Paris, December 2022

METHODS NOTE: PRODUCING OECD QUARTERLY AIR EMISSION ACCOUNTS

Why do we need quarterly estimates of greenhouse gas emissions?

The OECD supports countries in their efforts to progress towards net zero by 2050. Net zero is defined as cutting greenhouse gas (GHG) emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere by environmental 'sinks' such as oceans and forests.

Statisticians have the task of measuring progress towards net zero, for instance by tracking GHG emissions over time. At present, most OECD countries report such emissions data annually, with a time lag of between one and two years. Policy makers need more up-to-date and frequent information, as well as more granular data such as breakdowns by type of economic activity.

Why compile as Air Emission Accounts?

Our estimates track emissions of CO_2 and other GHGs that are released into the atmosphere. They are compiled for the Air Emissions Accounts (AEAs) of the System of Environmental-Economic Accounting (SEEA). We use the SEEA approach because it is consistent with international standards for compiling the national accounts, which makes it easier to monitor the impact of the economy on the environment. The national accounts present countries' economic and financial accounts using agreed methods and definitions and produce well-known macroeconomic statistics such as Gross Domestic Product (GDP).

The AEAs are similar to the emissions inventories compiled by countries for the United Nations Framework Convention on Climate Change (UNFCCC)[1]. The UNFCCC emissions inventories are territory-based, while AEAs and other SEEA accounts are compiled on a residency basis[2] and hence include emissions from international air and maritime transport.

What is not included

Air emissions are split into GHG emissions[3] and air pollutants[4]. Concentration of GHGs in the atmosphere is responsible for the greenhouse effect and hence global warming. Air pollutants are harmful to human health and detrimental to the environment and biodiversity, but they do not have a direct impact on the rise of temperature of the air and oceans. Therefore, although our quarterly estimates are compiled on the basis of the AEAs, they comprise only GHG emissions; they do not include air pollutants.

Data sources and breakdowns

Information reported by countries under the UNFCCC, commonly referred to as inventories, comprises emissions resulting from human activities broken down by the categories relating to emissions sources, as

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[1] UNFCCC is a multilateral environmental agreement signed between June 1992 and June 1993 by 154 states at the United Nations Conference on Environment and Development (UNCED).

[2] The residency principle implies reporting emissions generated by all residents of a country, irrespective of where the emissions take place.

[3] GHGs include: Carbon dioxide (CO_2), Hydrofluorocarbons (HFCs), Methane (CH_4) Perfluorocarbons (PFCs), Nitrous oxide (N_2O), Sulphur hexafluoride (SF_6) and Nitrogen trifluoride (NF_3).

[4] Air pollutants include: Carbon monoxide (CO), Particulates (PM_2 less than 2.5µm; PM_{10} less than 10µm), Nitrogen oxides (NO_X), Acidifying gases (ACG), Sulphur oxides (SO_X), Non methane volatile organic compounds (NMVOC), Ammonia (NH_3) Ozone precursors (O_3PR).

defined in the guidance of the Intergovernmental Panel on Climate Change (IPCC)[5].

The AEAs break down GHG emissions by type of economic activity rather than by IPCC categories. Type of economic activity is based on the International Standard Industrial Classification of All Economic Activities (ISIC) that is used by all SEEA accounts and by the national accounts. The AEA estimates also include GHG emissions from household consumption activities. Thus, they offer a means of monitoring the impact of the economy on the environment, including which types of economic activity emit the most GHGs or how patterns of consumption affect emissions. They can also be used for economic policy analyses that require comparability with production and consumption from the national accounts.

Quarterly AEAs adopt the same accounting principles, definitions and structure as the annual AEAs. The estimation procedure for each country may include up to 469 annual time series resulting from the product of the 67 economic and household activities by the seven GHGs[6].

However, the availability of annual data varies significantly across countries. In the European Union (EU), the accounts are broken down by 64 NACE[7] categories plus three household activities (heating/cooling, transport, and other) across ten GHG and air pollutants, with time series starting as early as 1990[8].

The information tends to be less detailed for non-EU OECD economies. For instance, Australia and Canada produce total GHG estimates but no breakdown by individual gases. Moreover, time series may be shorter than in the EU member countries[9]. For countries reporting only inventories estimates to UNFCCC but not producing the SEEA accounts, such as United States or Japan, existing GHG emissions need to be mapped to the ISIC economic activities. However, such a procedure only allows breaking down annual emissions by a limited set of economic activities. Moreover, the estimates can only include CO_2, CH_4 and N_2O, not total GHGs.

Finally, for those countries estimating neither annual SEEA-based accounts nor inventories on a regular basis (Chile, Costa Rica, Israel and Mexico), data on emissions is obtained from the Emissions Database for Global Atmospheric Research (EDGAR, Crippa et al., 2021). This has to be mapped to the ISIC[10].

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[5] The IPCC categories are set out in Table 8.2 Classification and definition of categories of emissions and removals of IPCC Reporting Guidance Volume 1 available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_8_Ch8_Reporting_Guidance.pdf

[6] In order to allow aggregation, quarterly GHG emissions are compiled in CO_2 equivalents only. Corresponding annual figures are disseminated in various metrics corresponding to equivalent global warming potential (GWP) of other gases. For instances, one metric ton of methane (CH_4) released in the atmosphere has 25 times the GWP of CO_2 carbon dioxide. Thus, one metric ton of CH_4 is equivalent to 25 metric tons of CO_2 equivalent. GWPs are available at: https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions#eq-10

[7] Nomenclature statistique des activités économiques dans la Communauté européenne" (NACE) is the industry standard classification system used in the European Union (EU). Correspondence tables between NACE and ISIC can be found here.

[8] Longer time series are available for Bulgaria (1988), Hungary (1985), Poland (1988) and Slovenia (1986).

[9] Australia from 2009 to 2016; Canada from 2009 to 2019.

[10] Flachenecker, F., E. Guidetti and P. Pionnier, 2018, "Towards global SEEA Air Emission Accounts: Description and evaluation of the OECD methodology to estimate SEEA Air Emission Accounts for CO2, CH4 and N2O in Annex-I countries to the UNFCCC", OECD Statistics Working Papers, No. 2018/11, OECD Publishing, Paris,

BOX 1: How are annual emissions estimated?

Emissions, either inventories or accounts, can be estimated through physically monitoring the quantities of gases released into the atmosphere (e.g., CO_2 released via the smokestacks of larger emitters) or using emissions factors, i.e., coefficients that convert activity data into GHG emissions. For instance, if in a certain period an industry uses 10,000 litres of diesel, of which the emissions factor is 2.68 kg of CO_2 per litre of combusted diesel, the emissions can be calculated as product of the number of litres of diesel by coefficient, resulting in the 26.8 metric tons of CO_2.

Moreover, inventories can be the starting point to construct the SEEA air emissions accounts (inventory-first approach). Two adjustments are needed: (i) an adjustment of scope to move from a territory-based to a residency-based recording and the inclusion of international transportation in total emissions, and (ii) an adjustment to break down the emission sources into production activities and households.

Alternatively, estimates can be based on energy accounts, or energy supply and use tables, measured in quantity units – (energy-first approach) by transforming the combustion related energy inputs for each of the different fossil energy products into air emissions. However, this approach will only produce energy-related emissions, thus other sources must be used to derive the non-energy related GHG emissions.

Manual for air emissions accounts, Eurostat (2015)

Timeliness

Countries included in Annex I of the UNFCCC[11] report annual inventories of GHG emissions by mid-April each year[12], for the year ending 15 months earlier (e.g., they reported in April 2022 for the year 2020). Non-Annex I countries have even less stringent reporting obligations. The SEEA annual accounts are also disseminated with significant delays. In Europe, where the release calendar is regulated[13], national statistical offices publish the AEAs within the 21 months after the end of the year, while for some of non-EU OECD countries, they are published up to 24 months after the end of the year.

In 2021, the OECD, the statistical office of the EU (Eurostat), the International Monetary Fund (IMF), the United Nations Statistical Division (UNSD) and the International Energy Agency (IEA) established a task team to produce quarterly GHG emissions estimates in a timelier manner. For example, the OECD estimates, use extrapolation to extend GHG emissions estimates up to six quarters beyond the latest annual data point so that they are published soon after the latest quarter of GDP estimates.

[11] The list of countries in Annex I includes: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, European Economic Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, United States of America.

[12] The reporting guidelines on annual inventories for Parties included in Annex I to the Convention can be found at https://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2

[13] Regulation (EU) No 691/2011 https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32011R0691

The task team set up in 2021 discussed both methods and the division of the work. Eurostat is responsible for producing estimates for EU countries, the OECD for its non-EU member countries, and the IMF for the rest of the world. As part of the work of the task team, the international organisations have also reached out to countries so that national and international approaches are aligned as much as possible.

Indirect estimation of quarterly AEAs

The method we adopted to produce quarterly AEAs builds on well-established econometric techniques employed by some national statistical offices to estimate the quarterly national accounts. If the procedure used to estimate the annual data cannot be replicated for the sub-annual estimates because a full set of sub-annual (monthly or quarterly) data is not available, as in the case of GHG emissions, an indirect approach may be used instead.

The indirect approach entails deriving the sub-annual variable of interest by interpolating the existing annual estimates and extrapolating the periods for which annual figures are not yet available. The process, known as temporal disaggregation, shares similar properties and the same kind of techniques as those used in benchmarking[14]. The estimations rely on the use of sub-annual 'predictor indicator' variables (e.g., monthly energy statistics, short-term production volume indices, or quarterly value added) suitable for approximating the quarterly behaviour of the unknown 'target' variable. The indirect approach may be used to estimate quarterly GDP[15] or flash estimates and forecasts for GDP and other indicators. In this case, we use it to estimate quarterly AEAs.

A pragmatic approach

To make full use of all available sub-annual information, temporal disaggregation should be performed at the highest possible level of disaggregation. However, given the differences between the information available for the annual AEAs in different countries, a pragmatic approach had to be adopted in designing the estimation plan for the quarterly AEAs. Firstly, the plan required a module to fill gaps in key variables (e.g., total GHGs). Second, we needed to get the right balance between, on the one hand, a sufficiently disaggregated level of estimation and, on the other hand, maintaining the number of target variables at a manageable level and preserving the international comparability of the estimates.

Bottom-up estimation strategy

Once the most polluting sectors are selected and predictor indicators identified, quarterly emissions are first estimated at ISIC sections level for the most relevant GHGs. Typically, these include CO_2, CH_4, N_2O and, whenever relevant, also for HFCs, PFCs and SF_6. However, quarterly emissions can be estimated at higher level of ISIC aggregation (e.g., by groups of ISIC sections such as total services) if annual AEAs are only available in this format.

Thereafter, for each ISIC section, the sum of estimated quarterly emissions by GHG obtained in the first stage is used as predictor variable to temporally disaggregate the total GHGs of the ISIC section. Similarly, the sum of quarterly total GHGs by ISIC section is used as the input (i.e., a new predictor indicator) into the temporal disaggregation of a higher level of aggregation of the ISIC sections. For example, first we

[14] The main distinction is that in benchmarking, the sub-annual series to be benchmarked consists of the same variable as the annual benchmarks, while in temporal disaggregation the sub-annual series differ from the annual series.
[15] France, Italy, Portugal, Spain, Switzerland.

estimate CO_2, CH_4, N_2O and HFC emissions generated by households for housing, water, electricity, gas and other fuels and transport. Then we add these components together to produce quarterly estimates of total GHGs generated by households. Such an approach allows accounting for residual categories, such as 'Other' (defined as Households *minus* Non-specified), for which no specific indicator can be identified. This strategy is also flexible enough to enable the estimation plan to be modified whenever better predictor indicators become available.

Quarterly air emissions are estimated through the Chow-Lin[16] regression-based methods (maximum likelihood version) as implemented in the R-package "tempdisagg" by Sax and Steiner[17].

Selection of sub-annual predictor indicators

Depending on the data availability at country level, the chosen sub-annual predictor indicators typically include:

- Quarterly National Accounts
    - Value added by ISIC/NACE activities
    - Final consumption expenditure of households
- Short-term Economic Indicators
    - Index of Industrial Production
    - Turnover in wholesale retail trade
- Energy data
    - Electricity generation by type of energy

A combination of two approaches was used to choose the best predictor indicators:

(i) a qualitative approach utilising theoretical assumptions on the relationship between the sub-annual data and the annual target; and

(ii) a purely statistical approach that maximises the correlation between the annualised sub-annual predictor indicator and the target variable.

Deterministic variables (e.g., a constant or linear trend) were also considered whenever no suitable sub-annual variable could be identified for those sectors of economic activity for which some emissions are relevant, for instance for methane emissions by livestock in some countries.

Seasonal adjustment and weather-related effects

Emissions may vary over the months and quarters reflecting the fluctuations in polluting activities such as the combustion of fossil fuels in electricity generation, production of transport services, heating and cooling people's homes; industrial processes and solvent use, for example in the chemical and mining industries; agriculture; waste treatment; and emissions of volatile organic compounds from plants.

Prior to their use as inputs in our temporal disaggregation, the predictor indicators are adjusted for

[16] Chow, G. C. and Lin, A.-l. (1971). Best linear unbiased interpolation, distribution, and extrapolation of time series by related series, The Review of Economics and Statistics 53(4): 372 – 75.
[17] C. Sax and P. Steiner. tempdisagg: Methods for Temporal Disaggregation and Interpolation of Time Series, 2013. URL http://CRAN.R-project.org/package=tempdisagg. R package version 0.22. [p80]

seasonality[18], calendar[19] and working day[20] variations ('seasonally adjusted').

Sub-annual statistics are typically seasonally adjusted by national statistical authorities. If chosen sub-annual predictor indicators were available only in the raw format (not seasonally adjusted by the national source), we carried out seasonal adjustment using the X13 procedures as implemented in R-JDemetra+.

By removing the seasonal components, consecutive periods can be compared. However, seasonal adjustment procedures do not eliminate all weather-related movements in the data. In fact, they only eliminate predictable and recurrent seasonal fluctuations. Any weather-related movement caused by divergence from the normal seasonal fluctuations, such as prolonged heat waves or extremely cold winters, will remain in the seasonally adjusted data as part of the irregular component. Deviations from normal weather conditions are likely to generate an increase in the demand of electricity for heating and air conditioning, resulting in higher emissions if electricity is generated from fossil fuel combustion.

To remove the effects due to extreme weather conditions, some national statistical offices[21] have started implementing weather normalization techniques. Weather-normalized estimates can potentially provide a clearer indication of the underlying trends; but is a rather new concept which is less generally accepted at present than seasonal adjustment. We have decided not to apply such techniques to our data for the time being.

Dissemination

The results are published as data series on the OECD database, which provides quarterly estimates of total GHGs for the OECD area as a whole. A breakdown by major economic activities is also available.

In addition to the OECD estimates, Eurostat produces quarterly estimates of GHG emissions by economic activity without seasonal adjustment for EU countries. The IMF publishes experimental quarterly estimates of GHG emissions for the world and selected groups of countries. The IMF's estimates are seasonally adjusted and include breakdowns by GHG type and by industry and households.

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[18] Seasonality refers to the fluctuations that happen every year at the same time and with the similar magnitude and direction.

[19] Calendar adjustments are statistical methods used to remove the effect due to the changing number of particular weekdays or holidays in different periods (months, quarters or years).

[20] Working-day adjustment techniques remove the effects caused by changing number of working days (Monday - Friday) in different periods (typically months).

[21] For example, the Australian Department of Climate Change and Energy Efficiency, with the assistance of the time series analysis section of the Australian Bureau of Statistics, has implemented such a correction to Quarterly National Greenhouse Gas Inventory Data.