



World Resources Institute

## CAIT: GREENHOUSE GAS SOURCES & METHODS

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World Resources Institute

This document accompanies the Climate Analysis Indicators Tool (CAIT), version 6.0.

<http://cait.wri.org>

### About this Document

This document describes the greenhouse gas (GHG) emissions data sources, descriptions, and methodologies included in CAIT. Information about other data and indicators in CAIT can be found in separate supporting documentation available on the CAIT website.

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**CAIT, version 3.0 beta**

The Climate Analysis Indicators Tool (CAIT) provides a comprehensive and comparable database of greenhouse gases and other climate-relevant indicators.

**Click one of the links below to start using CAIT.** Use the navigation bar to the left to access the complete feature set.

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## List of Acronyms

CDIAC	Carbon Dioxide Information Analysis Center (of the U.S. Dept. of Energy)
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
EIA	Energy Information Administration (of the U.S. Dept. of Energy)
EDGAR	Emissions Database for Global Atmospheric Research
EPA	United States Environmental Protection Agency
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
N <sub>2</sub> O	Nitrous Oxide
OECD	Organization for Economic Co-operation and Development
PFC	Perfluorocarbon
RIVM	Netherlands Institute of Public Health and the Environment
SF <sub>6</sub>	Sulfur Hexafluoride
SRES	Special Report on Emission Scenarios
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute



## 1. Introduction

Over the coming decade, governments will need to make important decisions with respect to a wide range of issues under the UN Climate Change Convention (UNFCCC). To effectively address issues that are important to all Parties to the Convention, data and information are needed to support decision-making. With this need in mind, World Resources Institute (WRI) aims to provide an information and analysis tool—the Climate Analysis Indicators Tool (CAIT)—to build capacity and help support future policy decisions made under the Climate Convention and in other fora. CAIT is an information and analysis tool on global climate change that provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators.

This supporting documentation to CAIT describes the sources and methodologies used to compile the greenhouse gases (GHGs) included in CAIT. This includes CO<sub>2</sub> from fossil fuels and cement manufacture, CO<sub>2</sub> from land-use changes, and five non-CO<sub>2</sub> gases. Together, these constitute the main gases and sources contributing to climate change. Other relevant supporting documentation can be found on the CAIT website (<http://cait.wri.org>).

### 1.1. CAIT Products

CAIT is not a single tool, but a set of tools, each with its own purpose. Each is available free of charge from the CAIT website (<http://cait.wri.org>). The principal CAIT products are briefly described below.

- **CAIT** (online) operates through a web-based interface. CAIT includes a wide variety of climate-relevant data and indicators that can be viewed through an interactive and customizable interface. For GHG emissions-related indicators, CAIT's interface allows the user in most instances to choose particular years, sectors, gases, and countries to display. CAIT includes numerous analysis features that allow for a range of comparisons across gases, sectors, countries, and years (including with graphing and charting tools). Three additional modules accompany CAIT that incorporate different data and indicators:
  - **CAIT-UNFCCC** is a basic interface for viewing and analyzing official GHG emissions data submitted by UNFCCC Parties to the Convention Secretariat.
  - **CAIT-U.S.** is an interface for viewing data, indicators, and policy development pertaining to U.S. *states*.<sup>1</sup>
  - **CAIT-V&A** is an interface for viewing data and indicators related to countries' vulnerability and adaptive capacity (V&A).<sup>2</sup>

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<sup>1</sup> CAIT-U.S. includes only GHG data from the U.S. Environmental Protection Agency. Accordingly, this supporting document does not apply to CAIT-U.S.

<sup>2</sup> CAIT-V&A includes no GHG emissions data. Accordingly, this supporting document does not apply to CAIT-V&A.



## 1.2. Countries & Regions in CAIT

CAIT includes *country*-level GHG emissions data for all Parties to the UNFCCC as well as two non-Parties that are members of the UN (Brunei and Iraq).<sup>3</sup> Overall, the CAIT database includes 186 countries. This covers all UNFCCC Parties, except Liechtenstein, Marshall Islands, Micronesia, Monaco (combined with France), San Marino (combined with Italy), and Tuvalu. For these countries, there was inadequate emissions data. The European Union is also included as a “country” because the European Community (a unit of the EU) is a Party to the Convention. Taiwan (Chinese Taipei), which is neither a UN member nor a Convention Party, is also included in CAIT. This exception is made because Taiwan (Chinese Taipei) is a significant source of GHG emissions.

Three categories of regions are also included in CAIT:<sup>4</sup>

1. *8 Geographic regions* (e.g., sub-Saharan Africa, South America).
2. *17 UNFCCC regions and other organizations* (e.g., Annex I, G-77/China, OPEC).
3. *User-Defined regions*. Users can define (and save) their own regions (under the Customize menu in CAIT).

To the extent possible, CAIT includes emissions from all greenhouse gases and major emission sources for each country and region (see [Section 9.2](#) for more information about regional calculations in CAIT). Thus, as described in this document, data sources cover CO<sub>2</sub> emissions from energy, cement manufacture, and land-use changes as well as from non-CO<sub>2</sub> gases such as CH<sub>4</sub> and N<sub>2</sub>O. For a given country, as many as seven GHG data sources may be used (including sector-level data). The full listing of GHG emission sources for all countries included in CAIT is shown in [Appendix A](#). (This appendix covers *national level* emissions only; for information about sector-level sources, see [Section 5](#).)

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<sup>3</sup> Non-Parties are specified in CAIT with an asterisk "\*".

<sup>4</sup> See *Notes & Definitions*, within CAIT for a full listing of regions and their definitions.



## 2. CO<sub>2</sub> from Fossil Fuels and Cement Manufacture

This section describes the decision criteria, data sources, and methodologies used to compile the CO<sub>2</sub> emissions data in CAIT (excluding CO<sub>2</sub> emissions from land-use change).

### 2.1. CO<sub>2</sub> from Fossil Fuels: Data Sources and Selection Criteria

There are several sources of CO<sub>2</sub> emissions from fossil fuels widely used by the climate policy and science communities, including databases provided by the Carbon Dioxide Information Analysis Center (CDIAC)<sup>5</sup>, the International Energy Agency (IEA), the UNFCCC, and the Energy Information Administration (EIA). In deciding which database to use for the Climate Analysis Indicators Tool, 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.

<b>Table 1. Evaluating Carbon Dioxide Databases</b> <i>Scoring: * = Low; **** = High</i>			
<b>Database</b>	<b>Geographic Coverage</b>	<b>Temporal Coverage</b>	<b>Accuracy</b>
CDIAC	**** Almost all countries†	**** (1751 - 2005)	**
IEA	*** 134 countries	*** (1960 or 1971 - 2005)	***
UNFCCC	* Annex I; many others missing	* 1990 - 2006	****
EIA	**** Almost all countries†	** (1980 - 2005)	**

**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 Marland et al., 2008; IEA, 2007; UNFCCC, 2008; EIA, 2007.  
 † 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<sub>2</sub> 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, discussed in greater detail in [Section 7](#), is regarded as the most accurate. These data are found in official submissions by Parties under the Climate Convention. Many UNFCCC inventories are 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). However, official UNFCCC data extends only back to 1990, and excludes many countries that have never submitted national communications. Annex I (industrialized) countries tend to have excellent coverage from 1990 to 2006, although there are some exceptions, most notably for economies in transition some of which have not reported timely inventories. For non-Annex I

<sup>5</sup> CDIAC refers to Marland et al. 2007.



(developing) countries, most countries have reported a national communication, from which one or two years of inventory data can be derived. Some non-Annex I Parties have not yet submitted any inventory data.

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 regular edition of CAIT and creating a separate module within CAIT (called CAIT-UNFCCC), which has *only* UNFCCC data, as described in [Section 7](#).

IEA's database also scores relatively high regarding accuracy. This is due to several factors, including the use of recognized IPCC methodologies, the wealth of available documentation explaining methodologies, and the use of both bottom-up (sectoral) and top-down (reference) emission estimates. IEA has compared its results to UNFCCC inventory submissions to help identify and address problems related to methods, input data, or emission factors (IEA, 2007).

The ratings for accuracy are also influenced by WRI's own analysis of the datasets. This involved analyzing the degree to which CO<sub>2</sub> estimates from CDIAC,<sup>6</sup> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> from fossil fuels in the following way:

- **IEA.** For 25 industrialized (OECD) countries, IEA data are used in CAIT for the years 1960 to 2005. For 106 (mostly developing) countries, IEA data are used for the years 1971 to 2005. Overall, IEA data covers 131 of 185 countries in CAIT. As of 2008, 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 in CAIT from 1850 to 1959 for 25 industrialized (OECD) countries, and from 1850 to 1970 for the other 106 countries for which IEA has data (see above). For 53 countries that lack IEA data, CDIAC data is used up to 2005. Data prior to 1850, though available from CDIAC for some countries, was excluded due to especially limited geographic coverage.
- **EIA.** For Lesotho, neither CDIAC nor IEA provided any CO<sub>2</sub> data. Thus, EIA data are used from 1980 to 2005 (with no coverage prior to 1980).
- A complete country-by-country listing of sources and notes can be found in [Appendix A](#). Box 1 offers some further information on the data sources used.

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,

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<sup>6</sup> Cement data was removed from CDIAC for the purposes of this analysis.



comparability can be endangered when data points from different sources (using different methodologies) are placed side-by-side. Here, data covering the past few decades is mostly from IEA; however 53 countries are from CDIAC (and one from EIA). Similarly, the time-series data for the 131 countries covered by IEA includes a “stitch” where the source changes from CDIAC to IEA (either from 1959-60 or 1970-71).

However, these shortcomings may not be especially problematic. In many cases the difference between IEA and CDIAC data for a “stitch year” (e.g., 1960 for France) is not particularly significant. Also, the 53 countries using CDIAC data over the past few decades are generally small countries (together constituting about 0.2 percent of global emissions). In any case, users should be aware of “stitch years,” particularly when using CAIT’s *Trends Analysis* tools.

### **Box 1. Information on Key CO<sub>2</sub> Data Sources used in CAIT**

CDIAC (1751-2005). 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. See Marland et al. (2008) in [References](#).

EIA (1980-2005). The United States Energy Information Administration estimates CO<sub>2</sub> 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 (2007), is available in [References](#).

IEA (1960-2005). IEA’s Reference Approach contains total CO<sub>2</sub> emissions from fuel combustion as calculated using the IPCC Reference Approach and corresponds to IPCC Source/Sink Category 1 A with the following exception. The Reference Approach is based on the supply of energy in a country and as a result, all inventories calculated using this method include fugitive emissions from energy transformation (e.g., from oil refineries) that are normally included in Category 1 B. For this reason, Reference Approach estimates are likely to overestimate national CO<sub>2</sub> emissions (relative to an exact calculation using IPCC Source/Sink Category 1 A). For more information, see IEA (2007) in [References](#).

## **2.2. CO<sub>2</sub> from Cement Manufacture**

Carbon dioxide is a well known byproduct of cement manufacturing (as cement is calcined to produce calcium oxide). Estimates of CO<sub>2</sub> emitted during cement production, based on data from the U.S. Department of Interior’s Geological Survey, are available from CDIAC (Marland et al., 2008).<sup>7</sup>

These estimates of CO<sub>2</sub> from cement manufacture, which cover 1928 to the present, are included in CAIT’s CO<sub>2</sub> *National Totals* (See [Section 6](#)). CO<sub>2</sub> from cement manufacture can also be viewed under the *Industrial Processes* sector in CAIT (see [Section 5.2](#)).

<sup>7</sup> This is an important difference between CDIAC and IEA databases.



### 2.3. Methodology for Historical Emission Estimates

Country boundaries have changed significantly over the past century, particularly during the years following World Wars I and II and the early 1990s. Considering that CAIT uses greenhouse gas 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<sub>2</sub> from fossil fuels and CO<sub>2</sub> 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 305 million tonnes of carbon (MtC) (step 1). Emissions for all former Soviet Republics in 1990-94 were about 4,247 MtC (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 in order 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.

<b>Table 2. Emission Estimates for Newly-Formed Countries</b>						
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
<b>A. Countries Divided</b>						
U.S.S.R						
	Armenia	1850-1989	1990	1990-94	0.4%	0.4%
	Azerbaijan	1850-1989	1990	1990-94	1.6%	0.7%
	Belarus	1850-1989	1990	1990-94	2.9%	2.5%
	Estonia	1850-1989	1990	1990-94	0.8%	0.7%
	Georgia	1850-1989	1990	1990-94	0.6%	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	0.5%	0.4%
	Lithuania	1850-1989	1990	1990-94	0.8%	1.3%
	Moldova	1850-1989	1990	1990-94	0.7%	0.3%
	Russian Federation	1850-1989	1990	1990-94	61.6%	62.5%
	Tajikistan	1850-1989	1990	1990-94	0.3%	0.3%
	Turkmenistan	1850-1989	1990	1990-94	1.2%	1.1%
	Ukraine	1850-1989	1990	1990-94	17.3%	17.3%
	Uzbekistan	1850-1989	1990	1990-94	3.8%	6.7%
<b>Note:</b> Cement shares use 1992-96.						
Yugoslavia						
	Bosnia & Herzegovina	1890-1989	1990	1990-94	15.5%	3.6%
	Croatia	1890-1989	1990	1990-94	16.9%	35.4%
	Macedonia	1890-1989	1990	1990-94	9.0%	9.8%
	Serbia & Montenegro	1890-1989	1990	1990-94	46.4%	33.8%
	Slovenia	1890-1985	1986	1990-94	12.2%	17.3%
<b>Note:</b> 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%
<b>Note:</b> 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	3.6%	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%
	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%



<b>Table 2. Emission Estimates for Newly-Formed Countries</b>						
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
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%
<b>Note:</b> 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>B. Countries United</b>						
Germany (East and West)	Germany	1945-69	1970	n/a	100%	100%
<b>Note:</b> 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. CO<sub>2</sub> from Land Use Changes

CAIT includes estimates of CO<sub>2</sub> from land use change developed by Houghton (2003a). These estimates cover 1950 to 2000 for most countries of the world and are based on a global and regional analysis of land-use change by Houghton (2003b). A full description of the methods and results of Houghton (2003a) are provided on the CAIT website.<sup>8</sup>

Users should note that the errors associated with these national estimates are substantial. Based on recent analyses of tropical deforestation, the emissions of carbon from tropical countries, as determined by Houghton (2003b), may be high by a factor of two. If one considers the uncertainty in estimates of carbon stocks in tropical forests, an additional error of  $\pm 50$  percent is possible. Thus, these estimates of national sources and sinks of carbon from land-use change are uncertain on the order of  $\pm 150$  percent for large fluxes, and  $\pm 50$  MtC per year for estimates near zero.

Many industrialized countries have submitted estimates of CO<sub>2</sub> from land use change to the UNFCCC through their annual inventory submissions (1990 to present). (This data can be viewed in CAIT-UNFCCC.) Industrialized country estimates from Houghton (2003a)—which are included in CAIT—differ significantly from these official estimates. In most cases, official estimates tend to show larger fluxes (positive or negative) than Houghton (2003a). Estimates from Houghton are much closer to a “net zero” emission flux from the land use sector, which somewhat dampens the effects of their inclusion for industrialized countries. Four exceptions to this are Canada (UNFCCC, 2007 shows a sink and Houghton, 2003a, shows a large source), Ireland (Houghton, 2003a, shows a modest sink and UNFCCC, 2007, shows a modest source), Portugal (Houghton, 2003a, shows a slightly larger sink than UNFCCC, 2007), and Slovakia (UNFCCC, 2007 shows a modest sink and Houghton, 2003a, shows a modest source).<sup>9</sup>

CAIT users should be aware of these uncertainties and deviations from officially reported estimates, particularly when examining CO<sub>2</sub> from land use change estimates for a *specific year* (i.e., under the Yearly Emissions indicator).

**Note:** In 2008, Dr. Houghton produced an updated inventory of CO<sub>2</sub> emissions from land-use change and forestry through 2005 (Houghton, 2008). However, these estimates include regional fluxes only (1850-2005), not country-level estimates, and therefore have not yet been integrated into the CAIT platform. Users interested in these data can access the data set directly through the CDIAC website: <http://cdiac.ornl.gov/trends/landuse/houghton/houghton.html>.

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<sup>8</sup> See **Data Note: Emissions (and Sinks) of Carbon from Land-Use Change**, available at: <http://cait.wri.org/downloads.php>.

<sup>9</sup> Comparisons here are for 2000.



## 4. Non-CO<sub>2</sub> Gases

Five non-CO<sub>2</sub> gases are included in CAIT: methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>). Estimates for these gases are drawn primarily from EPA (2006) and cover four recent years only: 1990, 1995, 2000, and, *for a limited number of countries*, 2005. All non-CO<sub>2</sub> emissions in CAIT are expressed in carbon (or CO<sub>2</sub>) equivalents using 100 year global warming potentials found in the IPCC Second Assessment Report (IPCC, 1996a).

EPA (2006 and 2008) provides details regarding emission collection and estimation methodologies, as well as the typically high uncertainties associated with CH<sub>4</sub> and N<sub>2</sub>O 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. The differences between official data submitted to the UNFCCC (either through national inventories or national circumstances) and (EPA, 2006) are, in most cases, not substantial. Any differences may be due to the methodologies employed by EPA to improve consistency. As noted, CAIT users should be aware that emissions of non-CO<sub>2</sub> gases have high uncertainty levels.

### 4.1. CH<sub>4</sub> and N<sub>2</sub>O

EPA (2006) estimates of CH<sub>4</sub> and N<sub>2</sub>O emissions are broken down into sector and sub-sector level detail. The *National Total* CH<sub>4</sub> estimates in CAIT are calculated by summing the following individual sector or subsector estimates in EPA (2006):

- Biomass Combustion
- Stationary and Mobile Sources
- Oil & Natural Gas Systems
- Coal Mining
- Other Industrial non-Agriculture
- Enteric Fermentation
- Manure
- Rice
- Other Agricultural Sources
- Landfills
- Wastewater
- Other

*National Total* N<sub>2</sub>O estimates in CAIT are calculated by summing the following individual sector or subsector estimates in EPA (2006):

- Biomass Combustion
- Stationary and Mobile Sources
- Adipic and Nitric Acid Production
- Other Industrial non-Agriculture
- Manure
- Agricultural Soils
- Other Agricultural Sources
- Human Sewage
- Other (Waste)

As discussed below in [Section 5](#), much of the data from these detailed source categories are available in CAIT. The above source categories are 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.



EPA (2006) CH<sub>4</sub> and N<sub>2</sub>O emissions estimates cover 90 CAIT countries (see [Appendix A](#)). These countries comprise approximately 89 percent of global CH<sub>4</sub> and N<sub>2</sub>O emissions (remaining emissions are split among eight regions, such as “Rest of Africa”). For the (mostly very small) countries where EPA estimates were not available, estimates from the Emissions Database for Global Atmospheric Research (EDGAR) were used. (For more information about EDGAR data, see EDGAR 3.2 Fast Track 2000 by RIVM/TNO, under [References](#).) EDGAR country-level data for CH<sub>4</sub> and N<sub>2</sub>O covers only 1990, 1995, and 2000.

For country-level details on data sources, see Appendix A. Emission estimates from EDGAR in CAIT do not cover specific sectors and sub-sectors.

#### 4.2. HFCs, PFCs, and SF<sub>6</sub>

EPA (2004 and 2006) includes estimates of HFCs, PFCs, and SF<sub>6</sub> 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<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>, NF<sub>3</sub>). SF<sub>6</sub> 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.

HFCs, PFCs, and SF<sub>6</sub> estimates cover all countries in CAIT (for 1990, 1995, and 2000) except Congo, Cook Islands, Fiji, Niue, Papua New Guinea, Samoa, and the Seychelles (see [Appendix A](#)). Only the 90 countries reported in EPA (2006) have data available for 2005.



## 5. Sector-Level GHG Emissions Data

CAIT includes *sector-level* data. 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. 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 summarizes (1) all of the sector data included in CAIT, (2) how that data maps to IPCC

Table 3. Summary of CAIT Sector Data				
CAIT Sector Category	CAIT Sector Contents	IPCC Category	Gas	Data Source (years)
<u>Energy</u>		1		
Electricity & Heat <sup>1</sup>	Electricity & heat plants (fossil fuels) - Public plants (electricity, heat, CHP) - Autoproducers (electricity, heat, CHP) Other Energy Industries (fossil fuels)	1 A 1 a 1 A 1 A 1 b,c	CO <sub>2</sub> CO <sub>2</sub> CO <sub>2</sub>	IEA (1980 to 2005) IEA (1980 to 2005) IEA (1980 to 2005)
Manufacturing & Const.	Manufacturing & Const. (fossil fuels)	1 A 2	CO <sub>2</sub>	IEA (1980 to 2005)
Transportation	Transportation (fossil fuels)	1 A 3	CO <sub>2</sub>	IEA (1980 to 2005)
Other Fuel Combustion <sup>2</sup>	Other Sectors (fossil fuels) Biomass Combustion Stationary and Mobile Sources	1 A 4 1 A 5 1 A 5	CO <sub>2</sub> CH <sub>4</sub> , N <sub>2</sub> O CH <sub>4</sub> , N <sub>2</sub> O	IEA (1980 to 2005) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05)
Fugitive Emissions	Gas Venting/Flaring Oil & Natural Gas Systems Coal Mining	1 B 2c 1 B 2 1 B 1	CO <sub>2</sub> CH <sub>4</sub> , N <sub>2</sub> O CH <sub>4</sub> , N <sub>2</sub> O	EIA (1980 to 2005) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05)
<u>Industrial Processes</u>	Cement Adipic and Nitric Acid Production Other Industrial non-Agriculture All Fluorinated Gases	2 A 1 2 B 2,3 2 2	CO <sub>2</sub> N <sub>2</sub> O CH <sub>4</sub> , N <sub>2</sub> O HFCs,PFCs,SF <sub>6</sub>	CDIAC (1980 to 2005) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05)
<u>Agriculture</u> <sup>3</sup>	Enteric Fermentation (Livestock) Livestock Manure Management Rice Cultivation Agricultural Soils Other Agricultural Sources	4 A 4 B 4 C 4 D 4	CH <sub>4</sub> CH <sub>4</sub> , N <sub>2</sub> O CH <sub>4</sub> N <sub>2</sub> O CH <sub>4</sub> , N <sub>2</sub> O	EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05)
<u>Land Use Change &amp; Forestry</u>	All	5	CO <sub>2</sub>	Houghton (1950-2000)
<u>Waste</u>	Landfills (Solid Waste) Wastewater Treatment Human Sewage Other	6 A 6 B 6 B 6 D	CH <sub>4</sub> CH <sub>4</sub> N <sub>2</sub> O CH <sub>4</sub> , N <sub>2</sub> O	EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05) EPA (90, 95, 2000, 05)
<u>International Bunkers</u>	Aviation Bunkers Marine Bunkers	1 A 3ai 1 A 3di	CO <sub>2</sub> CO <sub>2</sub>	IEA (1980 to 2005) IEA (1980 to 2005)
<b>Sources:</b> IPCC, 1996b; IEA, 2007; CAIT-UNFCCC. <b>Notes:</b>				
<sup>1</sup> 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 <i>autoproducers</i> and <i>other energy industries</i> . <i>Autoproducers</i> 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 <sub>2</sub> and energy statistics from the IEA do not allow for this. <i>Other energy industries</i> refer to emissions from fuel combusted in association with production and processing (for example, petroleum refineries) of fossil fuels, and is thus not strictly electricity or heat (IEA, 2007).				
<sup>2</sup> Emissions from fuel combustion in (1) commercial and institutional buildings, (2) residential buildings, (3) agriculture, forestry, or domestic inland, coastal and deep-sea fishing, and (4) remaining non-specified emissions (IEA, 2007).				
<sup>3</sup> Consistent with IPCC Source/Sink categories, CO <sub>2</sub> associated with fuel combustion in the agricultural sector is included under the Energy, not Agriculture Sector.				



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<sub>2</sub> from fossil fuel combustion, but emissions from CH<sub>4</sub> and N<sub>2</sub>O may also be significant, particularly in the *Fugitive Emissions* subsector (CH<sub>4</sub>). The information below pertaining to CO<sub>2</sub> is drawn primarily from IEA (2007). Information on CH<sub>4</sub> and N<sub>2</sub>O is drawn primarily from EPA (2006). More information about these sources can be found in the sections above dealing with CO<sub>2</sub> from fossil fuel combustion ([Section 2](#)) and non-CO<sub>2</sub> gases ([Section 4](#)). The discussion here is limited to primarily sectoral issues.

### *i. Electricity/Heat*

The CAIT sub-sector *Electricity/Heat* includes CO<sub>2</sub> emissions from “Main Activity Electricity & Heat Production,” “Unallocated Autoproducers,” as well as “Other Energy Industries,” all drawn from IEA (2007). 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 (2007), “Main Activity Electricity and Heat Production” covers 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 category corresponds to IPCC Source/Sink Category 1 A 1 a. See IEA (2007) 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 (2007), “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 (2007), “Other Energy Industries” contains emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries. This category corresponds to the IPCC Source/Sink Categories 1 A 1 b and 1 A 1 c. The IEA notes that, according to the IPCC Guidelines, emissions from coke inputs to blast furnaces can either be counted here or in the Industrial Processes category. Accordingly, care must be taken not to double count certain emissions in this category with Industrial Processes. 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<sub>2</sub> data included in the Industrial Processes category is CO<sub>2</sub> from cement manufacturing.

ii. *Manufacturing/Construction*

The CAIT sub-sector *Manufacturing/Construction*, drawn from IEA (2007), includes CO<sub>2</sub> emission from fossil fuel combustion in the following activities:

- Iron and Steel
- Chemicals and Petrochemicals
- 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 Ind/Transf/Energy

In CAIT, emissions from the above activities are summed into a single yearly estimate for *Manufacturing/Construction*. See IEA (2007) for specific emission estimates for each of the activities listed above (including disaggregated by fuel sources).

*Manufacturing/Construction* corresponds to the IPCC Source/Sink Category 1 A 2. However, the IEA (2007) notes that in the 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 here. Because of IEA's data collection methods, emissions from autoproducers are shown as a separate item ("Unallocated Autoproducers"). The IEA (2007) also notes that Manufacturing Industries and Construction includes emissions from coke inputs into blast furnaces, which may be reported either in the transformation sector, the industry sector or the separate IPCC Source/Sink Category 2, Industrial Processes.

iii. *Transportation*

The CAIT sub-sector *Transportation*, drawn from IEA (2007), includes CO<sub>2</sub> emission from fossil fuel combustion in the following activities:

- Domestic air transport (commercial, private, agricultural, military, etc.)
- Road vehicles
- Rail
- Pipeline transport
- National 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 (2007) for specific emission estimates for each of the activities listed above (including disaggregated by fuel sources).

*Transportation* corresponds to the IPCC Source/Sink Category 1 A 3. However, consistent with the IPCC Guidelines (1996b), emissions from international bunkers (aviation and marine) are accounted for separately.

*iv. Other Fuel Combustion*

The CAIT sub-sector *Other Fuel Combustion* includes CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emission from the following activities:

- CH<sub>4</sub> and N<sub>2</sub>O from Biomass Combustion (EPA, 2006)
- CH<sub>4</sub> and N<sub>2</sub>O from Stationary and Mobile Sources (EPA, 2006)
- CO<sub>2</sub> from Other Sectors (IEA, 2007)

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<sub>4</sub> and N<sub>2</sub>O emissions from “Stationary & Mobile Sources” and “Biomass Combustion” are drawn from EPA (2006). Along with CO<sub>2</sub> (which is accounted for elsewhere) and ambient air pollutants, emissions of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> from “Other Sectors” (IEA, 2006), 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.

*v. Fugitive Emissions*

The CAIT *Fugitive Emissions* subsector includes the following CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions:

- CO<sub>2</sub> from Natural Gas Flaring/Venting (EIA, 2007)
- CH<sub>4</sub> and N<sub>2</sub>O from Oil & Natural Gas Systems (EPA, 2006)
- CH<sub>4</sub> and N<sub>2</sub>O from Coal Mining (EPA, 2006)

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<sub>2</sub> emissions



from gas flaring are drawn from EIA (2007). CH<sub>4</sub> and N<sub>2</sub>O from “Oil & Natural Gas Systems” and “Coal Mining” are drawn from EPA (2006).

## 5.2. Industrial Processes

The CAIT *Industrial Processes* sector includes:

- CO<sub>2</sub> emissions from Cement Manufacture (CDIAC; Marland et al., 2008)
- N<sub>2</sub>O emissions from Adipic and Nitric Acid Production (EPA, 2006)
- N<sub>2</sub>O and CH<sub>4</sub> emissions from Other Industrial (non-agriculture) (EPA, 2006)
- HFCs, PFCs, and SF<sub>6</sub> (EPA, 2004; 2006)

CO<sub>2</sub> emissions from Cement Manufacture, drawn from CDIAC (Marland et al., 2008), is described in [Section 2.2](#). N<sub>2</sub>O emission from Adipic and Nitric Acid Production are drawn from EPA (2006). Emission estimates of high global warming potential (GWP) gases, namely HFCs, PFCs, and SF<sub>6</sub>, are drawn from EPA (2004; 2006).

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<sub>4</sub> and N<sub>2</sub>O emission from the following activities:

- CH<sub>4</sub> from Enteric Fermentation (Livestock) (EPA, 2006)
- CH<sub>4</sub> and N<sub>2</sub>O from Livestock Manure Management (EPA, 2006)
- CH<sub>4</sub> from Rice Cultivation (EPA, 2006)
- N<sub>2</sub>O from Agricultural Soils (EPA, 2006)
- CH<sub>4</sub> and N<sub>2</sub>O from Other Agricultural Sources (EPA, 2006)

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<sub>2</sub> 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 & Forestry* sector, drawing on Houghton (2003a) 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<sub>4</sub> and N<sub>2</sub>O emission from the following activities:

- CH<sub>4</sub> from Landfills (Solid Waste) (EPA, 2006)
- CH<sub>4</sub> from Wastewater Treatment (EPA, 2006)



- N<sub>2</sub>O from Human Sewage (EPA, 2006)
- CH<sub>4</sub> and N<sub>2</sub>O from Other (Waste) (EPA, 2006)

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

## 5.6. International Bunkers

The CAIT *International Bunkers* sector, drawn from IEA (2007), includes CO<sub>2</sub> 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 (2006) for specific country-level emission estimates Aviation and Marine Bunkers (including disaggregated by fuel sources). These CAIT sector matches to IPCC Source/Sink Category 1 A 3 (a *i* and d *i*). Unless specified by the user, emissions from International Bunkers are not included in CAIT *National Totals*. In accordance with IPCC methodologies, these emissions are to be excluded from national totals and reported separately.



## 6. National GHG Totals

CAIT calculates a National Total of GHG emissions for each country.<sup>10</sup> National Total calculations can be made at the level of individual gases (e.g., CO<sub>2</sub> or CH<sub>4</sub>), or multiple gases collectively (e.g., CO<sub>2</sub> plus CH<sub>4</sub>), depending upon which gases are selected on CAIT's control panel (Figure 1). The contents of National Total calculations for *non-CO<sub>2</sub> gases* are described above in [Section 4](#). This section concerns primarily National Total calculations for CO<sub>2</sub> and national total calculations for CO<sub>2</sub> in combination with other GHGs (i.e., CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, and SF<sub>6</sub>).

**Figure 1.** Control Panel for Yearly Emissions

The screenshot shows a web interface for selecting emission parameters. It features a 'Year' dropdown menu with '2000' selected, a 'National Total' dropdown menu, and a row of checkboxes for CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, PFC, HFC, and SF<sub>6</sub>. Below these are two more checkboxes: 'Include Land-Use Change & Forestry' and 'Include Intl Bunkers'. A 'Data Availability' link is visible on the left, and an 'Update' button is on the right.

First, National Total calculations are extremely sensitive to data availability. It is not possible, for example, to calculate a National Total for *all GHGs* in 2004. This is due to the lack of non-CO<sub>2</sub> data availability in CAIT for the year 2004. (In CAIT-UNFCCC, however, some countries do have non-CO<sub>2</sub> data for recent years, e.g., 2005.) Accordingly, where certain data are unavailable, the National Total calculation will not be an accurate reflection of a country's true total. The most recent year where all data are available is 2000 (for all CAIT countries) and 2005 (for 90 countries). Data availability in CAIT can easily be checked by clicking on the link marked "data availability" within CAIT's control panel (Figure 1). More detailed country-by-country data availability can be viewed under CAIT's Notes and Definitions.

Second, the National Total is, in general, a sum of the data from each of the individual sectors. Accordingly, a National Total will include emissions from Energy, Industrial Processes, etc., summed into a single number. However, there is one exception to this general rule:

- (1) *CO<sub>2</sub> from Land Use Change and Forestry (LUCF)* and *CO<sub>2</sub> from International Bunkers*. In accordance with IPCC Guidelines and UNFCCC GHG inventories, emissions from these sources are not automatically included in national totals. For LUCF, this is in part due to very high data uncertainties. For emission 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. In order for these totals to be included in National Total calculations, the user must specify their inclusion by checking the relevant boxes in the CAIT control panel (Figure 1).

An example of a National Total is as follows: if all gases were selected, Canada's National Total for the year 2000 would comprise the following:

- Energy sector:
  - o CO<sub>2</sub> from fossil fuel combustion (IEA, 2007; sectoral approach)
  - o CO<sub>2</sub> from gas flaring (EIA, 2007)
- Industrial Processes sector:

<sup>10</sup> This appears as the first item on the drop-down box located on the Yearly Emissions page (<http://cait.wri.org/cait.php?page=yearly&mode=view>). See Figure 1.



- CO<sub>2</sub> from cement manufacture (Marland et al., 2008)
- HFCs, PFCs, and SF<sub>6</sub> (EPA, 2006) (see [Section 4.2](#) for a description of specific emission sources included)
- Agriculture and Waste sectors: CH<sub>4</sub> and N<sub>2</sub>O (EPA, 2006) (see [Section 4.1](#) for a description of specific CH<sub>4</sub> and N<sub>2</sub>O emission sources included)
- Land Use Change and Forestry sector (if manually selected): Houghton, 2003.
- International Bunkers (if manually selected): IEA, 2006.



## 7. UNFCCC Greenhouse Gas Emissions Data (CAIT-UNFCCC)

As discussed in [Section 1.1](#), CAIT-UNFCCC complements the basic version of CAIT. GHG emissions data in CAIT, as described in the preceding sections, draw on *unofficial* data sources. CAIT-UNFCCC, by contrast, uses only official GHG data sources. All GHG data in CAIT-UNFCCC are drawn from official submissions by Parties to the UNFCCC Secretariat. These data, in raw form, are available to the public from the UNFCCC website.<sup>11</sup>

Data were gathered by WRI from three different UNFCCC sources:

1. National Inventory Submissions in the Common Reporting Format (CRF). Most Parties included in Annex I to the Climate Convention (i.e., industrialized countries) submit annual inventories to the UNFCCC Secretariat using the CRF system. WRI has used the most recent CRF submissions from Annex I Parties in CAIT-UNFCCC (in most cases, 2004).
2. UNFCCC Online Database. This database was used by WRI primarily to gather data for non-Annex I (i.e., developing) countries that have submitted national communications to the UNFCCC Secretariat in accordance with Articles 4 and 12 of the UN Framework Convention on Climate Change. To access this database, see UNFCCC (2007) in [References](#).
3. National Communications. Countries submit national communications on an ongoing basis. Accordingly, some inventory data from non-Annex I national communications are not yet included in the UNFCCC Online Database. WRI periodically will extract inventory data from national communications directly, and include that data in CAIT-UNFCCC.

**Table 4. Summary of CAIT-UNFCCC Sector Data**

CAIT-UNFCCC Category	IPCC Category	GHG Sources/Sinks	Gases
National Total		All sectors	Six gases
Energy	1	Fuel combustion & fugitive emissions from fuels	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Electricity/Heat	1 A 1	Energy Industries (Includes public electricity & heat production, petroleum refining, solid fuel manufacturing, and other energy industries.)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Manufacturing/Construction	1 A 2	Manufacturing Industries & Construction	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Transportation	1 A 3	Transport	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Other Fuel Combustion	1 A 4 1 A 5	Other Sectors (Category 1 A 4: includes commercial/institutional, residential, agriculture/forestry/fishing) & Other (Category 1 A 5)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Fugitive Emissions	1 B	Fugitive Emissions from fuels (coal, oil, gas; venting & flaring)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Industrial Processes	2	Industrial Processes (Includes production of cement, chemicals, metals, halocarbons, sulfur hexafluoride, and others.)	Six gases
Agriculture	4	Agriculture (Includes enteric fermentation, manure management, rice cultivation, agricultural soils, and others.)	CO <sub>2</sub> , <sup>†</sup> CH <sub>4</sub> , N <sub>2</sub> O
Land Use Change & Forestry	5	Land Use Change & Forestry (Includes changes in biomass stocks, forest and grassland conversion, soils and others.)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Waste	6	Waste (Includes landfills, wastewater, and others)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
International Bunkers	1 A 3 <i>ai</i> 1 A 3 <i>di</i>	International aviation (international bunkers) and international marine (bunkers)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O
Other (includes solvents)	3 & 7	Solvent and other product use (Category 3) and other (Category 7)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O

**Sources.** IPCC, 1996b; CAIT-UNFCCC. **Notes.** † CO<sub>2</sub> associated with fuel combustion in the agricultural sector is not included under the IPCC Source/Sink category of “Agriculture.”

<sup>11</sup> United Nations Framework Convention on Climate Change (<http://unfccc.int>).



Official UNFCCC inventories are prepared in accordance with IPCC methodologies (IPCC, 1996b). These methodologies generate detailed sector-level data. Table 4 illustrates how CAIT-UNFCCC's sector categories match to IPCC Source/Sink categories. In many cases, CAIT-UNFCCC shows less sectoral detail than is technically possible (e.g., *Fugitive Emissions* could be disaggregated by fuels).

GHG data from the UNFCCC in CAIT spans the period from 1990 to 2005. Most (although not all) Annex I Parties have full inventories covering this time period. Most non-Annex I Parties that have submitted a national communication have included an inventory for one or two years (typically 1990 and/or 1994). The complete availability of UNFCCC data can be seen within CAIT-UNFCCC (by clicking on the [Data Availability](#) link, on the left hand menu bar). The availability of official UNFCCC data is generally much sparser than unofficial data used in CAIT, although UNFCCC may in some cases be more accurate and complete (with respect to gas coverage and sectoral detail). For example, Table 5 shows that the *Electricity/Heat* sector in CAIT-UNFCCC includes CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, whereas the comparable sector in CAIT includes only CO<sub>2</sub>.



## 8. Greenhouse Gas Projections

CAIT includes 11 emission projections (ranging from 2030 to 2100) generated by a variety of models. Like any future emission projections, there is significant uncertainty in the model projections included here. Accordingly, they should be used with care. Projections in CAIT are for CO<sub>2</sub> from fossil fuels only.

### 8.1. Special Report on Emissions Scenarios (6 projections)

Six projections are included from the IPCC Special Report on Emission Scenarios (SRES) (IPCC, 2000). These six scenarios encompass four combinations of demographic change, social and economic development, and broad technological developments, corresponding to the four “families” of IPCC scenarios (A1, A2, B1, B2). Two of the scenario groups of the A1 family (A1FI, A1T) explicitly explore alternative energy technology developments, holding the other driving forces constant. Each of these scenarios (A1, A2, B1, B2, A1FI, A1T) has an illustrative “marker scenario,” which is included in CAIT. Five models are responsible for generating these scenarios: AIM (A1), ASF (A2), IMAGE (B1), MESSAGE (B2 and A1T), and MINICAM (A1F1). According to the IPCC, these scenarios span a wide range of uncertainty and each should be considered equally sound. Box 2 offers summary descriptions of the IPCC family of scenarios.

#### Box 2. IPCC Special Report on Emissions Scenarios (SRES)

**A1.** The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

**A2.** The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

**B1.** The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

**B2.** The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative “marker” scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

**Source:** IPCC, 2001b.



Each SRES marker scenario includes four regions, roughly categorized as: (1) OECD (as of 1990), (2) Central and Eastern Europe and other Newly Independent States (i.e., economies in transition), (3) Asia (excluding Middle East), and (4) Africa, Latin America, and Middle East. A *World* region is also included. SRES projections extend to 2100. For more information about SRES scenarios, including the precise geographic composition of these regions, see IPCC, 2000.

## 8.2. Energy Information Administration (3 projections)

CAIT includes three projections based on output from the Energy Information Administration's (EIA) World Energy Projections Plus (WEPS+) model and System for the Analysis of Global Energy markets (SAGE) (EIA, 2008). According to EIA (2008), "WEPS+ is a system of sectoral energy models that provide a loosely linked, integrated equilibrium modeling system. It is used primarily to provide alternative energy projections based on different assumptions for GDP growth and fossil fuel prices." The model projections—which cover 16 regions or countries—are generally dependent on aggregate supply prices, GDP levels, and population, and include regional carbon dioxide projections (EIA, 2008).

SAGE "...is a regional model that provides a technology-rich basis for estimating regional electricity consumption. For each region, SAGE/GEM inputs reference case estimates of electricity demand (e.g., commercial, industrial, residential, and transportation) that were developed on the basis of economic and demographic projections in WEPS+. Projections of electricity generation...to meet the electricity demands are estimated on the basis of each region's existing electricity use patterns, the existing stock of electricity generation equipment, and the characteristics of available new electricity generation technologies, and fuel supply." For more information, see <http://www.eia.doe.gov/oiaf/ieo/appj.html>.

In CAIT, the three EIA projections based on WEPS+/SAGE are labeled EIA High, EIA Reference, and EIA Low. Using calculated average annual growth rates, WRI has interpolated between EIA published data points in each case to provide annual projections.

EIA emission projections are not fully disaggregated by country. However, for many large countries (including Brazil, China, India, Mexico, U.S., and others), country-specific projections are available. Based on the countries and regions in the model, WRI has also constructed an "Annex I" and a "non-Annex I" region, both of which are included in CAIT. EIA projections extend until 2030.

## 8.3. International Energy Agency

CAIT includes CO<sub>2</sub> projections from IEA (2008), which are derived from the long-term energy projections of the World Energy Model (WEM). Information on the WEM can be found at [http://www.worldenergyoutlook.org/docs/weo2008/WEM\\_Methodology\\_08.pdf](http://www.worldenergyoutlook.org/docs/weo2008/WEM_Methodology_08.pdf). The WEM includes 21 geographic regions (including several large countries individually, such as China, India, Russia, the U.S., and others). Based on the countries and regions in the model, WRI has also constructed an "Annex I" and a "non-Annex I" region, both of which are included in CAIT. IEA projections extend until 2030. Using calculated average annual growth rates, WRI has interpolated between IEA published data points to provide annual projections.



#### 8.4. POLES

CAIT includes projections from the POLES model, which was developed at Institut d'Economie et de Politique de l'Energie in Grenoble, France (European Commission, 2003). POLES is a world simulation model for the energy sector. It works in a year-by-year recursive simulation and partial equilibrium framework, with endogenous international energy prices and lagged adjustments of supply and demand by world region. GDP and population are the main exogenous variables. Additional information about the model structure can be found in Blanchard (2002: 240). The POLES model is geographically disaggregated into 38 countries or regions (including most EU countries individually, as well as several large countries, such as China, India, Japan, Brazil, the U.S., and others). Poles projections extend until 2030.



## 9. Additional Methodological Issues

### 9.1. Data Uncertainties

Data underpinning the indicators may suffer from 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. If users wish to *not* examine particular gases or sources, CAIT's user-interface will allow those gases or sources to be excluded.

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<sub>2</sub> 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. Analysis by Andres et al. (2000) showed that by 1993, revisions of 1983 data (10 years previous) amounted to an average 8.8 percent decrease, with 25 countries making revisions larger than  $\pm 10$  percent. CDIAC also has made expert judgments regarding national data quality, considering data from OECD countries to be the highest quality.

Second, despite uncertainties in CO<sub>2</sub> from fossil fuels, uncertainties are larger for non-CO<sub>2</sub> gases. For U.S. emissions, the largest uncertainties are for N<sub>2</sub>O emissions. Using IPCC Tier 2 uncertainty estimation methods, EIA (2002) estimated uncertainties surrounding a simulated mean of CO<sub>2</sub> (-1.4% to 1.3%), CH<sub>4</sub> (-15.6% to 16%), and N<sub>2</sub>O (-53.5% to 54.2%). Uncertainty bands appear smaller when expressed as percentages of *total* estimated emissions: CO<sub>2</sub> (-0.6% to 1.7%), CH<sub>4</sub> (-0.3% to 3.4%), and N<sub>2</sub>O (-1.9% to 6.3%). Uncertainties surrounding non-CO<sub>2</sub> emissions are expected to be greater in developing countries, due in some cases to weak underlying activity data and uncertain emission factors.

Finally, uncertainties are probably the largest for CO<sub>2</sub> from land use change (see discussion in [Section 3](#)).

### 9.2. Regional Emission Totals

Some GHG data sources used in CAIT (e.g., CDIAC) include their own regional totals (e.g., for “Asia”). However, we have not used any of these published regional totals in CAIT. Instead, regional totals are calculated *within* CAIT. The reason is that we have compiled data from a large number of sources, and *regional definitions across different sources are not uniform*. For that reason, there may be discrepancies between regional totals found here and those in other published sources. (Regional definitions used in CAIT can be found under the *Notes & Definitions* links.)

The only exception to this rule is *World* totals. We have used published world totals from various sources because the countries included in CAIT do not constitute 100 percent of the global coverage. Hong Kong and a variety of small territories, principalities, and other non-states are excluded. Therefore, to give the “percentage of world total” figures more accuracy, we have used published world totals.



An important caution regarding regional totals is that, in some cases, data are not available for all countries included in CAIT. Accordingly, *regional totals will be affected by these data gaps*.<sup>12</sup> We have not made any effort to correct for missing country data in the regional calculations. In many cases, data gaps will not have a significant effect on emissions for particular regions (e.g., lack of data for Afghanistan will have little influence on G-77/China totals).

For *National Totals* of CO<sub>2</sub>, most countries have data extending back to at least 1950. However, many countries do lack emissions data prior to 1950, and very few countries have data extending back to 1850 (the beginning of the CAIT time series). Exact coverage emissions data at the country-level (including for non-CO<sub>2</sub> gases) can be found in [Appendix A](#).

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<sup>12</sup> This problem is more significant for GDP and Energy Use data in CAIT. For more information, see Methodologies, under CAIT's *Notes & Definitions*.



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## Appendix A. Summary of Country-by-Country Data Sources and Notes

Country	CO <sub>2</sub> from Fossil Fuels	CO <sub>2</sub> from Land Use	Non-CO <sub>2</sub> Gases (1990, 1995, 2000, 2005)	
		Change & Forestry	CH <sub>4</sub> & N <sub>2</sub> O	HFCs, PFCs, SF <sub>6</sub>
Afghanistan	1949-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Albania	1933-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Algeria	1916-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Angola	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Antigua & Barbuda	1957-2005 (CDIAC)	No data	EDGAR	EPA
Argentina	1887-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Armenia	1850-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Australia	1860-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Austria	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Azerbaijan	1850-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Bahamas	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Bahrain	1933-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Bangladesh	1946-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates, 1946-1971 (E. & W. Pakistan).	1950-2000 (Houghton)	EPA	EPA
Barbados	1928-2005 (CDIAC)	No data	EDGAR	EPA
Belarus	1850-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates prior to 1992 (USSR).	1992-2000 (Houghton)	EPA	EPA
Belgium	1850-1959 (CDIAC); 1960-2005 (IEA)	No data	EPA	EPA
Belize	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Benin	1950-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EDGAR	EPA
Bhutan	1970-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Bolivia	1928-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Bosnia & Herz.	1885-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates prior to 1992 (Yugoslavia).	1990-2000 (Houghton)	EDGAR	EPA
Botswana	1972-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Brazil	1901-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Brunei	1933-1970 (CDIAC); 1971-2005 (IEA)	No data	EDGAR	EPA
Bulgaria	1881-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Burkina Faso	1950-2005 (CDIAC). Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EDGAR	EPA
Burundi	1950-2005 (CDIAC). Based on WRI estimates, 1950-61 (Rwanda-Urundi)	1950-2000 (Houghton)	EDGAR	EPA
Cambodia	1946-2005 (CDIAC). Based on WRI estimates, 1946-54 (French Indochina)	1950-2000 (Houghton)	EPA	EPA
Cameroon	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Canada	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Cape Verde	1950-2005 (CDIAC)	No data	EDGAR (no 2000)	EPA
Central Afr. Rep.	1950-2005 (CDIAC). Based on WRI estimates, 1950-58 (French Equatorial Afr.)	1950-2000 (Houghton)	EDGAR	EPA
Chad	1950-2005 (CDIAC). Based on WRI estimates, 1950-58 (French Equatorial Afr.)	1950-2000 (Houghton)	EDGAR	EPA
Chile	1895-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
China	1899-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Colombia	1921-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Comoros	1959-2005 (CDIAC)	No data	EDGAR	EPA
Congo	1950-1970 (CDIAC); 1971-2005 (IEA). Based on WRI estimates, 1950-58 (French Equatorial Afr.)	1950-2000 (Houghton)	EDGAR	EDGAR (90 & 95)
Congo, Dem. Rep.	1920-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Cook Islands	1969-2005 (CDIAC)	1993-2000 (Houghton)	EDGAR (no 2000)	EPA



Country	CO <sub>2</sub> from Fossil Fuels	CO <sub>2</sub> from Land Use	Non-CO <sub>2</sub> Gases (1990, 1995, 2000, 2005)	
		Change & Forestry	CH <sub>4</sub> & N <sub>2</sub> O	HFCs, PFCs, SF <sub>6</sub>
Costa Rica	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Côte d'Ivoire	1950-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EDGAR	EPA
Croatia	1885-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1991 (Yugoslavia).	1976-2000 (Houghton)	EPA	EPA
Cuba	1941-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Cyprus	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Czech Republic	1860-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1860-1970 (Czechoslovakia).	1976-2000 (Houghton)	EPA	EPA
Denmark	1850-1959 (CDIAC); 1960-2005 (IEA) Excludes Greenland and the Danish Faroes, except prior to 1990, where data on oil for Greenland were included with the Danish statistics.	1950-2000 (Houghton)	EPA	EPA
Djibouti	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Dominica	1949-2005 (CDIAC)	No data	EDGAR	EPA
Dominican Rep.	1947-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Ecuador	1917-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Egypt	1911-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
El Salvador	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Equat. Guinea	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Eritrea	1939-1970 (CDIAC); 1971-2005 (IEA)	No data	EDGAR (no 2000)	EPA
Estonia	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1850-1927 and 1940-91 (USSR).	1992-2000 (Houghton)	EPA	EPA
Ethiopia	1941-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Fiji	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EDGAR (90 & 95 only)
Finland	1860-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
France	1850-1959 (CDIAC); 1960-2005 (IEA) Includes Monaco, and excludes overseas departments, including French Polynesia, Guadeloupe, Martinique, and La Réunion. (CDIAC and IEA).	1950-2000 (Houghton)	EPA	EPA Includes Monaco
Gabon	1950-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-58 (French Equatorial Afr.)	1950-2000 (Houghton)	EDGAR	EPA
Gambia	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Georgia	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Germany	1850-1969 (CDIAC); 1970-2005 (IEA) Includes former East and West Germany, 1945-69.	1950-2000 (Houghton)	EPA	EPA
Ghana	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Greece	1867-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Grenada	1950-2005 (CDIAC)	No data	EDGAR	EPA
Guatemala	1941-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Guinea	1950-2005 (CDIAC) Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EDGAR	EPA
Guinea-Bissau	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Guyana	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Haiti	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Honduras	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Hungary	1851-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Iceland	1936-1959 (CDIAC); 1960-2005 (IEA)	No data	EPA	EPA
India	1858-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Indonesia	1889-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Iran	1911-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Iraq	1927-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Ireland	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Israel	1930-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Italy	1860-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA



Country	CO <sub>2</sub> from Fossil Fuels	CO <sub>2</sub> from Land Use	Non-CO <sub>2</sub> Gases (1990, 1995, 2000, 2005)	
		Change & Forestry	CH <sub>4</sub> & N <sub>2</sub> O	HFCs, PFCs, SF <sub>6</sub>
	Includes San Marino and the Vatican (CDIAC and IEA).		Includes San Marino	
Jamaica	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Japan	1868-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
	Includes Okinawa (IEA). Excludes the Ryukyu Islands, prior to 1950 (CDIAC). The IEA notes that the Japanese National Communication uses fiscal years, whereas the IEA uses calendar years.			
Jordan	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Kazakhstan	1850-1970 (CDIAC); 1971-2005 (IEA)	No data	EPA	EPA
	Based on WRI estimates prior to 1992 (USSR).			
Kenya	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Kiribati	1961-2005 (CDIAC)	No data	EDGAR	EPA
Korea (North)	1909-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
	Based on WRI estimates prior to 1945 (United Korea).			
Korea (South)	1909-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
	Based on WRI estimates prior to 1945 (United Korea).			
Kuwait	1946-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Kyrgyzstan	1850-1970 (CDIAC); 1971-2005 (IEA)	No data	EPA	EPA
	Based on WRI estimates prior to 1992 (USSR).			
Laos	1946-2005 (CDIAC)	1950-2000 (Houghton)	EPA	EPA
	Based on WRI estimates, 1946-54 (French Indochina)			
Latvia	1850-1970 (CDIAC); 1971-2005 (IEA)	1992-2000 (Houghton)	EPA	EPA
	Based on WRI estimates, 1940-91 (USSR).			
Lebanon	1931-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Lesotho	1980-2005 (EIA)	1950-2000 (Houghton)	EDGAR	EPA
Liberia	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Libya	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Lithuania	1850-1970 (CDIAC); 1971-2005 (IEA)	1992-2000 (Houghton)	EPA	EPA
	Based on WRI estimates prior to 1992 (USSR).			
Luxembourg	1945-1959 (CDIAC); 1960-2005 (IEA)	No data	EPA	EPA
Macedonia	1885-1970 (CDIAC); 1971-2005 (IEA)	No data	EPA (CH <sub>4</sub> ); EDGAR (N <sub>2</sub> O)	EPA
	Based on WRI estimates prior to 1990 (Yugoslavia).			
Madagascar	1945-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Malawi	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
	Based on WRI estimates, 1950-63 (Rhodesia-Nyasaland)			
Malaysia	1890-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
	Malaysia includes "Peninsular Malaysia" from 1890-1969. Based on WRI estimates, 1950-56 (Malaya-Singapore).			
Maldives	1971-2005 (CDIAC)	No data	EDGAR	EPA
Mali	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
	Based on WRI estimates, 1950-57 (French West Africa).			
Malta	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Mauritania	1950-2005 (CDIAC)	No data	EDGAR	EPA
	Based on WRI estimates, 1950-57 (French West Africa).			
Mauritius	1950-2005 (CDIAC)	No data	EDGAR	EPA
Mexico	1891-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Moldova	1850-1970 (CDIAC); 1971-2005 (IEA)	No data	EPA	EPA
	Based on WRI estimates prior to 1992 (USSR).			
Mongolia	1950-2005 (CDIAC)	1950-2000 (Houghton)	EPA	EPA
Morocco	1928-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Mozambique	1927-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Myanmar	1928-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Namibia	1990 (CDIAC); 1991-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Nauru	1964-2005 (CDIAC)	No data	EDGAR	EPA
Nepal	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Netherlands	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
	Excludes Surinam & Netherlands Antilles (CDIAC and IEA).			
New Zealand	1878-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA



Country	CO <sub>2</sub> from Fossil Fuels	CO <sub>2</sub> from Land Use	Non-CO <sub>2</sub> Gases (1990, 1995, 2000, 2005)	
		Change & Forestry	CH <sub>4</sub> & N <sub>2</sub> O	HFCs, PFCs, SF <sub>6</sub>
Nicaragua	1942-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Niger	1950-2005 (CDIAC) Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EDGAR	EPA
Nigeria	1915-1970 (CDIAC); 1971-2005 (IEA) The variation in emissions for 1993 and 1994 are due to problems in the underlying energy data. Oil export data for these two years are from the Energy Commission of Nigeria. (IEA)	1950-2000 (Houghton)	EPA	EPA
Niue	1970-2005 (CDIAC)	No data	EDGAR (no 2000)	EPA
Norway	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Oman	1964-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Pakistan	1946-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1946-1971 (E. & W. Pakistan).	1950-2000 (Houghton)	EPA	EPA
Palau	1955-2005 (CDIAC)	No data	EDGAR	EPA
Panama	1948-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Papua New Guinea	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EDGAR (90 & 95 only)
Paraguay	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Peru	1884-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Philippines	1907-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Poland	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Portugal	1870-1959 (CDIAC); 1960-2005 (IEA) Includes the Azores and Madeira.	1950-2000 (Houghton)	EPA	EPA
Qatar	1949-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Romania	1858-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Russian Federation	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	1950-2000 (Houghton)	EPA	EPA
Rwanda	1950-2005 (CDIAC) Based on WRI estimates, 1950-61 (Rwanda-Urundi)	1950-2000 (Houghton)	EDGAR	EPA
Saint Kitts & Nevis	1957-2005 (CDIAC) Includes Anguilla (1957-80)	No data	EDGAR (no 2000)	EPA
Saint Lucia	1950-2005 (CDIAC)	No data	EDGAR	EPA
Saint Vincent & Grenadines	1950-2005 (CDIAC)	No data	EDGAR	EPA
Samoa	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR (no 2000)	EPA
Sao Tome & Principe	1951-2005 (CDIAC)	1965-2000 (Houghton)	EDGAR (no 2000)	EPA
Saudi Arabia	1936-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Senegal	1949-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-57 (French West Africa).	1950-2000 (Houghton)	EPA	EPA
Serbia & Montenegro	1885-1970 (CDIAC); 1971-2005 (IEA) Formerly the "Federal Republic of Yugoslavia"; Based on WRI estimates prior to 1988 (Yugoslavia).	1976-2000 (Houghton)	EDGAR	EPA
Seychelles	1963-2005 (CDIAC)	No data	EDGAR	EPA
Sierra Leone	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Singapore	1950-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-56 (Malaya-Singapore).	1988-2000 (Houghton)	EPA	EPA
Slovakia	1860-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1860-1970 (Czechoslovakia).	1993-2000 (Houghton)	EPA	EPA
Slovenia	1885-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1980 (Yugoslavia).	1992-2000 (Houghton)	EPA	EPA
Solomon Isl.	1952-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
South Africa	1884-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Spain	1850-1959 (CDIAC); 1960-2005 (IEA) Includes the Canary Islands.	1950-2000 (Houghton)	EPA	EPA
Sri Lanka	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Sudan	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Suriname	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA



Country	CO <sub>2</sub> from Fossil Fuels	CO <sub>2</sub> from Land Use	Non-CO <sub>2</sub> Gases (1990, 1995, 2000, 2005)	
		Change & Forestry	CH <sub>4</sub> & N <sub>2</sub> O	HFCs, PFCs, SF <sub>6</sub>
Swaziland	1950-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Sweden	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Switzerland	1858-1959 (CDIAC); 1960-2005 (IEA) Includes Liechtenstein.	1950-2000 (Houghton)	EPA	EPA
Syria	1931-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Taiwan	1896-1970 (CDIAC); 1971-2005 (IEA)	No data	EDGAR (no 2000)	EPA
Tajikistan	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Tanzania	1950-1970 (CDIAC); 1971-2005 (IEA) Includes Tanganyika & formerly indep. Zanzibar, 1950-69.	1950-2000 (Houghton)	EDGAR	EPA
Thailand	1947-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Togo	1950-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Tonga	1950-2005 (CDIAC)	1982-2000 (Houghton)	EDGAR	EPA
Trinidad & Tobago	1909-1970 (CDIAC); 1971-2005 (IEA)	No data	EDGAR	EPA
Tunisia	1916-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EDGAR	EPA
Turkey	1865-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Turkmenistan	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Uganda	1950-2005 (CDIAC)	1950-2000 (Houghton)	EPA	EPA
Ukraine	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
United Arab Emirates	1959-1970 (CDIAC); 1971-2005 (IEA)	No data	EPA	EPA
United Kingdom	1850-1959 (CDIAC); 1960-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
United States of America	1850-1959 (CDIAC); 1960-2005 (IEA) Includes Puerto Rico, Guam, the Virgin Islands and the Hawaiian Free Trade Zone.	1950-2000 (Houghton)	EPA	EPA
Uruguay	1932-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Uzbekistan	1850-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates prior to 1992 (USSR).	No data	EPA	EPA
Vanuatu	1962-2005 (CDIAC)	1950-2000 (Houghton)	EDGAR	EPA
Venezuela	1904-1970 (CDIAC); 1971-2005 (IEA)	1950-2000 (Houghton)	EPA	EPA
Vietnam	1892-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1928-54 (French Indochina); Includes Former North and South Vietnam, 1955-69.	1950-2000 (Houghton)	EPA	EPA
Yemen	1950-1970 (CDIAC); 1971-2005 (IEA) Includes Former North and South Yemen, 1950-70.	1950-2000 (Houghton)	EDGAR	EPA
Zambia	1950-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-63 (Rhodesia-Nyasaland)	1950-2000 (Houghton)	EDGAR	EPA
Zimbabwe	1903-1970 (CDIAC); 1971-2005 (IEA) Based on WRI estimates, 1950-63 (Rhodesia-Nyasaland)	1950-2000 (Houghton)	EDGAR	EPA

**Note on Cement Manufacture & Flaring:** All countries include emissions from cement manufacture (CDIAC) from 1928-2005 and from gas flaring (EIA) from 1980-2005.

#### Emission Source Key:

**CDIAC** Marland, G., T.A. Boden, and R. J. Andres. 2008. "Global, Regional, and National Fossil Fuel CO<sub>2</sub> Emissions." In *Trends: A Compendium of Data on Global Change*. Carbon Dioxide Information Analysis Center (CDIAC), Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. Available online at: <http://cdiac.ornl.gov/trends/emis/overview.html>.

**EIA** EIA. 2007. *International Energy Annual 2005*. Available online at: <http://www.eia.doe.gov/iea/carbon.html>.

**EDGAR** EDGAR 3.2FT2000 by RIVM/TNO. 2005. Olivier, J.G.J., Van Aardenne, J.A., Dentener, F., Ganzeveld, L. and J.A.H.W. Peters. Recent trends in global greenhouse gas emissions: regional trends and spatial distribution of key sources. In: "Non-CO<sub>2</sub> Greenhouse Gases (NCGG-4)", A. van Amstel (coord.), page 325-330. Millpress, Rotterdam, ISBN 90 5966 043 9. Available at: <http://www.mnp.nl/edgar/>.



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- EPA** EPA. 2006 (revised). "Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020." Available at: <http://www.epa.gov/nonco2/econ-inv/international.html>.
- Houghton** Houghton, R.A. 2003. "Emissions (and Sinks) of Carbon from Land-Use Change." (Estimates of national sources and sinks of carbon resulting from changes in land use, 1950 to 2000). Report to the World Resources Institute from the Woods Hole Research Center. Available at: <http://cait.wri.org>.
- IEA** IEA. 2007. CO2 Emissions from Fuel Combustion (2007 edition). Available online at: [http://data.iea.org/ieastore/co2\\_main.asp](http://data.iea.org/ieastore/co2_main.asp).  
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