Office for National Statistics

Article

Developing quarterly greenhouse gas emissions accounts, UK: May 2022

Sets out a potential framework to develop annual greenhouse gas (GHG) emissions accounts on a quarterly basis. Also outlines potential issues and future work.

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Release date:
12 May 2022

Next release:
To be announced

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1 . Overview of developing quarterly greenhouse gas emissions accounts

National Statistical Institutes (NSIs) have looked to develop new economic indicators beyond the traditional production concept of Gross Domestic Product (GDP). There are international frameworks available, particularly the System of Environmental Economic Accounting (SEEA), along with an emerging Beyond GDP programme of work.

This aims to develop more socially inclusive and environmentally sustainable indicators of progress alongside those for economic performance. This includes improving climate change indicators, particularly higher-frequency estimates of greenhouse gas (GHG) emissions. These new economic measures will help policymakers and the wider public to better understand the relationship between how and what we produce and consume, and its environmental impact. There has been interest in this research within the UK, other NSIs, and internationally.

We propose to produce quarterly estimates of UK GHG emissions on a residence basis, in line with the National Accounts. These emissions estimates are currently produced annually nine months after the end of the year, on a provisional basis, with final estimates available after 18 months. These experimental estimates would be a first for the UK and bring such measures closer to the timeliness and frequency of GDP. Quarterly territorial emissions statistics are produced retrospectively by the Department for Business, Energy and Industrial Strategy (BEIS) but are not directly comparable with GDP. Quarterly estimates of UK GHG emissions on a residence basis would potentially provide new insights into their path and the implications for sustainability.

We propose a framework for how we could model these experimental GHG emissions. In line with recent international research on this topic, this uses predictor indicators that have a co-relation with GHG emissions. We have included illustrative estimates to support public communication on how such modelling might look in practice.

We hope that publishing these initial proposals will advance our "Beyond GDP" research, providing more timely and frequent insights into climate change to inform the wider public debate. We welcome feedback on improving how we model these estimates.

2 . UK estimates of greenhouse gas emissions

Our estimates of UK greenhouse gas (GHG) emissions are one of three measures, alongside those published on a territorial and consumption or footprint basis. These three measures are explained and compared in this Measuring UK greenhouse gas emissions article on the UK climate change statistics portal.

Territorial-based estimates

The Department for Business, Energy and Industrial Strategy (BEIS) produces territorial-based estimates, which are used to inform progress on the UK-wide emissions target; this includes a target of net zero for UK GHG emissions by 2050. These are emissions that are produced within the UK's geographical borders. They take into account emissions from businesses located in the UK, no matter where they are registered in the world, and emissions from the activities of people living in and visiting the UK. There are a number of exclusions from these emissions estimates. Most notably, these are:

- emissions from international aviation and shipping
- emissions from the burning of biomass for energy production
- emissions associated with the production of goods and services that the UK imports from other countries

Residence-based estimates

The Office for National Statistics (ONS) produces residence-based estimates in accordance with the System of Environmental Economic Accounting (SEEA). Emissions by UK residents and UK-registered businesses are measured, regardless of where those emissions occur. Residence-based estimates exclude emissions from foreign visitors and foreign businesses in the UK. They also differ from territorial-basis emissions in that they include emissions associated with international shipping and aviation. The residency principle enables the greenhouse gas (GHG) emissions to be comparable with the National Accounts, including gross domestic product (GDP). This allows us to produce estimates of emission intensity at the economy level and industry level. It also provides insight into whether there is any decoupling between economic output and GHG emissions.

Consumption-based estimates

The Department for Environment, Food and Rural Affairs (DEFRA) produces consumption-based estimates of emissions, also known as the UK's carbon footprint. These account for emissions through the supply chain of goods and services consumed in the UK wherever they are produced in the world. They allow for emissions from UK imports but exclude emissions arising from UK produced goods that are exported.

Emissions estimates used in our research

Our research on producing experimental quarterly estimates of GHG emissions considers the residence-based estimates that ONS produces only. The main source of information for these is the UK's National Atmospheric Emissions Inventory (NAEI). This provides air emissions data, calculated from activity data and using emission factors, for all relevant sources in the UK on a territory basis.

Emissions are then mapped to industries using the Standard Industrial Classification (SIC) 2007. In some cases, there is a direct map between the source of emissions and the industry. For other instances, the split of the emissions across industries must be estimated using appropriate data. The residence principle (where adjustments are made to include emissions from UK residents and UK-registered businesses based overseas, and exclude emissions from foreign residents and foreign businesses in the UK) is then applied to the data.

Compiling the inventory and applying the residence principle is a complex process. Uncertainties in the many data sources required in this compilation process will be reflected in the final estimates. The process of allocating territorial emissions to SIC 2007 also introduces further uncertainty. Further information can be found in:

- the UK GHG emissions (territory basis) release (PDF, 623KB)
- our Environmental accounts on air emissions quality and methodology information (QMI) article
- the NAEI database

3 . Proposed publication timelines

Final residence-based greenhouse gas (GHG) emission estimates are currently produced annually around 18 months after the reference period. Our provisional annual estimates are published around nine months after the reference period. Residence-based GHG emissions are therefore not available as quickly as territorial emissions and traditional economic indicators, such as gross domestic product (GDP).

Subject to stakeholder feedback, we have created a potential publication timeline for residence-based GHG estimates that will be published in the next year, including our first experimental quarterly estimates. These are:

- provisional annual GHG emissions from 2021, due to publish in September 2022
- experimental quarterly GHG emissions for Quarter 1 (Jan to Mar) 2022, due to publish late 2022
- final annual GHG emissions from 2021, due to publish June 2023

The need for the provisional annual estimates of GHG emissions will be reviewed if and when a quarterly measure is developed.

We will provide further updates on these publications soon.

4 . Temporal disaggregation of quarterly estimates of GHG emissions

Much of the National Atmospheric Emissions Inventory and the economic information needed to compile residence-based greenhouse gas (GHG) emissions estimates are only available with a lag. Higher frequency estimates therefore require modelling. This involves temporal distribution between the available annual benchmark years and extrapolation beyond the latest available annual benchmark year. This approach follows the practice of some other national statistical institutes. See New Zealand's Greenhouse gas emissions methodology article and Sweden's New method for up-to-date environmental accounts article (PDF, 2.65MB) for examples of this.

This form of benchmarking can be carried out using higher-frequency predictor indicators to approximate the quarterly profile of emissions. These aim to provide the unknown quarterly behaviour of the level of emissions produced, where these predictors have a co-relation with GHG emissions. This benchmarking process converts the quarterly movements in the predictor indicator(s) into units of emissions, with the annual estimates of emissions serving as the benchmarks that capture the level of activity for any given year.

The temporal distribution process aims to preserve the within-year changes of these higher-frequency indicators as much as possible, while ensuring that the benchmarking constraint is respected. However, for the most recent periods, we must extrapolate beyond the last available year we have our annual benchmark of emissions for. The process takes the quarter-on-quarter movement in the predictor indicator to extend our experimental estimates beyond that year. This inevitably leads to more uncertainty because there is no longer a benchmark for those quarters.

These predictors would ideally reflect information that is closest to the physical source of emissions for each industry [note 1], providing the annual benchmarks are produced on the same methodological basis. This would then have the potential to capture any changes in the GHG intensity of production and minimise the loss of accuracy from the extrapolation process.

Notes for: Temporal disaggregation of quarterly estimates of GHG emissions

1. There are also GHG emissions on a residence basis that relate to households, which will have to be considered as part of future research.

5 . Choice of predictor indicators

We follow the principles for using predictor indicators to capture proxy quarterly movements in greenhouse gas (GHG) emissions, as outlined in Eurostat's Estimates of quarterly greenhouse gas emissions accounts article (PDF, 1,153KB). Stats NZ explain that "the conceptual accuracy of the indicator will need to take into consideration the nature of the emitting process" in their Greenhouse gas emissions methodology article.

Direct indicators are preferable because these relate more to the process of the GHG emission itself, for example, the production of coal, gas, or oil. By contrast, indirect indicators need to be correlated with the level of GHG emissions. These would ideally have a conceptual relationship that reflects the nature of the activity or production processes, for example, volume measures of economic activity or population numbers.

One option might be to consider gross value added (GVA) as a predictor. In the UK, output is considered a proxy for GVA in early estimates, which relies on there being the same co-movements in output and intermediate consumption. GVA captures the value of an industry's outputs less the value of intermediate inputs used in the production process. Given that GHG emissions are a function of how and what we produce and consume, an industry-level GVA indicator would seemingly capture the relationship between what output is produced and how much GHG is emitted in a unit of output at the industry level. These proxy movements would capture the information on any "between" industry effect (the change in the composition of output that is produced, which might be more or less intensive in terms of GHG emissions emitted). They would also be available earlier and in a higher frequency; for example, GHG emissions could be published alongside gross domestic product (GDP) on a quarterly basis, approximately six weeks after the reference quarter.

However, our preliminary research reinforces the importance of modelling predictors that capture the "within" industry effect. These are the structural changes in how any output is produced, particularly at the industry level. A GVA indicator will not necessarily capture these types of changes, given that there is the scope for there to be some decoupling between emissions and economic output over time. If so, this would be reflected in a bias in the one-year ahead forecasts that we would be extrapolating. Furthermore, it would not be possible to apply this type of predictor to emissions that are related to households.

Instead, we consider indicators that are available from the Department for Business, Energy and Industrial Strategy (BEIS) Energy trends publication. This provides information on UK energy production, consumption and trade, for energy overall, and by specific fuels. Carbon dioxide accounts for the majority of GHG emissions, and largely results from energy use. Changes in energy use patterns are therefore likely to lead to changes in GHG emissions. The use of information published in BEIS's Energy trends publication as a predictor indicator is also in line with how BEIS estimates provisional GHG emissions (PDF, 181KB).

In this initial research, we have used energy consumption from fossil fuels as a predictor indicator. To reflect the fact that the residence-based GHG emissions include emissions from biomass, we have also added to this energy consumption from bioenergy and waste. This likely results in a slight overestimation of the level of GHG-related energy consumption, because it includes some energy from renewable sources (such as solar). Because emissions from biomass have been increasing in the GHG emissions (residence basis) in recent years, it is important to capture them in the predictor indicator. However, we are more interested in changes in these predictors for benchmarking, rather than the level of those indicators.

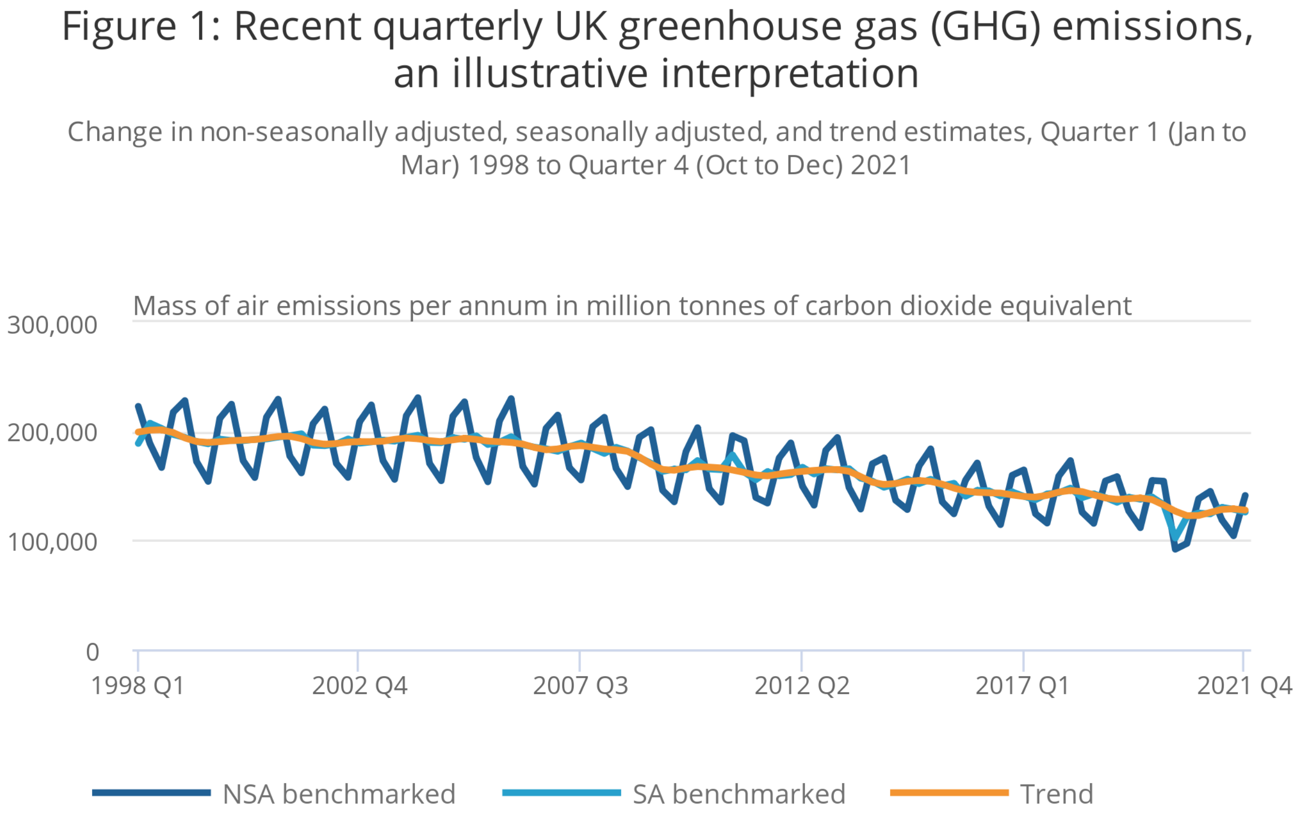
We intend to develop this methodology to use better-targeted predictor indicators informed by user feedback. We want to publish our first experimental estimates of GHG emissions later this year, reflecting the feedback we receive.

6 . Illustrative estimates of quarterly residence-based emissions

Our preliminary research initially uses quarterly estimates of these energy indicators as the predictor indicator for the whole economy (Figure 1). We have taken the latest published annual estimates of greenhouse gas (GHG) emissions on a residence basis and then derived benchmarked quarterly estimates. These are based on energy consumption from fossil fuels and emissions from biomass as our one predictor indicator. To aid the communication of these illustrative estimates, we have seasonally adjusted these benchmarked outputs. We have also reduced the volatility of these estimates by including the underlying trend.

Figure 1: Recent quarterly UK greenhouse gas (GHG) emissions, an illustrative interpretation

Change in non-seasonally adjusted, seasonally adjusted, and trend estimates, Quarter 1 (Jan to Mar) 1998 to Quarter 4 (Oct to Dec) 2021



Source: Office for National Statistics – Environmental Accounts, Department for Business, Energy and Industrial Strategy – Energy Trends

Notes:

1. These quarterly estimates have been derived by the process of Denton benchmarking. We then carried out seasonal adjustment on the quarterly estimates using the standard X-13-ARIMA approach. This is because the Department for Business, Energy and Industrial Strategy (BEIS) energy trends indicators include seasonal components. We have applied the constraint that the non-seasonally and seasonally adjustment estimates have been benchmarked to the annual GHG emissions estimates that we publish; see “SA benchmarked”.

2. The quarterly trend estimates are derived by smoothing the seasonally adjusted estimates; see “Trend”.

Table 1 shows how these benchmarked figures might be communicated, including the movements in the underlying trend figures and the seasonally adjusted estimates.

Table 1: Recent quarterly UK greenhouse gas (GHG) emissions, an illustrative interpretation
Change in trend and seasonally adjusted estimates, Quarter 1 (Jan to Mar) 2020 to Quarter 4 (Oct to Dec) 2021

	Quarter-on-quarter change in trend estimates (%)	Quarter-on-quarter change in seasonally adjusted estimates (%)	Quarter-on-year change in trend estimates (%)	Quarter-on-year change in seasonally adjusted estimates (%)
Quarter 1 2020	-3.6	-5.0	-3.8	-1.5
Quarter 2 2020	-4.3	-23.2	-8.3	-26.9
Quarter 3 2020	-3.2	19.0	-11.7	-11.8
Quarter 4 2020	0.1	2.9	-10.7	-10.6
Quarter 1 2021	2.3	-0.6	-5.1	-6.4
Quarter 2 2021	2.2	4.8	1.3	27.6
Quarter 3 2021	0.5	-1.3	5.1	5.8
Quarter 4 2021	-0.9	-2.0	4.1	0.8

Source: Office for National Statistics – Environmental Accounts, Department for Business, Energy and Industrial Strategy – Energy Trends

This is an illustrative example to show how this temporal disaggregation would look in practice. We are still carrying out research on identifying the most appropriate high-level predictors, which we hope will be informed by user response. We also recognise that choosing alternative indicators might lead us to reconsidering the implications on how to present the trend and seasonally adjusted indicators.

We also recognise that it might be more effective to use industry-level predictors, as well as indicators that represent non-carbon dioxide emissions. Our priority is to carry out stakeholder engagement to identify what these proxy indicators might be, and which are available, particularly for those industries that currently produce the most GHG emissions. These are:

- the electricity, gas, steam and air conditioning supply industry
- the manufacturing industry
- the transport and storage industry

Appropriate indicators for emissions relating to households as captured within the residence-based emissions, mostly from heating and domestic travel, will also be identified.

Examples we are currently considering include:

- net electricity generation by fuel type for the electricity, gas, steam, and air conditioning industry
- transport fuel use for households' transport activities (mainly road)
- total domestic fuel use for households' heating

These predictor indicators are from the Department for Business, Energy and Industrial Strategy (BEIS) Energy trends publication, which is available on a three-month lag after the reference quarter. We have only focused on the headline GHG emissions for the UK economy as part of this work. However, we will explore how best to produce these experimental estimates at the industry level. We will consider whether it is best to apply any identified predictor indicators directly to an industry or whether to apply to the process and then apportion across industries.

We will also carry out further work to explore the real-time performance of these extrapolated figures. This involves reproducing modelled estimates of these extrapolated GHG emissions, based on the information that was available at that time. As we now know emissions for those periods, these forecast errors can then be evaluated to provide some insight into how useful these predictors are as part of this exercise.

7 . Conclusion

We have produced a framework to estimate quarterly estimates of UK greenhouse has (GHG) emissions on a residence basis. Further research is needed to identify the most appropriate predictors at the industry level, particularly for those industries with the highest levels of GHG emissions.

We also need to consider how best to produce industry-level estimates, including those emissions that are related to households. For example, it might be best to apply predictor indicators at the industry level (if available), or it might be more appropriate to focus on the process of GHG emissions and then consider how best to apportion these movements across industries. We are working to identify other predictors, and have included some potential ones that could be considered for the experimental estimates that we publish later this year.

We will also explore how to validate any provisional findings to give confidence in the experimental figures that are produced, which we recognise will be subject to uncertainty. It is also essential that there is transparency around the strengths and weaknesses of any experimental estimates that are produced. Given that there might be uncertainty around the true estimate, it is essential that there is full transparency about how these estimates are being compiled.

We welcome user feedback on these proposals and further comments to help inform how this work is carried out.

8 . Related links

UK Environmental Accounts: 2021
Bulletin | Released 3 June 2021
Measuring the contribution of the environment to the economy, the impact of economic activity on the environment, and society's response to environmental issues.

Greenhouse gas emissions intensity, UK: 2020 provisional estimates
Bulletin | Released 21 September 2021
Measuring the contribution of the environment to the economy, the impact of economic activity on the environment, and society's response to environmental issues.

Energy Trends: March 2022
Bulletin | Released 31 March 2022
A quarterly bulletin by the Department for Business, Energy and Industrial Strategy (BEIS) containing statistics on all major aspects of energy in the UK.