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FIGARO - CO2 estimates

Methodological note

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Commission européenne, 2920 Luxembourg, LUXEMBOURG - Tel. +352 43011

1 INTRODUCTION

This note documents the methodology used for the estimation of CO_2 emissions, produced by Eurostat in the framework of the FIGARO (Full International and Global Accounts for Research in input-Output) project.

In May 2021, Eurostat's Unit C.5 published for the first time the EU inter-country supply-use and input-output tables (EU-IC-SUIOTs). These tables represent all domestic and international flows in NACE Rev. 2 (64*64 activities/products). The dataset covers 45 countries (including the 27 EU Member States), plus a 'rest of the world' aggregate. These tables are to be updated on an annual basis, in line with the latest macroeconomics aggregates.

Also in 2021, Eurostat Unit E.2 started a pilot project to estimate CO_2 emissions accounts for the 45+1 geographical entities, which could serve as environmental extension to the FIGARO data set in order to enable Leontief-type modelling. For the 27 EU Member States, plus United Kingdom, Norway, Switzerland and Turkey, CO_2 accounts reported to Eurostat was available[1]. For the remaining countries, a methodology had to be developed by Eurostat to estimate the respective CO2 emissions accounts. This note further describes the methodology applied by Eurostat to obtain a complete set of estimates for all countries, with a breakdown by 64 production activities and one household category.

2 IDENTIFICATION OF THE TARGET VARIABLES

The CO_2 estimates are to be used as input for the production of carbon footprints through Leontief-type of modelling, by combining them with FIGARO's Inter-country Input-Output tables (ICIOT).

In order to apply the modelling, the 'target' variables to be estimated need to match the required detail from the FIGARO ICIOT. This means a quite high detail by industry and country, necessarily covering the emissions from the entire world. This includes:

- Reference area: 27 EU Member States plus 15 non-EU countries and one 'rest of the World' aggregate
- Air pollutant: CO_2
- Time period: 2010 to *n*-2 (*n* being the year when data are estimated)
- Industrial coverage: classification of economic activities NACE Rev. 2 (including households' activities) – NACE A*64 activities. Additionally, total emissions by households are also calculated (although not integrated in the ICIOT modelling, they are added on top to calculate the total footprint). This leads in total to 65 distinct classes at the most detailed level; no sub-totals or totals are calculated.

3 DATA SOURCES AND ESTIMATION METHOD

The geographical coverage of FIGARO includes 46 countries/regions: 27 EU Member States 18 non-EU countries and a rest of the World block. For the EU Member States, Eurostat launches annually an AEA data collection, which is the primary source for the CO_2 emissions. Some non-

[1] CO2 is included in European air emissions accounts (Regulation (EU) 691/2011)

EU countries also report AEA to Eurostat, although the dataset is not always complete. For the remaining countries, no official AEA is available to Eurostat.

This divides the countries in three groups, for which a separate procedure/methodology is needed:

- Countries report to Eurostat a complete AEA dataset (time and industry-wise) – see chapter 3.1;
- Countries report to Eurostat an incomplete AEA dataset (time and/or industry-wise) – see chapter 3.2;
- Countries do not report AEA to Eurostat – see chapter 3.3.

Table 1 presents the geographical coverage of the CO_2 estimates, as well as the countries included in each of the three groups mentioned above.

Table 1 - Geographical coverage of CO2 estimates

			Complete AEA available (see chapter 3.1)	Incomplete AEA available (see chapter 3.2)	No AEA available (see chapter 3.3)
1-27	EU27	European Union	x		
28	UK	United Kingdom			x
29	US	United States			x
30	AR	Argentina			x
31	AU	Australia			x
32	BR	Brazil			x
33	CA	Canada			x
34	CH	Switzerland		x	
35	CN	China			x
36	ID	Indonesia			x
37	IN	India			x
38	JP	Japan			x
39	KR	South Korea			x
40	MX	Mexico			x
41	NO	Norway		x	
42	RU	Russia			x

43	SA	Saudi Arabia			x
44	TR	Turkey	x		
45	ZA	South Africa			x
46	RoW	Rest of the World			x
		Count	28	2	16

3.1 Eurostat's annual AEA

Air emissions accounts record flows of gaseous and particulate materials emitted into the atmosphere as a result of economic activity. Eurostat's annual AEA are a subset of European environmental-economic accounts. They offer a detailed breakdown for 64 emitting industries (production activities), plus households, as defined in the national accounts of EU countries. Eurostat collects the accounts annually (see Annex I of Regulation 691/2011).

AEA data are normally published in December and cover the necessary time period to be estimated in the context of this FIGARO related exercise: 2010 to one year before the year when data are reported (e.g. by December 2021, data should be available until reference year 2020). This means that the European AEA data are available before the FIGARO tables are disseminated (normally available in May).

Eurostat's annual AEA are multi-dimensional data cubes including several hundreds of data points per time period and geographical entity. It includes the following five dimensions:

- GEO – geopolitical entity (reporting)
- TIME – reference year
- AIRPOL – 7 air pollutants and 6 greenhouse gases (13 substances plus groupings) – the six greenhouse gases, all expressed in CO_2-equivalents, are CO_2, N_2O, CH_4, HFC, PFC, and NF3_SF6. In addition, the gases N2O and CH4 are also available in their simple mass weight, i.e. not converted into CO2-equivalents.
- NACE_R2 – classification of economic activities NACE Rev. 2 (including households' activities) – NACE A*64 plus three classes of households' activities – this leads in total to 67 distinct classes at the most detailed level; in addition several sub-totals and totals.
- UNIT – unit of measure – tonnes and thousand tonnes

Whenever available, Eurostat's annual AEA is the primary source for the estimation of FIGARO-based carbon footprints. In the AEA dataset published in December 2023, data was available for 30 of the 46 geographical entities to be covered. However, only for the 27 EU Member States and Turkey the AEA dataset was complete for all necessary industries and years. For these countries, AEA data was used exactly as reported.

For the methodology applied to countries presenting an incomplete AEA, see the next section.

3.2 Methodology for countries reporting incomplete AEA to Eurostat

The data reported to Eurostat in the course of the 2023 AEA data collection were complete for all EU Member States and Turkey. However, this was not the case for other European countries (e.g. EFTA members, EU candidate countries, potential EU candidates), some of which are also reporting AEA to Eurostat. An incomplete dataset means that not all reference years or not all NACE divisions for a given reference year are reported.

For the other countries having missing reference years or NACE in the AEA dataset, Eurostat developed a gap-filling procedure.

Before gap-filling, a preparatory step is necessary. NACE divisions including emissions from other NACE, as well as NACE divisions having their emissions reported 'elsewhere', need to be both changed to 'not available' (e.g. if NACE A01 and A02 are reported together in NACE A01, both NACE would be changed to 'not available').

In order to gap-fill, Eurostat used as auxiliary data the estimates produced for those countries. These estimates were produced applying the same procedure as for the countries for which AEA was not available (see chapter 3.3).

The gap-filling procedure goes as follows:

- If a reference year is completely missing, a bottom-up approach is followed. This means that the most detailed NACE divisions are estimated by applying the same year-on-year change rates as in the auxiliary data (i.e. as in the estimates produced for those countries – see 3.3). The superior totals are then calculated accordingly, through the respective sum.
- If only certain NACE divisions are 'not available' for a given reference year (i.e. if a total is available, but more detailed NACE sectors are 'not available'), then a top-down approach is followed. In such case, the relative contributions to the total of each NACE division in the auxiliary data are used to split the total through the NACE categories below.

The result is a complete dataset which will serve as environmental extension to the calculation of carbon footprints for the concerned countries.

3.3 Methodology for countries which do not report AEA to Eurostat

3.3.1 AEA data published by countries

In the case of the United Kingdom, Eurostat used data[2] made available online by UK's Office for National Statistics.

3.3.2 Estimation for countries without AEA

For countries not having available AEA with the necessary level of detail, Eurostat developed an estimation method, which uses as main source the estimates available in JRC's EDGAR database, complemented with air and maritime transport emissions made available by the OECD. In the next chapters, this method is described in more detail.

3.3.2.1 EDGAR database

The starting point for the estimation procedure is the EDGAR database. EDGAR is a global database of anthropogenic emissions of greenhouse gases and air pollution, developed and maintained by the Joint Research Centre (JRC) of the European Commission. EDGAR provides independent emission estimates[3] compared to what reported by European Member States or by Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a consistent IPCC methodology.

In the EDGAR database, emissions are available for the 45 countries included in FIGARO. Emissions by the 'rest of the world' are calculated as the difference between the world total and the sum of the emissions by those 45 countries.

A correspondence between the industrial classification of EDGAR CO_2 emissions and NACE rev. 2 classification is available in Table 2.

Table 2 – Industrial classification in the IEA CO_2 emissions from fuel combustion and correspondence to NACE rev. 2 classification[4]

Industries in EDGAR database		Code in NACE rev.2.1 classification
Code	**Label**	
1.A.1.a	Main Activity Electricity and Heat Production	D
1.A.1.bc	Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries	C19, C24, D
1.A.2	Manufacturing Industries and Construction	B to C18, C20 to C33, E36 to F
1.A.3.a	Civil Aviation	See chapter 3.3.2.3
1.A.3.b_noRES	Road Transportation no resuspension	All NACE except U, households
1.A.3.c	Railways	H49

[2] https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsatmosphericemissionsgreenhousegasemissionsbyeconomicsectorandgasunitedkingdom

[3] See also EDGARv6.0 website, Crippa et al. (2021) or the DOI link.

1.A.3.d	Water-borne Navigation[5]	See chapter 3.3.2.2
1.A.3.e	Other Transportation	H49
1.A.4	Residential and other sectors	A01 to A03, G45 to G47, H52 to T, households
1.A.5	Non-Specified	D, G45 to T
1.B.1	Solid Fuels	C19, C24
1.B.2	Oil and Natural Gas	B, C19 to C21, D
2.A.1	Cement production	C23
2.A.2	Lime production	C23
2.A.3	Glass Production	C23
2.A.4	Other Process Uses of Carbonates	C20, C23
2.B	Chemical Industry	C20
2.C	Metal Industry	C24
2.D	Non-Energy Products from Fuels and Solvent Use	C16 to G45, households
3.C.2	Liming	A01
3.C.3	Urea application	A01
4.C	Incineration and Open Burning of Waste	A01, B to C33, E37-E39, M74-M75, Q86, Q87_Q88, S96
5.B	Fossil fuel fires	B

From Table 2, one can identify two types of NACE allocation:

- 1-to-1: emissions from one industry from the EDGAR dataset are allocated to only one NACE rev.2 division (or households)
- 1-to-N: emissions from one industry from the EDGAR dataset are allocated to more than one NACE rev.2 divisions (or households)

The second type of allocations (1-to-N) requires a distribution key, specifying the percentages to allocate to each NACE (or households).

The standard procedure to develop a distribution key for NACE allocation is to derive a distribution key for each NACE concerned, which is calculated as follows:

$$AEA_{EU} / P1_{EU} * P1_{C} \quad \text{(eq. 2)}$$

where, for a given period[6], AEA_{EU} are the CO_2 emissions of the respective NACE division in the EU (in thousand tonnes), $P1_{EU}$ is the monetary output of the same NACE division in the EU (in euros) and $P1_{C}$ is the monetary output of the NACE division in country C.

Table 3 – Example of the calculation of a distribution key for 'Other Process Uses of Carbonates (code 2.A.4), as obtained from the dataset IEA CO2 from combustion. The allocation between NACE C17 and C18 is based on the calculated distribution key

[5] Emissions from maritime navigation are described in chapter 3.3.2.2.

[6] Distribution keys are based on the figures from the maximum number of years where data are available for the three necessary variables (P1, AEA and PEFA). For example, in 2021, distribution keys were calculated based on the aggregated figures for the period 2014-2018.

			EDGAR	
			2.A.4 Other Process Uses of Carbonates	
			AEA_{EU} / $P1_{EU}$ * $P1_C$ (in kt)	Distribution key
NACE	**C20+C23**	**Total**	14 579.5	1.0
	C20	Manufacture of paper and paper products	12 146.3	0.8
	C23	Printing and reproduction of recorded media	2 433.2	0.2

For the EDGAR item 'road transport no resuspension (1.A.3.b_noRES)', a specific calculation is applied, replacing the AEA component in eq. 2 with data obtained from PEFA[7]:

$$PEFA_{EU\_P14\&P17} / P1_{EU} * P1_C \quad \text{(eq. 3)}$$

where, for a given period[6], $PEFA_{EU\_P14\&P17}$ is the emission-relevant energy use of 'motor spirit (without bio)' and 'transport diesel (without bio)' by the concerned NACE division in the EU (in terajoules) (obtained from Eurostat's PEFA), $P1_{EU}$ is the monetary output of the same NACE division in the EU (in million euros) and $P1_C$ is the monetary output of the NACE division in country C (in million euros).

The method described cannot be applied for the allocation to households, since there is no monetary output (P1) for private households.

- The item 'road transport no resuspension (1.A.3.b_noRES)' is multiplied by coefficient 0.6;
- For 'Non-Energy Products from Fuels and Solvent Use (2.D)', the coefficient 0.053 is applied;
- The coefficient for 'Residential and other sectors (1.A.4)' is country-specific and was calculated based on UNFCCC data for the respective country and calculating the average share of CRF 1.A.4.b (residential) in CRF 1.A.4, in the period 2010-2021. For non-Annex I countries, since data are not available with such detail, EU figures were used to obtain the coefficients.

For these three items, the remaining emissions are allocated to NACE divisions based on the method described in the previous paragraphs.

Emissions by the 'rest of the world' are calculated as the difference between the world total and the sum of the emissions by the 45 countries being estimated.

[7] Eurostat's Physical Energy Flow Accounts

3.3.2.2 CO2 from maritime navigation

Emissions from water transport services (NACE H50) follow a specific estimation method. The starting point are the EDGAR items 'water-borne navigation (1.A.3.d)' and 'international maritime bunkers'.

The procedure for the item 'water-borne navigation (1.A.3.d)' is straightforward, since the same figure is attributed to NACE H50 of the respective country.

Concerning the item 'international marine bunkers', Eurostat applies a distribution key which is calculated based on the data obtained from the dataset OECD maritime transport CO2 emissions (experimental).

This experimental dataset includes annual, quarterly, and monthly carbon dioxide emissions from maritime transport. These are estimated by the OECD based on a consistent methodology across countries and include emissions from both domestic and international voyages. The source for the estimations is ship-tracking information collected via Automatic Identification System (AIS) transponders, covering all large vessels (above 300 gross tonnage) around the world, accessed via the United Nations Global Platform.

The extraction details are described in Table 4.

Table 4 – Extraction details of emissions from maritime transport (OECD database)

Parameter	Selection
Vessel type	All vessels
Country	All
Measure	tonnes of CO_2-equivalent OECD estimation
Time & Frequency	Annual

The following calculation is applied:

- Based on the OECD data, a year- and country-specific share is calculated by dividing the respective emissions by the global emissions (i.e. total for all countries, for that year).
- These shares are then multiplied by the values available in EDGAR for 'international marine bunkers', to obtain country- and year-specific emissions, which are then allocated to NACE H50.

3.3.2.3 CO_2 from aviation

The OECD maintains and regularly updates an air transport CO_2 emissions database, which includes annual, quarterly and monthly information on CO_2 emissions related to aviation flights. Emissions are estimated for 186 countries, following both territory and residence principles. The main source used for the estimation of these CO_2 emissions is a database compiled by the International Civil Aviation Organisation (ICAO) with all commercial passenger and freight flights around the world.

Carbon dioxide emissions by NACE H51, following the residence principle (as applied in AEA), are directly available from this dataset. Eurostat extracts this data from the OECD database to attribute to NACE H51 of the respective country. Table 5 shows the extraction details.

Additionally, estimates by NACE H51 for all countries are aggregated to calculate a world total. Based on the difference between these emissions and the sum of the emissions by the 45 countries being estimated, one can obtain the emissions by NACE H51 in the 'rest of the world'.

Table 5 – Extraction details of emissions from air transport (OECD database)

Parameter	Selection
Source of emissions	Air transport - Industry H51 (ISIC rev.4): (A)+(B)+(D)+(E)+(F)
Pollutant	Carbon dioxide
Measure	tonnes of CO_2-equivalent
Flight type	All flights
Frequency	Annual
Seasonality	Non-seasonally adjusted

4 FUTURE WORK

Eurostat plans to estimate CO_2 emissions accounts for the 46 FIGARO countries/regions on a regular basis. To facilitate this annual process, the above described estimation methodology has been implemented in form of an EXCEL tool. Eurostat is always seeking for means to improve the method and the tool.