HFC estimates include emissions from refrigeration/AC, aerosols, solvents, foams, fire extinguishing, semiconductors (HFC-23), flat panel displays, and HCFC-22 production. PFCs estimates include emissions from aluminum and semiconductors (CF_4, C_2F_6, C_3F_8, NF_3). SF_6 estimates include emissions from semiconductors, magnesium, and electricity transmission and distribution. As discussed in Section 5.2, all of these emissions fall within the *Industrial Processes* sector. These totals are summed and reported together in CAIT as a single indicator: F-gas emissions.

5. Sector-Level GHG Emissions Data

CAIT includes *sector-level* data from 1990-2012. This section describes the framework for examining sector-level GHG emissions in CAIT.

To the extent possible, in presenting sector data in CAIT, WRI has followed the IPCC Common Reporting Framework used by the UNFCCC (IPCC, 1996b). The sectors included in CAIT are: *Energy*, *Industrial Processes*, *Agriculture*, *Land Use Change and Forestry*, *Waste*, and *International Bunkers*. *Energy* also includes five subsectors (e.g., *Electricity/Heat*). International Bunkers are shown as a sector, but separately from *Energy* and *National Total*, in accordance with IPCC Guidelines. Please note that IEA reported transport emissions for world total includes *international marine bunkers* and *international aviation bunkers*, which are not included in *transport* at a national or regional level. As shown in this section, all six GHGs are included within their appropriate sectors or subsectors, so far as the data will allow.

Table 3. Summary of CAIT Sector Data

CAIT Sector Category	CAIT Sector Contents	IPCC Category	Gas	Data Source
Energy		1		
Electricity & Heat[1]	Electricity & heat plants (fossil fuels)			
	- Public plants (electricity, heat, CHP)	1 A 1 a	CO_2	IEA
	- Autoproducers (electricity, heat, CHP)	1 A	CO_2	IEA
	Other Energy Industries (fossil fuels)	1 A 1 b,c	CO_2	IEA
Manufacturing & Const.	Manufacturing & Const. (fossil fuels)	1 A 2	CO_2	IEA
Transportation	Transportation (fossil fuels)	1 A 3	CO_2	IEA
Other Fuel Combustion[2]	Other Sectors (fossil fuels)	1 A 4	CO_2	IEA
	Biomass Combustion	1 A 5	CH_4, N_2O	EPA
	Stationary and Mobile Sources	1 A 5	CH_4, N_2O	EPA
Fugitive Emissions	Gas Venting/Flaring	1 B 2c	CO_2	EIA
	Oil & Natural Gas Systems	1 B 2	CH_4	EPA
	Coal Mining	1 B 1	CH_4	EPA
	Other Energy Sources	1 B 1, 2	CH4, N_2O	EPA
Industrial Processes	Cement	2 A 1	CO_2	CDIAC
	Adipic and Nitric Acid Production	2 B 2,3	N_2O	EPA
	Other Industrial non-Agriculture	2	CH_4, N_2O	EPA
	All Fluorinated Gases	2	HFCs,PFCs,SF_6	EPA
Agriculture[3]	Enteric Fermentation	4 A	CH_4	FAO
	Manure Management	4 B	CH_4, N_2O	FAO
	Rice Cultivation	4 C	CH_4	FAO
	Agricultural Soils	4 D	N_2O	FAO
	Other Agricultural Sources	4	CH_4, N_2O	FAO
Land-Use Change & Forestry	Land Use Total (Forest land, cropland, grassland and biomass burning)	5	CO_2, CH_4, N_2O	FAO
Waste	Landfills (Solid Waste)	6 A	CH_4	EPA
	Wastewater Treatment	6 B	CH_4	EPA
	Human Sewage	6 B	N_2O	EPA
	Other Non-Agricultural Sources (Waste and Other)	6 D	CH_4, N_2O	EPA
International Bunkers	Aviation Bunkers	1 A 3a*i*	CO_2	IEA
	Marine Bunkers	1 A 3d*i*	CO_2	IEA

Sources: IPCC, 1996b; IEA, 2014 ; EPA 2012. **Notes**:

[1] Refers mainly, but not exclusively to electricity and heat (including CHP) produced by entities whose primary activity is to supply the public. Here, this category also includes *autoproducers* and *other energy industries*. *Autoproducers* generate electricity, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned. Ideally these emissions should be allocated to the sector for which the electricity and/or heat was generated. CO_2 and energy statistics from the IEA do not allow for this. *Other energy industries* refer to emissions from fuel combusted in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries (IEA, 2014).

[2] Emissions from fuel combustion in commercial/institutional activities, residential, agriculture/forestry, fishing and other emissions not specified elsewhere. (IEA, 2014).

[3] Consistent with IPCC Source/Sink categories, CO_2 associated with fuel combustion in the agricultural sector is included under the Energy, not Agriculture Sector.

Table 3 summarizes (1) all of the sector data included in CAIT, (2) how that data maps to IPCC categorizations, and (3) the sources of the data used. The remainder of this section examines in more detail the contents of CAIT sectors and subsectors. It also explains the ways in which CAIT sectors, due to either gaps or inconsistencies in the data, differ from IPCC Source/Sink Category definitions.

5.1. Energy

The *Energy* sector in CAIT consists of five subsectors: *Electricity/Heat*, *Manufacturing/Construction*, *Transportation*, *Other Fuel Combustion*, and *Fugitive Emissions*. Most energy emissions come from CO_2 from fossil fuel combustion, but emissions from CH_4 and N_2O may also be significant, particularly in the *Fugitive Emissions* subsector (CH_4). The information below pertaining to CO_2 is drawn primarily from IEA (2014). Information on CH_4 and N_2O is drawn from EPA (2012). More information about these sources can be found in the sections above dealing with CO_2 from fossil fuel combustion (Section 2) and non-CO_2 gases (Section 4). The discussion here is limited to primarily sectoral issues.

i. Electricity/Heat

The CAIT sub-sector *Electricity/Heat* includes CO_2 emissions from "Main activity producer of electricity and heat," "Unallocated autoproducers," as well as "Other energy industry own use," all drawn from IEA (2014). These three sectors are combined into a single subsector in CAIT so as to best approximate IPCC subsector 1 A 1 (Energy Industries). The three components of this subsector are described below in more detail.

According to the IEA (2014), "Main activity producer of electricity and heat" contains the sum of emissions from main activity producer electricity generation, combined heat and power generation and heat plants. Main activity producers (formerly known as public utilities) are defined as those undertakings whose primary activity is to supply the public. They may be publicly or privately owned. This corresponds to IPCC Source/Sink Category 1 A 1 a. See IEA (2014) for specific emission estimates of main activity producer electricity generation, combined heat and power generation, and heat plants (including disaggregated by fuel sources).

According to the IEA (2014), "Unallocated Autoproducers" contains the emissions from the generation of electricity and/or heat by autoproducers. Autoproducers are defined as undertakings that generate electricity and/or heat, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned. In the 1996 IPCC Guidelines, these emissions would normally be distributed between industry, transport and "other" sectors.

According to the IEA (2014), "Other energy industry own use" contains emissions from fuel combusted in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction, and other energy-producing industries. This corresponds to the IPCC Source/Sink Categories 1 A 1 b and 1 A 1 c. According to the Revised 1996 IPCC Guidelines, emissions from coke inputs to blast furnaces can either be counted here or in the Industrial Processes source/sink category. Within detailed sectoral calculations, certain non-energy processes can be distinguished. In the reduction of iron in a blast furnace through the combustion of coke, the

primary purpose of the coke oxidation is to produce pig iron and the emissions can be considered as industry process. Care must be taken not to double count these emissions in both Energy and Industrial Processes. In the IEA estimations, emissions from energy industry own use have been included in this category. Following on the IEA, in CAIT these emissions have been included only here and not in Industrial Processes. There will be no double counting in CAIT because, as described below, the only CO_2 data included in the Industrial Processes category is CO_2 from cement manufacturing.

ii. Manufacturing/Construction

The CAIT sub-sector *Manufacturing/Construction*, drawn from IEA (2014), includes CO_2 emission from fossil fuel combustion in the following activities:

- Iron and Steel
- Chemicals and Petrochemical
- Non-Ferrous Metals
- Non-Metallic Minerals
- Transport Equipment
- Machinery
- Mining and Quarrying
- Food and Tobacco
- Paper, Pulp and Printing
- Wood and Wood Products
- Construction
- Textile and Leather
- Non-specified Industry
- Non-Energy Use Industry/Transformation/Energy

In CAIT, emissions from the above activities are summed into a single yearly estimate for *Manufacturing/Construction*. See IEA (2014) for specific emission estimates for each of the activities listed above (including disaggregated by fuel sources).

Manufacturing industries and construction contains the emissions from combustion of fuels in industry. The IPCC Source/Sink Category 1 A 2 includes these emissions. However, the IEA (2014) notes that in the 1996 IPCC Guidelines (IPCC, 1996b), IPCC Category 1 A 2 also includes emissions from industry autoproducers that generate electricity and/or heat. These emissions are not included in a way that allows the energy consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item ("Unallocated Autoproducers"). The IEA (2014) also notes that Manufacturing Industries and Construction also includes emissions from coke inputs into blast furnaces, which may be reported either in the transformation sector, other energy industry own use, the industry sector or the separate IPCC Source/Sink Category 2, Industrial Processes.

iii. Transportation

The CAIT sub-sector *Transportation*, drawn from IEA (2014), includes CO_2 emission from fossil fuel combustion in the following activities:

- Domestic aviation (commercial, private, agricultural, military, etc.)

- Road
- Rail
- Pipeline transport
- Domestic navigation
- Non-specified transport
- Non-energy use in transport

In CAIT, emissions from the above activities are summed into a single yearly estimate for *Transportation*. See IEA (2013) for specific emission estimates for each of the activities listed above (including disaggregated by fuel sources).

Transportation contains emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation bunkers, which are not included in transport at a national or regional level (except for World transport emissions). This includes domestic aviation, domestic navigation, road, rail and pipeline transport, and corresponds to the IPCC Source/Sink Category 1 A 3. IEA (2014) notes that the data are not collected in a way that allows the autoproducer consumption to be split by specific end-use and therefore, this publication (IEA, 2014) shows autoproducers as a separate item (unallocated autoproducers). IEA also notes that, starting in the 2006 edition, military consumption previously included in domestic aviation and in road should be in non-specified other. See the publication for further details.

iv. Other Fuel Combustion

The CAIT sub-sector *Other Fuel Combustion* includes CO_2, CH_4, and N_2O emission from the following activities:
- CH_4 and N_2O from Biomass Combustion (EPA, 2012)
- CH_4 and N_2O from Stationary and Mobile Sources (EPA, 2012)
- CO_2 from Other Sectors (IEA, 2013)

In CAIT, emissions from the above activities are summed into a single yearly estimate for *Other Fuel Combustion*. This CAIT sector corresponds to the IPCC Source/Sink Categories 1 A 4 and 1 A 5.

CH_4 and N_2O emissions from "Stationary & Mobile Sources" and "Biomass Combustion" are drawn from EPA (2012). Along with CO_2 (which is accounted for elsewhere) and ambient air pollutants, emissions of CH_4 and N_2O can arise from fossil fuel combustion. These emissions are accounted for in "Stationary & Mobile Sources." For "Biomass Combustion," estimates may capture emissions that result from incomplete combustion of fuels such as charcoal or fuel wood.

Ideally, much of the emissions in these source categories would be distributed to the CAIT sectors *Electricity/Heat* (1 A 1), *Manufacturing/Construction* (1 A 2), or *Transportation* (1 A 3). However, the underlying data did not permit allocation to these more specific categories. Accordingly, "Biomass Combustion and "Stationary & Mobile Sources" are included together in CAIT's *Other Fuel Combustion* category (consistent with the IPCC Guidelines, Category 1 A 5). The *Other Fuel Combustion* category in CAIT also includes CO_2 from "Other Sectors" (IEA,

2012), which contains the emissions from commercial/ institutional activities, residential, and agriculture/forestry/fishing as well as other emissions not specified elsewhere that are included in the IPCC Source/Sink Category 1 A 4 and 1 A 5. IEA (2014) notes that in the Revised 1996 IPCC Guidelines, the category also includes emissions from autoproducers in the commercial/public services, residential and agriculture that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item (unallocated autoproducers).

v. Fugitive Emissions

The CAIT *Fugitive Emissions* subsector includes the following CO_2, CH_4, and N_2O emissions:
- CO_2 from Natural Gas Flaring/Venting (EIA, 2013)
- CH_4 from Natural Gas & Oil Systems (EPA, 2012)
- CH_4 from Coal Mining (EPA, 2012)
- CH_4 and N_2O from Other Energy Sources (Fugitives from Natural Gas& Oil, and Solid Fuels) (EPA, 2012)

Gas flaring refers to the practice of burning of gas that is released in association with oil production. Gas is flared either as a means of disposal or for safety reasons. CO_2 emissions from gas flaring are drawn from EIA (2013). CH_4 and N_2O from "Oil & Natural Gas Systems", "Coal Mining", and "Other Energy Sources" are drawn from EPA (2012).

5.2. Industrial Processes

The CAIT *Industrial Processes* sector includes:
- CO_2 emissions from Cement Manufacture (CDIAC; Boden et al., 2015)
- N_2O emissions from Adipic and Nitric Acid Production (EPA, 2012)
- N_2O and CH_4 emissions from Other Industrial (non-agriculture) (EPA, 2012)
- F-gases: HFCs, PFCs, and SF_6 (EPA, 2012)

CO_2 emissions from Cement Manufacture, drawn from CDIAC (Boden et al., 2015), is described in Section 2.2. N_2O emissions from Adipic and Nitric Acid Production are drawn from EPA (2012). Emissions estimates of high global warming potential (GWP) gases, namely HFCs, PFCs, and SF_6, are drawn from EPA (2012).

This sector is compiled so as to best match IPCC Source/Sink Category 2 (Industrial Processes). However, IPCC Guidelines (1996b) include several subsectors under Industrial Processes that, due to lack of data, are not included in CAIT. These include emissions from, *inter alia*, the chemical industry and iron and steel production. In CAIT, as noted above, some of these emissions may instead be included in the Energy sector under Manufacturing and Construction.

5.3. Agriculture

The CAIT *Agriculture* sector includes CH_4 and N_2O emission from the following activities, drawing on data from the Statistic Division of the Food and Agriculture Organization of the United States (FAOSTAT), as described in Section 4:
- CH_4 from Enteric Fermentation (Livestock) (FAO, 2014)

- CH_4 and N_2O from Livestock Manure Management (FAO, 2014)
- CH_4 from Rice Cultivation (FAO, 2014)
- N_2O from Agricultural Soils (FAO, 2014)
    - Synthetic Fertilizers
    - Manure Applied to Soils
    - Manure Applied to Pasture
    - Crop Residues
    - Cultivation of Organic Soils
- CH_4 and N_2O from Other Agricultural Sources (FAO, 2014)
    - Burning – Crop Residues
    - Burning - Savanna

This sector is compiled in CAIT so as to best match IPCC Source/Sink Category 4 (Agriculture) (IPCC, 1996b). Users should note, however, that this category does not include CO_2 emissions from fossil fuels associated with agricultural activities. These emissions are included in IPCC Source/Sink Category 1 A 4 (Energy, Other Sectors).

5.4. Land-Use Change & Forestry

Emissions in the CAIT *Land-Use Change and Forestry (Net emissions/removals)* sector, drawing on data from the Food and Agriculture Organization of the United Nations, are described above in Section 3. This CAIT sector best matches IPCC Source/Sink Category 5 (Land-Use Change & Forestry) (IPCC, 1996b).

5.5. Waste

The CAIT *Waste* sector includes CH_4 and N_2O emission from the following activities:
- CH_4 from Landfills (Solid Waste) (EPA, 2012)
- CH_4 from Wastewater Treatment (EPA, 2012)
- N_2O from Human Sewage (EPA, 2012)
- CH_4 and N_2O from Other (Waste) (EPA, 2012)

This sector is compiled in CAITso as to best match IPCC Source/Sink Category 6 (Waste) (IPCC, 1996b).

5.6. International Bunkers

The CAIT*International Bunkers* sector, drawn from IEA (2013), includes CO_2 emissions from the following activities:
- Aviation Bunkers
- Marine Bunkers

In CAIT, emissions from Aviation and Marine Bunkers are summed into a single yearly estimate for *International Bunkers*. See IEA (2013) for specific country-level emission estimates Aviation and Marine Bunkers (including disaggregated by fuel sources). This CAIT sector matches to IPCC Source/Sink Category 1 A 3 (a *i* and d *i*). In accordance with IPCC methodologies, these emissions are to be excluded from national totals and reported separately. ***Accordingly, except for World***

Total GHG emissions, emissions from International Bunkers are not included in CAIT National Totals.

6. National GHG Totals

CAIT provides National Total GHG emissions with and without LUCF (Land-Use Change and Forestry) for each country.[8] The contents of National Total calculations for *non-CO_2 gases* are described above in Section 4. This section concerns primarily National Total calculations for Total GHGs (i.e., CO_2, CH_4, N_2O, and F-gases).

First, National Total calculations are extremely sensitive to data availability. Accordingly, the National Total GHG Emissions might not be calculated in CAIT where only non-CO_2 data are available (e.g., Eritrea and Palau in 1990 and 1991), the National Total GHG Emissions might not be an accurate reflection of a country's true total when only partial CO_2 emissions data are available (e.g., fugitive emissions). More detailed country-by-country data availability can be viewed in Country Profile pages within CAIT[9].

Second, the National Total is, in general, a sum of the data from each of the individual sectors/gases. Accordingly, a National Total will include emissions from Energy, Industrial Processes, etc., summed into a single number. However, there is an exception to this general rule. In accordance with IPCC Guidelines and UNFCCC GHG inventories, emissions from land-use change and forestry (LUCF) and international bunkers are not automatically included in national totals. For LUCF, this is in part due to high data uncertainties. For emissions from International Bunker fuels (which are estimated based on the location of marine and aviation refueling), this is mainly due to difficulties in attributing international emissions to individual countries. ***Indicators for country GHG totals with LUCF and without LUCF are therefore presented separately. International Bunker totals are only available in the GHG Emissions by Sector table and are not included as part of a country's total reported emissions.***

As an example, the United States' National Total **for the years 1990-2012** would therefore comprise the following sector data:

- Energy sector:
    - CO_2 from fossil fuel combustion (IEA, 2014; sectoral approach)
    - CO_2 from gas flaring (EIA, 2014)
- Industrial Processes sector:
    - CO_2 from cement manufacture (Boden et al., 2015)
    - F-gases: HFCs, PFCs, and SF_6 (EPA, 2012)
- Agriculture sector:
    - CH_4 and N_2O (FAO, 2014) (see Section 4.1 for a description of specific CH_4 and N_2O emission sources included)
- Waste sector:
    - CH_4 and N_2O (EPA, 2012) (see Section 4.1 for a description of specific CH_4 and N_2O emission sources included)
- Land Use Change and Forestry sector ("including LUCF" indicator only): CO_2, CH_4, N_2O (FAO, 2014).
- International Bunkers are included in the "Emissions by sector" table only): CO_2 (IEA, 2014)

[8] This appears as the first item on the left-side data table menu of CAIT (http://cait.wri.org/historic).
[9] This can be viewed by clicking the "i" icon next to a country/state/region name in the data tables.

However, it is important to note that our calculation approach for the national totals indicators actually relies on a gas aggregation method (i.e., the sum of CO_2 emissions (see Sector 2) and non-CO_2 emissions (see Sector 4)) to produce the estimated emissions totals and "emissions by gas" estimates. This is due to limited data availability of sector-level emissions data for all countries. Thus, the sum of sectors might not coincide with the sum of gases for a particular country; this is especially true for the 50 countries which lack IEA data.

An example of how the United States' National Total **for the year 2012** would be compiled using a gas aggregation approach is as follows:

- CO_2 emissions total
    - CO_2 from fossil fuel combustion (IEA, 2014)
    - CO_2 from gas flaring (EIA, 2014)
    - CO_2 from cement manufacture (Boden et al., 2015)
    - CO_2 from land use change and forestry ("with LUCF" indicator only; FAO, 2014)
- CH_4 emissions total
    - CH_4 from agriculture (FAO, 2014)
    - CH_4 from land use change and forestry (FAO, 2014)
    - CH_4 from waste (EPA, 2012)
    - CH_4 from industrial process (EPA, 2012)
- N_2O emissions total
    - N_2O from agriculture (FAO, 2014)
    - N_2O from land use change and forestry (FAO, 2014)
    - N_2O from waste (EPA, 2012)
    - N_2O from industrial process (EPA, 2012)
- F-gas emissions total (EPA, 2012)

In addition, CAIT reports the National Total CO_2 emissions from 1850 to 2012, which is included in the data subset: CO_2 Emissions Totals. See Section 2 for a detailed description of CO2 emissions data.

7. Additional Methodological Issues

Data underpinning the GHG data in CAIT 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 CO_2 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 uncertainly for global CO_2 emissions from fossil fuels is relatively low, about 8%. For non-CO_2 GHG emissions, CH_4 and F-gases have relatively 'intermediate' uncertainties of around 20%, while N_2O has a higher uncertainty of around 60%. CO_2 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 emission factor measurements for technologies no longer in use. " (IPCC, 2014)

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