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Session 2D-1, Environmental Accounting, Natural Capital and Productivity

Abstract: The urgency of abating climate change highlights the need to monitor progress towards nationally determined contributions (NDCs) on a timely basis. This paper exemplifies the partnership between Eurostat, the IEA, the IMF, OECD and the UNSD in developing quarterly GHG emissions accounts by industry and households. This partnership has already led to the regular publication by Eurostat and the IMF of quarterly GHG emissions accounts. The OECD will follow soon. This paper outlines the underlying methodology to prepare these accounts, presents possible applications and explores avenues for future work, with the aim to inspire statisticians in other countries to publish quarterly air emissions accounts.

JEL-codes: C80: Data Collection General, D62: Externalities, E01: Measurement and Data on National Income and Product Accounts and Wealth • Environmental Accounts

Keywords: quarterly emissions accounts, climate change, international cooperation.

[1] "The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management".

1. INTRODUCTION

Countries regularly update their Paris agreement climate action plans to reduce their greenhouse gas (GHG) emissions.[2] Yet, official data on GHG emissions are usually only published annually with a lag of 12 to 24 months, if published at all. The urgency of abating climate change highlights the need to track progress towards these targets on a regular and timely basis, including at a higher quarterly frequency.

Recognizing this data gap, the International Monetary Fund (IMF), in close cooperation with other international organizations and institutions, launched a program to estimate quarterly GHG emissions, on a global and regional basis, by emitting industry and households as a "proof of concept" that such quarterly air emission accounts could be published roughly in line with the timetable of quarterly GDP estimates.

There is also a partnership by Eurostat, the International Energy Agency (IEA), the IMF, the Organization for Economic Cooperation and Development (OECD) and the United Nations Statistics Division (UNSD) to establish a Task Team. The Task Team's mandate is to design a consistent methodological approach—based on source data availability—that can be used to develop country-level quarterly GHG emissions accounts by industry and households. The objective is to produce quarterly GHG emissions data consistent with GDP statistics as timely as possible with the widest country coverage possible. This partnership has already led to the regular publication by Eurostat and the IMF of quarterly GHG emissions accounts for European Union (EU) countries and others. The data are available with a lag of approximately 4-5 months starting with the first quarter of 2010.[3] Moreover, the OECD will soon publish quarterly GHG emission accounts for the OECD region. To streamline the process and have a consistent set of estimates amongst international organizations, it is envisioned that these data can be shared among international organizations without duplicating efforts.

This paper aims to inspire statisticians in other countries to publish quarterly GHG emissions accounts.[4] The next section (2) discusses the conceptual underpinnings of these quarterly emissions accounts and explains the main differences between emissions inventories and accounts. Section 3 dives into the data and compilation issues and the selection of predictors on a quarterly basis. Section 4 showcases the analytical usefulness of emissions accounts. Section 5 provides avenues for future improvements.

2. CONCEPTUAL BACKGROUND

Quarterly air emissions accounts adopt the same principles, definitions, and structure as the annual air emissions accounts. The latter is one type of accounts developed in the System of

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[2] GHGs include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases (F-gases). F-gases are hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride.

[3] Due to a limited country coverage of sub-annual data (energy statistics, indexes of industrial production, gross value-added data), the missing countries are grossed up based on the developments as estimated for the neighboring countries in the region. For the initial release of the CID, the IMF decided to only release the data at regional level even though they are estimated at the country-level. As the methodology is further refined, the IMF will consider releasing country level estimates.

[4] Currently, only four countries (Netherlands, New Zealand, Sweden, and the United Kingdom) do so.

Environmental-Economic Accounts (SEEA) to record anthropogenic[5], i.e., human induced, emissions by resident economic units as classified by the International Standard Industrial Classification of All Economic Activities (ISIC) and by households. The development of quarterly accounts is exclusively motivated by the need to catch as timely as possible the most recent developments in GHG emissions. Following business cycles, as quarterly GDP is supposed to do, will be irrelevant in the case of GHG emissions and the need to structurally abate them. In fact, strong business cycle movements may blur reviewing the structural trends of GHG emissions against the reduction targets as set in the individual countries.

The SEEA is the international statistical standard to record and present internationally comparable environmental accounts and their link to economic activity. The SEEA framework is consistent with the SNA, following similar underlying concepts such as the resident recording principle. The residency principle is crucial when defining the economic activities belonging to a specific country's economy.

The use of the ISIC ensures that statistics on value added, resource extraction and the emission of residual waste flows follow the same classification of activities, allowing for their mutual comparability. In other words, SEEA-based air emissions accounts are directly comparable to the economic information on production and consumption, as obtained from the SNA. By following the SEEA standard, the emissions accounts are readily used for environmental-economic analyses such as environmental intensity calculations and consumption-based carbon footprint analysis.

The inventory for GHGs is another framework to collect and structure data on anthropogenic GHG emissions. Its common reporting format is under the UN Framework Convention on Climate Change (UNFCCC). This framework is designed for the purpose of systematically collecting information on GHG emissions. It takes stock of emissions generated within the territory of a particular country by the different sources (e.g., electricity production, manufacturing, transport). International aviation and shipping are excluded from the country inventory totals, given their international nature, but are available as separate memo items. There are two parties under the UNFCCC with Annex I countries[6] committed to producing annual GHG emission inventories, while others report data on a best effort basis usually with longer lags.

In contrast to the UNFCCC inventory, the SEEA classifies the emissions generated by all residents of a country, irrespective of where the emissions take place. This accounting principle entails that all emissions from international transportation are assigned to the countries in which the operators of these transport services reside. Just as a reference, international shipping and aviation account for around 700 (1.8%) and 600 (1.6%) metric tons of CO2 emissions respectively. The percentages address their shares to the worldwide sum of emissions of CO2.

Both the UNFCCC inventory and the SEEA follow a 'direct recording principle' which means emissions are recorded at the level of those processes or industries where they are released. So, in the accounts, emissions generated by power plants are not attributed to the electricity

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[5] Natural flows of GHG emissions (for example, from volcanoes and forest fires) are excluded.

[6] There are 43 Annex I reporters (42 countries plus the European Union). See https://unfccc.int/parties-observers.

consumers. The SEEA based emissions accounts are eminently fit to serve input-output analysis by which such emissions can be attributed to final users.

Both emissions inventories and accounts rely on various techniques to estimate air emissions. Emissions can be estimated directly through emissions monitoring (e.g., CO2 released via the smokestacks of larger emitters). They can also be measured indirectly. A common approach is the use of emissions factors: a coefficient that converts activity data into GHG emissions. If in a certain period an industry may use 10,000 liters of diesel, of which the emissions factor is 2.68 kg per liter of combusted diesel. This will typically result in 26.8 metric tons of carbon emissions. Although in practice the estimation will often be performed at a more detailed level, a simplified emissions model would take the following form:

Emissions (*e*) = Activity Data (*ad*) × Emission Factor (*ef*)

Often, the inventories are the starting point to construct the SEEA air emissions accounts, as described in the Eurostat (2015) Manual for Air Emissions Accounts. The Manual explains that there are at least two ways to produce SEEA air emissions accounts, the *inventory-first* and the *energy-first* approaches.

- The *inventory-first* approach takes the emission inventory as the starting point. 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.
- The *energy-first* approach can be used when energy accounts, or energy supply and use tables, measured in quantity units, are available. They can be used to transform 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.

The inventory-first method provides an easier bridging between inventory and accounts data, as shown in Box 1. Statistical discrepancies may occur between the UNFCCC inventories and the SEEA air emission accounts derived from the energy-first approach when different sets of energy data and emission factors are used. Another potential source of statistical differences is that national statistical offices are often compiling the emissions accounts while the environmental agencies are often responsible for producing the inventories.

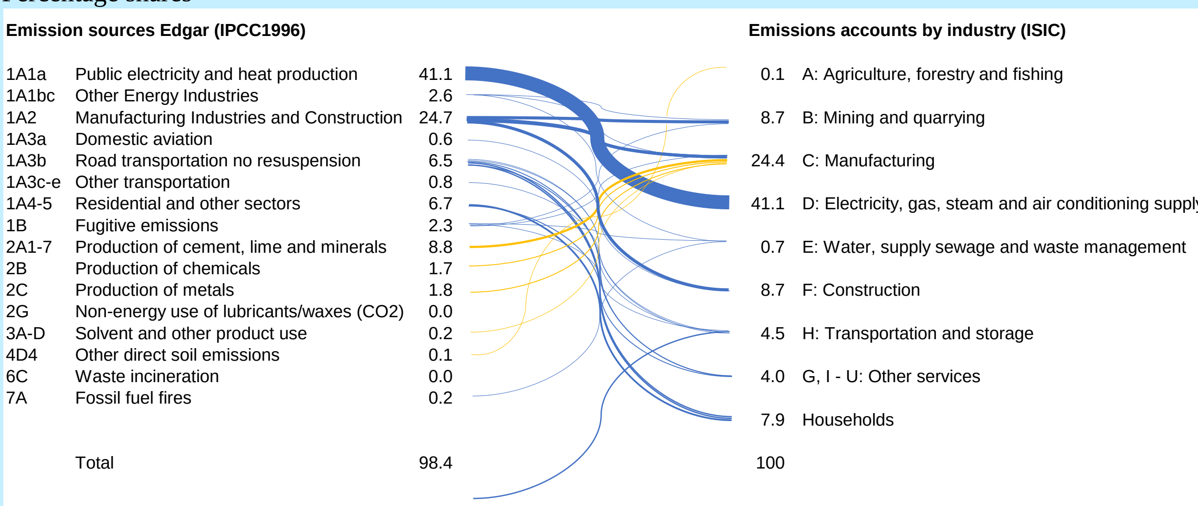
Despite the slight conceptual differences in terms of scope between the two frameworks, usually the majority of GHG emissions national totals are from resident units' activities on the territory of the respective country. However, especially for small economies, the emission-relevant activities of non-residents in the territory and the emission-relevant activities of residents abroad may be significant in relation to the national totals. Another difference is that the inventories also capture changes in carbon stocks originating from land use, land use change, and forestry (LULUCF), which are not included in the SEEA accounts.

Box 1
Assigning the CO2 emissions to industries and households, the example of China

For China, the EDGAR database is used to obtain the annual emissions data. Before starting the temporal disaggregation and compiling the quarterly estimates, the classification of emissions sources must be aligned to the industries and household as identified in the emissions accounts. The chart below visualizes how the two classifications of emissions sources in EDGAR on the left side, and activities (ISIC and households) on the right are matched.

The blue lines refer to emissions from fuel combustion. The orange lines refer to emissions from other processes such as production of cement and metals. The chart shows that the larger part of the CO2 emissions (84 percent) originates from fossil energy use. China is not unique in this respect in that for most countries fossil energy use is the largest contributor to GHG emissions.

Chart Box1
Conversion of CO2 emissions from EDGAR emissions sources to the ISIC industry classification, China, 2018
Percentage shares



Source: EDGAR, IMF estimates

Various methods can be applied to convert emission inventory-based data to an industry-based recording. Several but not all the mappings are one-to-one. Some of the emissions sources must be allocated to various industries. For example, transport is carried out by a wider range of activities than the transport sector alone. The IMF derived the concordance using Eurostat data, both the emissions inventories and the accounts for all EU member states. With the help of these two datasets, the likelihood of assigning (portions of) a certain source to a certain industry were analyzed. This information was used to compile a transformation matrix. The chart above shows that only a limited number of emission sources in this matrix are critical.

If the emissions from international bunkers (shipping and aviation) are added to the transportation sector (the lowest blue line not assigned to any of the EDGAR emissions sources for China), the air emissions accounts are 1.6 percent higher than the EDGAR data. In EDGAR, similarly to the UNFCCC inventories, the emissions from international bunkers are separately recorded as a memo item and are not included in the total country GHG emissions estimates. In the accounts, these emissions are assigned to individual countries based on information on the relative sizes of the transport industries.

Lastly, both frameworks report GHG emissions in metric tons of CO2-equivalents, which is the amount of CO2 emissions with the same global warming potential as one metric ton of another GHG.[7] For example, one metric ton of CH4 (methane) released has 25 times the global warming potential of carbon dioxide released in the atmosphere. Thus, one metric ton of CH4 is equivalent to 25 metric tons of CO2 equivalent.[8]

3. ESTIMATIONS - FROM ANNUAL TO QUARTERLY ACCOUNTS

Annual accounts

As the goal is to estimate timely GHG emissions consistent with GDP, the annual SEEA-based air emissions accounts serve as the annual target (benchmark) of the quarterly estimates. Since SEEA's endorsement by the United Nations Statistical Commission in 2012 (and in some cases prior to its endorsement) countries have been working to implement environmental accounts within their jurisdiction. The annual accounts are available for the EU Member States because it is obligatory to report them on an annual basis no later than 21 months after the reference year.[6] The harmonized EU reporting template provides detailed information on 64 NACE/ISIC activities and three household activities (heating/cooling, transport, and other). The air emissions accounts database on the IMF's CID includes the Eurostat collected data as well as air emissions accounts for 7 non-EU OECD economies (though not necessarily at the same level of detail as in the EU reporting template). Therefore, the data published on the IMF CID contains 34 country-reported SEEA-based annual air emissions accounts, mainly from advanced (European) economies.

For the countries that do not produce SEEA-based accounts, the annual data must be obtained from other sources. Where available, the priority is to use the country-reported UNFCCC inventory data (Annex I countries only) as the starting point.[9] The inventory data is the source for 10 countries in the dataset.[10] For the remaining economies, estimates are obtained from the Emissions Database for Global Atmospheric Research (EDGAR, Crippa et al., 2021) (188 economies in the dataset). As the inventories, the EDGAR database classifies GHG emissions by source, thus the EDGAR datasets must be mapped to the ISIC classification of economic activities. Overall, the annual dataset contains 232 economies (countries plus territories) which are used in calculating the world and regional (sub)aggregates by the IMF. Therefore, the 232

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[7] The Global Warming Potential (GWP) is the extent to which a gas contributes to the greenhouse effect. The IPCC prescribes which GWP should be used per gas. The IPCC Fourth Assessment Report recommends a GWP for CH4 equal to 25 while the Firth Report recommends a value of 28.

[8] https://www.c2es.org/content/global-stocktake-an-opportunity-for-ambition/
Global warming potentials as specified by the group of Party is available at: https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions#eq-10

[9] This is only for the Annex I countries. Non-Annex I country reported inventories, if available, are not incorporated into the dataset. The EDGAR dataset is used instead.

[10] Note that for Australia and Canada the inventories are the starting point as the SEEA accounts are only available at the level of GHG and do not provide information on the individual greenhouse gases.

economies included in the IMF dataset are the 193 UN member countries plus territories of countries separately identified in the EDGAR dataset.[11] As shown in Table 1, the largest number of economies is obtained from EDGAR

Table 1
IMF Annual Dataset Used to Construct World and Regional Aggregates

The UNFCCC Annex I data provides extensive details on the sources of GHG emissions generally allowing for a one-to-one correspondence to the ISIC classification at the level of detail at which the quarterly GHG estimates take place (discussed further below). However, in a few cases, assumptions are made about the mapping of the sources to industries or households. Data for Japan, Kazakhstan, Russia, Ukraine, and the United States use the OECD methodology and have been sourced from the OECD database. For the other UNFCCC Annex I countries, the IMF uses a similar but streamlined approach. For example, in the case of emissions from cars and motorcycles rather than trying to split this source, it is entirely mapped to households as most of these vehicles will be used for consumption purposes. Similarly, the other transportation sources (e.g., trucks, buses, domestic aviation) are mapped entirely to the transportation industry.

The EDGAR data, as publicly available, provides less detail on emission sources as compared to the UNFCCC Annex I dataset. For example, instead of a breakdown of emissions from cars, trucks, buses, etc., it contains a breakdown for road transportation. Consequently, more redistributions from EDGAR sources to ISIC sections are required. Such a method is expected to be less precise than a SEEA-based air emission account that would be compiled by the statisticians of national statistical offices.

Quarterly accounts

Since annual data on GHG emissions serve as a target, the quarterly estimation technique follows an approach that is commonly applied in the compilation of quarterly GDP statistics.[12] The basic principle of temporal disaggregation is to distribute the annual time series into quarterly values (backward series) and to extrapolate those quarters for which annual accounts are not yet available (forward series). Both steps, distribution and extrapolation, are performed with auxiliary information i.e., sub-annual "predictors" or "indicators" which are considered sufficiently suited to approximate the quarterly developments of GHG emissions.

The GHG emission accounts can best be described as a multi-dimensional data cube consisting of the following four dimensions: geography, GHG, activity (industries and households) and time. Since the level of detail by activity and GHG varies considerably across countries an

[11] For example, Puerto Rico and Guam are U.S. territories but their GHG emissions are separately recorded from the GHG emissions of the United States.

[12] For information of various temporal disaggregation techniques see the IMF's Quarterly National Accounts Manual (2017) and ESS Guidelines on Temporal Disaggregation, Benchmarking and Reconciliation (2018).

estimation plan is required to reduce all categories of these dimensions to a manageable number of time series for the quarterly estimation process.

Creating the quarterly estimation structure

The first step in developing an estimation plan is to identify the target variables, that is the level of detail for which quarterly GHG emissions accounts are estimated (estimation level). In the case of countries that regularly produce annual air emissions accounts, the annual level of detail varies. In the case of EU member states, the annual GHG emission accounts dataset contains 402 time series for each country (67 economic activities * 6 GHGs). When the level of detail is significant it is practical to identify a more aggregated estimation structure for the quarterly estimates. Several considerations are relevant to determine the estimation level: (i) identify the economic activities that contributed most significantly to air emissions; (ii) consider the range of sub-annual predictors available in a timely manner (i.e., less than 90 days after the reference quarter); and (iii) review the level of detail for which the results will be disseminated (dissemination level).

Since CO2 emissions make-up the bulk of GHG emissions, a particular focus has been placed on estimating CO2 emissions at a more detailed estimation level by industry. For example, if annual GHG emissions data for the manufacture of other non-metallic mineral products (ISIC division 23, which includes cement manufacturing) and manufacture of basic metals (ISIC divisions 24 which includes steel manufacturing) are available as well as sub-annual data (e.g., index of industrial production) then the estimation of quarterly GHG emissions is performed at this level of detail.

For the countries that do not produce annual air emission accounts at the minimum required breakdown for the estimation plan, the UNFCCC and EDGAR data are converted into air emission accounts as described above. Since the available level of detail varies widely across countries, the publication level of economic activities at the quarterly frequency follows the countries with the lowest level of detail.

Review of monthly and quarterly data

The Task Team began by reviewing international organizations’ databases for possible indicators. This was done to reduce the burden of new data collections on authorities and to ensure widespread country coverage utilizing similar concepts, classifications, and data formats. In some limited cases, given a country’s importance in contributing to GHG emissions, certain sub-annual data are sourced directly from individual country's websites (e.g., sub-annual data obtained for the United States).

Two approaches were considered for selecting indicators: (i) a qualitative approach utilizing assumptions on the relationship between the sub-annual data and the annual target; and (ii) a purely statistical approach that considers all sub-annual input data provided for a particular economy and picks the "best" predictor utilizing correlations.

Preferably, both the qualitative and quantitative characteristics of sub-annual indicators should be assessed when setting up the temporal disaggregation model. The qualitative dimension refers to the existence of a plausible relationship between the estimated variable and its predictor. For instance, predicting the cluster of CO2 emissions from combustion is likely to be construed in accordance with fossil energy use data. The quantitative dimension refers to their correlation with the annual target.

The rationale for thoroughly checking statistical correlations is twofold. First, the basket of predictors is in many cases sparsely filled, especially for less advanced statistical systems. If so, a selection based on the best possible correlation seems reasonable. Second, temporal disaggregation requires a certain level of correlation between the annual and quarterly series in order to generate acceptable results.

Indicators are needed when the quarterly emission estimates are usually not readily available. The set of data available to produce quarterly GHG emission accounts is limited compared to the annual dataset. Annual emission statistics may be based on directly observed emissions and supplemented by the emissions from smaller sources calculated from detailed energy statistics. These data will usually not be available in full detail at a sub-annual level.

As soon as the annual accounts become available, the previously compiled quarterly accounts will be made consistent with the annual estimates. Revisions of the quarterly GHG emissions accounts vis-à-vis the annual accounts should preferably be small and unbiased. They should also be carefully examined to evaluate the validity of the quarterly estimation process and to readjust the measurement process where needed.

When defining an estimation plan and executing the estimations, Eurostat and the IMF follow a slightly different path mainly due to the availability of data and the larger set of economies that the IMF estimates (Eurostat covers 27 countries, while the IMF approach aims for global coverage). Both approaches are discussed in more detail below.

The Eurostat quarterly estimation process

Eurostat condenses down the annual level of detail for the quarterly estimation process, which consists of 46 time series (NACE/ISIC industries and household activities by gas combinations) and, for the majority, applies a standard method to produce quarterly GHG emissions estimates. Table 2 provides detailed information on the predictor variables identified for the standard method cases. Annex 1 shows Eurostat’s estimation level.

Table 2
Eurostat's list of sub-annual predictors for the standard method cases

The standard method essentially utilizes the sub-annual indicators to temporally disaggregate the annual target and then extrapolate the most recent quarters for which the annual estimate is not yet available all in one estimation procedure. The standard methods include two techniques:

- The ‘Denton proportional first difference variant method’ aims at minimizing changes in the sub-annual series, while ensuring that the benchmarking constraint (i.e., the sum of the four quarters is equal to the annual value) is being respected (cf. Eurostat 2013, 2018).
- Otherwise, static regression methods are used such as Chow-Lin, Fernandez and Litterman (idem).

The selection of which technique to utilize was based on the (i) the plausibility of the quarterly estimates as computed by each of these techniques; and (ii) the quality of forecasts by assessing simulated historical annual emissions accounts with the published time series. In general, the Denton method is the default method used by Eurostat.[13] The calculations are performed at the EU country level. The EU aggregate is calculated as the sum of 27 EU member states.

Although ideally the sub-annual predictors should as closely as possible predict the quarterly trends in emissions, the following should be considered. First, quarterly trends in GHG emissions data are not necessarily known. This makes it difficult to assess the prediction strength of potential predictors. Its prediction power can only be assessed based on annual correlations. Second, the basket of available sub-annual predictors is rather limited. Therefore, Eurostat decided to select the sub-annual predictors mainly based on their alleged causality with the respective emission sources. Eurostat's assignment of predictors to the 46 time-series is presented in Annex 2.

For a few target variables, predictors cannot be readily selected either due to the specific temporal trends as observed for the target variable, or because of the unavailability of suitable predictors. For those variables several specific estimation methods are put in place.

Methane emissions from waste management

In the EU, methane (CH4) emissions from waste management show a stable downward trend over the years and it seems reasonable to simply extrapolate this trend. These entries in the annual air emissions accounts are temporally disaggregated by using the Boot, Feibes and Lisman (1967) method.[14] In other words, it is assumed that for this series any quarterly pattern is non-existent. The quarters beyond the available annual air emissions accounts (forward quarterly series) are estimated by a weighted moving-average of the three latest quarterly observations.

Emissions of methane and nitrous oxide from agriculture

No suitable sub-annual predictor could be identified for the *emissions of methane (CH4) and nitrous oxide (N2O) from agriculture.* When annual data are not yet available the annual emissions are extrapolated using annual rates of change for livestock. The Boot, Feibes and Lisman technique is applied to temporally disaggregate the annual emissions.

Emissions of carbon dioxide from air transport

For the emissions of CO2 from air transport, the Denton method is applied. But the quarterly time series of the predictor is manually composed by using the following two data sources:

- For the period 2010-2018, the annual air emissions accounts whereby the annual estimate is simply divided by four quarters of equal size.

[13] For more information on the method see Eurostat's Estimates of Quarterly Greenhouse Gas Emissions Accounts Methodological Note.

[14] The Boot, Feibes and Lisman (1967) method corresponds to Denton's proportional first variant method with a constant as a predictor (IMF 2017).

- From 2019 onward the monthly OECD data on CO2-emissions by air transport (discussed later in the chapter) are aggregated to quarterly time series.

Emissions of carbon dioxide from water transport

Unlike other time series in the estimation plan, *emissions of CO2 from water transport* do not have a country-specific predictor. Instead, the EU aggregate for fuel delivered to international marine bunkers is used and is expected to reflect the overall activity levels of marine transport in European seaports.

Eurostat Aggregation for dissemination

The quarterly accounts are compiled for each EU member state according to the method explained above. In each quarterly estimation cycle, the complete time series starting from 2010-Q1 is re-calculated and is therefore subject to revision. The data are not seasonally adjusted.

The results are then aggregated for dissemination. First, the various GHGs, expressed in CO2-equivalents, are summed-up to a total GHG aggregate. Second, the EU aggregate is calculated bottom-up from the quarterly accounts of the 27 EU member states. Third, the estimation level of detail (i.e., the 46 timeseries) are aggregated to 9 groupings of economic activities (8 industries and total activities by households). The 9 groupings are disseminated for the EU total (Annex 3). Only total GHG emissions are published at the country level.

The IMF quarterly estimation process

The IMF quarterly measurement system for non-EU countries must be sufficiently flexible to adapt to the specific data structures of individual countries as well as handling a variety of large datasets with wide country coverage. Given the goal of producing the estimates within 4-5 months after the reference quarter the IMF estimation process is more general in scope and less able to deal with specific estimation issues as discussed in the Eurostat estimation process.

One of the benefits of the IMF constructing the annual air emission accounts is that a uniform classification structure can be applied for this set of economies, facilitating the estimation process. For those non-EU economies producing annual air emission accounts, the first step is to create a common structure for which the quarterly estimation process is performed. In other words, loading the annual accounts and the sub-annual predictors into the compilation system requires careful database management in terms of data consistency, aligning variations in data frequency (months, quarters, years), structure (a variety of classifications), and content. Therefore, the IMF does not release country level data at this point and restricts the release to regional and global aggregates.

The IMF estimation process uses similar source data to what is described above for Eurostat. The sub-annual datasets used by the IMF for the quarterly estimates are (details are in Annex 4):

- Energy statistics and heating degree days (IEA, monthly).
- Gross value added in constant prices (IMF and OECD, quarterly).
- Index of industrial production (UNIDO, quarterly; IMF and Australian Bureau of Statistics, monthly).

- Data for the US on carbon dioxide emissions (EIA, monthly), on value added by industry (BEA, quarterly), on construction spending (Census Bureau, monthly) and on meat production (USDA, quarterly).
- External Trade (IMF and WTO, monthly).
- Transportation data (OECD, quarterly).
- Labor Force (IMF, monthly).

Table 3 shows the use of the sub-annual predictors by region and their contribution to the aggregate for the quarterly GHG emissions. The first point to note is the lack of energy statistics for certain (sub)regions of the world, such as in Africa or parts of Asia. Such data are important for monitoring the transitions to a carbon neutral world. This lack of availability of sub-annual source data is one of the reasons why monthly and quarterly indexes of industrial production (or sometimes gross value added) are the only source used in estimating the quarterly GHG emissions for some regions.

Table 3
Sub-annual predictors by region for the 110 economies used in the quarterly estimation

These sub-annual datasets do not provide world coverage. While the IMF utilizes 232 economies for constructing the annual world GHG emissions aggregate, the quarterly air accounts estimates are available for only 110 economies, including the 27 EU countries. These 110 economies represent 92 percent of the world total of GHG emissions. Countries omitting quarterly estimates are imputed using the regional averages estimates using countries for which quarterly data exist.

As with the Eurostat method, the IMF's estimation plan follows a clustering of activities and gases. It targets the breakdown by industries and households taking into consideration the relevance and availability of sub-annual predictors. The plan has three country groupings that divides countries based on the availability of source data and the structure of their annual air emission accounts. Annex 5 provides a discussion of the estimation structure.

Sub-annual data are seasonally adjusted, either by the source or, if not, by the IMF. Compared to the Eurostat method, this is a significant methodological difference. By assuring that all predictors are seasonally adjusted, the quarterly emissions accounts as estimated by the IMF are seasonally adjusted as well. One important argument to seasonally adjust predictors prior to their use is that their quarterly patterns may not necessarily correspond to the quarterly patterns of emissions (further pros and cons of seasonal adjustment are discussed later in this chapter).

Most of the selections of quarterly predictors are based on the highest time series correlations. So, while the Eurostat method follows mostly a predetermined selection of predictors, the IMF method selects for each quarterly estimate the best performing predictors based on historical correlations while checking the plausibility of the results. Annex 6 shows the results of analysis. Annex 7 provides a flowchart of the steps in the estimation process.

Box 2 provides a first impression of how well the IMF estimation process performs when compared to the quarterly estimates as published by the statistical offices.

Box 2
Comparing the IMF quarterly estimates with those published by Statistics New Zealand.

New Zealand is one of only a handful of countries that publish quarterly GHG emissions accounts. This provides the opportunity to compare the IMF methods and results with those published by Statistics New Zealand (Stats NZ).

The experimental quarterly account, as published by Stats NZ, uses annual estimates of emissions by industry and households and, using sub-annual data, provides more timely emissions estimates. The annual GHG emissions by industry and households account uses the latest New Zealand's GHG Inventory and a range of economic data sources to measure emissions form industry and households. Stats NZ's emissions accounts series are compiled using the SEEA.

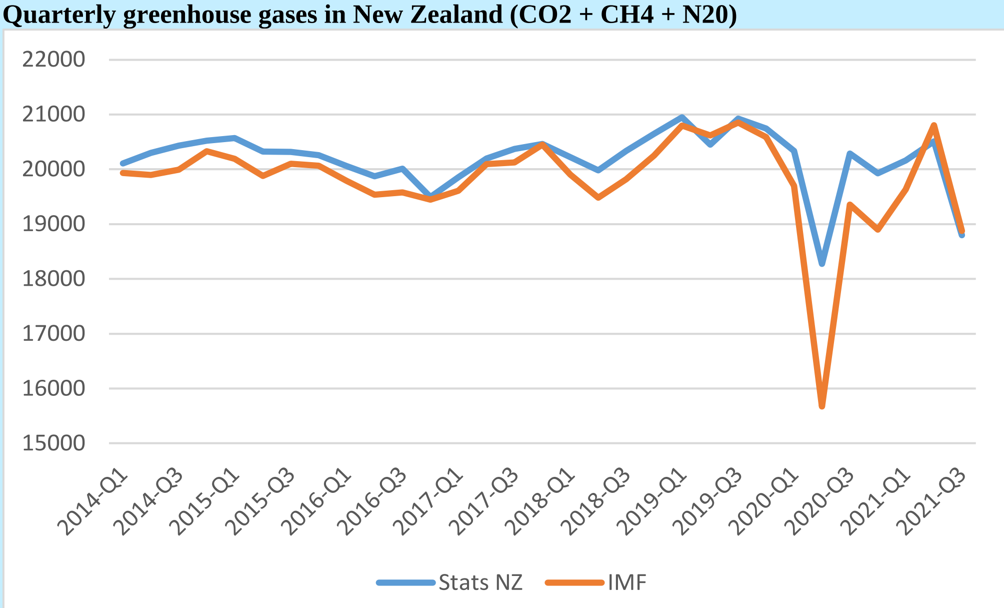
The experimental quarterly estimates are available for seven industry groups (which are aggregations of industries based on the Australian and New Zealand Standard Industrial Classification 2006), along with household direct emissions. The quarterly accounts cover CO2, CH4, N20, F-gases and the sum of these four gases based on CO2 equivalents.

The accounts are seasonally adjusted which allows for showing quarter-on-quarter movements. The accounts become available five months after the reference quarter.

The following data sources are used as input data: (1) annual GHG emissions, (2) quarterly energy statistics, (3) quarterly GDP, and (4) additional data sources including electricity use, card transaction data, prices, and transport statistics.

Chart Box2 shows that the IMF estimated quarterly GHG emissions approximates the quarterly movements as measured by Stats NZ quite well. However, during specific events such as the Covid lock down, the two estimates are less strongly correlated with the IMF projecting a much stronger decline than Statistics New Zealand.

Chart Box2
Quarterly greenhouse gases in New Zealand (CO2 + CH4 + N20)



Source: Statistics New Zealand, IMF estimates

IMF Aggregation for dissemination

Because the first and second group contains a highly aggregated estimation structure for certain GHGs, these quarterly emissions need to be broken down into more detail industries to facilitate aggregation by industry across all types of gas. Therefore, for the backward series, the allocation factor is the structure of annual air emissions accounts. For the forward series, the allocation factor is the structure of the latest available annual air emissions accounts.

The system generates results at various levels of aggregation: countries, (sub)regions and the world. The IMF disseminates data for 9 groupings of economic activities (8 industries and total activities by households), the same 9 groupings that Eurostat publishes. However, Eurostat disseminates total GHG emissions for the 9 groupings, while the IMF disseminates these 9 groupings by four types of GHGs (CO2, CH4, N2O and F-gases). Regional and subregional quarterly estimates are derived by aggregating the economies when there is full coverage of a (sub)region or benchmarking when there is not full coverage.

Seasonal adjustment and weather-related effects

Emissions may vary greatly over the seasons since demand for electricity and heating varies depending on temperature and weather. Furthermore, emissions may fluctuate from quarter to quarter based on the underlying fluctuations in the economy. The estimates produced by Eurostat for the EU aggregate clearly show a pattern of having higher emissions in the first and fourth quarters and lower emissions in the second and third (Chart 1). The question then becomes: should the GHG emissions be adjusted, and if so, how? Should the “standard” seasonal adjustment process typically done for economic statistics in order to see the most recent trend be utilized or should the emissions data be “weather adjusted” as is done by Statistics Netherlands when producing their quarterly CO2 emissions data?

Chart 1
EU GHG emissions - All activities and households

Seasonal adjustment aims to strengthen the interpretation of sub-annual statistics (quarterly, monthly, weekly, daily) by separating out individual elements contributing to the overall movement of the phenomenon under study. They hence reveal what is new in the time series. The seasonal patterns are often a dominant feature of sub-annual unadjusted data, masking the underlying signal. By removing seasonal patterns, seasonal adjustment not only permits the clear identification of the most recent trends but also allows doing so in as close to real-time as possible. In particular, the use of seasonally adjusted data allows for trend identification months in advance of the year-over-year change, which is the only possible comparison when using non-adjusted figures.

But the patterns seen in sub-annual data go beyond the seasonal variability of weather conditions. Three components in seasonality are typically identified: (i) weather-related; (ii) institutional; and (iii) calendar effects. The recurring weather effects due to the seasonal changes are well-known, reflecting the change in anthropomorphic activities resulting from recurring weather changes of the four seasons. The institutional component refers to statutory holidays or industry-specific norms, such as the effects of regular annual vacations and scheduled shutdowns may have on the data. The third component of seasonality, the calendar effect, results from months having different numbers of working weekdays, from one year to another.

The “standard” seasonal adjustment process will not exclude all weather-related effects. The seasonal adjustment process will only remove the predictable seasonal fluctuations from the unadjusted data, whereas any divergence from the normal seasonal fluctuations as part of the irregular component will still influence the seasonally adjusted data. Thus, seasonal adjustment will not eliminate the effects on energy consumption and emissions of prolonged heat waves or extremely cold winters. In other words, to isolate the long-term trends in GHG emissions, some statistical institutes have started implementing weather normalization.

While the seasonal adjustment process removes regular seasonal or calendar related fluctuations, the weather normalization additionally corrects for deviations from average conditions. As a result, weather normalization potentially provides a clearer indication of the underlying trends particularly in the case of air emissions data. The adjustment is motivated by the fact that any excesses in demand for electricity for heating and cooling (air conditioning) is likely to depend on deviations from normal weather conditions. These temperature fluctuations can have a significant impact on the seasonally adjusted emissions, since electricity generation and gas consumption represent a large portion of total greenhouse gas emissions. As a result, the introduction of the “temperature anomaly adjustment” has the potential to offer a better picture of the underlying trends in the emissions time series. For example, the Australian Department of Climate Change and Energy Efficiency, with the assistance of the “time series analysis section” of Australian Bureau of Statistics have so far implemented such a correction to Quarterly National Greenhouse Gas Inventory Data. It is worth noting that while seasonal adjustment does not affect the annual sum, weather normalization, as well as some calendar adjustments do.

Furthermore, while seasonal adjustment is well-established, particularly in economic time series, the weather normalization is a rather new concept which will require additional and thorough testing before it will have gained the level of experience like seasonal adjustment. There are ongoing discussions amongst the task team about what type of adjustments should be applied for producing the quarterly GHG emissions accounts. Furthermore, Eurostat intends to perform seasonal adjustment and disseminate as soon as the associated methodological issues are settled by the task team. This will further strengthen international cooperation as discussed in Section 5.

4. APPLICATIONS – TYING THE EMISSIONS ACCOUNTS TO ENERGY ACCOUNTS

Worldwide, CO2 emissions account for about 75 percent of all greenhouse gases and more than 85 percent of all CO2 emissions originate from the combustion of fossil fuel. Abating worldwide GHG by 50 percent in 2030 can probably not be done without limiting our consumption of fossil energy. Similarly, accounting for GHG emissions is impossible without a solid foundation of statistics on energy. Emission inventories and accounts both heavily rely on energy statistics, which implies monitoring GHG cannot be done without a proper collection of energy data. Energy statistics also help highlight critical developments in GHG emissions over time and provide policy leads on how to develop socially optimal emission abatement strategies.

In the examples below (Chart 2), annual emission statistics from EDGAR, energy statistics from the IEA[15] and GDP volume growth data as collected by the World Bank were brought together to quantify the dynamics in CO2 emissions over time. The IEA also publishes monthly energy statistics. However, the monthly data do not provide all details required for our analysis. The three datasets are brought together and used in a decomposition analysis in which the annual changes in emissions are broken down into four change components:[16]

- Those due to the changes in the *fossil fuel mix*. For example, when power plants replace coal by gas, this will lead to lower emissions.
- Changes in the *fossil energy share* in total energy use will also affect emissions. For example, the substitution of fossil energy for renewable energy will lead to lower emissions.
- Energy saving will lead to lower *energy intensities*. Obviously, lower energy use will lead to lower emissions.
- The final change component is *economic growth* as measured by real GDP change. When everything else is assumed unchanged, economic growth will lead to increased energy consumption and thus to rising greenhouse gas emissions.

Chart 2

Decomposition analyses of the annual changes in CO2 emissions from combustion

The green line displays the CO2 emissions from combustion over time. The bars show the cumulative changes over time as decomposed into each of the four change factors. There is a logical relationship between the two types of graphs. Looking at the global level:

Emissions from combustion in 1971	13 867
+ Cumulative increases: economic growth (■)	+ 32 510
− Cumulative decreases: fuel mix (■), fossil energy share (■), energy intensity (■)	− (830 + 4 094 + 8 735)
= Emissions from combustion in 2018	32 718

The four graphs in chart 2 show that, throughout the world, developments can be quite different. In China (1990-2018) the economic growth component substantially surpassed emission abatements, leading to an overall rise in CO2 emissions. An opposite development is noticeable in the UK where in the period 1971-2018 the effects of fuel mix, fossil energy share and energy intensity changes contributed each significantly to the overall downward trend in CO2 emissions.

[15] The IEA publication "World Energy Balances Highlights 2021" provides a full world coverage and includes the production and use data of 45 individual countries.

[16] Mark De Haan (2001) A Structural Decomposition Analysis of Pollution in the Netherlands, Economic Systems Research, 13:2, 181-196, DOI: 10.1080/09537320120052452.

At the world level, abatement measures have not been able to compensate even half the amount of emission increases resulting from economic growth.

Clearly, sub-annual (monthly) energy statistics already are an important subset of estimators in the quarterly emissions accounts as released by Eurostat and the IMF. Still, further research seems warranted to explore how sub-annual energy use as the dominant source of CO2 emissions can be introduced further into the quarterly measurement framework. One way to possibly do this is by using for the most critical energy consumers such as power plants fuel consumption as a predictor rather than an econometric selection of estimators. It may turn out that estimators selected via the strongest historic correlations may not necessarily be capturing or anticipating the most recent energy developments in upcoming energy transformation.

Obviously, another way forward may be refining or expanding the current use of fossil energy-based predictors. These represent the fossil energy used in electricity production and a country's total energy supply of oil and gas. The variable oil supply is quite aggregated in terms of the variety of oil products it represents. It needs to be determined whether more granular data (as far as available) would be adding news or noise to the quarterly GHG emissions accounts.

5. AVENUES FOR FUTURE WORK AND RESEARCH

The quality of the quarterly GHG accounts depend on the quality of the sub-annual data series that are used to construct the accounts. This paper has shown that it is possible to produce global and regional aggregate estimates for a handful of industries using publicly available data. National Authorities could build on this work by improving the quality of these estimates by using more precise and granular sub-annual indicators.

Strengthening international cooperation

National statistical offices (NSOs), especially those countries which are amongst the top 20 GHG emitters, could begin by adapting the IMF and Eurostat methods to their own circumstances. Techniques could be refined by taking advantage of more detailed source data, especially on energy statistics, that may be available at the individual country level. This may require capacity development. One way to create broader awareness of the need for timely GHG emissions statistics is to facilitate knowledge sharing in the form of workshops and courses. The IMF Statistics Department is in the process of designing a course on climate change statistics.

In the meantime, the international organizations will be further aligning their dissemination strategies. A 'three-stage rocket' strategy is foreseen in which Eurostat will release data for the EU countries, followed by the OECD for OECD countries, and then the IMF for the world and (sub)regional GHG emission accounts. The intent of this approach is that the OECD will directly adopt the results published by Eurostat while the IMF will do the same with respect to the OECD and Eurostat releases. This three-stage dissemination will guarantee that the three releases will not show any discrepancies.

Emissions from international transport at country level

The transformation of the annual UNFCCC and EDGAR data to emissions accounts requires two steps of which only one is currently put into practice. While the IMF method takes care of the transformation of the classification of emissions (from emission source to the SEEA-based recording of emissions by industries and households), the conversion does only partially and provisionally include the territory-resident adjustment explained earlier in this chapter.

The work recently carried out by the OECD on aviation is promising.[17] The OECD publishes a comprehensive monthly dataset about the CO2 emissions from aviation. Its main source is the International Civil Aviation Organisation (ICAO) which covers all commercial passenger and freight flights around the world. For each flight, this database includes information on the departure and arrival airports, the operating airline and the type of aircraft used. From 2019 onwards, the ICAO data source is an Automatic Dependent Surveillance- Broadcast (ADS-B) system and for years prior to 2019 the estimates are based on a database of scheduled flight information. The dataset includes comprehensive information on the emissions from domestic and international flights. In addition, it provides the breakdown of whether these flights are operated by resident or non-resident operators. In other words, at least for aviation, this is a valuable source to make the transition of a territory-based to a resident-related based recording of emissions. In addition, it is by itself a valuable source for the calculation of sub-annual CO2 emissions and in this capacity already used by Eurostat.

A similar dataset on international shipping is currently under construction by the OECD. It goes without saying that this would benefit the construction of GHG emissions accounts.

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TABLES

Table 1. IMF Annual Dataset Used to Construct World and Regional Aggregates

SEEA EU (27)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
SEEA Non-EU (7)	Colombia, Iceland, New Zealand, Norway, Switzerland, Turkey, United Kingdom
UNFCCC (10)	Australia, Belarus, Canada, Japan, Kazakhstan, Liechtenstein, Monaco, Russia, Ukraine, United States
EDGAR (188)	Remaining economies

Source: IMF

Table 2. Eurostat's list of sub-annual predictors for the standard method cases

Predictor label	Predictor code	Provider	Data set name	Data set code
Gross value added in agriculture, forestry and fishing	B1G_A	Eurostat	Gross value added and income A*10 industry breakdowns	namq_10_a10
Gross value added in industry	B1G_B-F	Eurostat	Gross value added and income A*10 industry breakdowns	namq_10_a10
Index of industrial production in other non-metallic mineral products	IIP_C23	UNIDO	UNIDO Quarterly Index of Industrial Production	quarterly_iip
Index of industrial production in basic metals	IIP_C24	UNIDO	UNIDO Quarterly Index of Industrial Production	quarterly_iip
Net electricity generation from combustible fuels	NELE_CF	Eurostat	Net electricity generation by type of fuel	nrg_cb_pem
Gross inland deliveries – observed - of motor gasoline and road diesel	GID_ROADFUEL	Eurostat	Supply and transformation of oil and petroleum products - monthly data	nrg_cb_oilm
International marine bunkers and final consumption transport sector of oil products (EU27 aggregate)	FUELGDOIL_INTMAR_EU	Eurostat	Supply and transformation of oil and petroleum products - monthly data	nrg_cb_oilm
CO2 emissions air transport	OECD_AIR	OECD	Air transport CO2 emissions	airtrans_CO2

Gross value added in service industries	B1G_G-U	Eurostat	Gross value added and income A*10 industry breakdowns	namq_10_a10
Heating degree days	HDD_IEA	IEA	Heating degree days (reference temperature 18°C and threshold temperature 15°C.	HDDThold18
Gross value added in all NACE activities (excl. NACE A)	B1G_TOTXA	Eurostat	Gross value added and income A*10 industry breakdowns	namq_10_a10
Index of turnover in wholesale and retail trade	TOVT_G	Eurostat	Turnover and volume of sales in wholesale and retail trade - quarterly data	sts_trtu_q
Gross domestic product at market prices, in current prices, million euro	GDP	Eurostat	GDP and main components (output, expenditure and income)	namq_10_gdp

Source: Eurostat's Estimates of Quarterly Greenhouse Gas Emissions Accounts

Table 3. Sub-annual predictors by region for the 110 economies used in the quarterly estimation

Percentage shares, average 2010 - 2020

Regions	**Crops &Livestock**	**Degree Day**	**Emissions**	**Energy**	**External Trade**	**Gross value added**	**Index of industrial production**	**Labor Force**	**Meat production**	**Transport**	**Grand Total**
Africa						0.02	4.53				4.55
Northern Africa							1.64				1.64
Sub-Saharan Africa						0.02	2.89				2.91
Americas			7.97	0.78	0.04	9.6	4.08	0.03	0.06	0.89	23.46
Latin America and the Caribbean				0.73	0.04	2.91	3.5	0.03		0.33	7.53
Northern America			7.97	0.06	0	6.69	0.59		0.06	0.56	15.93
Asia				16.36	0.93	3.89	32.35	0.3		0.75	54.57
Central Asia							0.7	0.16		0.34	1.21
Eastern Asia				13.73	0.85	0.1	20.67	0.01		0.21	35.57
South-eastern Asia						1.12	4.11	0.13			5.35
Southern Asia				2.32		1.45	5.4				9.17
Western Asia				0.3	0.07	1.23	1.47	0		0.2	3.27
Europe	0.01	0		4.08	0.04	2.66	7.47	0.48		1.26	16

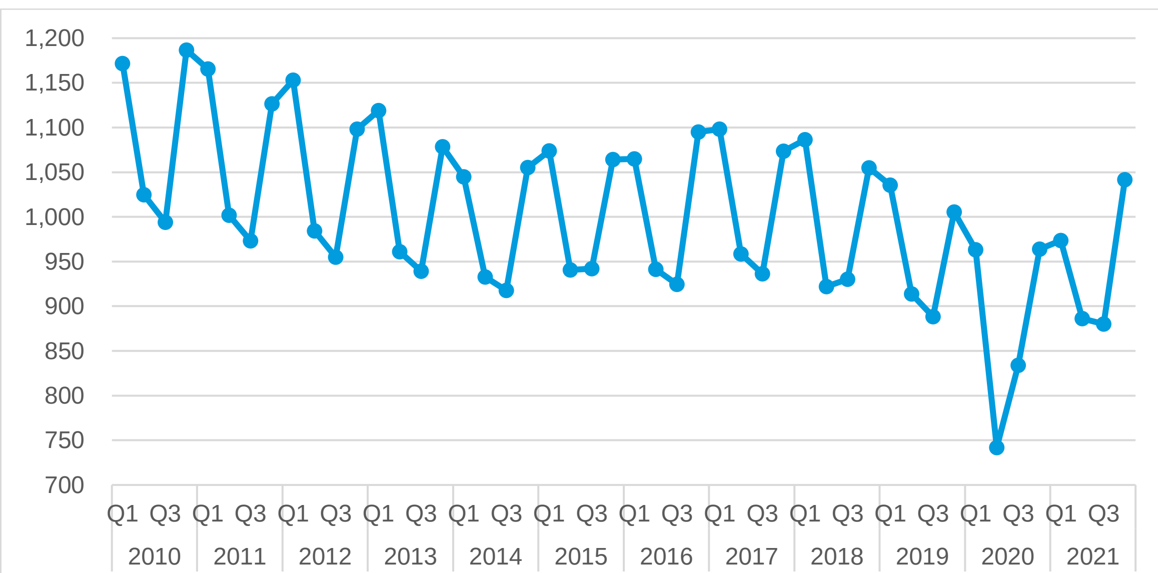
Eastern Europe				0.54		1.53	5	0.01		0.3	7.38
Northern Europe				0.47		0.44	0.6	0.43		0.28	2.22
Southern Europe		0		0.77	0	0.37	1.01	0		0.14	2.3
Western Europe	0.01			2.3	0.04	0.32	0.86	0.04		0.54	4.11
Oceania				0.03		0.69	0.7			0	1.42
Oceania sub-regions				0.03		0.69	0.7			0	1.42
Total	0.01	0	7.97	21.25	1.01	16.86	49.13	0.81	0.06	2.9	100

Source. IMF estimates.
Note: There could be differences between the Eurostat estimates and the IMF estimates due to the selection of different sub-annual predictor variables. In the future the IMF will simply take Eurostat's EU-27 estimates.

CHARTS

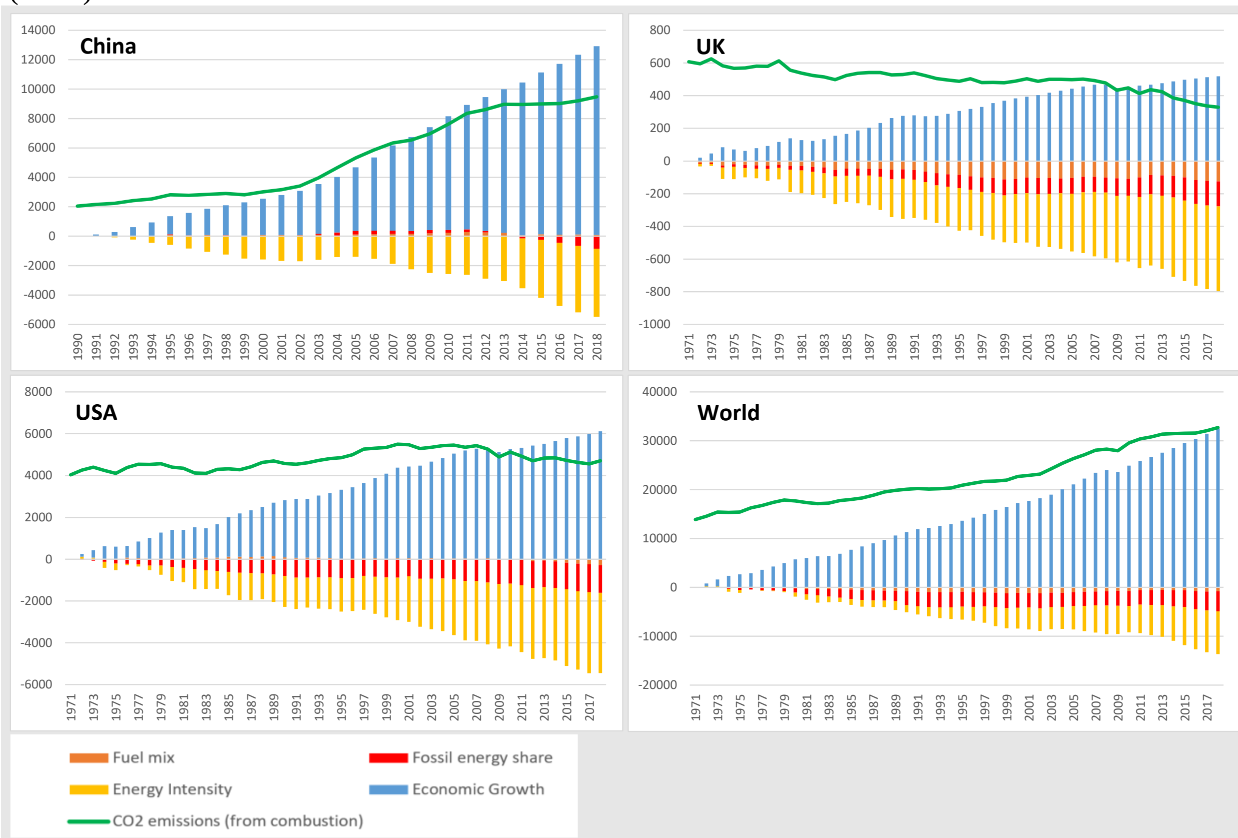
Chart 1. EU GHG emissions - All activities and households

Millions of tons of CO2 equivalents



Source: Eurostat.

Chart 2. Decomposition analyses of the annual changes in CO2 emissions from combustion (in Mt)



Source: EDGAR, IEA, World Bank.

ANNEX 1 – ESTIMATION PLAN OF EU MEMBER STATES, IMPLEMENTED IN FEBURARY 2022

		A	B	C	C23	C24	D	E	F	G	H49	H50	H51	H52	H53	I	J	K	L	M	N	O	P	Q	R	S	T	U	HH_HEAT	HH_TRA	HH_OTH	TOTAL_HH
1	CO2_A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	CH4_A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	N2O_A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	FGAS_A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	CO2_B	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	CH4_B	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	N2O_B	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	FGAS_B	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	CO2_C23	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	CO2_C24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	CO2_CXC23_C24	0	0	1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	CH4_C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	N2O_C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	FGAS_C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	CO2_D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	CH4_D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	N2O_D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	FGAS_D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	CO2_E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	CH4_E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	N2O_E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	FGAS_E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	CO2_F	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	CH4_F	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	N2O_F	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	FGAS_F	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	CO2_G	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	CH4_G	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	N2O_G	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	FGAS_G	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	CO2_H49	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	CO2_H50	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	CO2_H51	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	CO2_HXH49-H51	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	CH4_H	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	N2O_H	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	FGAS_H	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	CO2_I-U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
39	CH4_I-U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
40	N2O_I-U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
41	FGAS_I-U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
42	CO2_HH_TRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
43	CO2_HH_HEAT_OTH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
44	CH4_HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
45	N2O_HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
46	FGAS_HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0

ANNEX 2 –EUROSTAT'S ASSIGNMENT OF PREDICTORS

AEA data point of greenhouse gas emissions	Predictor code
Target	Predictor code
CO2_A	B1G_A
CH4_A	-
N2O_A	-
FGAS_A	namq_10_gdp
CO2_B	B1G_B-F
CH4_B	B1G_TOTXA
N2O_B	B1G_TOTXA
FGAS_B	namq_10_gdp
CO2_C23	IIP_C23
CO2_C24	IIP_C24
CO2_CXC23_C24	B1G_B-F
CH4_C	B1G_TOTXA
N2O_C	B1G_TOTXA
FGAS_C	namq_10_gdp
CO2_D	NELE_CF
CH4_D	B1G_TOTXA
N2O_D	B1G_TOTXA
FGAS_D	namq_10_gdp
CO2_E	B1G_B-F
CH4_E	-
N2O_E	B1G_TOTXA
FGAS_E	namq_10_gdp
CO2_F	B1G_B-F
CH4_F	B1G_TOTXA
N2O_F	B1G_TOTXA
FGAS_F	namq_10_gdp
CO2_G	B1G_G-U
CH4_G	B1G_TOTXA
N2O_G	B1G_TOTXA
FGAS_G	sts_trtu_q
CO2_H49	GID_ROADFUEL
CO2_H50	FUELGDOIL_INTMAR_EU
CO2_H51	AIRTRANS_CO2
CO2_HXH49-H51	B1G_G-U
CH4_H	B1G_TOTXA
N2O_H	B1G_TOTXA
FGAS_H	namq_10_gdp
CO2_I-U	B1G_G-U
CH4_I-U	B1G_G-U
N2O_I-U	B1G_G-U
FGAS_I-U	B1G_G-U
CO2_HH_TRA	GID_ROADFUEL
CO2_HH_HEAT_OTH	HDD_IEA
CH4_HH	B1G_TOTXA
N2O_HH	B1G_TOTXA
FGAS_HH	namq_10_gdp

ANNEX 3 – EUROSTAT DISSEMINATION LEVEL

NACE based classification of economic activities for which quarterly emissions (all GHG gases expressed as CO_2-equivalents) are presented, implemented in February 2022.

	NACE_R2 as in [env_ac_ainah]	A	B	C	D	E	F	G	H49	H50	H51	H52	H53	I	J	K	L	M	N	O	P	Q	R	S	T	U	HH_HEAT	HH_TRA	HH_OTH	TOTAL_HH
1	TOTAL_HH - All NACE activities plus households	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	A - Agriculture, forestry and fishing	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	B - Mining and quarrying	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	C - Manufacturing	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	D - Electricity, gas, steam and air conditioning supply	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	E - Water supply; sewerage, waste management and remediation activitie	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	F - Construction	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	H - Transportation and storage	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	G-U_X_H - Services (except transport and storage)	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
10	HH - Total activities by households	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0

ANNEX 4 – SUB-ANNUAL INDICATORS USED BY THE IMF IN TEMPORAL DISAGGREGATION OF THE ANNUAL AEA

Variable/Source/Frequency/Indicator	# Economies	# AEA	Emission Share to total of 110 countries (%)
Crops & Livestock			**0.01**
.. FAO			***0.01***
.... Annual			*0.01*
...... Annual Total Crops and livestock products-Rice, paddy Distributed with Denton	1	1	0.01
Degree Day			**0**
.. IEA			***0***
.... Monthly			*0*
...... IEA Heating degree days (18C or 65F)	1	1	0
Emissions			**7.97**
.. USA			***7.97***
.... Monthly			*7.97*
...... Coal Electric Power Sector CO2 Emissions	1	1	0.06
...... Distillate Fuel Oil Industrial Sector CO2 Emissions	1	1	0
...... HGL Transportation Sector CO2 Emissions	1	1	0.04
...... Natural Gas, Excluding Supplemental Gaseous Fuels, Residential Sector CO2 Emissions	1	1	0.01
...... Petroleum, Excluding Biofuels, Industrial Sector CO2 Emissions	1	1	0.02
...... Total Energy Commercial Sector CO2 Emissions	1	1	4.22
...... Total Energy Transportation Sector CO2 Emissions	1	1	1.38
...... Transportation Share of Electric Power Sector CO2 Emissions	1	1	2.24
Energy			**21.25**
.. IEA			***21.25***
.... Monthly			*21.25*
...... Coal, Peat and Manufactured Gases_Net Electricity Production	12	12	1.7

...... Combustible Renewables_Net Electricity Production	9	11	0.25
...... Electricity_Distribution Losses	9	8	0.51
...... Electricity_Final Consumption (Calculated)	18	18	1.24
...... Electricity_Net Electricity Production	5	8	1.42
...... Electricity_Total Exports	5	6	0.04
...... Electricity_Total Imports	5	6	0.06
...... Electricity_Used for pumped storage	4	6	0.05
...... Geothermal_Net Electricity Production	2	2	0.01
...... Hydro_Net Electricity Production	10	14	0.56
...... Natural Gas_Net Electricity Production	15	14	0.3
...... Not Specified_Net Electricity Production	3	2	0.04
...... Nuclear_Net Electricity Production	3	5	0.04
...... Oil and Petroleum Products_Net Electricity Production	13	6	1.48
...... Oil.Oil	1	1	0.01
...... Other Combustible Non-Renewables_Net Electricity Production	8	7	0.09
...... Other Renewables_Net Electricity Production	1	1	0.03
...... Solar_Net Electricity Production	7	9	0.04
...... Total Combustible Fuels_Net Electricity Production	14	6	13.21
...... Total Renewables (Geo, Solar, Wind, Other)_Net Electricity Production	5	6	0.06
...... Wind_Net Electricity Production	7	7	0.09
External Trade			**1.01**
.. WTO			***1.01***
.... Monthly			*1.01*
...... WTO_M_Goods_Vol_Index__Merchandise import volume indices - quarterly Total merchandise-WTO	4	29	0.89
...... WTO_X_Goods_Vol_Index__Merchandise export volume indices - quarterly Total merchandise-WTO	3	3	0.12
Gross value added			**16.86**
.. IFS			***6.71***
.... Quarterly			*6.71*
...... Gross Value Added, Real, By ISIC Rev. 4, Accomodation and Food Service, Seasonally Adjusted, Domestic Currency	2	14	0.06
...... Gross Value Added, Real, By ISIC Rev. 4, Administrative and Support Service, Seasonally Adjusted, Domestic Currency	3	3	0
...... Gross Value Added, Real, By ISIC Rev. 4, Agriculture, Forestry and Fishing, Seasonally Adjusted, Domestic Currency	19	15	0.47
...... Gross Value Added, Real, By ISIC Rev. 4, Arts, Entertainment and Recreation, Seasonally Adjusted, Domestic Currency	2	3	0.03
...... Gross Value Added, Real, By ISIC Rev. 4, Business services, Seasonally Adjusted, Domestic Currency	1	2	0
...... Gross Value Added, Real, By ISIC Rev. 4, Construction, Seasonally Adjusted, Domestic Currency	7	12	0.26

...... Gross Value Added, Real, By ISIC Rev. 4, Education, human health and social work, Seasonally Adjusted, Domestic Currency	1	1	0
...... Gross Value Added, Real, By ISIC Rev. 4, Education, Seasonally Adjusted, Domestic Currency	2	8	0.02
...... Gross Value Added, Real, By ISIC Rev. 4, Electricity, gas, steam and air conditioning supply, Seasonally Adjusted, Domestic Currency	3	9	0.31
...... Gross Value Added, Real, By ISIC Rev. 4, Financial and Insurance Activities, Seasonally Adjusted, Domestic Currency	12	20	0.33
...... Gross Value Added, Real, By ISIC Rev. 4, Industry and Construction,Seasonally Adjusted, Domestic Currency	5	5	0.02
...... Gross Value Added, Real, By ISIC Rev. 4, Information and Communication, Seasonally Adjusted, Domestic Currency	13	21	0.52
...... Gross Value Added, Real, By ISIC Rev. 4, Manufacturing, Seasonally Adjusted, Domestic Currency	10	12	0.09
...... Gross Value Added, Real, By ISIC Rev. 4, Mining and quarrying, Seasonally Adjusted, Domestic Currency	3	15	0.24
...... Gross Value Added, Real, By ISIC Rev. 4, Other Service Activities, Seasonally Adjusted, Domestic Currency	1	1	0.07
...... Gross Value Added, Real, By ISIC Rev. 4, Other services, Seasonally Adjusted, Domestic Currency	9	11	2.23
...... Gross Value Added, Real, By ISIC Rev. 4, Professional, Scientific and Technical Activities, Seasonally Adjusted, Domestic Currency	3	5	0.01
...... Gross Value Added, Real, By ISIC Rev. 4, Public administration and defence; compulsory social security, Seasonally Adjusted, Domestic Currency	2	4	0.04
...... Gross Value Added, Real, By ISIC Rev. 4, Real Estate Activities, Seasonally Adjusted, Domestic Currency	9	8	0.28
...... Gross Value Added, Real, By ISIC Rev. 4, Trade, transport, accommodation and food, Seasonally Adjusted, Domestic Currency	5	7	0.05
...... Gross Value Added, Real, By ISIC Rev. 4, Transportation and Storage, Seasonally Adjusted, Domestic Currency	3	6	0.01
...... Gross Value Added, Real, By ISIC Rev. 4, Water supply; sewerage, waste management and remediation activities, Seasonally Adjusted, Domestic Currency-I	1	4	0
...... Gross Value Added, Real, By ISIC Rev. 4, Wholesale and retail trade; repair of motor vehicles and motorcycles, Seasonally Adjusted, Domestic Currency-	2	4	0.11
...... IFS_Real_GDP	17	32	1.56
.. OECD			***3.93***
.... Quarterly			*3.93*
...... A: Agriculture, forestry and fishing	5	4	0.24
...... B: Mining and quarrying + C: Manufacturing + D: Electricity, gas, steam and air conditioning supply + E: Water supply; sewerage, waste management and remediation activities	2	2	0.03
...... B1GVTotal	6	9	0.42
...... B1GVTotal_ex_A	4	3	0.31
...... C: Manufacturing	2	2	0.01

...... F: Construction	6	8	0.03
...... G: Wholesale and retail trade; repair of motor vehicles and motorcycles + H: Transportation and storage + I: Accommodation and food service activities	4	4	0.27
...... G_U: Services	3	2	0.04
...... J: Information and communication	4	4	0.06
...... K: Financial and insurance activities	3	4	0.03
...... L: Real estate activities	4	4	0.05
...... M: Professional, scientific and technical activities + N: Administrative and support service activities	8	8	0.27
...... O: Public administration and defence; compulsory social security + P: Education + Q: Human health and social work activities	6	8	1.43
...... 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 organisations and bodies	11	15	0.74
.. USA			***6.21***
.... Quarterly			*6.21*
...... Ambulatory health care services	1	1	0.01
...... Amusements, gambling, and recreation industries	1	1	0.04
...... Broadcasting and telecommunications	1	1	0.16
...... Construction	1	2	0.52
...... Finance, insurance, real estate, rental, and leasing	1	1	0.12
...... Health care and social assistance	1	1	0.54
...... Machinery	1	2	0.25
...... Motor vehicles, bodies and trailers, and parts	1	1	0.02
...... Oil and gas extraction	1	1	0.03
...... Real estate and rental and leasing	1	1	1.87
...... Social assistance	1	1	0.28
...... State and local_Private goods-producing industries1	1	2	2.03
...... Support activities for mining	1	1	0.36
Index of industrial production			**49.13**
.. ABS			***0.49***
.... Monthly			*0.49*
...... Electricity, gas, water and waste services (D);	1	2	0.48
...... Manufacturing (C); Food, beverage and tobacco products;	1	1	0
...... Manufacturing (C); Machinery and equipment;	1	1	0
.. IFS			***5.78***
.... Monthly			*5.78*
...... IFS_IPI	10	31	0.8
...... IFS_IPI_Const	13	16	0.16
...... IFS_IPI_Energy_Elec	16	24	2.56

...... IFS_IPI_Manufacturing	22	31	1.76
...... IFS_IPI_Mining	9	26	0.5
.. UNIDO			***42.87***
.... Quarterly			*42.87*
...... B_Mining and quarrying	30	32	1.36
...... C_Ex.C22-C24Total manufacturing	12	16	0.17
...... C_Ex.C23-C24Total manufacturing	17	18	0.75
...... C_Total manufacturing	28	29	2.7
...... C10_Food products	18	25	0.97
...... C11_Beverages	16	23	0.43
...... C12_Tobacco products	18	28	6.2
...... C13_Textiles	20	28	0.83
...... C14_Wearing apparel	14	22	0.32
...... C15_Leather and related products	25	29	3.39
...... C16_Wood products, excluding furniture	19	27	1.3
...... C17_Paper and paper products	18	24	1.08
...... C18_Printing and reproduction of recorded media	24	26	0.64
...... C19_Coke and refined petroleum products	23	32	1.69
...... C20_Chemicals and chemical products	26	24	0.5
...... C21_Pharmaceuticals,medicinal chemicals, etc.	23	25	0.72
...... C22_C24 Rubber, plastics others metallic and non metallic, and basic metal products	13	16	0.45
...... C22_Rubber and plastics products	12	18	0.5
...... C23_C24 others non metallic products and basic metals products	22	24	3.35
...... C23_Other non	28	27	0.52
...... C24_Basic metals	24	27	2.29
...... C25_Fabricated metal products, except machinery	10	13	0.31
...... C26_Computer, electronic and optical products	14	22	1.13
...... C27_Electrical equipment	21	23	1.36
...... C28_Machinery and equipment n.e.c.	16	18	7.46
...... C29_Motor vehicles, trailers and semi	16	27	0.91
...... C30_Other transport equipment	13	23	0.57
...... C31_Furniture	18	17	0.22
...... C32_Other manufacturing	21	26	0.48
...... C33_Repair and installation of machinery/equipment	8	10	0.28
Labor Force			**0.81**
.. IFS			***0.81***
.... Monthly			*0.81*
...... IFS_Labor_Force_NUM	19	34	0.81
Meat			**0.06**

.. USA			***0.06***
.... Quarterly			*0.06*
...... Exports-WASDE_LambMutton	1	1	0.06
Transportation			**2.9**
.. OECD			***2.9***
.... Quarterly			*2.9*
...... First registrations of brand new passenger cars	8	21	0.43
...... Total inland waterways freight transport	3	4	0
...... Total motor fuel deliveries to the road sector	14	20	0.99
...... Total rail freight transport	12	17	0.42
...... Total rail passenger transport	24	17	0.9
...... Total road freight transport	6	8	0.15
...... Total road motor vehicle traffic	4	6	0.01

ANNEX 5 –IMF ESTIMATION PLAN

The IMF’s estimation plan divides economies in 3 groupings based on the availability of source data and the structure of the annual air emission accounts.

The first group is more aggregated than the Eurostat mapping as outlined above and is presented in Table A5.1. It consists of 17 clusters including 10 activities for breaking down the CO2 emissions, three activities for CH4 and two activities for N2O and F-Gases. It specifically addresses the contributions of potentially high pollutive activities such as manufacture of non-metallic mineral products (including cement production), basic metals (including steel production) and three types of transport. Currently the first group contains 31 economies.

The second group applies to three economies (Colombia, New Zealand and Turkey) with reasonably detailed sub-annual datasets but not sufficient to meet the first group’s estimation structure. It includes 15 clusters similar to the first group except for transportation which is combined in a single category (Table A5.2).

The third group represents those economies with limited sub-annual data availability. Its estimation plan consists of 34 clusters whereby CO2, CH4, N20 are broken down for 10 activities and F-gases are broken into 4 activities (Table A5.3). The third group is the largest, existing of 76 economies. Although this clustering includes more categories, it lacks detail on the specific industries and households as targeted in the first and second groups. For ease of processing, no further aggregation was performed on the structure of the original annual data, which is similar to the level of detail in which the data are disseminated.

Table A5.1 – IMF Estimation plan for the first Group

Code	Description	FGAS	CH4	N2O	CO2
Total Ind + HH ex. A and E	Total Ind + HH ex. A and E		X		
IND-HH ex A	Total excluding A			X	
IND-HH ex G	Total excluding G	X			
A	Agriculture, forestry and fishing		X	X	X
B C E F ex C23 C24	Mining, Manufacturing, Water and Waste, Construction excl. non-metallic mineral products and basic metals				X
C23	Manufacture of other non-metallic mineral products				X
C24	Manufacture of basic metals				X
D	Electricity, gas, steam and air conditioning supply				X
E	Water supply; sewerage, waste management and remediation activities		X		
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	X			
ROAD	H49 + HH trans				X
H50	Water transport				X
H51	Air transport				X
SERVICES G H52 H53 I-U	Other services excl. Transport				X
HH HEAT OTH	Household excl. Transport				X

Table A5.2 – IMF estimation plan for the second Group

Code	Description	FGAS	N2O	CH4	CO2
Total Ind + HH ex. A and E	Total Ind + HH ex. A and E		X		
IND-HH ex A	Total excluding A			X	
IND-HH ex G	Total excluding G	X			
A	Agriculture, forestry and fishing		X	X	X

B_C_E_F_ex_C24-C25	Mining, Manufacturing, Water and Waste, Construction excl. non-metallic mineral products basic metals and metal products				X
C24-C25	Manufacture of basic metals and fabricated metal products, except machinery and equipment				X
D	Electricity, gas, steam and air conditioning supply				X
E	Water supply; sewerage, waste management and remediation activities		X		
G	Wholesale and retail trade; repair of motor vehicles and motorcycles				X
H	Transportation and storage				X
I-U	Other services: I - U				X
IND-NS	Industries non specified				X
HH-TOTAL	Households				X

Table A5.3 – IMF estimation plan for the third Group

Code	**Description**	**CO2**	**CH4**	**N2O**	**FGAS**
A	Agriculture, forestry and fishing	X	X	X	
B	Mining and quarrying	X	X	X	
C	Manufacturing	X	X	X	X
D	Electricity, gas, steam and air conditioning supply	X	X	X	
E	Water supply; sewerage, waste management and remediation activities	X	X	X	
F	Construction	X	X	X	
SERVICES	Other services: G, I – U	X	X	X	X
H	Transportation and storage	X	X	X	X
IND-NS	Industries non specified	X	X	X	
HH-TOTAL	Households	X	X	X	X

ANNEX 6 – IMF MANUAL SELECTION OF INDICATORS

In the IMF approach, most of the selections of quarterly predictors are based on the highest time series correlations ('Un-prescriptive' category in the chart below).

In case of unexpected or unlikely results, some of the predictors or temporal disaggregation models may in a subsequent step be manually selected ('Prescriptive' category in the chart below). The graph below shows that the IMF hybrid strategy which matches prescribed and unprescribed mappings with suitable temporal disaggregation technique (the hybrid model uses Denton-Cholette and Chow-Lin) provides the lowest weighted mean absolute percentage error (MAPE). The calculation of the extrapolation error based only on total emissions will produce a lower figure but would mislead the analysis as errors might cancel out during the aggregation of gases, industries and countries. The MAPE uses a bottom-up approach from the estimation level (cluster) to the aggregation of country.

Chart A6.1 - 2018 weighted MAPE for temporal disaggregation model by indicator type and selection method

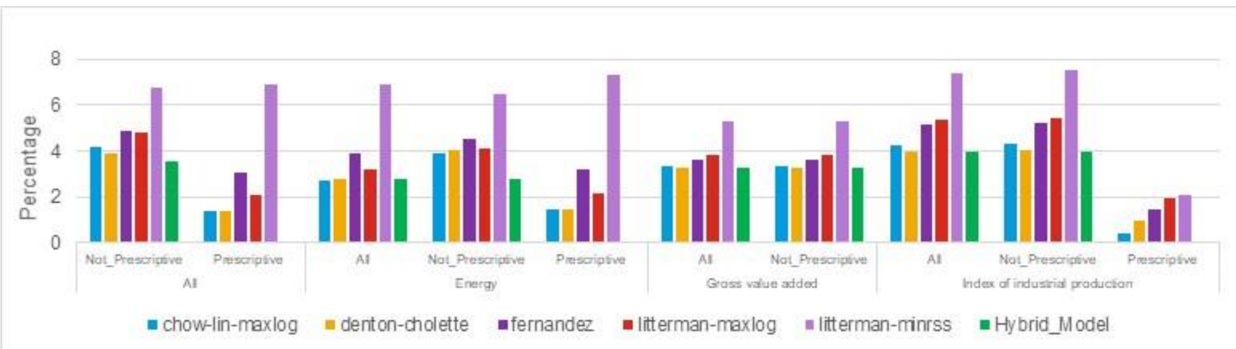
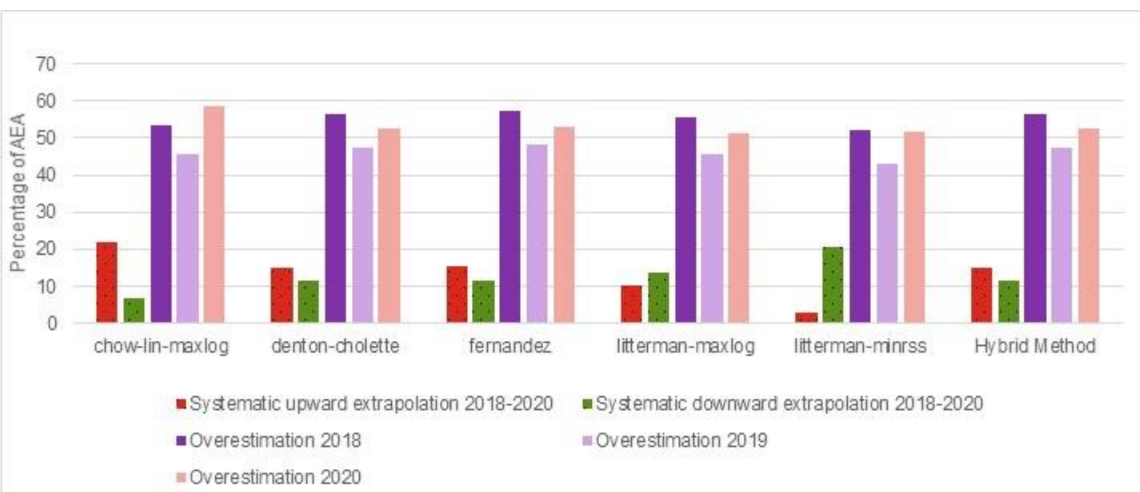
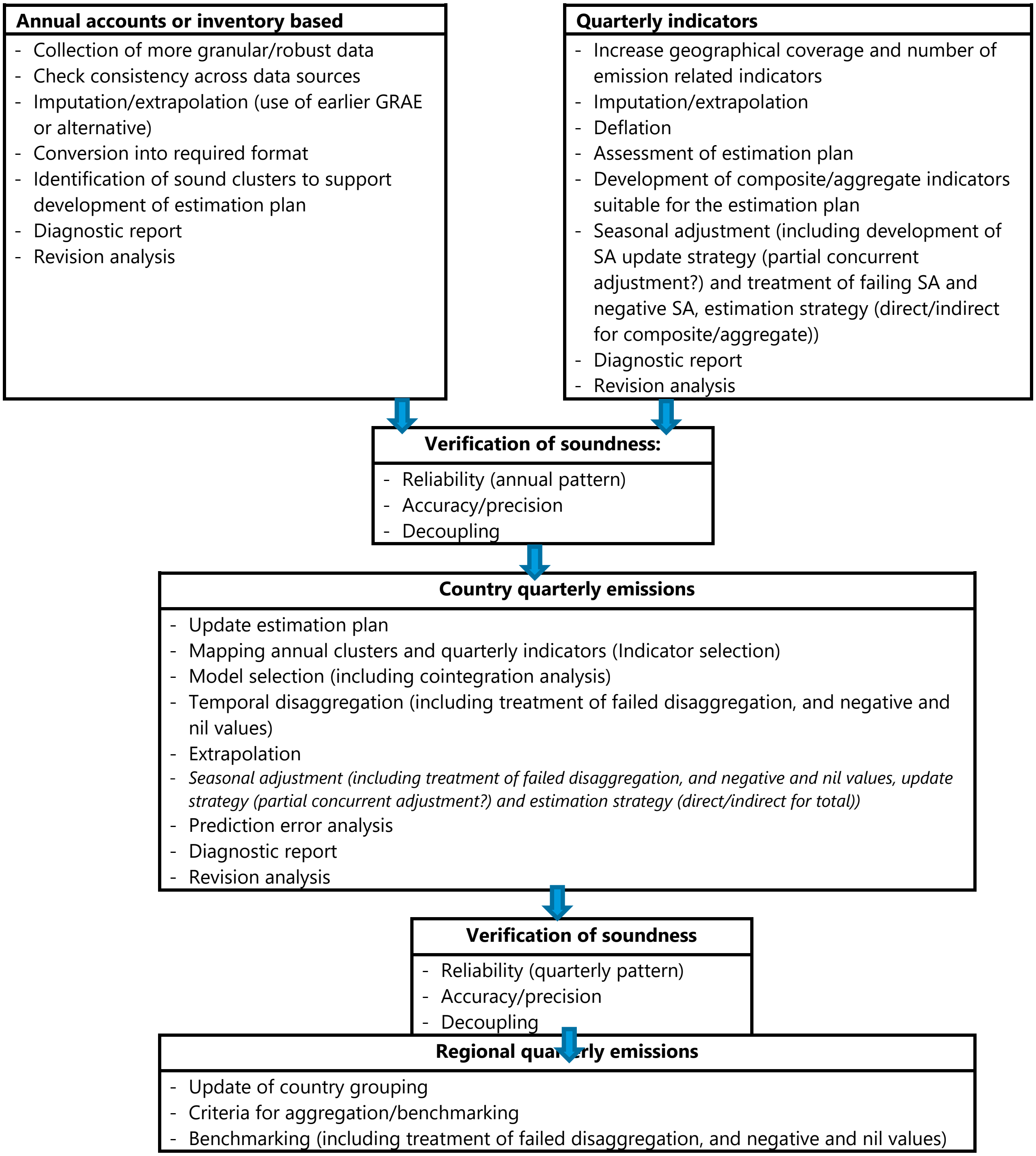


Chart A6.2 - Systematic bias of temporal disaggregation methods



Another sensitivity analysis carried out by the IMF is the persistence of extrapolation bias for forward series from 2018 to 2020. When a model is well calibrated, lower systematic extrapolation bias is a desirable property to reflect that the residual is randomly distributed. The graph below shows that the IMF hybrid model which uses Denton-Cholette and Chow-Lin embeds this feature with only 15 percent of clusters displaying a systematic upward extrapolation bias and 10 percent of clusters with a systematic downward extrapolation bias. Using only Chow-Lin method with the current indicator selection strategy would result in 20 percent of clusters with a systematic upward extrapolation bias.

ANNEX 7 – IMF'S PRODUCTION SYSTEM FLOWCHART



- *Seasonal adjustment (including treatment of failed disaggregation, and negative and nil values, update strategy (partial concurrent adjustment?) and estimation strategy (direct/indirect for total))*
- Development of method to benchmark countries without quarterly emissions
- Prediction error analysis
- Diagnostic report
- Revision analysis