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Greenhouse Gas Emissions Data: Concepts and Data Availability

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Note by the Secretariat

This paper is part of the OECD programme of work on tracking countries' progress towards the Paris Agreement goals (joint project between Statistics and Data Directorate, Environment Directorate, and Economics Department). It has been developed in collaboration with the organisation's International Programme for Action on Climate (IPAC) and is intended to inform discussions by the Technical Expert Group (TEG) of the IPAC that brings together experts from OECD member countries, interested non-member countries, international organisations and non-governmental organisations. The paper incorporates comments from the IPAC TEG, the OECD Working Party on Environmental Information (WPEI) and the OECD Working Party on National Accounts (WPNA).

This paper was written by Santaro Sakata from the OECD's Statistics and Data Directorate and Rodrigo Pizarro and Abenezer Zeleke Aklilu from the Environment Directorate. Nathalie Girouard, Head of the Environmental Performance and Information Division in the Environment Directorate, and Sarah Barahona, Head of the National Accounts Division in the Statistics and Data Directorate, supervised.

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Abstract

Greenhouse gas (GHG) emissions data is essential for tracking progress towards the Paris Agreement's global temperature goals. In addition to the emissions inventories based on the Intergovernmental Panel on Climate Change guidelines, which are used for tracking progress under the framework of the Paris Agreement, there are other GHG emissions datasets that cater to different users and policy objectives. This paper evaluates three OECD datasets on GHG emissions: Air emissions – Greenhouse gas emissions inventories, Agricultural greenhouse gases emissions, and the Air Emissions Accounts (AEAs) based on the System of Environmental-Economic Accounting. It also looks at one dataset from the International Energy Agency: CO_2 emissions from fuel combustion.
It discusses the inventory and AEA approaches in terms of accounting principles (production- versus demand-based, territory versus residence), as well as classifications and scope of emissions. It looks at the coverage of the GHG emissions datasets and identifies the data gaps. Finally, the paper outlines several steps to enhance data coverage and quality of the datasets.

Keywords: Territory principle, Residence principle, Production- and demand-based emissions, Emissions source classifications, Official greenhouse gas emissions data gaps.

JEL Codes : C82, E01, Q54, Q56.

Résumé

Les données sur les émissions de gaz à effet de serre (GES) sont essentielles pour suivre les progrès réalisés vers les objectifs de température mondiale de l'Accord de Paris. Outre les inventaires d'émissions basés sur les lignes directrices du Groupe d'experts intergouvernemental sur l'évolution du climat, qui sont utilisés pour suivre les progrès réalisés dans le cadre de l'Accord de Paris, il existe d'autres ensembles de données sur les émissions de GES qui répondent à différents utilisateurs et objectifs politiques. Ce document évalue trois ensembles de données de l'OCDE sur les émissions de GES : Émissions atmosphériques – Inventaires des émissions de gaz à effet de serre, Émissions de gaz à effet de serre dans l'agriculture, et Comptes d'émissions aériennes (CEA) basés sur le Système de comptabilité économique et environnementale (SCEE). Il examine également un ensemble de données de l'Agence internationale de l'énergie : les émissions de CO_2 provenant de la combustion des carburants. Il examine les approches des inventaires et des CEA en termes de principes comptables (basés sur la production ou la demande, sur le territoire ou la résidence), ainsi que de classifications et d'étendue des émissions.

Il examine la couverture des ensembles de données sur les émissions de GES et identifie les lacunes en matière de données. Enfin, le document décrit les mesures visant à améliorer la couverture et la qualité des ensembles de données.

Mots clés : Principe du territoire, Principe de la résidence, Émissions basées sur la production et la demande, Classification des sources d'émissions, Lacunes dans les données officielles sur les émissions de gaz à effet de serre.

Codes JEL : C82, E01, Q54, Q56.

Executive summary

Climate change is a consequence of the increase in the concentration of greenhouse gases (GHGs) in the atmosphere. Human-induced GHG emissions are generated through a multitude of economic activities, both production and consumption. To implement appropriate policy responses governments and relevant stakeholders require detailed and comprehensive data on GHG emissions.

The objective of this paper is to present an overview of concepts and data availability of the GHG emissions datasets currently available at the OECD and at the International Energy Agency (IEA).

A key characteristic of the datasets published by the OECD and the IEA is that data is official since it is either reported by countries or estimated based on methodologies validated by countries. The datasets discussed in this report are:

1. Air emissions – Greenhouse gas emissions inventories, compiled by the OECD Environment Directorate (ENV);
2. Agricultural greenhouse gases emissions, compiled by the OECD Trade and Agriculture Directorate (TAD);
3. Air Emissions Accounts (AEAs), compiled by the OECD Statistics and Data Directorate (SDD);
4. CO_2 emissions from fuel combustion, compiled by the IEA as part of its database on Greenhouse Gas Emissions from Energy.

The review identifies differences reflecting the fact that the four datasets serve different analytical purposes. The datasets are built on different accounting principles and classifications. There are differences in years covered, level of source disaggregation, coverage of gases, countries, and regions.

Each dataset has one or more dimensions where data coverage can be further improved, for example, geographical coverage, length of time series, timeliness, coverage of gases and emissions source coverage or granularity.

The paper reaffirms the need to expand and improve available GHG emissions data to fill these data gaps and support a wide range of analytical questions. This can be approached with a strategy consisting of the following elements:

1. Expand current questionnaires and official data sources.
2. Extend current data collection efforts to OECD partner countries in alignment with other international frameworks and initiatives.
3. Develop and validate official data estimation methodologies.
4. Enhance consistency across existing datasets and develop a single, internally consistent GHG emissions database.

This strategy can be implemented as part of OECD's efforts to substantially increase coverage of official, validated, and comprehensive GHG emissions data.

1 Introduction

Climate change affects human welfare directly and indirectly through pathways such as food, health, shelter, and the environment. It is not only an environmental problem but also a political, economic, and social one, posing a range of complex and interconnected policy challenges. For this reason, countries require extensive information and indicators to understand the impacts across human and environmental systems and, above all, the appropriate policy responses.

Within climate change statistics, information on greenhouse gas (GHG) emissions plays a key role. Emissions data is essential to assess countries' mitigation efforts as well as the impact of policy responses. Given the wide array of possible analytical and policy objectives, it is not surprising that different approaches have been developed to collect, estimate and structure GHG emissions data.

All these approaches may be valid if they have different objectives, answer different questions, and connect to different classification systems and structures. However, their use may generate confusion for analysts, governments and other stakeholders. For example, what are the methodological differences between the different datasets? What are production-based and demand-based GHG emissions? What is the difference between the GHG emissions source categories by the Intergovernmental Panel on Climate Change (IPCC) and the economic activities used in Air Emissions Accounts of the System of Environmental-Economic Accounting (SEEA)? These are some of questions that are addressed in this paper.

The objective of this paper is to review the current GHG emissions datasets available at the OECD and the IEA. It assesses their different methodological approaches, examines their main data sources, and explores data coverage. In doing so, the paper presents an overview of what is currently available at the OECD and identifies the data gaps. At the same time, it helps users understand each dataset and determine which is most appropriate for their purposes.

The paper is also a contribution to the OECD's work to develop a single GHG emissions database. This database will be internally consistent in the sense that it will be possible to reconcile different estimates of the same variable (such as emissions levels) by adjusting for known differences between the datasets, such as the territory principle versus the residence principle. It will support analytical work that will include tracking progress towards climate change mitigation targets and measuring carbon footprints as well as contributing to the OECD's flagship initiative known as the Inclusive Forum on Carbon Mitigation Approaches (IFCMA).

The outline of the rest of this paper is as follows. Section 2 discusses the different GHG emissions data accounting principles and emissions source classification systems in use and identifies the main elements for defining the scope of emissions included in reporting. Section 3 presents an overview and assessment of the various GHG emissions datasets available on the OECD statistical portal. Section 4 suggests the next steps that should be taken to enhance data coverage and presentation.

2 Emissions data compilation principles

Greenhouse gases

Greenhouse gases (GHGs) refer to a group of gases that concentrate in the earth's atmosphere and absorb infrared radiation, not allowing heat to escape to outer space and generating what is known as the natural greenhouse effect. This is the reason why the earth is warm enough to sustain life. However, since the industrial revolution, the concentration of GHGs in the atmosphere, principally due to the emissions from human activities, has risen almost by 70% (European Envronment Agency, 2023[1]) increasing the average temperature of the earth by more than one degree Celsius.

The main GHGs induced by human activity are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (F-gases).[1] GHGs have a different atmospheric lifetime and potency for global warming. While CO_2 can remain in the atmosphere for hundreds or thousands of years, the lifetime of CH_4 and N_2O is estimated to be 11.8 years and 109 years respectively (IPCC, 2021[2]). See Annex A for the global warming potential of different gases.

To implement climate-relevant policies, it is important to quantify total GHG emissions from human activities and identify their sources. How emissions are quantified and classified will depend on the gases and sectors identified (scope of emissions), the definition and classification of emissions sources and the principles used in aggregating and allocating emissions across sources. These methodological choices determine how GHG emissions are reported.

The different gases responsible for GHG concentrations in the atmosphere can be associated with different emissions sources related to production activities. GHG emissions can also be viewed in terms of the domestic final demand for goods and services, defined as final consumption expenditure plus gross fixed capital formation (investment) plus changes in inventories. Thus, the emissions sources of GHG can be measured either from the perspective of production or of demand for goods and services. These two measurement perspectives align with the international System of National Accounts (SNA) and System of Environmental-Economic Accounting (SEEA) Central Framework and are referred to in this paper as one of the "accounting principles" that are used to structure GHG emissions datasets.

Another key distinction is how GHG emissions are allocated to countries. This may be based on the physical location of the emissions or on the residence of the emitting economic agent, that is the economic territory where the agent (e.g. a company or household) has its centre of predominant economic interest.

The scope, classification and principles applied will depend on the policy and analytical objectives. Several approaches have been developed. This will be discussed in the following section.

[1] See Annex A for the full list of GHGs identified by the IPCC.

Frameworks for compiling greenhouse gas emissions data

GHG emissions data can be compiled according to different measurement frameworks developed for different purposes. The most important frameworks for recording anthropogenic GHG emissions (i.e. the emissions caused by human activities) are: 1) emissions inventories, compiled according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC), and 2) Air Emissions Accounts (AEAs) compiled in accordance with the SEEA Central Framework, an international statistical standard adopted by the United Nations Statistical Commission.

It should be noted that this paper does not discuss data relating to emissions from natural processes such as volcano activity, forest fires, or emissions from unmanaged lands (e.g. thawing permafrost in remote areas). Readers interested in emissions from natural processes are referred to the SEEA Ecosystem Accounting framework (United Nations et al., 2021[3]), which has a broader scope. Its carbon account includes all emissions occurring within a country's territory both due to anthropogenic and natural causes.

The remainder of this section explains the IPCC emissions inventories and AEAs in greater detail by discussing their different approaches in relation to accounting principles, source classifications and scope of emissions included. These three dimensions are summarised in Box 2.1 and discussed in the remainder of this section.

Box 2.1. Dimensions used to structure GHG emissions data

I. Accounting principles

1. *What is the measurement perspective for GHG emissions?*
   a. Production basis
   b. Domestic final demand basis
2. *How are emissions allocated to countries?*
   a. Territory principle
   b. Residence principle

II. Source classification systems: how are GHG emissions sources defined and structured?

1. IPCC source categories commonly referred to as sectors and categories.
2. International Standard Industrial Classification of All Economic Activities (ISIC) (or its regional/national versions), defined in terms of economic activities.

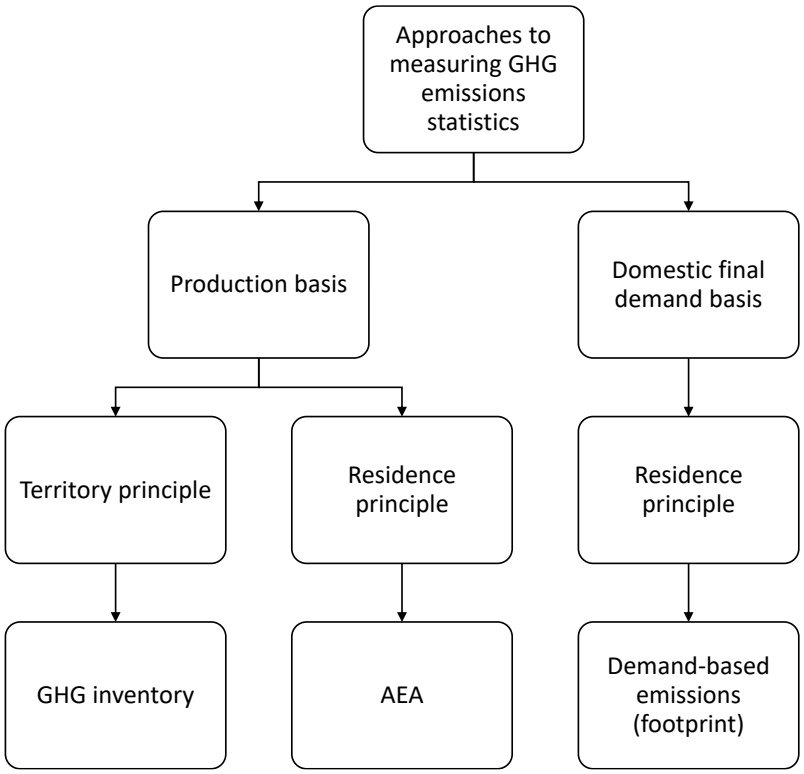
III. Scope of emissions: which gases, sources, processes and fuel types are covered?

1. Gases: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorinated gases (F-gases).
2. Sources: Examples of difference of source coverage based on different accounting principles are international transport and Land Use, Land Use Change and Forestry (LULUCF).
3. Emissions processes: Dataset may focus on specific emissions processes (e.g. emissions from fuel combustion).
4. Type of fuels: For example, dataset may include or exclude emissions from biomass used as a fuel (e.g. ethanol or biodiesel).

Accounting principles

The ways that GHG emissions are measured in the datasets are based on the accounting principles from the SNA and SEEA Central Framework outlined in Box 2.1. Figure 2.1 shows how these accounting principles relate to the different frameworks used for compiling GHG emissions data.

Figure 2.1. Accounting principles for GHG emissions data



Source: Adapted from (Statistics New Zealand, 2020[4]).

Production- versus demand-based emissions

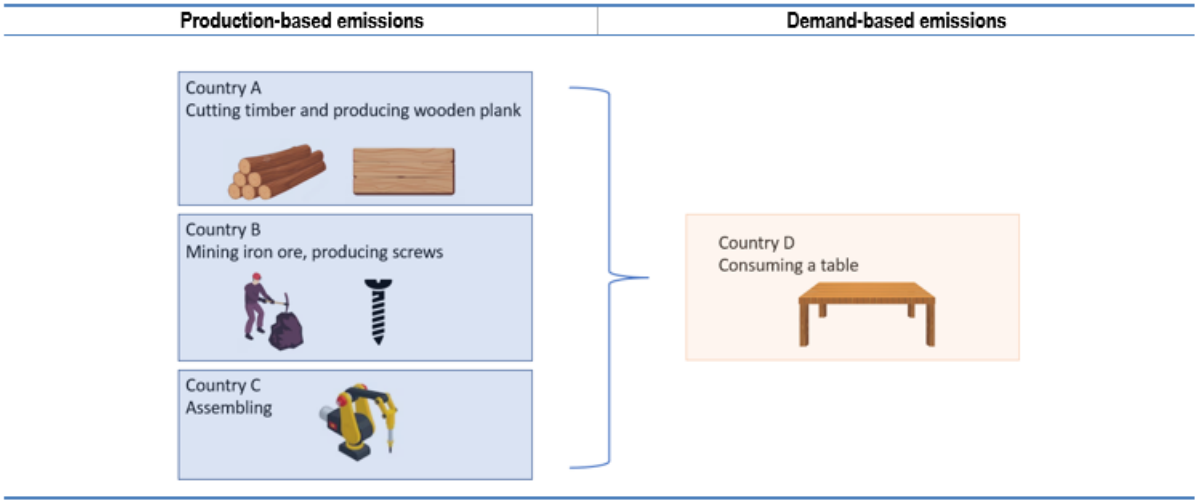
Production-based emissions refer to GHG emissions generated from production activities in a country's economy, regardless of where the products and services are consumed. Demand-based emissions take into account all the GHG emissions generated along global production chains. Demand-based emissions may also be referred to as consumption-based emissions or as a "carbon footprint". It is important to note that both production and demand-based estimates include the direct emissions from final consumption activities (e.g. emissions by households driving cars).[2] Both production and demand-based emissions can be analysed at the national level, the economic activity level and/or the product level.

Figure 2.2 illustrates production- and demand-based emissions involved in the production of a wooden table with inputs from different countries. According to the production-based accounting principle, CO_2 emissions are allocated to country A, B and C where the production process takes place (shown in blue in Figure 2.2) while according to the demand-based principle, CO_2 emissions along the production

[2] According to the SEEA Central Framework, emissions from accumulation processes (emissions from landfill) are included in addition to emissions generated by production activities of industries and consumption activities by households (United Nations, 2014[11]).

chain are allocated to country D where the final consumption and investment occurs (shown in orange in Figure 2.2).

Figure 2.2. Production- and demand-based emissions in the production of a wooden table

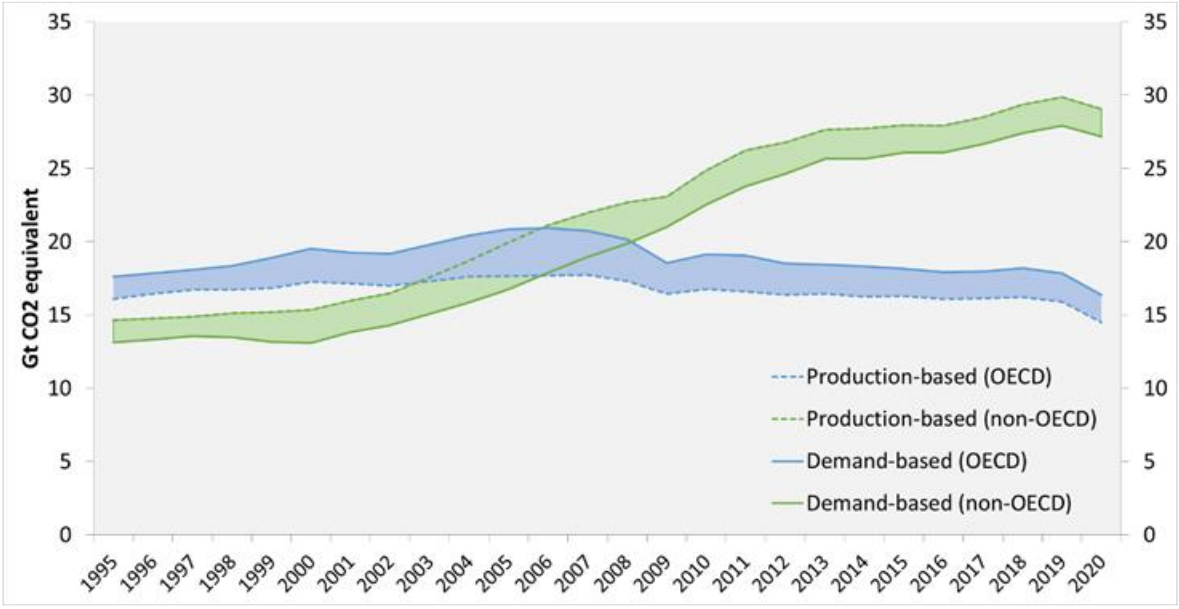


Note: Emissions from transport services are not considered in this example.
Source: Simplified example based on (OECD, 2016[5]).

Identifying the differences between production- and demand-based emissions is especially relevant to understand the role of international trade in GHG emissions. Figure 2.3 shows that aggregate GHG emissions for the OECD gradually increased up to around the mid-2000s and then slowly decreased both in terms of production-based and demand-based emissions. Total demand-based emissions are higher than total production-based emissions for OECD countries, which means that the OECD as a whole is a net importer of embodied GHG emissions in international trade. OECD net imports peaked in 2006 and have been gradually declining since then. On the other hand, total demand-based emissions are lower than total production-based emissions for non-OECD countries because non-OECD countries are, in the aggregate, net exporters of embodied GHG emissions in international trade.

Figure 2.3. Production- and demand-based GHG emissions

OECD and non-OECD countries, 1995 to 2020.



Note: Based on the OECD membership as of November 2021. Although demand-based emissions are higher than production-based emissions for the OECD countries as a whole, production-based emissions are higher than demand-based emissions for some individual OECD countries. In addition to international estimates, demand-based emissions estimated by countries are available for some countries.
Source: OECD. Preliminary calculations building on the methodology developed for the Trade in Embodied CO_2 (TECO2) database (Yamano and Guilhoto, 2020[6]).

Territory- versus residence-based emissions

Emissions can be allocated according to the territory or residence principle. Emissions based on the territory principle refer to the GHG emissions generated by entities within a specific geographical area, usually a national or subnational jurisdiction, regardless of the resident status of the entity generating the emissions. On the other hand, emissions based on the residence principle refer to the GHG emissions from the activities of resident units whether the emissions take place in the territory of the jurisdiction or outside it. The residence principle underlies the SNA, according to which the economy "consists of all the institutional units which are resident in the economic territory of a country".[3] Resident units are defined as those agents that have a "predominant economic interest in the economic territory of that country; that is, when it engages for an extended period (one year or more being taken as a practical guideline) in economic activities on this territory" (United Nations, 2010[7]).

The main differences between territory- and residence-based emissions estimates relate to the different treatment of international tourism and transport. For instance, emissions generated by non-residents on the territory such as emissions from domestic air flights operated by a non-resident airline company are included in territory-based emissions, but not in residence-based emissions of the reference country.

[3] The economic territory of a country consists of the geographic territory administered by a government within which persons, goods and capital circulate freely. In addition to the geographic country, this includes airspace, any territorial waters and any territorial enclaves in the rest of the world. For further details see (Lequiller and Blades, 2014[47]).

The principal international reporting standards describing GHG emissions data have taken different approaches. National GHG inventories guidelines developed by the IPCC use the territory principle, while AEAs are based on residence-principle (see Box 2.2).

Box 2.2. IPCC National Inventories and SEEA Air Emissions Accounts

IPCC National Inventories approach

Countries use national emissions inventories as key information to support national and global mitigation policies. Emissions inventories are used for establishing and monitoring emissions reduction targets, such as the Nationally Determined Contributions (NDCs) under the Paris Agreement. Emissions inventories are compiled according to IPCC guidelines.

The IPCC guidelines for inventories define the geographic coverage as "emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction" (IPCC, 2006[8]) and therefore follow the territory principle.

Air Emissions Accounts (AEA)

The SEEA Central Framework is an international statistical standard with a comprehensive set of tables and accounts that guides the compilation of consistent and comparable statistics and indicators for policymaking, analysis and research on the environment-economy nexus. It is based on the same accounting principles as the SNA.

The SEEA AEAs record air emissions to the environment by resident economic units (businesses and households) for GHGs as well as other air pollutants (such as fine dust particles).

Due to the use of similar definitions and classifications as applied in economic statistics, the AEAs can be used for a wide range of policy analysis. For example, emissions intensities per industry can be calculated by dividing emissions per industry by output (or value added) from the corresponding industry to see if decoupling between economic output and environmental pressure is taking place.

The alignment of AEAs with other environmental accounts under the SEEA framework enhances the consistency across different statistics, for example through cross-domain validation with data in physical energy flow accounts or as inputs into economy-wide material flow accounts.

The AEA provides essential data for environmentally extended input-output analysis to compile demand-based GHG emissions, as the structure is aligned with input-output tables.

Emissions source classification systems

Once the accounting principles are defined, GHG emissions reporting requires emissions to be classified according to emissions source categories and subcategories. GHG emissions reporting usually follows the emissions source categories defined by the IPCC guidelines or the International Standard Industrial Classification of All Economic Activities (ISIC), which is used by the SNA and the SEEA.

Both the IPCC and ISIC classification systems allow a classification of emissions sources in a hierarchical structure with categories and sub-categories. Table 2.1 shows the highest-level categories. The most aggregated level of the IPCC classification system refers to five main sectors according to the 2006 IPCC guidelines and six main sectors in the 1996 IPCC guidelines used for the UN Framework Convention on Climate Change (UNFCCC) Common Reporting Framework for Annex-I Parties. In the case of the ISIC

classification, the highest level is “sections” (identified by letters of the alphabet), which are further divided into the 2-digit “divisions”, 3-digit “groups” and 4-digit “classes”.

Table 2.1. IPCC and ISIC (Revision 4) classification systems

Sectors in the 2006 IPCC guidelines	Sectors in the UNFCCC Common Reporting Format for Annex-I Parties, based on the Revised 1996 IPCC Guidelines	Sections in the ISIC, Rev.4
1. Energy	1. Energy	A. Agriculture, forestry and fishing
2. Industrial Processes and Product Use (IPPU)	2. Industrial Processes and Product Use (IPPU)	B. Mining and quarrying
3. Agriculture, Forestry and Other Land Use (AFOLU)	3. Agriculture	C. Manufacturing
4. Waste	4. Land Use, Land Use Change and Forestry (LULUCF)	D. Electricity, gas, steam and air conditioning supply
5. Other	5. Waste	E. Water supply; sewerage, waste management and remediation activities
	6 Other	F. Construction
		G. Wholesale and retail trade; repair of motor vehicles and motorcycles
		H. Transportation and storage
		I. Accommodation and food service activities
		J. Information and communication
		K. Financial and insurance activities
		L. Real estate activities
		M. Professional, scientific, and technical activities
		N. Administrative and support service activities
		O. Public administration and defence; compulsory social security
		P. Education
		Q. Human health and social work activities
		R. Arts, entertainment and recreation
		S. Other service activities
		T. Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
		U. Activities of extraterritorial organizations and bodies

Note: The 2006 IPCC Guidelines combined Agriculture and Land use change and forestry into Agriculture, Forestry and Other Land Use. Individual countries may apply their own national classification systems for emissions sectors or economic activities.
Source: (IPCC, 2006[8]), (United Nations, 2008[9]) (UNFCCC, 2013[10]).

The IPCC source categories refer to the emissions generated by actual physical sources and processes (see Annex A for details). ISIC categorises productive activities based on the inputs of goods, services, and factors of production; the process and technology of production; the characteristics of outputs; and the use to which the outputs are put (United Nations, 2008[9]). For instance, IPCC emissions category 3 “Agriculture” includes a sub-category 3.A “Enteric fermentation” as a process. In contrast, ISIC Section A “Agriculture, forestry and fishing” (the main economic activity) is disaggregated into Division 01 “Crop and animal production, hunting and related service activities”, and further into Group 014 “Animal production”.

The SEEA Central Framework uses the ISIC (United Nations, 2014[11]). AEAs compiled to date use Revision 4 (Rev.4) of the ISIC, although Rev.5 has recently been endorsed by the UN Statistical Commission. Regional/national classification systems can be also used for the AEAs such as the Statistical Classification of Economic Activities in the European Community (NACE) Revision 2 (Rev.2). ISIC Rev.4 and NACE Rev.2 are equivalent at the 2-digit division level and are used for the AEAs by the OECD and Eurostat respectively.

These classification systems may generate some confusion because emissions from the same source can be grouped into different categories. For example, according to the IPCC classification, emissions from agricultural transport are classified under the transport category in the Energy sector. However, since the ISIC classification is based on the principal activity[4] of the firm, these emissions would be classified under the agricultural section (A: “Agriculture, forestry and fishing”) in the AEAs. Emissions from transport activities would only be allocated to transport section (H: “Transportation and storage”) when the principal activity of the firm is transportation, i.e. it provides transportation services (Flachenecker, Guidetti and Pionnier, 2018[12]).

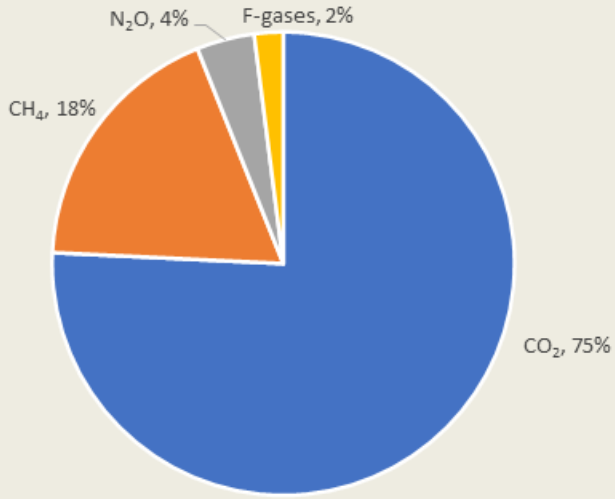
Which classification system to use will depend on the analytical objective. Classifying emissions by IPCC categories makes it possible to monitor emissions according to specific processes, such as emissions from transport based on fuel combustion across all industries. On the other hand, classifying emissions according to economic activity facilitates the analysis of GHG emissions combined with other economic data, for example by monitoring development of GHG emissions in relation to value added or employment. Box 2.3 shows the kind of analysis that can be done using the different approaches.

[4] The principal activity is defined as “the activity whose value added exceeds that of any other activity carried out within the same unit” in the SNA (United Nations, 2010[7]).

Box 2.3. Greenhouse gases and emissions sources

In 2019, CO_2 was responsible for 75% of all global net anthropogenic GHG emissions (Figure 2.4). CH_4, which mainly come from agriculture, waste, mining and flaring, contributed to 18% of the global net anthropogenic GHG emissions. N_2O, whose largest emissions source is agriculture, accounted for 4% of total net GHG emissions. F-gases are primarily emitted by industrial processes. They are extremely potent GHGs and its global warming potential can be over 10 000 times higher than that of CO_2. F-gases constituted 2% of global net GHG emissions in the same year (IPCC, 2022[13]).[5]

Figure 2.4. Global total net anthropogenic GHG emissions by type of gas in 2019

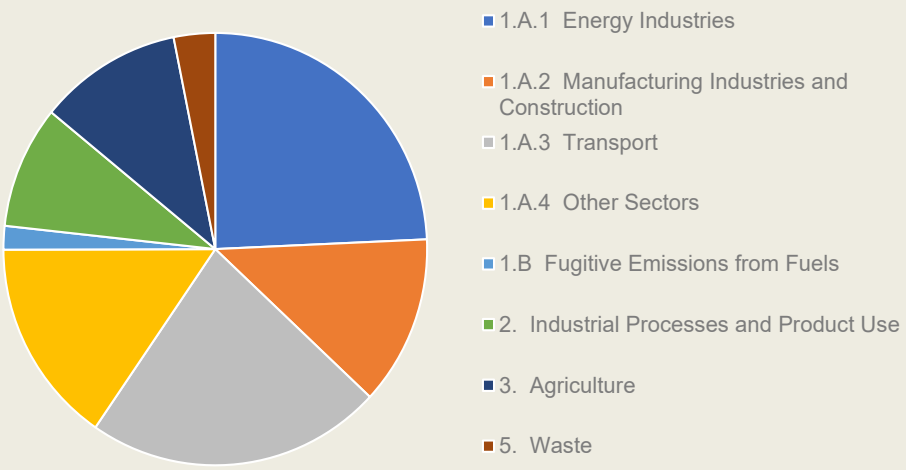


Source: (IPCC, 2022[13])

Emissions can be broken down by different classification systems. Taking the example of the European Union (EU), total GHG inventory emissions excluding LULUCF was 3 468 million tonnes of CO_2-equivalent in 2021 (OECD, 2024[14]) and total GHG account emissions in the same year was 3 665 million tonnes of CO_2-equivalent (excluding CO_2 emissions from biomass) (OECD, 2024[15]). GHG inventory and account can be broken down by IPCC categories and ISIC economic activities as in Figure 2.5 and Figure 2.6. IPCC category 1A Fuel combustion was the largest emissions source responsible for 75% of total inventory emissions excluding LULUCF, as energy fuel combustion in energy industries and fuel combustion for transport accounted for 24% and 23% of total GHG emissions respectively. From the perspective of industries and household, manufacturing industry accounted for the largest share of emissions (22%) followed by households (20%) and electricity, gas, steam and air conditioning supply industry (20%).

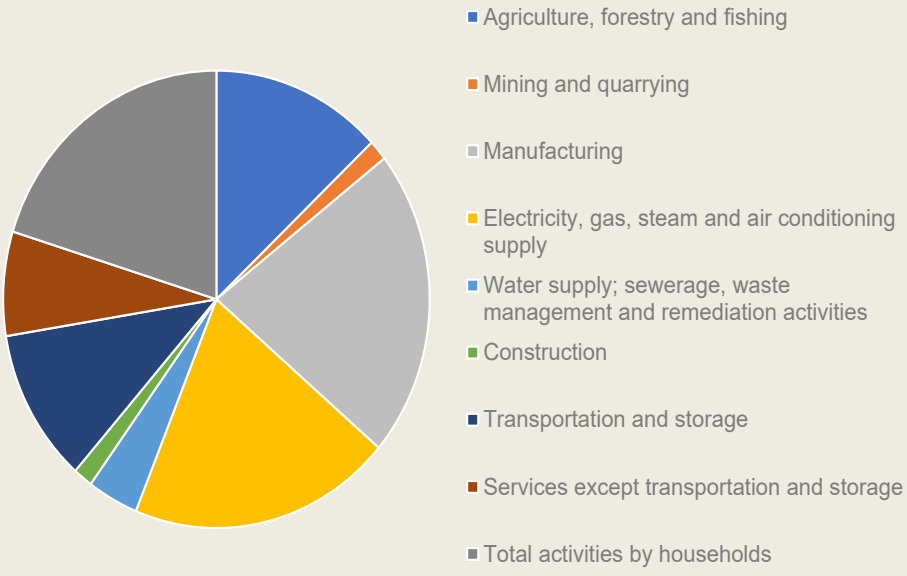
[5] Net GHG emissions refer to total GHG emissions minus CO_2 removals from the atmosphere by LULUCF.

Figure 2.5. GHG emissions inventory (excl. LULUCF) by IPCC category in the EU, 2021



Source: (OECD, 2024[14]).

Figure 2.6. GHG emissions account (excl. emissions from biomass) by ISIC economic activity and households in the EU, 2021



Source: (OECD, 2024[15]).

Correspondence between IPCC categories and ISIC economic activities

The IPCC guidelines explain the definition of emissions source categories and include a mapping to ISIC Revision 3 (IPCC, 2006[8]; IPCC, 1996[16]). Some IPCC sub-categories have a 1-to-1 correspondence to a specific ISIC division for example IPCC 1.A.2.c (Chemicals) directly corresponds to ISIC Rev.3 Division 24 (Manufacture of chemicals and chemical products). However, other IPCC sub-categories have more than one relevant ISIC division, for example IPCC 1.A.2.e (Food Processing, Beverages and Tobacco) could relate to ISIC Rev.3 Division 15 (Manufacture of food products and beverages) and/or 16 (Manufacture of tobacco products). Moreover, there is no mapping provided for some of the IPCC sub-categories in the IPCC guidelines.

Eurostat has developed a correspondence table between IPCC categories and NACE Rev.2 (corresponding to ISIC Rev.4).[6] The correspondence table is helpful for developing AEAs by allocating emissions from IPCC categories to corresponding economic activities. The correspondence between IPCC categories and ISIC economic activities is further discussed in Annex B.

Scope of emissions

The scope of emissions refers to which gases and emissions sources are covered, as well as emissions processes and fuel types (see Box 2.1). The compilation framework of accounts and inventories not only differs on accounting principles (territory vs. residence) and source classifications (IPCC categories vs. economic activities), but also on the scope of emissions covered.

For instance, the AEAs include international air and maritime transport emissions based on the residence principle. However, inventories do not include emissions from international bunkers in total emissions but only as a memo item (Eurostat, 2015[17]). Emissions from international bunkers are defined in the IPCC guidelines as emissions from fuel used by international aviation and shipping that departs from one country and arrives in a different country based on the territory principle (i.e. regardless of the residence of the transport operators).

Emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) are included in inventories, but not in the AEAs (Eurostat, 2015[17]).[7]

Another difference is that according to the IPCC guidelines, emissions from fuel use in road transport are by convention included in the emissions inventory of the country where the fuel is sold and not allocated based on the residence of the operator, or where the vehicle is driven and the emissions take place (IPCC, 2006[8]).

Moreover, CO_2 emissions from short-lived biomass combustion are excluded from the inventories. The IPCC guidelines assume that CO_2 emissions from the combustion of short-lived biogenic material is balanced by carbon uptake prior to harvest (IPCC, 2006[8]). The SEEA Central Framework recommends distinguishing CO_2 emissions from the burning of fossil fuels from CO_2 emissions from biomass but does not exclude CO_2 emissions from biomass from the scope (United Nations, 2014[11]).

As differences in scope can make analyses more difficult, it is common practice to compile bridge tables to reconcile the differences between accounts and inventories. Box 2.4 discusses how this is done.

[6] The Eurostat correspondence table is available at: https://ec.europa.eu/eurostat/web/environment/methodology.

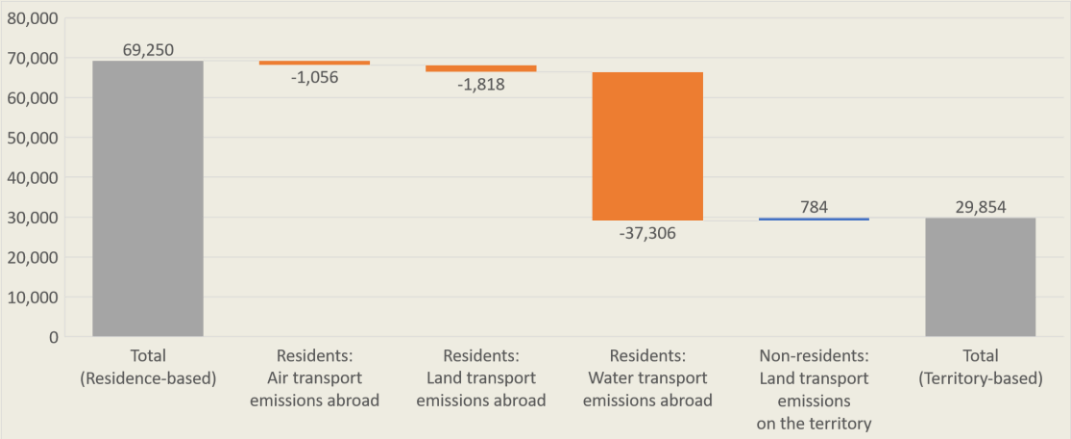
[7] The possible inclusion of emissions and removals from LULUCF in AEAs is currently under discussion as part of the revision of the SEEA Central Framework (Schenau, 2023[43]). In Canada, prescribed forestry burns which are part of the LULUCF sector of the inventory are included in the SEEA AEA, because they are considered to be directly related to the activities of the related industries.

Box 2.4. Bridging items between emissions inventories and emissions accounts

Bridge tables consist of several items covering adjustments due to the residence and territory principle and differences in scope of the emissions. Taking total residence-based emissions (excluding emissions from short-lived biomass combustion) as the starting point, emissions by national residents abroad (i.e. residents fueling outside the territory and all international air and maritime transport by resident units) are deducted and emissions by non-national residents on the territory (i.e. non-residents fueling on the territory for land transport as well as domestic air and maritime transport) are added to derive total territory-based emissions excluding LULUCF.

These bridging emissions can be significant for some countries. For example, Denmark has a large international maritime industry. CO_2 emissions from Danish resident units outside the Danish territory account for more than half of its total residence-based CO_2 emissions and, as shown in Figure 2.7, total emissions excluding LULUCF estimated by the IPCC inventory approach (territory basis) are less than the half of the emissions estimated by AEAs (residence basis). The difference in Denmark's case demonstrates the relevance of AEAs. As value added of the maritime industry is included in GDP, which uses the residence basis, when measuring the emissions intensity of the Danish economy (total emissions relative to GDP) all residence-based emissions should be included. Calculating emissions intensity based on the inventory totals would lead to a serious underestimation of the Danish economy's emissions intensity.

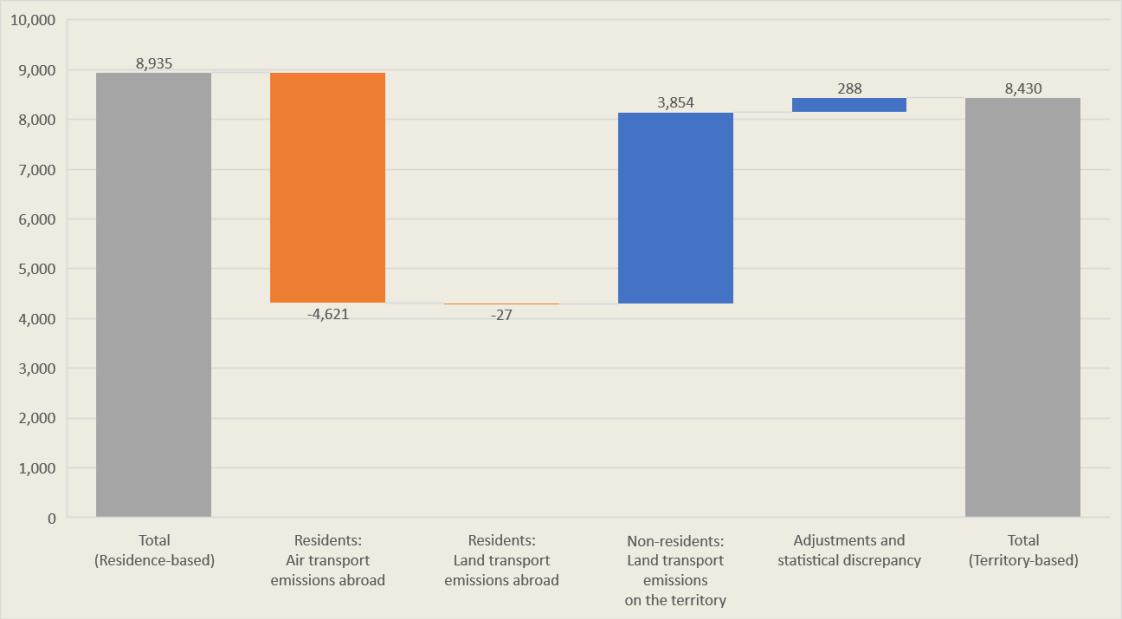
Figure 2.7. CO_2 emissions in Denmark in 2021, in kilotonnes



Note:. Residents means companies and households that are resident in the country. Non-residents means companies and households that are resident abroad. There are no CO_2 emissions from the NACE section U: Activities of extraterritorial organizations and bodies for Denmark.
Source: (OECD, 2024[15]).

In Luxembourg, CO_2 emissions from international air transport by resident airlines account for more than half of total CO_2 emissions in AEAs, but when moving to the inventories basis these are largely offset by emissions from land transport by non-resident units (for example vehicle from neighbouring countries) using fuels purchased on the territory of Luxemburg (Figure 2.8). In line with the accounting principle of road transport according to the IPCC, emissions by non-resident units operating land transport based on fuel purchases on the territory of Luxembourg are added to derive the inventory totals excluding LULUCF. Therefore, the total emissions shown in the inventories are only slightly lower than those shown in the AEAs.

Figure 2.8. CO_2 emissions in Luxembourg in 2021, in kilotonnes



Note: Residents means companies and households that are resident in the country. Non-residents means companies and households that are resident abroad. There are no CO_2 emissions from the NACE section U: Activities of extraterritorial organizations and bodies for Luxembourg.
Source: (OECD, 2024[15]).

3 OECD and IEA greenhouse gas emissions data

Overview of GHG emissions datasets

This section presents the data sources, accounting principles, data coverage and data collection strategy of four datasets of production-based greenhouse gas (GHG) emissions of the OECD[8] and the International Energy Agency (IEA). The datasets discussed are:

1. Air emissions - GHG emissions inventories, compiled by the OECD Environment Directorate (ENV);
2. Agricultural greenhouse gases emissions, compiled by the OECD Trade and Agriculture Directorate (TAD);
3. Air Emissions Accounts (AEAs), compiled by the OECD Statistics and Data Directorate (SDD); and
4. CO_2 emissions from fuel combustion, compiled by the IEA as part of its database on Greenhouse Gas Emissions from Energy.

These datasets contain official data reported by countries following internationally agreed guidelines and related manuals or estimated based on a methodology validated by countries. Conformity with international guidelines enhances the coherence of methodology used by countries within each dataset.

Table 3.1 provides a summary of the accounting principles, emissions source classification system and scope of emissions of each dataset. It also shows data coverage for the four datasets in terms of data sources, countries and regions and which years are available. Timeliness (in the last column of the table) is measured as the difference between the latest reference year and the release year of data.

Different datasets may be compiled from a common starting point in terms of the data. For example, GHG emissions inventories are often used as the main data input to compile AEAs, with the scope of emissions adjusted to the residence principle and emissions from emissions sources allocated to corresponding economic activities (see also Annex B for the inventory-first approach for compiling AEAs).

[8] The three OECD datasets are available on the OECD data dissemination platform OECD Data Explorer.

Table 3.1. Principles and data availability of GHG emissions datasets

Dataset	Production / Domestic final demand basis	Territory / Residence-principle	Source classification	Source classification granularity	Scope (Source)	Scope (Gas)	Data source	Number of countries/regions at OECD platform	Available year/Timeliness
Air emissions – GHG emissions inventories	Production	Territory	IPCC emissions source categories	12 categories	Total economy, excluding international transport, including LULUCF	All GHGs (limited availability for non-Annex-I countries)	UNFCCC data interface, UNFCCC BURs, OECD questionnaire	58 (63 including regions)	Max. 1990-2021 (29 years on average)/ At least t -2
Agricultural greenhouse gases emissions	Production	Territory	IPCC emissions source categories	12 categories (Agriculture), 8 categories (LULUCF)	Agriculture, LULUCF	Total GHG, CO_2, CH_4, and N_2O	UNFCCC data interface, OECD questionnaire, FAOSTAT	54 (55 including regions)	Max. 1985-2021 (32 years on average) / At least t-2
AEA	Production	Residence	ISIC economic activities (or its regional versions)	Max. 64 ISIC divisions	Total economy, including international transport, excluding LULUCF	All GHGs (less available for some countries)	Eurostat, Countries' websites (e.g. National Statistical Offices), Global questionnaire.	43	Max. 1990 – max. 2022 (18 years on average) / At least t-1
CO2 emissions from fuel combustion	Production	Territory	Flows (see Annex B)	34 flows	Emissions from fuel combustion	CO_2	IEA World Energy Statistics and IEA World Energy Balances, UNSD Energy Balances	150+ (212 including regions)	Max. 1960 – max. 2022 (47 years on average) / At least t-1

Note: Source classification granularity counts the number of mutually exclusive categories at the most disaggregated level. Relevant emissions categories under Agricultural greenhouse gases emissions are specific to each type of gas. Source classification granularity may be more detailed in the original data source. See Annex D for details. The IEA estimates non-CO_2 GHG emissions and fugitive emissions in separate datasets (see Footnote 10). In addition to emissions, the dataset on Air emissions - GHG emissions inventories includes other variables such as emissions intensities per capita, emissions intensities per unit of GDP, emissions trends and percentage by source, with 33 variables. Similarly, in the dataset on Agricultural greenhouse gases emissions there are 46 variables if other indicators such as emissions intensities and emissions trends are included. The Agricultural greenhouse gases emissions dataset includes total emissions of all GHGs, but sectoral disaggregation under Agriculture and LULUCF only for CO_2, CH_4 and N_2O.
Source: Authors' calculation based on OECD data dissemination platform as of 4 April 2024.

The GHG emissions inventories and AEAs are based on emissions data collected from countries, while the IEA's estimates on CO_2 emissions from fuel combustions are derived from energy statistics collected from countries. Although the IEA also estimates emissions of non-CO_2 GHGs from fuel combustion based on country data as part of its Greenhouse Gas Emissions from Energy database, this paper focuses on the dataset of CO_2 emissions from fuel combustion which is the most detailed dataset.[9] The IEA also provides estimates of fugitive emissions, but this dataset is out of scope of this paper because it includes unofficial estimates.[10]

The remainder of this section discusses each of the four production-based datasets in greater detail. Further information about these data sources is presented in Annex D. At the end of this section, there is also a short discussion of the OECD's estimates of GHG emissions embodied in international trade.

Air emissions - GHG emissions inventories

Overview

The OECD's dataset on Air emissions - GHG emissions inventories presents countries' data based on national inventories submitted to the UN Framework Convention on Climate Change (UNFCCC) and data collected through the OECD State of the Environment (SoE) questionnaire.

Emissions inventory data is the basis for setting national and international emissions mitigation objectives and targets. The GHG emissions inventories dataset is a multipurpose dataset which can be used for several analytical outputs and policy analysis such as country reviews, environmental performance reviews, and economic surveys (for the climate change and green growth chapters).

The data follows the emissions source classification of the 1996 IPCC guidelines and presents data for six main categories and six subcategories of Energy as presented in Annex B. The reported emissions are those generated within a country's jurisdiction from production activities. They align with the production-based and territory-based principles discussed in Section 2.

Data sources

The main data source is national GHG emissions inventories submitted to the UNFCCC (see Annex C). This is from UNFCCC Annex I countries – those that have commitments to report national emissions inventories on a regular basis. This data is complemented by data collected through the SoE questionnaire of the OECD's Environment Directorate in collaboration with the Trade and Agriculture Directorate. This questionnaire is sent to OECD countries that are not part of the UNFCCC Annex I, as well as to OECD accession candidates and partner countries. The SoE questionnaire asks countries to report data by gas and by main IPCC source categories. Biennial Update Reports (BURs) submitted by non-Annex I countries to the UNFCCC are used as an additional data source to fill in missing gaps.

[9] The GHG Emissions from fuel combustion (summary) dataset is available at (OECD, 2024[48]). The documentation accompanying the GHG Emissions from Energy database provides further details (IEA, 2023[27]).

[10] Fugitive emissions are intentional or unintentional release of GHGs that may occur during the extraction, processing, transformation and delivery of fossil fuels to the point of final use (IPCC, 2019[32]). The geographical coverage of the estimates of fugitive emissions is more limited than CO_2 emissions from fuel combustion. Moreover, not all data inputs are from official reporting. For example, emissions intensities derived from specific countries are used to compile estimates for other countries for which no reliable direct measurements are available. It should also be noted that fugitive emissions reported by countries to the UNFCCC might be underestimated (IEA, 2024[45]).

Geographic coverage, time series and timeliness

The data covers 63 countries and regions which includes all OECD member countries, accession candidates, key partners, and regions including the EU-27.

The time coverage of the data is from 1990 to 2021. However, timeliness and annual data availability varies across countries. For 43 Annex I parties, five regions and Kazakhstan,[11] complete data disaggregated by IPCC emissions source categories is available from 1990 to 2021 with a two-year time lag corresponding to the reporting requirement under the UNFCCC.[12] 14 non-Annex I parties included in the dataset have varying timeliness and have some missing data. Among countries covered under the OECD's International Programme for Action on Climate (IPAC), at least one year of observation for all IPCC emissions source categories is missing for 14 countries.[13] [14] Table 3.2 presents a summary.

Table 3.2. Data availability summary for Air emissions - GHG emissions inventories

Countries and regions	Number of countries and regions	Available years	Timeliness	Source granularity	GHGs
Annex I	43	1990 – 2021	2-year lag	12 IPCC emissions sources	All GHGs
Non-Annex I	20	1990 – 2021 Max missing: 15 countries in 2021. No country is missing in 2010.	Min: 2-year lag Max: 21-year lag	12 IPCC emissions sources	All GHGs

Note: Sectoral granularity counts the number of mutually exclusive categories on most disaggregated level. This may be more detailed in the original data source. See Annex D for details.
Source: IPAC calculation based on (OECD, 2024[14]). Data as of 4 April 2024.

Sources and gases

Emissions source coverage for the main emissions categories - Energy, Industrial processes and product use, Agriculture, Waste, and Land Use, Land Use Change and Forestry (LULUCF) – has the same availability as GHG aggregates (totals). However, currently the OECD questionnaire requests detailed data only on the main IPCC categories so data for sub-subsectors (such as Road Transportation and Railways) is not available for most non-Annex I countries (see also Annex D).

The dataset contains 63 countries and regions and 32 years from 1990 to 2021. However, data availability varies across gases. Aggregate GHG emissions data is available for 93% of observations and 85% for

[11] There are 43 Annex I parties including the European Union.

[12] Countries are expected to transition to submit their emissions inventories following the reporting requirements of the Enhanced Transparency Framework (ETF) of the Paris Agreement. The dataset will have a two- or three-year time lag in the Biennial Transparency Report under the ETF (UNFCCC, 2018[35]).

[13] Countries with at least one year of observation missing are Argentina, Brazil, Chile, China, Colombia, Costa Rica, India, Indonesia, Israel, Mexico, Peru, Korea, Saudi Arabia, and South Africa.

[14] The IPAC countries are: all 38 OECD member countries (Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom, United States), key partner economies (Brazil, People's Republic of China, India, Indonesia, South Africa), six accession candidate members (Argentina, Brazil, Bulgaria, Croatia, Peru, Romania), other G20 country (Saudi Arabia) and Malta.

CO_2, CH_4 and N_2O. The dataset is complete for 2010 and has data missing for one country in 2000, 2012, and 2016.

Data collection strategy and updating

The OECD's Air emissions - GHG emissions inventories is updated annually with the national inventories' submissions to the UNFCCC and additional data collected through the OECD questionnaire. The OECD questionnaire has been sent out every year since 2010 to the UNFCCC non-Annex I countries under OECD membership and its partner countries. The countries that have replied to the questionnaire are Argentina, Chile, Colombia, Costa Rica, Israel, Korea, and Mexico, and South Africa.

Future data collection will benefit from submissions of Biennial Transparency Reports under the Enhanced Transparency Framework of the Paris Agreement (see Annex A) and extension of geographical coverage of the OECD questionnaire to other countries covered under the IPAC.

Agricultural greenhouse gases emissions

Overview

The OECD dataset of Agricultural greenhouse gases emissions provides data on GHG emissions from agriculture and LULUCF disaggregated by relevant gases and emissions sources. This dataset provides data for agriculture and LULUCF at a higher level of disaggregation than the dataset on Air emissions - GHG emissions inventories. It follows the same approach as the OECD's Air emissions - GHG emissions inventories. Agriculture and LULUCF categories are classified following the IPCC guidelines. The data is compiled according to production- and territory-based principles.

The Agricultural greenhouse gases emissions dataset is useful for policy analysis of GHG emissions from agriculture and LULUCF. This dataset has been used to answer various questions relating to emissions trends and targets, climate change and sustainability in the agricultural emissions sources.

Data Sources

The Agricultural greenhouse gases emissions dataset builds on the inventory submissions to the UNFCCC (see Annex C), which is supplemented by data collected through the OECD's Agri-environmental Indicators questionnaire. The questionnaire is sent to countries by OECD's Trade and Agriculture Directorate in collaboration with the Environment Directorate, targeting the same set of non-Annex I countries discussed under the data sources description of the Air emissions - GHG emissions inventories dataset. Furthermore, the Agricultural greenhouse gases emissions dataset is complemented with additional data from FAOSTAT (FAO, 2024[18]).

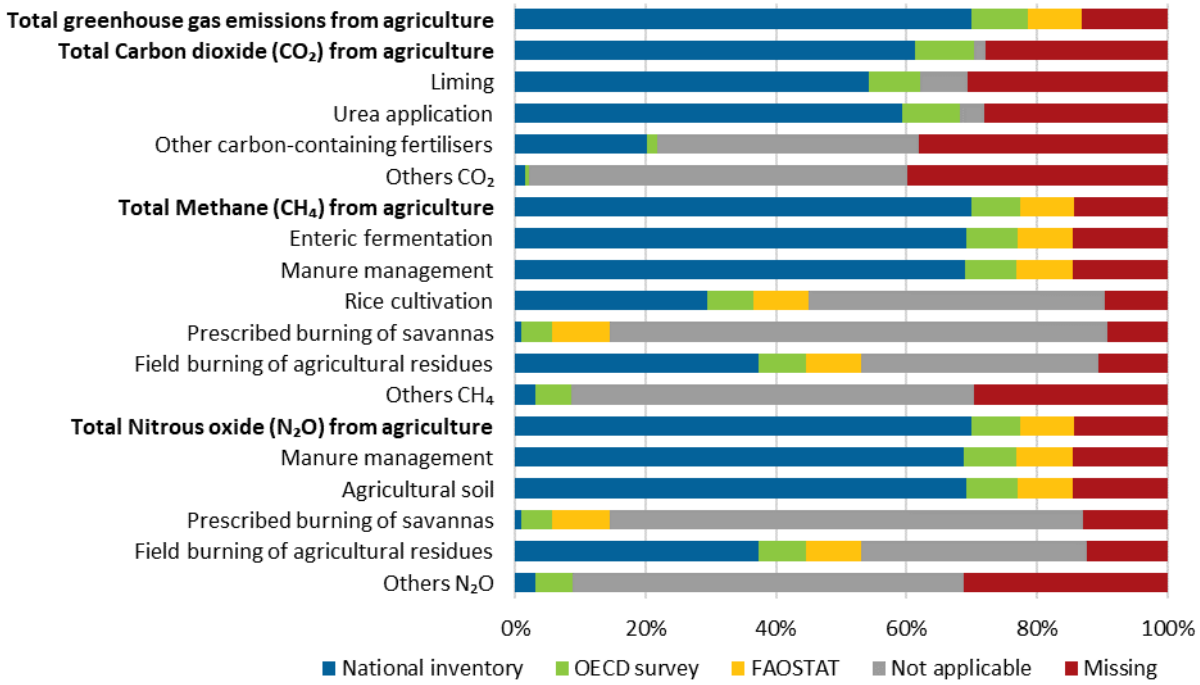
Geographic coverage, time series and timeliness

The data covers 55 countries[15] from 1985 to 2021 (with different lengths of timeseries across countries). Data coverage varies across countries, years, gases, and IPCC source categories. There is a total of 2035

[15] Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Korea (the Republic of), Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands (the), New Zealand, Norway, Philippines (the), Poland, Portugal, Romania, Russian Federation (the), Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Türkiye, Ukraine, United Kingdom, United States of America (the), Viet Nam.

possible observations per variable in the dataset, but data availability varies by category and sub-category (Figure 3.1 and Figure 3.2). Figure 3.1 shows data availability for the agriculture category, where the UNFCCC inventory data (70% of total observations) is complemented with data collected through the OECD questionnaire which adds an additional 9% of total observations and data from FAOSTAT makes up 8% of the observations. However, 13% of observations are missing. Data availability decreases for some of the detailed sources and gases.

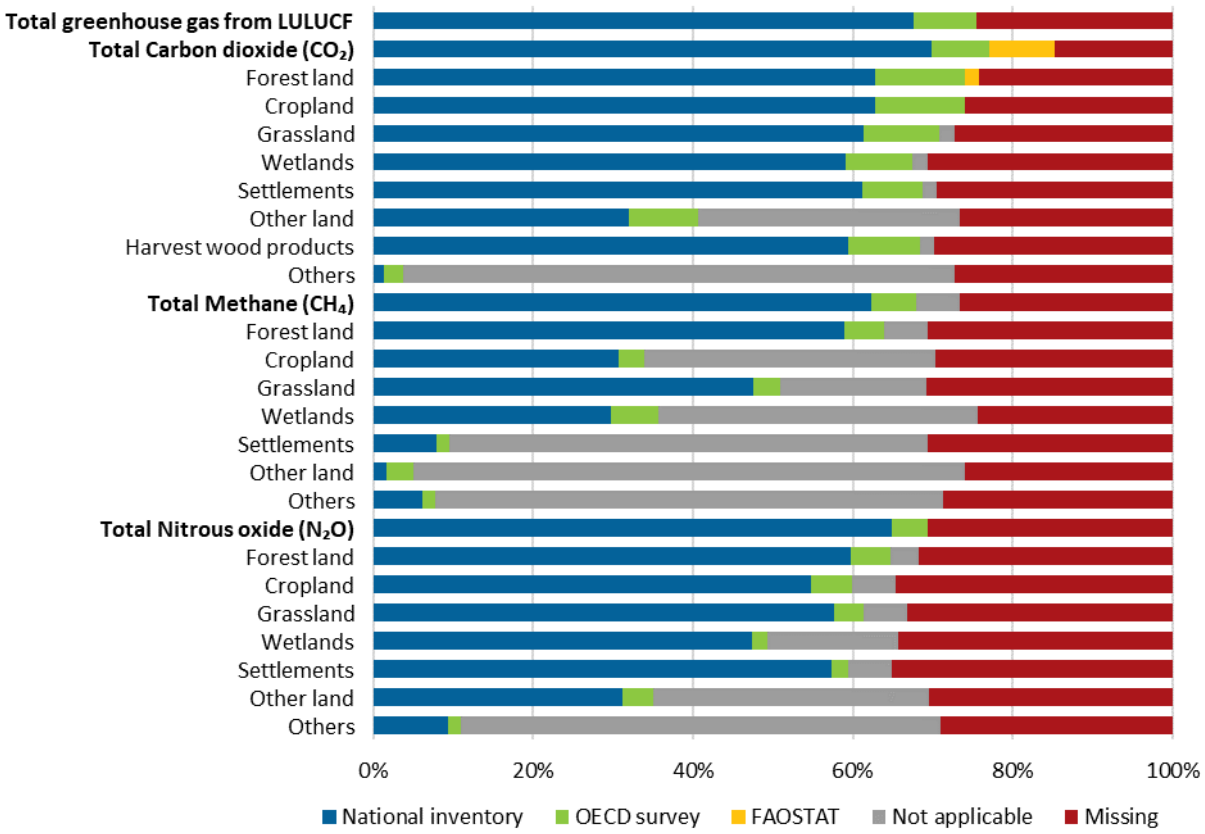
Figure 3.1. Data availability for agriculture across IPCC categories and gases in OECD's Agricultural greenhouse gases emissions dataset



Note: The legend "National inventory" indicates data from the UNFCCC GHG emissions data interface. Data availability as of 4 April 2024.
Source: IPAC calculations based on (UNFCCC, 2023[19]) and (OECD, 2024[14]).

Figure 3.2 shows data availability of total GHG emissions and removals from LULUCF disaggregated by different gases and land use type. OECD's Agricultural greenhouse gases emissions indicators supplement the inventory data by extending data availability by 8% in the case of total greenhouse gas from LULUCF, by 7% in the case of total CO_2 from LULUCF, by 6% in the case of total CH_4 from LULUCF, and by 4% in the case of total N_2O from LULUCF. In addition, 8% of the data for total CO_2 from LULUCF comes from FAOSTAT.

Figure 3.2. Data availability for LULUCF across IPCC categories and gases in OECD's Agricultural greenhouse gases emissions dataset



Note: The legend "National inventory" indicates data from the UNFCCC GHG emissions data interface. Data availability as of 4 April 2024.
Source: IPAC calculations based on (UNFCCC, 2023[19]) and (OECD, 2024[14]).

The data timeliness for Annex I countries is two years after the reference year corresponding to the inventory submission requirements under the Kyoto Protocol. Timeliness of the data for non-Annex I countries varies by country depending on data availability. Table 3.3 summarises data availability of this dataset.

Table 3.3. Data availability summary for Agricultural greenhouse gases emissions

	Number of countries	Available years	Timeliness	Source granularity	GHGs
Annex I and EU-27	40	1990 – 2021, Variable availability: 1985 – 1990	2-year lag	12 categories (Agriculture), 8 categories (LULUCF)	CO_2, CH_4, N_2O
Non-Annex I	15	Variable availability: 1985 – 2021	Up to 6-year lag	12 categories (Agriculture), 8 categories (LULUCF)	CO_2, CH_4, N_2O

Note: The dataset includes total emissions of all GHGs but includes source disaggregation under Agriculture and LULUCF only for CO_2, CH_4 and N_2O.
Source: (OECD, 2024[20]). Data as of 4 April 2024.

Data collection strategy and updating

The OECD's Agricultural greenhouse gases emissions dataset is updated at least once a year to incorporate new submissions of inventories to the UNFCCC and replies to the OECD SoE questionnaire.

Air Emissions Accounts

Overview

The AEA is a physical flow account of the SEEA Central Framework. It records emissions of gaseous and particulate substances to air from production activities by industries and consumption activities by households (United Nations, 2014[11]).

The SEEA Central Framework is based on the accounting structure and principles of the SNA, which allow integration of environmental and economic information. Therefore, the AEAs follow the production and the residence principle. The AEAs are classified according to economic activities based on the ISIC and its regional/national versions, as explained in Section 2.

The AEAs were developed to be able to compare emissions with other economic statistics such as GDP or value added from specific economic activities, for instance through indicators such as emissions intensity per unit of GDP. As the AEAs are based on the same measurement principle (residence) and classifications of economic activities as the SNA, they are also helpful for estimating CO_2 footprints (demand-based emissions) and modelling of future emissions trajectories.

Data sources

The OECD receives completed AEAs from Eurostat (for the EU member states as well as Iceland, Norway, Switzerland, Türkiye and Serbia) and also collects data from the websites of countries' National Statistical Offices (NSOs). The results are available on OECD data dissemination platform (OECD, 2024[15]). In 2023, the OECD started a global AEA data collection using a questionnaire designed in collaboration with the United Nations Statistics Division (UNSD). This questionnaire is described later in this section.

Geographic coverage, time series and timeliness

Currently, AEAs of 43 countries are available on the OECD data dissemination platform (see Annex D for the list of countries compiling AEAs). According to the results of a Global Assessment survey conducted by the UNSD, 50 countries are compiling AEAs.[16] The difference is mainly because the Global Assessment survey counts countries in different implementation stages including countries not yet regularly disseminating SEEA accounts (United Nations, 2023[21]).[17]

Most countries compiling AEAs are EU member states, since it is a requirement under the EU regulation establishing a common framework for the collection, compilation, transmission, and evaluation of SEEA accounts (European Union, 2011[22]).

[16] https://seea.un.org/content/2023-global-assessment-results.

[17] Countries which compile AEAs according to the 2023 Global Assessment Results but which are not included on the OECD data dissemination platform are: Bosnia and Herzegovina, Ecuador, Egypt, Ghana, Kazakhstan, Mongolia, North Macedonia, Republic of Moldova, and the Russian Federation. Korea and Türkiye do not compile AEAs according to the 2023 Global Assessment Results, but they are included on the OECD platform (Korea has discontinued compiling AEAs, but their previous AEAs are available on the OECD data dissemination platform).

The length of available AEA time series differs across countries. The EU Regulation 691/2011 requires the member states to include data from 2008 for the first data transmission. Thus the AEAs of the EU member states are reported at least from 2008, but some EU countries include earlier years (see Annex D). The latest reference year available is 2022, but some non-EU countries have not updated their AEAs recently. For example, the latest reference year of Korean AEAs is 2015, reported in 2018 (OECD, 2024[23]).

The timeliness of the AEAs varies considerably across countries. Although the EU requirement is for countries to transmit data within 21 months of the end of the reference year (European Union, 2011[22]), some European countries report AEAs with a time lag of 12 months. Eurostat publishes the AEAs at just over a year after the reference period, providing estimates for those countries that have not yet reported (see Annex D). AEAs are disseminated on the OECD data dissemination platform after validation.

Sources and gases

Total emissions in AEAs include emissions from industries and from households. The AEAs are reported according to the industry classification standard which is adopted by each NSO (ISIC Rev.4 or its regional/national version). The OECD organises AEAs according to 64 ISIC Rev.4 divisions for international comparability. Some countries report AEAs with more detailed economic activities according to their regional/national classification in their original publication of AEAs (see Annex D for details).

Emissions from consumption activities by households are classified into three categories: (1) Transport; (2) Heating and cooling; and (3) Other, based on the Central Product Classification (CPC) and Classification of Individual Consumption by Purpose (COICOP).

The AEAs record emissions of gaseous and particulate substances to the atmosphere. The global SEEA Data Structure Definitions (DSDs) for Air Emissions includes CO_2, Biomass CO_2, N_2O, CH_4, PFCs, HFCs, SF_6 and NF_3 as GHGs.[18] The EU regulation 691/2011 Annex I lists the air pollutants to be reported including GHGs: CO_2, Biomass CO_2, N_2O, CH_4, PFCs, HFCs and SF_6. In addition, NF_3, which is added to the reporting requirements of the UNFCCC Annex I countries' inventories later, is reported and disseminated as a value combined with SF_6 in the dataset of AEAs by Eurostat. By contrast, some other countries outside the EU have a more limited coverage of GHGs (e.g. only GHG-Aggregate or GHGs excluding F-gases). Annex D shows the gas coverage by country.

Table 3.4 summarises data availability of AEAs.

Table 3.4. Data availability summary for AEAs

	Number of countries	Available years	Timeliness	Source granularity	GHGs
EU member states	27	At least 2008-2022	Min. 12 months lag	64 ISIC Rev.4 Divisions	All
Non-EU member states	16	Oldest 1990 – Newest 2022 (average 16.7 years)	12 – 26 months lag	6 - 64 ISIC Rev.4 Divisions	Depends on country (GHG-total only, all GHGs etc.)

Note: Data availability differs across countries. See Annex D for detailed data availability on country level. For most of the countries for which Eurostat collect AEAs, AEAs are estimated by Eurostat for the most recent year.

[18] DSDs are available at https://registry.sdmx.org/data/datastructure.html. Non-GHG air pollutants included in DSDs for Air Emissions are Acidifying gases, Carbon monoxide, Ammonia, Non-methane volatile organic compounds, Nitrogen oxides, Ozone precursors, Particulate matter < 10µm, Particulate matter < 2.5µm and Sulphur oxides.

Source: (OECD, 2024[15]) Data as of 4 April 2024.

Data collection strategy and updating

Data collection strategy

The OECD collects data from Eurostat and websites of NSOs (see section on data source). In parallel, in collaboration with the United Nations Statistical Division (UNSD), the OECD has designed a global data collection questionnaire for AEAs to cover countries that are not reporting AEAs to Eurostat. The UNSD collects data of non-EU, non-OECD countries using the same questionnaire.

The global AEA data collection questionnaire is structured based on tiers with three different levels of gas coverage and industry disaggregation to be flexible for use by countries with different level of data availability. The most detailed template corresponds to the level of the details of the Eurostat questionnaire. The questionnaire is based on the Eurostat AEA questionnaire to ensure international comparability. It was tested with countries, improved based on their feedback and approved by the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA) in 2022. Data collection started in 2023.

OECD estimates to complement official AEAs

The OECD Statistics and Data Directorate maintains three datasets[19] to complement the officially reported AEAs: (1) annual and quarterly AEA estimates; (2) CO_2 emissions from flights (air transport), and; (3) CO_2 emissions from shipping (maritime transport). The last two datasets provide key bridging items (see Section 2) to reconcile the inventory-based and account-based emissions.

OECD annual and quarterly AEA estimates

The OECD estimates annual AEAs and quarterly AEAs (OECD, 2024[15]). Annual AEAs are compiled for four countries for which official AEAs are not regularly available. The emissions data source is the inventory data from UNFCCC Annex I countries. The countries covered by the OECD estimates are USA and three non-OECD countries that are UNFCCC Annex I countries and do not yet regularly disseminate official AEAs. Annual estimates cover CO_2, CH_4 and N_2O and are disseminated for the period of 2007-2020 (longest).[20]

In addition to the annual estimates, quarterly AEA estimates (seasonally adjusted) are published for total GHGs for the OECD as a whole.[21]

Air transport CO_2 emissions

The OECD estimates CO_2 emissions from air transport (flights). Monthly emissions estimates are available for individual countries with near global coverage by flight type (OECD, 2024[23]). CO_2 emissions are estimated based on near-real-time air traffic data provided by the International Civil Aviation Organisation (ICAO) (Clarke et al., 2022[24]). The estimates include a breakdown between domestic and international

[19] Links to these datasets can be found at Environmental-Economic Accounting - OECD.
[20] The inventory emissions reported by the UNFCCC Annex I countries are allocated to ISIC Rev.4 industries and households using the correspondence table proposed by Eurostat (https://ec.europa.eu/eurostat/documents/1798247/6191529/Annex I-%28Correspondence-between-CRF-NFR-NACE-Rev.-2%29-to-Manual-for-Air-Emissions-Accounts-%282015-edition%29/). The output share of each industry is used to allocate an inventory item to multiple industry categories where necessary. Time series and the level of industry disaggregation are limited by the availability of the UNFCCC inventory and output data. The estimated AEAs are based on the territory principle because the methodology to estimate emissions from bridging items to reconcile the residence and territory principles has not yet been fully established (Flachenecker, Guidetti and Pionnier, 2018[12]).
[21] Methodological notes explaining how the quarterly AEA estimates are produced are available here: https://www.oecd.org/sdd/eea/Methods-Note-Producing-OECD-Quarterly-Air-Emission-Accounts.pdf.

flights as well as a breakdown between resident and non-resident airlines. This can help countries estimate bridging items on emissions by residents abroad and emissions by non-residents on the territory.

Maritime transport CO_2 emissions (experimental)

The OECD estimates CO_2 emissions from maritime transport (shipping) based on data from a global ship-tracking system.[22] Experimental data was published in June 2023 for the first time (OECD, 2024[25]). As for air transport emissions, this data can help countries estimate bridging items on emissions by residents abroad and emissions by non-residents on the territory.

CO_2 emissions from fuel combustion (IEA)

Overview

The International Energy Agency (IEA) provides multiple datasets on GHG emissions from energy use as part of its Greenhouse Gas Emissions from Energy database. The IEA CO_2 emissions from fuel combustion dataset has a detailed breakdown and a long time series coverage and is calculated based on official energy statistics (OECD, n.d.[26]).

The IEA dataset on CO_2 emissions from fuel combustion is based on the production-based perspective and the territory principle, covering only emissions from CO_2, and focusing on the emissions process of fuel combustion. The CO_2 emissions from fuel combustion are calculated by the simplest methodology based on the 2006 IPCC guidelines that multiplies fuel consumption by an emissions factor (IEA, 2023[27]).

The split between domestic and international transport is determined based on the location of departure and arrival and not by the residency of the transport operator of airlines and ships. Thus, it is based on the territory principle. The dataset of CO_2 emissions from fuel combustion is useful for policy analysis of energy-intensive industries such as electricity production and transport.

Data sources

The IEA uses energy data published in its World Energy Statistics and World Energy Balances as the data source for fuel consumption. In addition, the IEA uses data from UNSD Energy Balances for supplementary countries. It applies emissions factors from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories to derive estimates of CO_2 emissions.

Geographic coverage, time series and timeliness

The dataset covers more than 150 countries, including all OECD countries, accession countries, key partners, G20 countries, EU member states and an estimate for the world total. Available years are from 1960 to 2022 for OECD countries and from 1971 to 2021 for non-OECD countries, with some exceptions. Thus, data is available approximately one or two years after the reference period.

Sources and gases

CO_2 emissions from fuel combustion covered in the dataset include IPCC category 1 A Fuel Combustion Activities and those which may be reallocated to IPCC category 2 Industrial Processes and Product Use (IEA, 2023[27]). Instead of the term “source category” or “economic activity”, the IEA-CO_2 dataset has the

[22] See New estimates provide insights on CO2 emissions from global shipping (oecdstatistics.blog) and (Clarke et al., 2023[46]).

dimension “flow” and contains a total of 34 unique flows. See Annex B for the list of flows and their correspondence to industries (Yamano and Guilhoto, 2020[6]). The term “energy flow” is defined by the United Nations as “the production, import, export, bunkering, stock changes, transformation, energy use by energy industries, losses during the transformation, and final consumption of energy products within the territory of reference for which these statistics are compiled” (United Nations, 2018[28]).

The IEA documentation (IEA, 2023[27]) refers to correspondence from many flows to a specific IPCC source category and their energy flows are directly compared to the reporting done by countries to the UNFCCC on a yearly basis as part of a collaborative data validation by the UNFCCC and the IEA. However, some of the energy flows do not include a direct reference to specific IPCC source categories. Those flows refer to one or more ISIC 2-digit divisions or in some cases more detailed groups and classes. For example, the IEA flow “Road” corresponds to the IPCC source category 1A3b “Road transportation”; the IEA flow “Chemical and petrochemical” corresponds to ISIC Rev.4 Division 20 “Manufacture of chemicals and chemical products” and Division 21 “Manufacture of pharmaceuticals, medicinal chemical and botanical products”; and the IEA flow “Iron and steel” corresponds to ISIC Rev.4 Group 241 “Manufacture of basic iron and steel” and Class 2431 “Casting of iron and steel”. Emissions covered by flows referring to ISIC economic activities are different from the emissions covered by the same ISIC economic activities in the AEA, because fuel used for transport by firm are reported under the transport sector in the IEA’s energy statistics (IEA, 2004[29]). In addition to flows, the dataset includes a dimension of products such as hard coal, natural gas, and crude oil.

The dataset on CO_2 emissions from fuel combustion covers only CO_2, but the IEA also estimates emissions of non-CO_2 GHGs and non-combustion emissions in additional datasets. Table 3.5 summarises data availability of CO_2 emissions from fuel combustion.

Table 3.5. Data availability summary for CO_2 emissions from fuel combustion

	Number of countries	Available years	Timeliness	Source granularity	GHGs
OECD countries	38	1960 – 2022 in principle	1 year lag	34 flows	CO2
Non-OECD countries	110+	1971 to 2021 in principle	1-2 year lag	34 flows	CO2

Note: See Annex D for details. Data as of 4 April 2024.

GHG emissions embodied in international trade

In addition to the production-based GHG emissions, the OECD also compiles estimates for GHG emissions embodied in international trade, to support analysis on demand-based emissions (see Box 3.1). These demand-based emissions are an application of production-based emissions (in combination with multi-regional input-output tables).

Box 3.1. OECD dataset on GHG emissions embodied in international trade

The GHG emissions embodied in international trade dataset, developed by the OECD Science Technology and Innovation (STI) Directorate, estimates GHG emissions embodied in domestic final demand. It also includes indicators on GHG emissions embodied in international trade derived from the IEA data on CO_2 from fuels combustion, national GHG emissions inventory, and the AEAs as the data source of emissions. Demand-based emissions are useful to understand the impact of global production systems on climate change.

Data is available for 76 countries as well as regional aggregates and rest of world estimates. It includes all OECD countries, accession countries, key partners, G20 countries and EU member states, and covers time series from 1995 to 2020. This dataset was released in 2023 with a time lag of around three years.

To derive demand-based emissions, GHG emissions by industry *i* in country *r* to meet final demand in country *s* are calculated by multiplying the emissions multiplier (emissions embodied in one unit of production) and global final demand matrix from the OECD Inter-Country Input-Output (ICIO) tables (OECD, 2022[30]). Demand-based emissions of country *s* are then calculated as the column sum of column *s* in matrix of GHG emissions plus direct emissions from final demand by households. For a more detailed presentation of the methodology see (Yamano and Guilhoto, 2020[6]). Modelling involves some assumptions and adjustments such as conversion of currencies to a common measure, harmonisation of industry aggregations, and considerations on purchasing power parities, trade mark-up and the differences in production for export and production for domestic consumption.

The total emissions are disaggregated into 45 ICIO industry groups based on the ISIC Rev.4 (listed in Table B.6 Annex B) and households. Table 3.6 summarises the current data availability for this dataset.

Table 3.6. Data availability summary for GHG emissions embodied in international trade

Number of countries	Available years	Timeliness	Source granularity	GHGs
76 countries and regions and rest of the world	1995 – 2020	Approx. 3 years	45 ICIO industry groups	GHGs

Note: Countries and regions included are all 38 OECD countries and 38 non-OECD countries and regions (Argentina, Bangladesh, Belarus, Brazil, Brunei, Bulgaria, Cambodia, Cameroon, China (People's Republic of), Côte d'Ivoire, Croatia, Cyprus, Egypt, Hong Kong, India, Indonesia, Jordan, Kazakhstan, Lao People's Democratic Rep., Malaysia, Malta, Morocco, Myanmar, Nigeria, Pakistan, Peru, Philippines, Romania, Russian Federation, Saudi Arabia, Senegal, Singapore, South Africa, Chinese Taipei, Thailand, Tunisia, and Ukraine, Viet Nam).
Source: Greenhouse gases footprints are available from https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm CO2 emissions embodied in international trade is explained in http://oe.cd/io-co2. Data will be available on OECD Data Explorer.

4 Summary and next steps

This paper discusses the accounting principles, emissions source classification systems, scope of emissions and data coverage of the four OECD and International Energy Agency (IEA) datasets of production-based greenhouse gas (GHG) emissions. These datasets have in common that they are based on emissions data officially reported by countries or estimates based on a methodology validated by countries.

The review highlights differences across the datasets. They are built on different accounting principles and classification structures because they serve different purposes. Users should be aware of these differences and select the appropriate dataset depending on the policy issue or analytical question. To summarise:

- The dataset on Air emissions - GHG emissions inventories is mainly based on national inventories reported under the UN Framework Convention on Climate Change (UNFCCC). It includes territory-based emissions data for the total economy broken down by Intergovernmental Panel on Climate Change (IPCC) source category excluding international transport and covers all GHGs for the period 1990-2021 for 63 countries and regions. However, coverage for non-Annex I countries is limited.
- The Agricultural greenhouse gases emissions dataset is also based on the inventories approach but focuses on emissions from the Agriculture and the Land Use, Land Use Change and Forestry (LULUCF) sectors of the IPCC categories. This dataset includes CO_2, CH_4 and N_2O from these sectors and covers 55 countries and regions for the period 1985-2021.
- The Air Emissions Accounts (AEAs) dataset covers total emissions by resident units including international transport and provides detailed emissions data for economic activity based on 64 divisions of the International Standard Industrial Classification of All Economic Activities (ISIC) for the period 1990-2022. The geographical coverage of this dataset is currently limited as only in Europe is there a legal base for reporting and global data collection only began in 2023.
- The dataset on CO_2 emissions from fuel combustion, which is part of the IEA's database on Greenhouse Gas Emissions from Energy, shows very detailed information with a global coverage and a long time series (1960-2022). Many, but not all, of the emissions flows have an equivalent to IPCC source categories. Some flows refer to ISIC economic activities but the scope of emissions under the same ISIC economic activities could be different from the AEAs due to treatment of transport emissions.

Each dataset has one or more dimensions where data coverage could be further improved, e.g. geographical coverage, time series/timeliness, gas coverage and emissions source coverage/granularity. To enhance the analytical usefulness of the existing datasets, the following strategy is proposed consisting of four related elements:

1. ***Expand current questionnaires and official data sources***. A limited extension of the OECD questionnaire and increased efforts for coordinated data collection across OECD countries can be implemented for data collection in relation to inventories and accounts. It is also proposed to capture and harmonise additional official data from expected emissions reporting under the Paris Agreement such as inventory reporting through the submission of Biennial Transparency

Reports starting December 2024. This would help increase data coverage, increase granularity, and improve consistency and validation across data sources.

2. ***Extend current data collection efforts to OECD partner countries. In alignment with other international frameworks and initiatives,*** it should be ensured that the engagement with OECD partners strengthens data collection efforts by filling in gaps in inventory data when not available (e.g. in the accession process) through, for example, the implementation of the OECD State of the Environment questionnaire. These countries are covered under the OECD's International Programme for Action on Climate (IPAC) and a new OECD initiative called Inclusive Forum on Carbon Mitigation Approaches (IFCMA). In the case of the AEAs, the OECD started global data collection in 2023 through the AEA questionnaire developed in collaboration with the UNSD and Eurostat. Moreover, the OECD chairs Area C (Development of Global Databases for SEEA) under the UN Committee of Experts on Environmental-Economic Accounting, which has as main objective improving international collaboration to collect and disseminate SEEA data. In addition, the OECD is closely collaborating with the third G20 Data Gaps Initiative which aims (as part of Recommendation 1) to develop internationally comparable annual AEAs and National Carbon Footprints for G20 economies.
3. ***Develop estimation methodologies and address data gaps.*** When data is not available, data gaps can be filled with estimates. For example, where official AEAs do not exist or are not disseminated regularly, the OECD estimates AEAs based on the UNFCCC Annex I inventory data based on a correspondence table and assumptions. The estimation methodology of AEAs could be further developed to extend the geographical coverage to non-Annex I countries. In the absence of both accounts and inventory data, AEA and inventory could be estimated using statistical methods (e.g. interpolation, extrapolation), or by using other sources of emissions data (e.g. IEA data on emissions from fuel combustion, PRIMAP-hist (Gütschow and Pflüger, 2023[31])), Emissions Database for Global Atmospheric Research (EDGAR) developed by the Joint Research Centre of the European Commission, and auxiliary information (e.g. IPCC emissions factors, economic activity data). Furthermore, to address data gaps relating to cross-border activities, the OECD has developed datasets covering CO_2 emissions from air transport and maritime shipping.
4. ***Enhance consistency across existing datasets***. Currently the four datasets reviewed in this paper exist as stand-alone datasets with different approaches. Consistency across datasets could be improved by the development of a user guide or through an integrated presentation of the data. The OECD is also working to develop a single, internally consistent GHG emissions database in which it will be possible to reconcile estimates from different datasets by adjusting for known differences between the datasets.

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Annex A. IPCC's guidelines

General

The IPCC provides guidelines for collecting, estimating, and reporting anthropogenic GHG emissions inventories through a series of guidelines and good practice documents which are applied by countries. These include anthropogenic GHG emissions and removals generated within a country's territory in a calendar year.

The main guidelines described below at the 2006 guidelines; but there was also a refinement to the guidelines in 2019. The IPCC's 2019 refinement states that "[n]ational inventories should include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction" (the territory principle) (IPCC, 2019[32]). It also outlines a set of specific guidelines for the emissions sources and activities that need clarification and attention, such as international maritime and air transport. For example, in the case of transport activities that cross international borders, emissions are registered in the country where the fuel was sold and these emissions from international bunkers should not be included in national totals but reported separately. In the case of activities, such as waste incineration, that release emissions during the process of production, use and destruction, emissions are estimated at each stage when and where they occur (IPCC, 2019[32]).

Countries can choose to follow different data compilation procedures under the IPCC's guideline. Presently, taking into account common but differentiated responsibilities, countries that belong to the UNFCCC Annex I and non-Annex I categories have different GHG inventory reporting requirements (see Table A.1 for summary of membership and reporting requirements). Decision 24/CP.19 of the UNFCCC stipulates that Annex-I Parties should apply the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (UNFCCC, 2013[10]).

Non-Annex I Parties submit data as part of their national communications (NC) or biennial update reports (BUR). The NCs shall be prepared in accordance with the guidelines contained in Decision 17/CP.8 in which Parties agreed that Non-Annex I Parties should use the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (UNFCCC, 2002[33]). They are also encouraged to apply the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000[34]). Under the Paris Agreement, however, each Party shall use the 2006 IPCC Guidelines and any subsequent version or refinement of the IPCC guidelines. From the end of 2024, both Annex I and non-Annex I Parties will complete Biennial Transparency Reports every two years under the Enhanced Transparency Framework in the Paris Agreement (UNFCCC, 2018[35]). This should help address the data gaps for Non-Annex I parties.

Table A.1. Membership and reporting requirements to the UNFCCC

	UNFCCC Annex-I, EU	UNFCCC Annex-I, Non-EU	UNFCCC Non-Annex-I
OECD	22 parties: AUT, BEL, CZE, DEU, DNK, ESP, EST, FIN, FRA, GRC, HUN, IRL, ITA, LTU, LUX, LVA, NLD, POL, PRT, SVK, SVN, SWE	10 parties: AUS, CAN, CHE, GBR, ISL, JPN, NOR, NZL, TUR, USA	6 parties: CHL, COL, CRI, ISR, KOR, MEX
OECD Accession	3 parties: BGR, HRV, ROU		3 parties: ARG, BRA, PER
OECD key partner			5 parties: BRA, CHN, IDN, IND, ZAF
Other G20	1 party: EU-27	1 party: RUS	1 party: SAU
Other EU-member	2 parties: CYP, MLT		
Reporting frequency	Annual (15 April)		National Communication every 4 years + Biennial Update Report. Irregular reference years.
Reported gas	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3		CO_2, CH_4, N_2O ('shall' to the extent possible), HFC, PFC, SF_6 ('encouraged')

Source: (UNFCCC, 2013[10]) for reporting requirements of Annex-I Parties, (UNFCCC, 2002[33]) for reporting requirements of NCs of non-Annex-I Parties.

Gases

The 2006 IPCC guidelines cover the following gases (IPCC, 2006[8]):

- carbon dioxide (CO_2).
- methane (CH_4).
- nitrous oxide (N_2O).
- hydrofluorocarbons (HFCs: e.g. HFC-23 (CHF_3), HFC-134a (CH_2FCF_3), HFC-152a (CH_3CHF_2)).
- perfluorocarbons (PFCs: CF_4, $C2F_6$, C_3F_8, C_4F_{10}, c-C_4F_8, C_5F_{12}, C_6F_{14}).
- sulphur hexafluoride (SF_6).
- nitrogen trifluoride (NF_3).
- trifluoromethyl sulphur pentafluoride (SF_5CF_3).
- halogenated ethers (e.g. $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$) other halocarbons not covered by the Montreal Protocol including CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, CH_2Cl_2.
- $C_3F_7C(O)C_2F_5$.
- C_7F_{16}.
- C_4F_6.
- C_5F_8.
- c- C_4F_8O.

In addition, the IPCC suggests that emissions of the ozone precursors nitrogen oxide (NOx), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO), and the aerosol precursors sulphur dioxide (SO_2) and ammonia (NH_3) should be reported if the country has prepared an inventory of these gases (IPCC, 2006[8]).

Definition of IPCC categories

The 2006 IPCC Guidelines group emissions and removals into five main sectors.

- Energy: comprises fuel combustion activities (energy industries, manufacturing industries and construction, transport, residential, and others), fugitive emissions from fuels (solid fuels, oil and natural gas, and other emissions from energy production), and carbon dioxide from transport and storage (transport of CO_2 via pipelines or ships, injections, and storage).
- Industrial Processes and Product Use (IPPU): comprises the mineral industry, chemical industry, metal industry, non-energy products from fuels and solvent use, electronics industry, product uses as substitutes for ozone depleting substances (such as refrigeration and air conditioning), other product manufacture and use (electrical equipment, medical and military applications, and others), and other (such as pulp and paper industry, food and beverages industry, and others).
- Agriculture, Forestry and Other Land Use (AFOLU): comprises livestock (enteric fermentation and manure management), land (forest land, cropland, grassland, wetlands, settlements, and other land), and aggregate sources and non- CO_2 emissions sources on land (such us rice cultivations, direct and indirect emissions from biomass burning, and others).
- Waste: comprises solid waste disposal (waste disposal sites), biological treatment of solid waste, incineration and open burning of waste, wastewater treatment and discharge, and others.
- Other.

Agriculture, Forestry and Other Land Use (AFOLU)

The 2006 IPCC Guidelines suggest presenting AFOLU as one of the five main sectors. However, the UNFCCC common reporting format (CRF) separated AFOLU into agriculture and LULUCF. Land use and related in emissions in agriculture are categorized under LULUCF. LULUCF plays a key and unique role because of its capability as a sink of atmospheric CO_2 emissions thereby being a source of emissions and a sink simultaneously.

The IPCC guidelines help harmonise country and regional level data production by providing steps that guide data production and parameters that help convert land and vegetation characteristics to their carbon equivalent. The 2019 IPCC refinement to the 2006 guidelines provides guidance for preparing annual GHG inventories in Agriculture, Forestry and Other Land Use (AFOLU). Land-use types are classified into forestland, cropland, grassland, wetlands, settlements, and other land. Each category is subdivided into land remaining in the same category and land converted from one category to another. Within each land-use category, carbon stock changes and emissions/removal estimations can involve five carbon pools that are biomass (above ground biomass and below ground biomass), dead organic matter (dead wood and litter) and soils (soil organic matter) ((IPCC, 2019[32]) Volume 4 Chapter 1). IPCC (2019) provides calculation steps and coefficients that can be used to convert each land type to biomass stock in tones of dry matter per hectare (tones d.m. ha-1) and biomass stock to carbon stock in tones of C ha-1 (Volume 4 Chapter 2).

Global warming potential

The effect of GHGs on global temperature and their ability to trap heat vary across gases. Accordingly, the IPCC recommends a common conversion factor called global warming potential (GWP) which translates the level of emissions of different GHGs into CO_2-equivalent. The GWP of a gas is determined by its molecular structure, radiative properties, and lifetime in the atmosphere. Gases with higher GWPs have stronger heat-trapping abilities and can persist in the atmosphere for longer periods of time. “GWP are calculated as the ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO_2 over a period of time (e.g. 100 years).” (IPCC, 2019[32]).

The resulting unit of measurement is carbon dioxide equivalent (CO_2eq) which transfers different gases to a common scale. The commonly used time horizon is 100 years which was made operational in the 1997 Kyoto Protocol (Myhre, 2013[36]). GWP accounts for both the direct and indirect effects of GHGs on climate change. Direct effects refer to the heat-trapping properties of a gas, while indirect effects consider its potential to influence other atmospheric processes.

The IPCC determines GWP based on scientific studies. Understanding of the effect of GHGs on global warming has evolved over the last decades as more and more research is conducted. As the scientific understanding and the consensus around the global warming potential of GHGs change, the IPCC updates its recommendations and GWP database. These updates are communicated in IPCC's Assessment Reports. Currently, the IPCC has released the sixth Assessment Report (AR6). To illustrate, based on the Sixth Assessment Report (AR6):

- CO_2 has a GWP of 1, regardless of the period of time used.
- CH_4-fossil is estimated to have a GWP of 29.8 ± 11 over 100 years.
- CH_4-non fossil is estimated to have a GWP of 27.0 ± 11 over 100 years.
- N_2O is estimated to have a GWP of 273 ± 130 over 100 years.

GWP allows policymakers, scientists, and environmental organizations to assess the overall impact of different GHGs and develop strategies to mitigate climate change. The UNFCCC decided that the Annex-I countries shall apply the GWP of the IPCC Fifth Assessment Report (AR5) by the end of 2024 (UNFCCC, 2022[37]).

Methods

The IPCC recommends a three-tiered approach to data compilation, Tier 1 being the simplest and Tier 3 being the most complex. As tiers increase uncertainty is reduced, but the complexity of data compilation and resource requirements increase. If needed, countries can use combination of Tiers for conducting inventories. Different IPCC categories have different tier methods. The Box A.1 presents the recommended methods for estimating AFOLU emissions.

Box A.1. Methods for reporting AFOLU emissions

Tier 1 methods are designed to be the simplest to use, for which equations and default parameter values (e.g. emissions and stock change factors) are provided in this volume. Country-specific activity data is needed, but for Tier 1 there are often globally available sources of activity data estimates (e.g. deforestation rates, agricultural production statistics, global land cover maps, fertilizer use, livestock population data, etc.), although this data is usually spatially coarse.

Tier 2 can use the same methodological approach as Tier 1 but applies emissions and stock change factors that are based on country- or region-specific data, for the most important land-use or livestock categories. Country-defined emissions factors are more appropriate for the climatic regions, land-use systems and livestock categories in that country. Higher temporal and spatial resolution and more disaggregated activity data is typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use or livestock categories. For a few source categories, the IPCC provides methodologies for estimating a country-specific emissions and stock change factors (e.g. CH_4 emissions from enteric fermentation).

At **Tier 3**, higher order methods are used, such as process-based models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national level. These higher order methods provide estimates of greater certainty than lower tiers. Such systems may include comprehensive field sampling repeated at regular time intervals and/or GIS-based systems of age, class/production data, soils data, and land-use and management activity data, integrating several types of monitoring. Pieces of land where a land-use change occurs can usually be tracked over time, at least statistically. In most cases these systems have a climate dependency, and thus provide source estimates with inter-annual variability. Detailed disaggregation of livestock population according to animal type, age, body weight etc., can be used. Models should undergo quality checks, audits, and validations and be thoroughly documented.

Source: IPCC (2019) Volume 4 page 1.11.

Emissions factors

The quality of GHG inventories depends, among other things, on the choice of emissions factors. According to the official IPCC definition, emissions factor is "a coefficient that quantifies the emissions or removals of a gas per unit activity" (IPCC, 2019[32]). The coefficients are constructed based on an average of a sample of measurements representative of different levels of activity under different operating conditions. The resulting emissions factor is seen as an emissions rate representative of these different measurements.

In accordance with IPCC good practice, the development of emissions factors can either be based on well sourced and documented literature or on the IPCC Emissions Factor Data Base (EFDB) (Penman et al., 2000[38]). The main objective is that the emissions factor should reflect the national circumstances of the country.

For each of the IPCC categories, the adopted Tier provides requirements for the collection of emissions factors. Each Tier imposes a choice of emissions factor which varies among the categories.

Uncertainties

IPCC (2019[32]) details steps and the scope of calculating uncertainties associated with reported inventories. Uncertainty is defined as "[l]ack of knowledge of the true value of a variable that can be described as a probability density function characterizing the range and likelihood of possible values." (IPCC, 2019[32]). Uncertainty analysis aims to qualitatively measure the precision of inventory data based on the expected uncertainty of the chosen methodology and input data. To determine which uncertainties in the inputs to an inventory contribute most to the total uncertainty, a sensitivity analysis is recommended.

For emissions factors based on country-specific measurements, the scientific literature that provided the original measurement is used to evaluate the uncertainty. In case the measurement and tests are not designed in such a way that the uncertainties can be formally assessed, an expert panel will provide an opinion, according to the Table 3.1 provided by the 2019 IPCC Guidelines (Volume 1, Chapter 3).

Regarding default emissions factors from the EFDB, the institution compiling national inventory should ensure that the default values accurately describe its own national circumstances. If the default estimate is deemed unrepresentative and the source category is important to the inventory, better assumptions will need to be made based on expert opinion.

It is important to note that default values are often simplifications and can introduce significant uncertainties into a national estimate. Therefore, it is best practice to use country-specific estimates where possible (IPCC, 2019[32]).

Annex B. Correspondence between ISIC and IPCC classifications

IPCC source classification in the emissions inventory

Inventory-based emissions data is classified according to the IPCC source categories based on actual physical sources and emissions processes. The UNFCCC Annex-I Parties submit their inventory based on the IPCC 2006 guidelines by using the Common Reporting Format (CRF) table (UNFCCC, 2013[10]). Table B.1 shows the source categories in the CRF summary table. More detailed categories are available under each emissions category in the CRF. Emissions from international bunkers (aviation and navigation) are not included in the inventory total but reported in the memo item. Chapter 8 of Volume 1 of the IPCC 2006 guideline defines source categories (IPCC, 2006[8]).

Table B.1. UNFCCC Annex-I Parties, Source Categories in the National Inventory (Summary)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	Total
Total								
1. Energy								
A. Fuel combustion (sectoral approach)								
1. Energy industries								
2. Manufacturing industries and construction								
3. Transport								
4. Other sectors								
5. Other								
B. Fugitive emissions from fuels								
1. Solid fuels								
2. Oil and natural gas								
C. CO_2 transport and storage								
2. Industrial processes and product use								
A. Mineral industry								
B. Chemical industry								
C. Metal industry								
D. Non-energy products from fuels and solvent use								
E. Electronic Industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use								
H. Other								
3. Agriculture								
A. Enteric fermentation								
B. Manure management								
C. Rice cultivation								
D. Agricultural soils								
E. Prescribed burning of savannas								
F. Field burning of agricultural residues								
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other								
4. Land use, land use change and forestry								
A. Forest land								
B. Cropland								
C. Grassland								
D. Wetlands								
E. Settlements								
F. Other land								
G. Harvested wood products								
H. Other								
5. Waste								
A. Solid waste disposal								
B. Biological treatment of solid waste								
C. Incineration and open burning of waste								
D. Waste water treatment and discharge								
E. Other								
6. Other								

Note: Shaded cells are not required to be filled in.
Source: Common Reporting Format, Summary 2 Table (UNFCCC, 2022[39]).

The UNFCCC Non-Annex I Parties use the Revised 1996 IPCC Guidelines for reporting the national inventory in NCs and BURs and are encouraged to use tables of the guidelines (UNFCCC, 2002[33]) (UNFCCC, 2011[40]). Table B.2 summarises the source categories which appear in the reporting tables in NCs for the Non-Annex I Parties. Emissions from international bunkers (aviation and navigation) are not included in the inventory total but reported in the memo item. Source categories are further disaggregated in the tables of the Revised 1996 IPCC Guidelines; however, the level of disaggregation is less detailed than the CRF used by the Annex-I countries. Thus, the source categories of the Annex I inventory and those of the non-Annex I inventory are currently not always comparable. As mentioned in Annex A, each Party shall use the 2006 IPCC Guidelines in the Biennial Transparency Reports in the Paris Agreement, whose first submission is due in 2024.

Table B.2 shows example of source categories up to 3-digit level (e.g. 1.A.3 Transport), however, the level of source disaggregation at the UNFCCC data interface is more limited for non-Annex I countries compared to Annex-I countries (e.g. many 4-digit-level sub-categories such as 1.A.3.b Road transportation are not included). This limited granularity of source category data can be an obstacle for detailed analysis of emissions sources.

Table B.2. UNFCCC Non-Annex-I Parties, Source Categories in the National Inventory (Summary)

Greenhouse gas source and sink categories	CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs	PFCs	SF_6
Total national emissions and removals							
1. Energy							
A. Fuel combustion (sectoral approach)							
1. Energy industries							
2. Manufacturing industries and construction							
3. Transport							
4. Other sectors							
5. Other							
B. Fugitive emissions from fuels							
1. Solid fuels							
2. Oil and natural gas							
2. Industrial processes							
A. Mineral products							
B. Chemical industry							
C. Metal production							
D. Other production							
E. Production of halocarbons and sulphur hexafluoride							
F. Consumption of halocarbons and sulphur hexafluoride							
G. Other							
3. Solvent and other product use							
4. Agriculture							
A. Enteric fermentation							
B. Manure management							
C. Rice cultivation							
D. Agricultural soils							
E. Prescribed burning of savannahs							
F. Field burning of agricultural residues							
G. Other							
5. Land-use change and forestry							
A. Changes in forest and other woody biomass stocks							
B. Forest and grassland conversion							
C. Abandonment of managed lands							
D. CO_2 emissions and removals from soil							
E. Other							
6. Waste							
A. Solid waste disposal on land							
B. Waste-water handling							
C. Waste incineration							
D. Other							
7. Other							

Note: Shaded cells are not required to be filled in.
Source: (UNFCCC, 2002[33]).

The OECD disseminates inventory-based emissions data in the dataset of Air emissions - Greenhouse gas emissions inventories on OECD data dissemination platform. The IPCC source categories are available on the aggregate level for the total GHGs (Table B.3). Only total emissions are available for individual gases such as CO_2 and CH_4.

Table B.3. Sector classification of greenhouse gas emissions as per OECD data dissemination platform

IPCC Sector	IPCC Categories
1 - Energy	1A1 - Energy Industries
	1A2 - Manufacturing industries and construction
	1A3 - Transport
	1A4 - Residential and other sectors
	1A5 - Energy - Other
	1B - Fugitive Emissions from Fuels
2 - Industrial processes and product use	
3 - Agriculture	
5 - Waste	
6 - Other	
Land use, land use change and forestry (LULUCF)	

Source: (OECD, 2024[14]).

ISIC classification in the AEAs

The OECD collects AEAs classified according to principal economic activities of firms and consumption activities of households and disseminates them on the OECD data dissemination platform. AEAs of different countries may use different regional industry classification systems with detailed categories, but are converted to the 64 ISIC Rev.4 divisions for international comparability (see Section 3). Table B.4 lists up the 64 ISIC Rev.4 divisions used in the collection of AEAs on the OECD platform.

Table B.4. Sector classification as per AEAs in OECD data dissemination platform

ISIC Rev.4 industries as per AEAs in OECD data dissemination platform
A01: Crop and animal production, hunting and related service activities
A02: Forestry and logging
A03: Fishing and aquaculture
B: Mining and quarrying
C10-C12: Manufacture of food products, beverages and tobacco products
C13-C15: Manufacture of textiles, wearing apparel and leather products
C16: Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17: Manufacture of paper and paper products
C18: Printing and reproduction of recorded media
C19: Manufacture of coke and refined petroleum products
C20: Manufacture of chemicals and chemical products
C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22: Manufacture of rubber and plastic products
C23: Manufacture of other non-metallic mineral products
C24: Manufacture of basic metals
C25: Manufacture of fabricated metal products, except machinery and equipment
C26: Manufacture of computer, electronic and optical products
C27: Manufacture of electrical equipment
C28: Manufacture of machinery and equipment n.e.c.
C29: Manufacture of motor vehicles, trailers and semi-trailers
C30: Manufacture of other transport equipment
C31-C32: Manufacture of furniture; other manufacturing

ISIC Rev.4 industries as per AEAs in OECD data dissemination platform
C33: Repair and installation of machinery and equipment
D: Electricity, gas, steam and air conditioning supply
E36: Water collection, treatment and supply
E37-E39: Sewerage, waste management, remediation activities
F: Construction
G45: Wholesale and retail trade and repair of motor vehicles and motorcycles
G46: Wholesale trade, except of motor vehicles and motorcycles
G47: Retail trade, except of motor vehicles and motorcycles
H49: Land transport and transport via pipelines
H50: Water transport
H51: Air transport
H52: Warehousing and support activities for transportation
H53: Postal and courier activities
I: Accommodation and food service activities
J58: Publishing activities
J59-J60: Motion picture, video, television programme production; programming and broadcasting activities
J61: Telecommunications
J62-J63: Computer programming, consultancy, and information service activities
K64: Financial service activities, except insurance and pension funding
K65: Insurance, reinsurance and pension funding, except compulsory social security
K66: Activities auxiliary to financial services and insurance activities
L: Real estate activities
M69-M70: Legal and accounting activities; activities of head offices; management consultancy activities
M71: Architectural and engineering activities; technical testing and analysis
M72: Scientific research and development
M73: Advertising and market research
M74-M75: Other professional, scientific and technical activities; veterinary activities
N77: Rental and leasing activities
N78: Employment activities
N79: Travel agency, tour operator reservation service and related activities
N80-N82: Security and investigation, service and landscape, office administrative and support activities
O: Public administration and defence; compulsory social security
P: Education
Q86: Human health activities
Q87-Q88: Residential care activities and social work activities without accommodation
R90-R92: Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities
R93: Sports activities and amusement and recreation activities
S94: Activities of membership organisations
S95: Repair of computers and personal and household goods
S96: Other personal service activities
T: Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U: Activities of extraterritorial organisations and bodies

Source: (OECD, 2024[15]).

The inventory-first approach is the most common approach to compile AEAs. In this method, emissions inventories are used as the starting point to compile AEAs. First, the system boundaries are adjusted from the territory principle to the residence principle. Second, emissions classified according to the IPCC source categories are assigned to industry categories and households. Finally, the bridging items are used to reconcile between AEAs and inventory. An alternative and complementary approach is the energy-first approach where energy statistics/balances are used as the starting point for estimating emissions from the

combustion of energy products, supplemented in a second stage by emissions from non-combustive processes. Some countries maintain emissions data at a very detailed level from which both the inventory and the account can be populated (Eurostat, 2015[17]).

In the step allocating emissions from IPCC inventory categories to AEAs, correspondence from inventory to industry categories is essential due to their differences focusing either on emissions sources or economic activities. The IPCC 2006 guidelines and the 2019 refinement to the 2006 guidelines refer to ISIC Rev.3 divisions, groups and classes where applicable in the definition of emissions sources. Some of the IPCC source (sub-) categories have a 1:1 relationship to a specific ISIC division, some other IPCC source categories have a 1:N relationship (one IPCC source category corresponding to multiple ISIC divisions) and many other IPCC source categories do not refer to any of ISIC divisions (IPCC, 2006[8]) (IPCC, 2019[32]).

The IPCC table on classification and definition of categories of emissions and removals is not always helpful to convert source categories to economic activities not only because many categories lack reference to ISIC divisions but also because it is based on the CRF for the first commitment period and does not refer to the ISIC Rev.4, but the ISIC Rev.3 even in its updated table in its 2019 refinement.

However, Eurostat developed a correspondence table between CRF and NACE Rev.2 (corresponding to ISIC Rev.4 at two-digit division level).[23] Some IPCC source categories have a 1:1 relationship to NACE Rev.2 divisions (e.g. from 1A1b Petroleum Refining to C19 Manufacture of coke and refined petroleum products) and some other IPCC source categories have a 1:N relationship to NACE Rev.2 divisions (e.g. from 1A2a Iron and steel to C24 Manufacture of basic metals and C25 Manufacture of fabricated metal products, except machinery and equipment). Split between multiple relevant economic activities is country specific. IPCC 1A3b Road transportation is applicable not only to households' transport and NACE H49 Land transport and transport via pipelines but also all other industries. Countries compiling AEAs with the inventory-first approach allocate emissions to economic activities based on the correspondence table and other data sources where needed.

IEA Flows and ICIO industry groups

Flow categories used in the IEA dataset are displayed in Table B.5 together with corresponding ICIO industries used for CO_2 emissions embodied in international trade. Some of the IEA flows have a direct equivalent neither to IPCC source categories nor to ISIC economic activities. Combining the concordance between IEA flows and ICIO categories in Table B.5 with the correspondence between ICIO industry groups and ISIC Rev.4 economic activities in Table B.6 is one possible way of bridging between IEA flows and ISIC economic activities. ICIO industry groups are organised in a hierarchical structure in Table B.7.

[23] Available from https://ec.europa.eu/eurostat/documents/1798247/6191529/Annex-I-%28Correspondence-between-CRF-NFR-NACE-Rev.-2%29-to-Manual-for-Air-Emissions-Accounts-%282015-edition%29/.

Table B.5. Concordance between CO_2 flows (IEA) and OECD ICIO industry classification

FLOWS in the IEA dataset			ICIO Industries
Rank	Code	Name	
1	CO2FCOMB	CO_2 Fuel Combustion	
1.1	ELECHEAT	Electricity and heat production	
1.1.1	MAINPROD	Main activity electricity and heat production	
1.1.1.1	MAINELEC *	Main activity electricity plants	D35
1.1.1.2	MAINCHP *	Main activity CHP plants	D35
1.1.1.3	MAINHEAT *	Main activity heat plants	D35
1.1.1.4	EPOWERPLT *	Own use in electricity, CHP and heat plants	D35
1.1.2	AUTOPROD	Unallocated autoproducers	
1.1.2.1	AUTOELEC *	Autoproducer electricity plants	Fuel
1.1.2.2	AUTOCHP *	Autoproducer CHP plants	Fuel
1.1.2.3	AUTOHEAT *	Autoproducer heat plants	Fuel
1.2	OTHEN *	Other energy industry own use	Fuel
1.3	TFC	Total final consumption	
1.3.1	TOTIND	Manufacturing industries and construction	
1.3.1.1	IRONSTL *	Iron and steel	D241_2431
1.3.1.2	CHEMICAL *	Chemical and petrochemical	D20T21
1.3.1.3	NONFERR *	Non-ferrous metals	D242_2432
1.3.1.4	NONMET *	Non-metallic minerals	D23
1.3.1.5	TRANSEQ *	Transport equipment	D29T30
1.3.1.6	MACHINE *	Machinery	D25T28
1.3.1.7	MINING *	Mining and quarrying	D07TD09
1.3.1.8	FOODPRO *	Food and tobacco	D10TD12
1.3.1.9	PAPERPRO *	Paper, pulp and printing	D17T18
1.3.1.10	WOODPRO *	Wood and wood products	D16
1.3.1.11	CONSTRUC *	Construction	D41T43
1.3.1.12	TEXTILES *	Textile and leather	D13T15
1.3.1.13	INONSPEC *	Non-specified industry	D22,D31T32
1.3.2	TOTTRANS	Transport	
1.3.2.1	ROAD *	Road	All industries + Households
1.3.2.2	DOMESAIR *	Domestic aviation	D51
1.3.2.3	RAIL *	Rail	D49
1.3.2.4	PIPELINE *	Pipeline transport	D49
1.3.2.5	DOMESNAV *	Domestic navigation	D50
1.3.2.6	TRNONSPE *	Non-specified transport	Fuel
1.3.2.7	AVBUNK *	Memo: International aviation bunkers	Estimated
1.3.2.8	MARBUNK *	Memo: International marine bunkers	Estimated
1.3.3	TOTOTHER	Other	
1.3.3.1	RESIDENT *	Residential	Households
1.3.3.2	COMMPUB *	Commercial and public services	D33,D36T39,D45T47,D52TD96
1.3.3.3	AGRICULT *	Agriculture/forestry	D01T02
1.3.3.4	FISHING *	Fishing	D03
1.3.3.5	ONONSPEC *	Non-specified other	D33,D36T39,D45T47,D52TD96

Note: * refers to unique flows.
Source: (Yamano and Guilhoto, 2020[6]).

Table B.6. ICIO industry groups in the emissions embodied in domestic final demand

N.	Code	Industry description	ISIC Rev.4 Divisions	Sections
1	D01T02	Agriculture, hunting, forestry	01, 02	A
2	D03	Fishing and aquaculture	03	
3	D05T06	Mining and quarrying, energy producing products	05, 06	B
4	D07T08	Mining and quarrying, non-energy producing products	07, 08	
5	D09	Mining support service activities	09	
6	D10T12	Food products, beverages and tobacco	10, 11, 12	C
7	D13T15	Textiles, wearing apparel, leather and related products	13, 14, 15	
8	D16	Wood and products of wood and cork	16	
9	D17T18	Paper products and printing	17, 18	
10	D19	Coke and refined petroleum products	19	
11	D20	Chemical and chemical products	20	
12	D21	Pharmaceuticals, medicinal chemical and botanical products	21	
13	D22	Rubber and plastics products	22	
14	D23	Other non-metallic mineral products	23	
15	D24	Basic metals	24	
16	D25	Fabricated metal products	25	
17	D26	Computers, electronic and optical products	26	
18	D27	Electrical equipment	27	
19	D28	Machinery and equipment n.e.c.	28	
20	D29	Motor vehicles, trailers and semi-trailers	29	
21	D30	Other transport equipment	30	
22	D31T33	Manufacturing nec; repair and installation of machinery and equipment	31, 32, 33	
23	D35	Electricity, gas, steam and air conditioning supply	35	D
24	D36T39	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39	E
25	D41T43	Construction	41, 42, 43	F
26	D45T47	Wholesale and retail trade; repair of motor vehicles	45, 46, 47	G
27	D49	Land transport and transport via pipelines	49	H
28	D50	Water transport	50	
29	D51	Air transport	51	
30	D52	Warehousing and support activities for transportation	52	
31	D53	Postal and courier activities	53	
32	D55T56	Accommodation and food service activities	55, 56	I
33	D58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60	J
34	D61	Telecommunications	61	
35	D62T63	Computer programming, consultancy and information services activities	62, 63	
36	D64T66	Financial and insurance activities	64, 65, 66	K
37	D68	Real estate activities	68	L
38	D69T75	Professional, scientific and technical activities	69 to 75	M
39	D77T82	Administrative and support services activities	77 to 82	N
40	D84	Public administration and defence; compulsory social security	84	O
41	D85	Education	85	P
42	D86T88	Human health and social work activities	86, 87, 88	Q
43	D90T93	Arts, entertainment and recreation	90, 91, 92, 93	R
44	D94T96	Other service activities	94,95, 96	S
45	D97T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	97, 98	T

Source: (OECD, 2021[41]).

Table B.7. ICIO Industry Aggregates List (Hierarchical Structure)

Code	Industry Description
D01T03	Agriculture, hunting, forestry and fishing
D01T02	Agriculture, hunting, forestry
D03	Fishing and aquaculture
D05T09	Mining and quarrying
D05T06	Mining and quarrying, energy producing products
D07T08	Mining and quarrying, non-energy producing products
D09	Mining support service activities
D10T33	Total Manufacturing
D10T12	Food products, beverages and tobacco
D13T15	Textiles, textile products, leather and footwear
D16T18	Wood and paper products and printing
D16	Wood and products of wood and cork
D17T18	Paper products and printing
D19T23	Chemicals and non-metallic mineral products
D19	Coke and refined petroleum products
D20T21	Chemicals and pharmaceutical products
D20	Chemical and chemical products
D21	Pharmaceuticals, medicinal chemical and botanical products
D22	Rubber and plastics products
D23	Other non-metallic mineral products
D24T25	Basic metals and fabricated metal products
D24	Basic metals
D25	Fabricated metal products
D26T27	Computer, electronic and electrical equipment
D26	Computer, electronic and optical equipment
D27	Electrical equipment
D28	Machinery and equipment, n.e.c.
D29T30	Transport equipment
D29	Motor vehicles, trailers and semi-trailers
D30	Other transport equipment
D31T33	Manufacturing n.e.c.; repair and installation of machinery and equipment
D35T39	Electricity, gas, water supply, sewerage, waste and remediation
D35	Electricity, gas, steam and air conditioning supply
D36T39	Water supply; sewerage, waste management and remediation activities
D41T43	Construction
D45T82	Total Business Sector Services
D45T56	Distributive trade, transport, accommodation and food services
D45T47	Wholesale and retail trade; repair of motor vehicles
D49T53	Transportation and storage
D49	Land transport and transport via pipelines
D50	Water transport
D51	Air transport
D52	Warehousing and support activities for transportation
D53	Postal and courier activities
D55T56	Accommodation and food service activities
D58T63	Information and communication
D58T60	Publishing, audiovisual and broadcasting activities
D61	Telecommunications
D62T63	IT and other information services

Code	Industry Description
D64T66	Financial and insurance activities
D68	Real estate activities
D69T82	Other business sector services
D69T75	Professional, scientific and technical activities
D77T82	Administrative and support services
D84T98	Public administration, education, health and other personal services
D84T88	Public administration, defence; education and health
D84	Public administration and defence; compulsory social security
D85	Education
D86T88	Human health and social work activities
D90T98	Other social and personal services
D90T96	Other community, social and personal services
D90T93	Arts, entertainment and recreation
D94T96	Other service activities
D97T98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
D05T39	Industry (mining, manufactures and utilities)
D41T98	Total services (including construction)
D45T98	Total services
D58T82	Information, finance, real estate and other business services
DINFO	Information industries
DMHH	Domestic households

Source: (OECD, 2021[41]).

Annex C. UNFCCC Data availability

The UNFCCC is mandated with overseeing official reporting of national GHG inventories. The covered gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3)) from five sectors which are energy; industrial processes and product use; agriculture; Land Use, Land Use Change and Forestry (LULUCF); and waste for Annex-I countries.[24]

The UNFCCC states that parties shall regularly provide a national inventory report of anthropogenic GHG emissions (United Nations, 1992[42]).However, the inventory submissions of non-Annex I countries have varying timelines and completeness in terms of emissions source and gas coverage. Therefore, not all GHG emissions data is available for all years, all emissions sources, sub-categories and all gases.

Currently available data at the UNFCCC inventory data interface for IPAC countries from 1990 to 2021 shows that data is missing for a minimum of two countries in 2000 and a maximum of 14 countries in 2020 and 2021 (See Table C.1). Countries with most missing information are Argentina, China, Colombia, Costa Rica, India, Peru, Saudi Arabia, and South Africa. These countries have at most six years of data presented on the UNFCCC inventory data interface out of the 31 years from 1990 to 2021.

[24] Non-Annex I countries submit inventory data in NCs and BURs based on the Revised 1996 IPCC Guidelines which include “Energy”, “Industrial Processes”, “Solvent and Other Product Use”, “Agriculture”, “Land-Use Change and Forestry” and “Waste”. There are very few non-Annex I countries that report values for the sector “Solvent and Other Product Use”.

Table C.1. IPAC countries that have at least one-year missing data in the UNFCCC inventory data interface for total GHG emissions including LULUCF between 1990 and 2021.

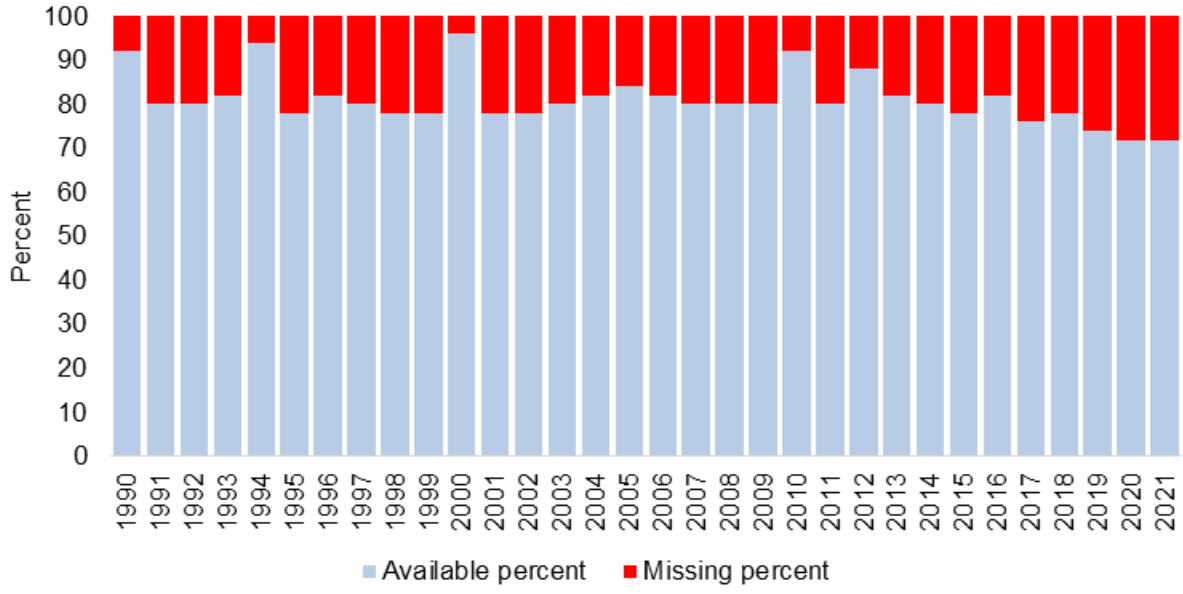
Data availability in UNFCCC GHG emissions inventory data interface.

Country	Number of parties	Data available years
Annex I	44	1990 to 2021*
Non-Annex I	148	1990 to 2021 Max: 29 years of data
Data available years for IPAC covered countries that have missing years**		
Argentina		1990, 1994, 1997, 2000, 2010, 2012
Brazil		1990 - 2016
Chile		1990, 1993, 1994, 2000, 2006, 2010, 2013, 2016, 2018
China		1994, 2005, 2010, 2012, 2014
Colombia		1990, 1994, 2000, 2004
Costa Rica		1990, 1996, 2000, 2005
India		1994, 2000, 2010, 2016
Indonesia		1990, 1991, 1992, 1993, 1994, 2000
Israel		1996, 2000, 2003 - 2020
Mexico		1990 - 2013
Peru		1994, 2000, 2010, 2012
Korea		1990 - 2018
Saudi Arabia		1990, 2000, 2010, 2012
South Africa		1990, 1994

Note: * Australia submitted the 2023 inventory containing data for 2021 using Common Reporting Table (CRT) for which the UNFCCC GHG emissions inventory data interface does not display data for 2021. ** IPAC countries that are not listed here have full data coverage from 1990 to 2021. This table considers data presented at the UNFCCC GHG emissions inventory data interface. Additional data is available at different countries' submission to the UNFCCC such as Biennial Update Reports.
Source: OECD summary based on UNFCCC GHG emissions data interface.

Figure C.1. Significant share of emissions data is missing in countries covered by IPAC

UNFCCC emissions data availability for IPAC countries.



Note: Data as of December 2023.
Source: UNFCCC inventory. IPAC calculation.

Data availability by gases and emissions sources

Further assessing the availability of inventory data for gases by year presented on Table C.2 shows the number of countries by year for which data is missing for the gas specified in columns titles. The table shows that data availability for aggregate GHGs, CO_2, CH_4 and N_2O is the same. However, missing data for F-gases is higher. This can be attributed to the reporting requirements for non-Annex I countries which are only encouraged to report F-gases (UNFCCC, 2002[33]).

Assessing availability of data for the main IPCC emissions sectors, which are Energy, Industrial processes and product use, Agriculture, Waste, and LULUCF, shows that data availability does not vary much across main sectors within a specific reference year.

Table C.2. Number of countries for which data is missing in UNFCCC inventory, by gas and year for IPAC covered countries

Year	GHG	CO_2	CH_4	N_2O	F-gases
1990	4	4	4	4	14
1991	10	10	10	10	14
1992	10	10	10	10	14
1993	9	9	9	9	13
1994	3	3	3	3	11
1995	11	11	11	11	11
1996	9	9	9	9	11
1997	10	10	10	10	10
1998	11	11	11	11	11
1999	11	11	11	11	11
2000	2	2	2	2	7
2001	11	11	11	11	11
2002	11	11	11	11	11
2003	10	10	10	10	11
2004	9	9	9	9	10
2005	8	8	8	8	10
2006	9	9	9	9	11
2007	10	10	10	10	11
2008	10	10	10	10	10
2009	10	10	10	10	10
2010	4	4	4	4	6
2011	10	10	10	10	10
2012	6	6	6	6	8
2013	9	9	9	9	9
2014	10	10	10	10	10
2015	11	11	11	11	11
2016	9	9	9	9	9
2017	12	12	12	12	12
2018	11	11	11	11	11
2019	13	13	13	13	13
2020	14	14	14	14	14
2021	14	14	14	14	14

Number of missing countries	0	2	10	15	20

Note: Data as of April 2024.
Source: IPAC calculation based on UNFCCC inventory data presented on data interface.

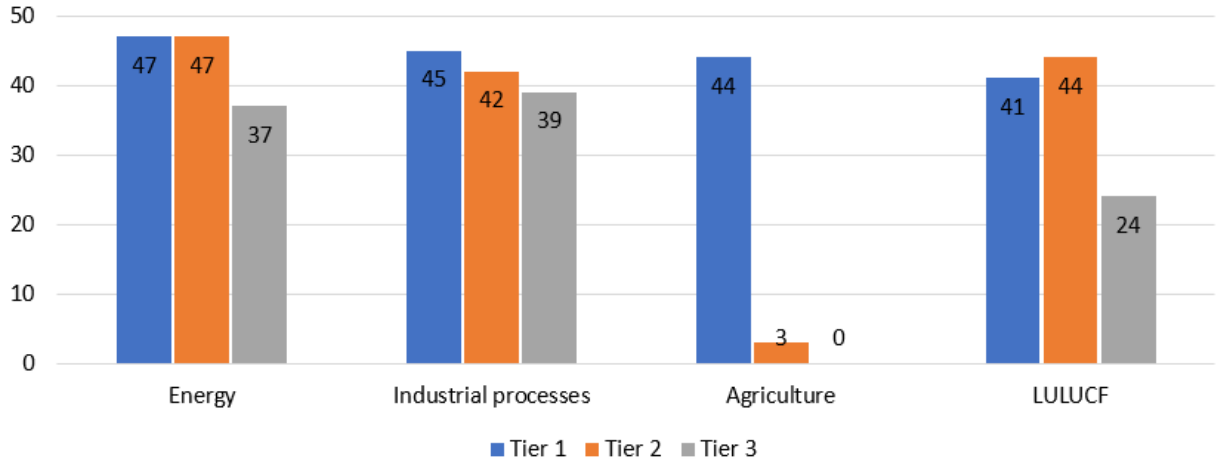
Data quality variation

The UNFCCC and the IPCC provide coordinated procedures for data reporting and compilation process respectively. The processes allow for a wide degree of flexibility of data gathering effort and reporting practices. Countries that belong to Annex I and non-Annex I categories have different GHG inventory reporting requirements. Countries can choose to follow different data compilation procedures under the IPCC guidelines.

Given that different requirements apply to different groups of countries and countries can follow different data compilation procedures, inventory data may vary substantially in quality. For example, Figure C.2 and Figure C.3 present the variation of methods and emissions factors used to compile the inventory data for the reference year 2020 by 49 countries with National Inventory Submissions in 2022. Tier 1 is the least detailed and the least demanding method. The most detailed method is Tier 3. Tier 2 and 3 are "generally considered to be more accurate on condition that adequate data is available to develop, evaluate and apply a higher tier method" (IPCC, 2019[32]). In addition to the three tiers provided by the IPCC, countries may use their own modelling techniques and specific data compilation methods.

Although the UNFCCC GHG emissions inventory is the only available global official inventory-based emissions database, the heterogeneous data compilation procedures used by countries limits the data's applicability for regional and global analysis.

Figure C.2. Number of countries that submitted National Greenhouse Gas Inventory to the UNFCCC by category of method applied for data compilation.



Note: The different data compilations refer to the IPCC guideline. Multiple methods can be applied by a single country for constructing data for a single sector. Data as of April 2024. The analysis covers the 51 IPAC countries.
Source: (UNFCCC, 2022[39]).

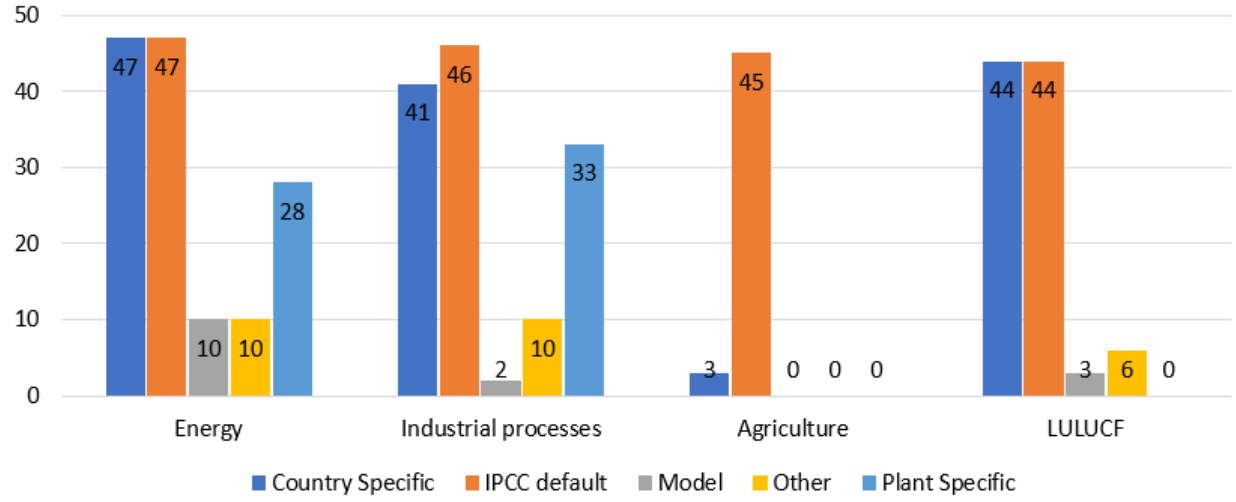
There are further differences in the data compilation, uncertainty calculation and data validation procedures required to be followed by Annex I Parties and non-Annex I Parties. Annex I Parties quantitatively estimate the uncertainties of the data used at least for the base year and the last inventory year, as well as the uncertainty of the trend between these two years. The calculation methods are provided by the 2006 IPCC Guidelines.

For non-Annex I Parties, however, uncertainty estimation is encouraged but not mandatory. To do so, they only need to apply the IPCC Good Practice Guidance and Uncertainty Management in National

Greenhouse Gas Inventories. This method does not provide estimates with a level of precision comparable to that of Annex I Parties.

In addition, Annex I countries incorporate recalculation steps into their methodology to ensure time series consistency. This additional step is done to improve the accuracy and completeness of the inventories. In line with this, Annex I countries must also develop an inventory quality assurance/quality control (QA/QC) plan and implement general inventory QC procedures in accordance with its QA/QC plan following the 2006 IPCC Guidelines. These steps make differences in the accuracy and reliability of national inventory preparation evident between Annex I and non-Annex I Parties.

Figure C.3. Number of countries that used different categories of emissions factors for GHGs data reporting.



Note: Multiple emissions factor categories can be used by a single country. Default is the emissions factor provided by the IPCC. The analysis covers the 51 IPAC countries.
Source: (UNFCCC, 2022[39]).

Annex D. Detailed data availability

Table D.1. Detailed data availability for OECD data on Air emissions - GHG emissions inventories

	Years	Emissions source granularity (OECD platform)	Emissions source granularity (Original data source)	GHGs
Annex- I countries	Complete data: 1990 - 2021	12 IPCC emissions sources	All IPCC sources	All GHGs
Non-Annex I countries	Variable data: 1990 - 2021			
Data available years for IPAC covered countries that have missing years				
Argentina	Data available: 1990 - 2018	12 IPCC emissions sources	All IPCC sources	All GHGs
Brazil	Data available: 1990 - 2016	12 IPCC emissions sources	All IPCC sources	All GHGs
Chile	Data available: 1990 - 2020	12 IPCC emissions sources	All IPCC sources	All GHGs
China (People's Republic of)	Data available: 1994, 2005, 2010, 2012, 2014	12 IPCC emissions sources	All IPCC sources	All GHGs
Colombia	Data available: 1990 - 2018	12 IPCC emissions sources	All IPCC sources	All GHGs
Costa Rica	Data available: 1990 - 2017	12 IPCC emissions sources	All IPCC sources	All GHGs
India	Data available: 1994, 2000, 2010, 2016	12 IPCC emissions sources	All IPCC sources	All GHGs
Indonesia	Data available: 1990 - 1994, 2000 - 2016	12 IPCC emissions sources	All IPCC sources	All GHGs
Israel	Data available: 1996, 2000, 2003 - 2020	12 IPCC emissions sources	All IPCC sources	All GHGs
Korea	Data available: 1990 - 2020	12 IPCC emissions sources	All IPCC sources	All GHGs
Mexico	Data available: 1990 - 2019	12 IPCC emissions sources	All IPCC sources	All GHGs
Peru	Data available: 1994, 2000, 2004 - 2019	12 IPCC emissions sources	All IPCC sources	All GHGs
Saudi Arabia	Data available: 1990, 2000, 2010, 2012, 2016	12 IPCC emissions sources	All IPCC sources	All GHGs
South Africa	Data available: 1990, 1994, 2000 - 2020	12 IPCC emissions sources	All IPCC sources	All GHGs

Note: Data availability varies within the IPCC emissions sources and within gases. See Annex B for summary of emissions source granularity at UNFCCC. Data as of 4 April 2024.

Table D.2. Detailed data availability for Agricultural greenhouse gases emissions

	Years	Emissions source granularity (OECD platform)	Emissions source granularity (Original data source)	GHGs
EU member states	Complete data: 1990 – 2021 Variable data: 1985 - 1990	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
Non-EU member states (UNFCCC Annex-I countries)	Complete data: 1990 – 2021	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
Non-EU membre states (UNFCCC non-Annex-I countries)	Variable data: 1985 - 1990	Variable availability: 12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Argentina	Data available: 1990 - 2014	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Chile	Data available: 1990 – 2020	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Colombia	Data available: 1990 – 2018	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Costa Rica	Data available: 1990 – 2017	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Israel	Data available: 1996, 2000, 2003 – 2020	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Korea	Data available: 1990 - 2020	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs
- Mexico	Data available: 1990 – 2019	12 categories (Agriculture), 8 categories (LULUCF)	All IPCC sources	All GHGs

Note: Data availability varies within the IPCC emissions sources and within gases. Data as of 4 April 2024.

Table D.3. Detailed data availability for AEA

	Years (OECD platform)	Emissions source granularity (OECD platform)	Emissions source granularity (Original data source)	GHGs (OECD platform)
EU member states (other than countries mentioned below)	2008 - 2022	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	All GHGs
- Belgium, Germany, Latvia	2000-2022			
- Denmark, Hungary, Malta, Netherlands, Portugal, Slovakia	1995-2022			
Australia	2004-2016	26 ISIC Rev.4 divisions + 2 Household categories	29 categories based on ANZSIC06 + 2 Household categories	GHG total
Canada	2009-2021	42 ISIC Rev.4 divisions + 2 Household categories	115 categories based on NAICS + 2 Household categories	GHG total
Colombia	2005-2021	39 ISIC Rev.4 divisions + Household	61 ISIC Rev.4 divisions + Household	GHG total, CO_2, CH_4, N_2O
Costa Rica	2017-2020	64 ISIC Rev.4 divisions + 3 Household categories	n/a	CO_2
Iceland	1995-2022	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	All GHGs
Japan	1991-2020	21 ISIC Rev.4 divisions + Household	24 JSIC categories + Household	CO_2, CH_4, N_2O
Korea	2005- 2015	10 ISIC Rev.4 divisions + Household	10 KSIC categories + Household	All GHGs
New Zealand	1990-2021	34 ISIC Rev.4 divisions + 3 Household categories	29 groups based on ANZSIC06 + 3 Household categories	All GHGs
Norway	2008-2022	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	All GHGs
Switzerland	1995-2021	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	All GHGs
Türkiye	1995-2021	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	CO_2, CH_4, N_2O
United Kingdom	1990-2022	63 ISIC Rev.4 divisions + Household	129 groups based on UK SIC 200 + 2 Household categories	All GHGs
USA	2012-2017	7 ISIC Rev.4 sections + Household	n/a	GHG total, CO_2, CH_4, N_2O
Indonesia	2014-2017	6 ISIC Rev.4 sections	6 industries	CO_2, CH_4, N_2O
Serbia	2010-2014	64 ISIC Rev.4 divisions + 3 Household categories	64 NACE Rev.2 divisions + 3 Household categories	CO_2, CH_4, N_2O
Ukraine	2017-2018	19 ISIC Rev.4 sections + Household categories	19 CTEA-2010 + 2 Household categories	GHG total, CO_2, CH_4, N_2O, HFC, SF_6

Note: For data available years, years with data of GHG totals or CO_2 are counted. For most of the countries for which Eurostat collects AEAs, the accounts are available up to 2021 and are estimated by Eurostat for the most recent year (2022). Since April 2024, Canada has made the GHG by gas type (for CO_2, CH_4 and N_2O) for reference years 2018 to 2021 available upon request. Mexico's AEA includes only non-GHG air pollutants and therefore is not included in this table. Regarding industrial granularity, for Colombia, the number of ISIC divisions is not the same in OECD data dissemination platform and in the original dissemination, because the original data include more detailed divisions in some sections which are aggregated in OECD platform. NAICS stands for North American Industry Classification System and ANZSIC06 for Australian and New Zealand Standard Industrial Classification 2006. JSIC stands for Japan Standard Industrial Classification. KSIC stands for Korean Standard Industrial Classification. SIC stands for Standard Industrial Classification and identical down to the four-digit class level with the NACE Rev.2. CTEA is National Classification of Economic Activities of Ukraine and harmonised with NACE. New Zealand's estimates are available for 114 industries, but aggregated to 29 groups for reporting purposes.
For gas, all GHGs in this table mean CO_2, CH_4, N_2O, PFCs, HFCs and SF_6. EU member states report SF_6 and NF_3 combined.
Data as of 23 February 2024.
Source: (OECD, 2024[15]) and websites of Eurostat and NSOs.

Table D.4. Detailed data availability for CO_2 emissions from fuel combustion

	Years	Emissions source granularity	GHGs
OECD countries (other than countries mentioned below)	1960-2022	34 flows	CO_2
Hungary	1965-2022		
Chile, Colombia, Costa Rica, Czech, Israel, Korea, Mexico, Slovakia	1971-2022		
Slovenia	1986-2022		
Estonia, Lithuania, Latvia	1990-2022		
Non-OECD countries (other than countries mentioned below)	1971-2021		
Albania, Argentina, Azerbaijan, Bulgaria, Bosnia and Herzegovina, Brazil, Croatia, Cyprus, Georgia, Kyrgyzstan, Kosovo, Morocco, North Macedonia, Malta, Montenegro, Romania, Serbia, Tunisia	1971-2022		
Equatorial Guinea	1981-2021		
Mongolia	1985-2021		
Armenia, Belarus, Kazakhstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan	1990-2021		
Namibia	1991-2021		
Eritrea	1992-2021		
Cambodia	1995-2021		
Laos, Mali, Suriname	2000-2021		
Palestine	2001-2021		
South Sudan	2012-2021		

Data as of 4 April 2024.