

Consumption-based accounts for the UK, 1990 to 2023: Summary of methods

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1 Consumption-based emission accounts

Greenhouse gas (GHG) emissions can be allocated to a country in different ways: (1) territorial-based, (2) production-based, and (3) consumption-based emission reporting.

1.1 Territorial emissions

The United Nations Framework Convention on Climate Change (UNFCCC) requires (Annex I and/or national governments that are Parties to the UNFCCC and/or the Kyoto Protocol) countries to submit annual National Emission Inventories. These inventories are used to assess the progress made by individual countries in reducing GHG emissions. The UNFCCC follows the Intergovernmental Panel on Climate Change's (IPCC) Guidelines for National GHG Inventories which is, "emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (IPCC, 2007). According to this definition, however, GHG emissions emitted in international territory, international aviation and shipping, are only reported as a memo and not allocated to individual countries.

In the UK, the Department for Energy Security and Net Zero (DESNZ) reports these emissions as the [UK's Greenhouse Gas Inventory](#) and they form the basis for reporting on progress towards our domestic and international emissions reduction targets. In this report, we call this account "**territorial-based emission inventories**".

1.2 Production emissions

In official reporting to Eurostat (the statistical office of the European Union), GHG emissions are allocated in a consistent manner to the system boundary for economic activities such as the Gross Domestic Product (GDP) used in the System of National Accounts (SNA). This boundary reporting is known as the residence principle. In the SNA, international aviation and shipping are typically allocated to countries based on the operator of the aircraft or vessel. Particularly in Europe (Eurostat), these inventories are often known as "National Accounting Matrices including Environmental Accounts (NAMEAs)".

In the UK, the Office for National Statistics (ONS) publishes this account as part of the [UK Environmental Accounts](#). The figures represent emissions caused by UK residents and industry whether in the UK or abroad but exclude emissions within the UK which can be attributed to overseas residents and businesses and those emissions from land use, land use change and forestry. In this report, we call these "**production-based emission inventories**".

1.3 Consumption emissions

Consumption-based emissions allocate emissions to the consumers in each country, usually based on final consumption as in the SNA but also as trade-adjusted emissions (Peters, 2008). Conceptually, consumption-based inventories can be thought of as consumption equals production minus exports plus imports (see Figure 1). Consumption-based emissions do not have to be reported officially by any country, but they are increasingly estimated by researchers (see review by Wiedmann, 2009).

In the UK, the Department for Environment, Food and Rural Affairs (Defra) publishes the [consumption-based emissions](#) calculated by the University of Leeds. In this report, we call these “**consumption-based emission inventories**” or “the Carbon Footprint”.

Table 1 provides a simplified view of what is included and excluded in each emissions account.

Table 1: Types of emissions inventories included in UK territorial, production and consumption accounts

Emissions from...	UK Territorial	UK Production	UK Consumption
industries owned by UK, located in UK making products consumed by UK	Yes	Yes	Yes
industries owned by UK, located in UK making products consumed by the rest of the world	Yes	Yes	No
industries owned by the rest of the world, located in UK making products consumed by UK	Yes	No	Yes
industries owned by the rest of the world, located in UK making products consumed by the rest of the world	Yes	No	No
industries owned by UK, located in the rest of the world making products consumed by UK	No	Yes	Yes
industries owned by UK, located in the rest of the world making products consumed by the rest of the world	No	Yes	No
industries owned by the rest of the world, located in the rest of the world making products consumed by UK	No	No	Yes

Emissions from...	UK Territorial	UK Production	UK Consumption
industries owned by the rest of the world, located in the rest of the world making products consumed by the rest of the world	No	No	No
bunker aviation and shipping owned by UK and used by UK residents	No	Yes	Yes
bunker aviation and shipping owned by the rest of the world and used by UK residents	No	No	Yes
bunker aviation and shipping owned by UK and used by the rest of the world residents	No	Yes	No
bunker aviation and shipping owned by the rest of the world and used by the rest of the world residents	No	No	No
UK citizens' activities within UK territory	Yes	Yes	Yes
rest of the world citizens' activities within UK territory	Yes	No	No
UK citizens' activities within the rest of the world territory	No	Yes	Yes
rest of the world citizens' activities within the rest of the world territory	No	No	No
land use, land use change and forestry	Yes	No	No

There is a marked difference in end results depending on the chosen emissions accounting system (Barrett et al., 2013). Due to issues of national sovereignty, binding agreements on emissions may focus primarily on territorial or production-based emission estimates.

Figure 1 demonstrates the relative sizes of the UK territorial, production and consumption emissions accounts. In this example we use data for 2023. The additional flows that are included in the production account (the Environmental Accounts) include: bunker fuels from aviation and shipping; emissions from renewables and waste derived fuels (biomass); the net emissions from the inclusion of overseas emissions from UK residents and the removal of domestic emissions from non-residents; and the removal of emissions from crown dependencies, overseas territories (the Channel Islands and Gibraltar) and land use, land use change and forestry (LULUCF).

The figure also reveals the portion of UK consumption emissions that originate abroad (the emissions embodied in imports) and those UK production emissions

which are exported. It is clear that there is a marked difference in end results depending on the chosen emissions accounting system (Barrett et al., 2013). Due to issues of national sovereignty, binding agreements on emissions may focus primarily on territorial-based emission estimates meaning that no targets are set for emissions associated with bunker fuels and imported products.

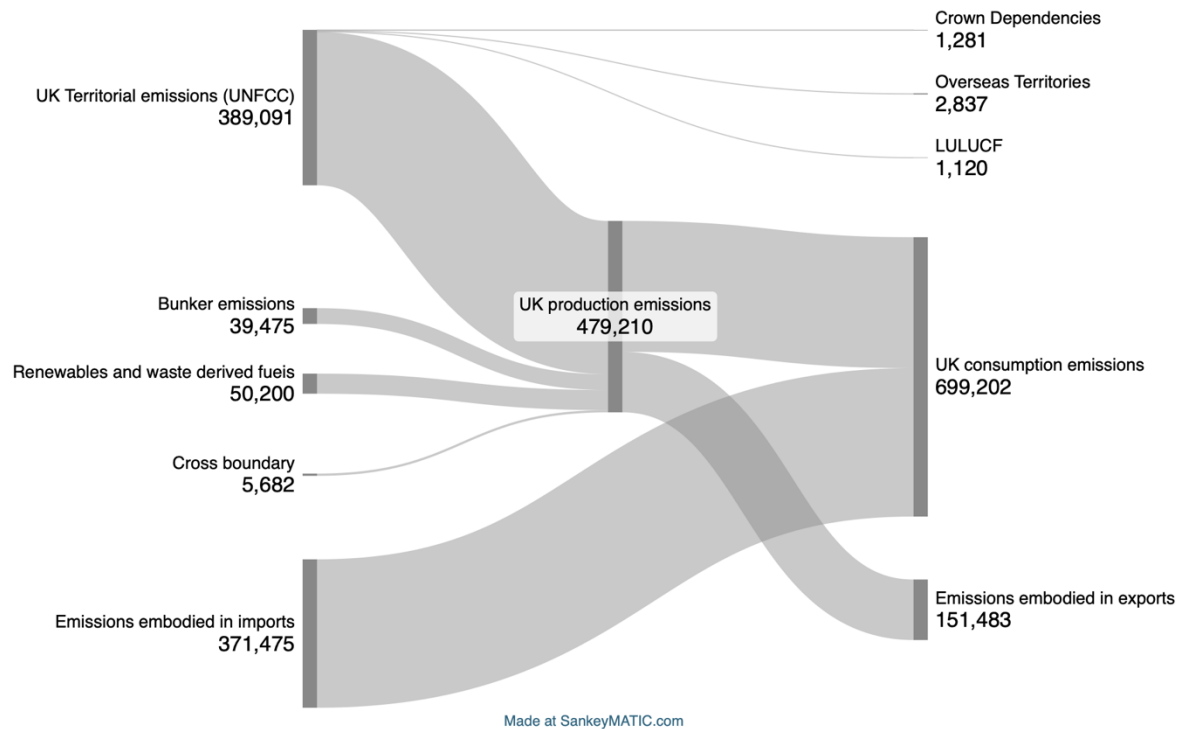


Figure 1: UK territorial, production and consumption emissions in 2023, measured in kilotonnes carbon dioxide equivalent (CO2e)

Source: University of Leeds; [ONS, Atmospheric emissions: bridging tables](#)

1.4 Greenhouse gasses included in the UK's consumption-based emissions

For the 2026 release of the UK consumption-based account we include the full suite of GHGs as reported to the UNFCCC, all measured in thousand tonnes (kilotonnes) carbon dioxide equivalent (CO2e). These are:

- carbon dioxide (CO2)
- methane (CH4)
- nitrous oxide (N2O)
- hydrofluorocarbons (HFC)
- perfluorocarbons (PFC)
- nitrogen trifluoride (NF3)
- sulphur hexafluoride (SF6)

Non-CO2 gasses are converted to CO2e using the [Global Warming Potential values](#) from the IPCC Fifth Assessment Report (AR5).

1.5 Material footprint accounts

The 2026 release of the UK consumption-based account also includes the ‘material footprint’. This is a measure of the global primary raw material extraction attributable to final domestic demand for goods and services by the residents of an institutional unit, typically a nation. The material footprint included in the UK consumption-based account is comprised of biomass, ore, fossil fuel materials and non-metallic minerals, all measured in kilotonnes. The [UK’s material footprint](#) is published by the ONS and [England’s material footprint](#) is published by Defra.

2 Multi-regional input-output methodology

2.1 Input-output methods

Input-output models have been adopted by environmental economists due to their ability to make the link between the environmental impacts associated with production techniques and the consumers of products. The Leontief input-output model is constructed from observed economic data and shows the interrelationships between industries that both produce goods (outputs) and consume goods (inputs) from other industries in the process of making their own product (Miller and Blair, 2009). Figure 2 shows the basic structure of a Leontief input-output model.

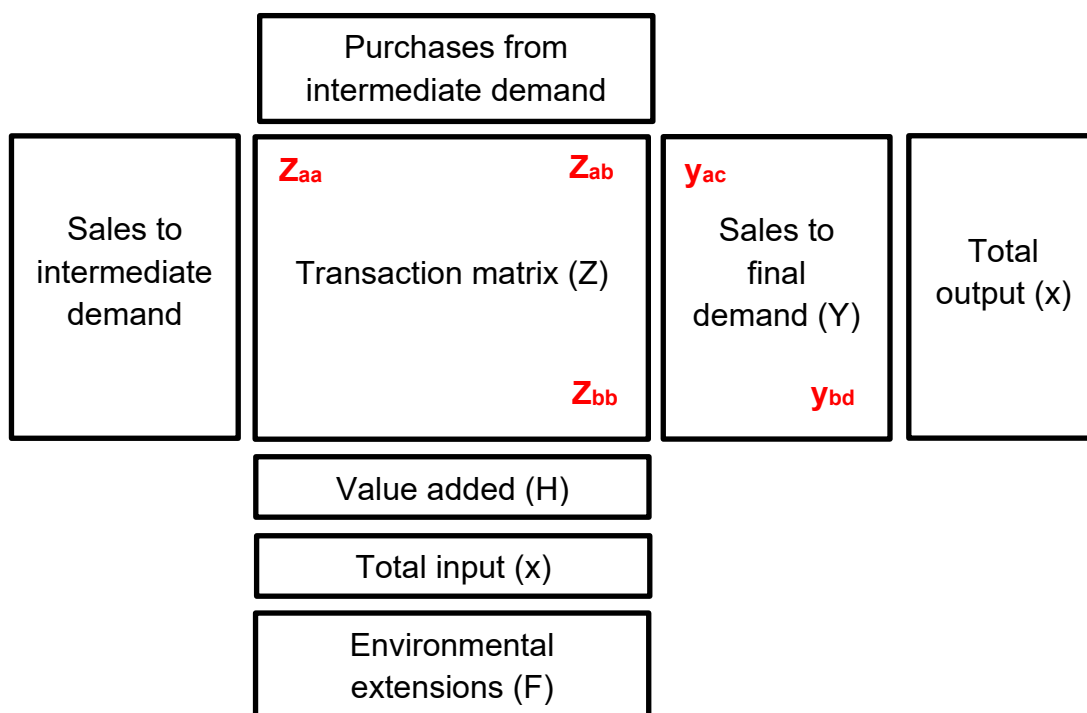


Figure 2: Basic structure of a Leontief input-output model

Consider the transaction matrix \mathbf{Z} ; reading across a row reveals which industries a single industry sells to and reading down a column reveals who a single industry buys from. A single element, z_{ij} , within \mathbf{Z} , represents the contributions from the i^{th} sector to the j^{th} industry or sector in an economy. For example, z_{aa} represents the ferrous metal contribution in making ferrous metal products, z_{ab} , the ferrous metal contribution to car products and z_{bb} the car production used in making cars. Final demand is the spend on finished goods. For example, y_{ac} is the spend on ferrous metal products by households as final consumers whereas y_{bd} is the spend on car products by government as final consumers.

The total output (x_i) of a particular sector can be expressed as:

$$x_i = z_{i1} + z_{i2} + \dots + z_{ij} + y_i \quad (1)$$

where y_i is the final demand for that product produced by the particular sector. If each element, z_{ij} , along row i is divided by the output x_i , associated with the corresponding column j it is found in, then each element in \mathbf{Z} can be replaced with:

$$a_{ij} = \frac{z_{ij}}{x_j} \quad (2)$$

to form a new matrix \mathbf{A} .

Substituting for (2) in equation (1) forms:

$$x_i = a_{i1}x_1 + a_{i2}x_2 + \dots + a_{ij}x_j + y_i \quad (3)$$

Which, if written in matrix notation is $\mathbf{x} = \mathbf{Ax} + \mathbf{y}$. Solving for \mathbf{y} gives:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \quad (4)$$

where \mathbf{x} and \mathbf{y} are vectors of total output and final demand, respectively, \mathbf{I} is the identity matrix, and \mathbf{A} is the technical coefficient matrix, which shows the inter-industry requirements. $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse (further identified as \mathbf{L}). It indicates the inter-industry requirements of the i^{th} sector to deliver a unit of output to final demand. Since the 1960s, the input-output framework has been extended to account for increases in the pollution associated with industrial production due to a change in final demand (Miller and Blair, 2009).

Consider, a row vector \mathbf{f} of annual CO2 emissions generated by each industrial sector

$$\mathbf{e} = \mathbf{f}\hat{\mathbf{x}}^{-1} \quad (5)$$

is the coefficient vector representing emissions per unit of output (where $\hat{\cdot}$ denotes matrix diagonalisation). Multiplying both sides of (4) by e' (where $'$ denotes matrix transposition) gives

$$e'x = e'Ly \quad (6)$$

and simplifies to

$$F = e'Ly \quad (7)$$

where F is the CO₂ emissions in matrix form allowing consumption-based emissions to be determined. F is calculated by pre-multiplying L by emissions per unit of output and post-multiplying by final demand. This calculation shows how a unit change in final demand y , increases the emissions by all industries to satisfy this change.

This system can be expanded to the global scale by considering trade flows between every industrial in the world rather than within a single country. This type of system requires a multi-regional input-output (MRIO) table. The latest audits of the main global MRIO initiatives describe six systems: the World Input-Output Database (WIOD), Eora, the Global Resource Input-Output Assessment (GLORIA), EXIOBASE, the Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) and the OECD's Inter-Country Input-Output (OECD-ICIO) tables.

2.2 Construction of the multi-regional input-output database

A UK carbon footprint model needs to be able to measure the impact of UK consumption of products considering domestic and foreign supply chains involved in production. This means the MRIO table needs to have information about flows of products from abroad to both UK intermediate and final demand. Production efficiencies vary between different producers meaning that the impact per pound spent may be larger for a product from country A than from country B.

The most accurate representation of the UK consumption-based account would measure the flow of products from every country and understand the emission intensities associated with each industry in every country. However, when we consider how the model may be used and practicalities such as model size, data storage capacity and model run times, aggregating trade partner countries is preferable.

The UKMRIO database contains 11 regions: the UK, Brazil, Russia, India, China, South Africa, the USA, Japan, the EU, the rest of the OECD and the rest of the world. We chose these regions because they represent important trade partners.

2.2.1 MRIO table structure

The ideal MRIO data table structure requires an MRIO table with all other nations' data at the 112-sector level. Each table in the MRIO database will be structured as shown in Figure 3. Blank cells are zero.

		UK supply table at 112 sectors			
			Other nations' supply tables at 112 sectors		
UK domestic use table at 112 sectors	Other nations' intermediate demand of UK products			UK final demand of UK products	Other nations' final demand of UK products
UK intermediate demand of other nations' products	Other nations' domestic use table at 112 sectors			UK final demand of other nations' products	Other nations' final demand of other nations' products
UK value added	Other nations' value added				

Figure 3: Table structure for the UKMRIO database

2.2.2 UK data from the ONS

UK supply and use tables (SUT) are currently supplied by the Office of National Statistics (ONS) at the 112-sector level for the years 1997 to 2023 and the 123-sector level for the years 1992 to 1996. All SUT tables follow the structure shown in Figure 4.

	Industries	Products			
Industries		Industry by product supply table			Sum of industrial output in basic prices
Products	Combined use table measured in purchaser's prices. Sum of domestic intermediate use, imports to UK intermediate demand and margins and taxes and products		Combined final demand for products (UK and foreign) by households, non-profit institutions serving households, national and local government, gross fixed capital valuables, changes in inventories	Exports of UK products	Sum of products in purchasers' prices
	Value added – wages and tax on production				
	Sum of industrial output in purchasers' prices	Sum of products in basic prices	Sum of final demand in purchasers' prices		

Figure 4: The UK supply and use table structure

We are unable to use the SUTs in their original form because (i) the use table is a combination of domestic and imports and (ii) the combined use table is in purchaser's prices, meaning that we must also strip out margins and taxes on products. In order to adjust the SUTs so that the use table is split by domestic use and imported use and to transform the data into basic prices, we make use of the analytical tables.

Detailed analytical tables are available for 1995, 2005, 2010 and 2013 to 2015. Less detailed analytical tables are available for 2016 to 2019 (see Figure 5). Analytical tables split the combined use table into a domestic use matrix and rows for imports,

product tax and further value-added components. The 1990 to 2005 tables are at the older 123 sector classification. A [mapping showing how to convert from 123 sectors to 112 sectors](#) is available on the ONS website. This data has been used to make a 112 by 123 weighted concordance matrix and all tables at 123 sectors are converted to 112 using this. Both the domestic and combined use tables are available for 1995, 2005, 2010 and 2013 to 2015. For 2016 to 2019, only the domestic use table is supplied. For 2016 to 2019 we generate a version of the combined use table using tax rates from 2016 and the imports use table for the year in question.

Domestic use table in basic prices (112x112 or 123x123)	Domestic final demand	Domestic exports from UK	Combined use table in basic prices (112x112 or 123x123)	Combined final demand	Combined exports from UK
Imports row (1x112 or 1x123)	Imported final demand		Total row (1x112 or 1x123)	Total final demand	

Figure 5: UK analytical table structures (domestic use and combined use for 1995, 2005, 2010 and 2013 to 2015 and domestic use only for 2016 to 2019)

Proportion of use that is domestic (112x112)	Proportion of final demand that is domestic (112x7)	Proportion of exports that is domestic by 112 products
Proportion of Use that is imported (by 112 industry)	Proportion of final demand that is imported by 7 final demand categories	

Figure 6: Domestic proportion table

The ONS also disaggregates UK production emissions to sectors in the economy and reports on these emissions as Environmental Accounts. Since the revision of the national Environmental Accounts in 2011, emissions data map to this 112-sector classification system.

2.2.3 Rest of world data from EXIOBASE v3.8.3 and FIGARO v2025

EXIOBASE v3.8.3, produced by the NTNU, TNO, SERI, Universiteit Leiden, WU and 2.-0 LCA Consultants (Tukker et al., 2013; Wood et al., 2015), is an MRIO database encompassing data for 49 regions. The database is available in a SUT structure with a homogenous sectoral classification comprising 163 industries and 200 products. EXIOBASE v3.8.3 produces tables from 1995 to present but tables post 2016 are nowcasted (that is, estimated based on trend data and some global totals). FIGARO,

produced by Eurostat is an MRIO database encompassing data for 36 regions. The database is available in a SUT structure with a homogenous sectoral classification comprising 64 industries and 64 products. FIGARO produces tables from 2010 to 2023. From EXIOBASE and FIGARO we extract the following:

- exports from the UK to other nations' intermediate demand
- exports from the UK to other nations' final demand
- imports to UK intermediate demand from other nations
- imports to UK final demand from other nations
- trade between other nations' intermediate demand
- final demand of other nations from other nations

Before the data can be used in the UKMRIO, it needs to be manipulated to the correct structure. We transform EXIOBASE and FIGARO so that the number of sectors is 112 and the regions are Brazil, Russia, India, China, South Africa, the USA, Japan, the EU, the rest of the OECD and the rest of the world (see Table 2). In addition, the data must be transformed from Euros to GBP.

Table 2: EXIOBASE regions aggregated to UKMRIO regions

UKMRIO database region	Regions from EXIOBASE	Regions from FIGARO
UK	UK	UK
Brazil	Brazil	Brazil
Russia	Russia	Russia
India	India	India
China	China	China
South Africa	South Africa	South Africa
USA	USA	USA
Japan	Japan	Japan
EU	Austria	Austria
	Belgium	Belgium
	Bulgaria	Bulgaria
	Croatia	Croatia
	Cyprus	Cyprus
	Czech Republic	Czech Republic
	Germany	Germany
	Denmark	Denmark
	Estonia	Estonia
	Spain	Spain
	Finland	Finland
	France	France
	Greece	Greece

UKMRIO database region	Regions from EXIOBASE	Regions from FIGARO
	Hungary	Hungary
	Ireland	Ireland
	Italy	Italy
	Latvia	Latvia
	Luxembourg	Luxembourg
	Lithuania	Lithuania
	Malta	Malta
	Netherlands	Netherlands
	Poland	Poland
	Portugal	Portugal
	Romania	Romania
	Sweden	Sweden
	Slovakia	Slovakia
	Slovenia	Slovenia
Rest of the OECD (Non-EU)	Norway	Norway
	Switzerland	Switzerland
	Canada	Canada
	Korea	Korea
	Mexico	Mexico
	Australia	Australia
	Turkey	Turkey
	Rest of Europe	
Rest of the world	Indonesia	Indonesia
	Rest of Africa	Argentina
	Rest of the Americas	Saudi Arabia
	Rest of Asia and Oceania	Rest of the world
	Rest of the Middle East	
	Taiwan	

2.2.4 Filling in the data gaps

We are aiming to produce annual tables in the format shown below. The following explains the steps taken to produce each element in the table.

		UK supply table at 112 sectors			
			Other nations' supply tables at 112 sectors		
UK domestic use table at 112 sectors	Other nations' intermediate demand of UK products			UK final demand of UK products	Other nations' final demand of UK products
UK intermediate demand of other nations' products	Other nations' domestic use table at 112 sectors			UK final demand of other nations' products	Other nations' final demand of other nations' products
UK value added	Other nations' value added				

Figure 7: Ideal structure for UKMRIO

2.2.4.1 Domestic supply table

$$\boxed{\text{UK supply table at 112 sectors}} = \boxed{\text{UK supply table at 112 sectors}}$$

The ONS supply tables can be directly placed into a UKMRIO table

2.2.4.2 Domestic use table

$$\boxed{\text{UK domestic use table at 112 sectors}} = \boxed{\text{UK combined use table at 112 sectors}} \times \boxed{\text{Proportion of use that is domestic}}$$

The domestic use tables are formed by taking the combined use tables and using the domestic proportions table to extract only the domestic industrial spends.

2.2.4.3 Domestic final demand of domestic sourced products

$$\text{UK final demand of UK products} = \text{UK final demand of all products} \times \text{Proportion of final demand that is domestic}$$

The domestic final demand tables are formed by taking the combined final demand tables and using the final demand domestic proportions tables to extract only the domestic final demand spends.

2.2.4.4 Rest of the world supply tables

$$\text{Other nations' supply tables at 112 sectors} = \text{Other nations' supply tables at 112 sectors}$$

Taken directly from EXIOBASE or FIGARO, converted to 112 sectors, 10 regions and into GBP

The supply tables for other regions are taken from EXIOBASE or FIGARO after being converted to the UK 112 sector 11 region format and converted to GBP.

2.2.4.5 Rest of the world use tables

$$\text{Other nations' use tables at 112 sectors} = \text{Other nations' use tables at 112 sectors}$$

Taken directly from EXIOBASE or FIGARO, converted to 112 sectors, 10 regions and into GBP

The supply tables for other regions are taken from EXIOBASE or FIGARO after being converted to the UK 112 sector 11 region format and converted to GBP.

2.2.4.6 Rest of the world final demand of rest of world sourced products

$$\text{Other nations' final demand of other nations products} = \text{Other nations' final demand of other nations products}$$

Taken directly from EXIOBASE or FIGARO, converted to 112 sectors, 10 regions and into GBP

The final demand tables for other regions are taken from EXIOBASE or FIGARO after being converted to the UK 112 sector 11 region format and converted to GBP.

2.2.4.7 Imports to domestic use tables

$$\text{Imports to intermediate row total} = \text{Sum of industrial output in basic prices} - \text{Sum of UK domestic use by industry} - \text{UK value added}$$

$$\begin{array}{|c|} \hline \text{UK} \\ \text{intermediate} \\ \text{demand of} \\ \text{other nations'} \\ \text{products} \\ \hline \end{array}
 =
 \begin{array}{|c|} \hline \text{Imports to} \\ \text{intermediate} \\ \text{row total} \\ \text{repeated 112} \\ \text{x 10 times} \\ \hline \end{array}
 \times
 \begin{array}{|c|} \hline \text{Proportion of} \\ \text{imports to UK} \\ \text{intermediate} \\ \text{demand by} \\ \text{industry and} \\ \text{region from} \\ \text{EXIOBASE} \\ \text{or FIGARO} \\ \hline \end{array}$$

To construct the UK imports to intermediate demand section, first a row vector of total imports to intermediate is constructed. We know that this amount must be equal to the total output in basic prices minus the domestic use table minus value added. This row vector is now disaggregated by source region and industry using proportions taken from EXIOBASE or FIGARO.

2.2.4.8 Imports to domestic final demand

$$\begin{array}{|c|} \hline \text{Imports to} \\ \text{final demand} \\ \text{row total} \\ \hline \end{array}
 =
 \begin{array}{|c|} \hline \text{Sum of final} \\ \text{demand in} \\ \text{purchasers'} \\ \text{prices} \\ \hline \end{array}
 \times
 \begin{array}{|c|} \hline \text{Proportion of} \\ \text{final demand} \\ \text{that is} \\ \text{imported} \\ \hline \end{array}$$

$$\begin{array}{|c|} \hline \text{UK final} \\ \text{demand of} \\ \text{other nations'} \\ \text{products} \\ \hline \end{array}
 =
 \begin{array}{|c|} \hline \text{Imports to} \\ \text{final demand} \\ \text{row total} \\ \text{repeated 112} \\ \text{x 10 times} \\ \hline \end{array}
 \times
 \begin{array}{|c|} \hline \text{Proportion of} \\ \text{imports to UK} \\ \text{final demand} \\ \text{by industry} \\ \text{and region} \\ \text{from} \\ \text{EXIOBASE} \\ \text{or FIGARO} \\ \hline \end{array}$$

To construct the UK imports to final demand section, first a row vector of total imports to intermediate is constructed. This is the total final demand multiplied by the proportion of final demand that is imported. This row vector is now disaggregated by source region and industry using proportions taken from EXIOBASE or FIGARO.

2.2.4.9 Exports from to domestic use

$$\begin{array}{|c|} \hline \text{UK exports} \\ \text{column total} \\ \hline \end{array}
 =
 \begin{array}{|c|} \hline \text{Exports of UK} \\ \text{products} \\ \hline \end{array}
 \times
 \begin{array}{|c|} \hline \text{Proportion of} \\ \text{exports that} \\ \text{is domestic} \\ \hline \end{array}$$

$$\text{UK exports} = \text{Exports to intermediate and final demand column repeated } 112 \times 10 + 1 \text{ times} \times \text{Proportion of UK exports to all destinations from EXIOBASE or FIGARO}$$

To construct the UK exports to both other nations' intermediate and other nations' final demand section, first a row vector of total exports is constructed. This is the total exports multiplied by the proportion of exports that is domestic (takes out foreign exports). This column vector is now disaggregated by source region, industry, and destination (intermediate or final demand) using proportions taken from EXIOBASE or FIGARO.

2.2.4.10 Domestic value added

$$\text{UK value added} = \text{UK value added}$$

The value added tables for the UK are taken directly from the SUTs.

2.2.4.11 Rest of world value added

$$\text{Other nations' value added} = \text{Other nations' value added} \quad \text{Taken directly from EXIOBASE or FIGARO, converted to 112 sectors, 10 regions and into GBP}$$

The value added tables for other regions are taken from EXIOBASE or FIGARO after being converted to the UK 112 sector 11 region format and converted to GBP.

2.3 Modelling and data issues and solutions

This section aims to describe the nature of any data or modelling issue, how a solution was developed and applied and discuss any assumptions or uncertainties that arise due to the steps taken.

2.3.1 Negative numbers, zeros and blanks in the UK data

Before working with the SUTs, any negative numbers in the final demand columns are zeroed and this number is added to the corresponding value-added cell to ensure that the tables still balance. Any further negative numbers are removed and replaced with 1×10^{-9} . This is because some of the balancing techniques applied later do not work with negative values. Many of the data manipulations required to format

the data into the correct structure involve a division. Division by zero is not possible, so any zeros or blanks are also replaced with 1×10^{-9} .

2.3.2 Missing analytical data

Analytical tables, which indicate the proportion of product to industry flow that is satisfied by *domestic* production are available for the years 1990, 1995, 2005, 2010, 2013 to 2015 and 2016 to 2019. Using these tables, we can calculate the proportion of all intermediate flows to UK industry that are domestic (by industry). We need a proportioning matrix for each of the years 1990 to 2019. For 2020 to 2023 we use the 2019 matrix. For the years between 1990 and 1995; 1995 and 2005; 2005 and 2010; and 2010 and 2013, we make linearly interpolated matrices bridging the known matrices as shown. Due to a lack of data, we are making assumptions about the exact proportions of products supplied to intermediate demand from domestic industry for the years 1991 to 1994, 1996 to 2004, 2006 to 2009, 2011 to 2012 and 2020 to 2023.

2.3.3 Reconciling the EXIOBASE and FIGARO data to the UKMRIO structure

Now that we have data on the total imports to UK intermediate demand, we need to disaggregate this row by industrial sectors from Brazil, Russia, India, China, South Africa, the USA, Japan, the EU, the rest of the OECD, and the rest of the world to show the source of imports. This data is taken from EXIOBASE or FIGARO but as discussed above, EXIOBASE and FIGARO need to be transformed to the UKMRIO table structure. We transform the whole of the EXIOBASE MRIO table and FIGARO MRIO table because we will be using sections elsewhere.

First, we transform the industries and products to 112 sectors. This can mean aggregating some sectors together and splitting some sectors into two or more parts. We use the UK's industrial output breakdown as weights to disaggregate other region's use table columns and the UK's product output breakdown to disaggregate other region's supply table columns. Using the UK data as weights for disaggregation is an assumption. Final demand, value added and environmental extension data are similarly aggregated and disaggregated.

Secondly, we aggregate the regions to form the 11 regions used in the UKMRIO.

Finally, the data is converted to GBP from Euros using currency conversion factors from the appropriate year. We use a 12-month average conversion rate.

Some of the EXIOBASE and FIGARO data, such as the portion representing trade between non-UK regions, is slotted straight into the UK model. Other data, such as the imports to UK intermediate demand and the exports from UK intermediate demand are used as proportions to help disaggregated information that we already know from the ONS UK tables.

2.3.4 Imports to UK intermediate demand

The first data requirement is a matrix showing the proportion of each intermediate flow to UK industry that is from Brazil, Russia, India, China, South Africa, the USA, Japan, the EU, the rest of the OECD, and the rest of the world products. This is a 10x112 by 112 rectangular matrix with column sum equal to one. The 1,120 rows are flows from foreign sectors. Because this is a matrix of proportions, we need not convert the matrix to GBP from Euros, and currency exchange rate issues are avoided.

The 'imports from' row (calculated from the UK combined use tables) is then multiplied down this proportional matrix to give the full intermediate flows to UK industry table.

2.3.5 Exports from UK to intermediate demand

The next use of the EXIOBASE and FIGARO data sets is to fill in the rows showing where UK products are intermediate demands to Brazil, Russia, India, China, South Africa, the USA, Japan, the EU, the rest of the OECD, and the rest of the world industry and final demand. EXIOBASE is used to make a proportional matrix of the use of UK products in the rest of the world intermediate and final demand. As described above, the trade block data from the full Eora model is used and manipulated to make 10 matrices of 112x112. However, at this stage we do *not* use the 'exports from' column from the UK combined use tables as the exports total. Instead, we know that the sum of the 'exports from' is equal to the sum of the imports to UK intermediate demand plus the different in the UK's value added and the final demand for UK products from both domestic and foreign consumers. This total is multiplied by the proportional matrix where the total of the whole matrix is one (rather than the total of the rows or the total of the columns).

Final demand from the UK tables includes the final demand of imported goods so we need to use the analytical tables again to make a domestic proportion table. Final demand of UK products by the rest of the world is taken from the UK trade blocks of the full EXIOBASE or FIGARO database and multiplied by an exchange rate currency conversion factor to get the data in the right unit. Clearly this introduces some uncertainty into the model because we use the same conversion factor for each region and sector, when it is likely that the conversion factors should be sector and country specific. However, at present, this data is not available.

2.3.6 Balancing the whole table

The table now needs to be balanced to ensure that total imports equal total output – in other words the row and column sums should be the same. The technique known as RAS iteratively re-proportions the table making adjustments to ensure first that

the column sums are correct then the column. The process is repeated until a desired level of accuracy is acquired.

To determine the true row and column sum vectors we use the fact that there are certain row and column totals that are set because the sum of the supply tables is fixed.

Figure 8 explains how the row and column sums are determined.

		UK supply table				A
			Rest of the world supply table			B
UK domestic use table	Intermediate demand from UK			UK final demand of UK	All rest of the world final demand of UK	C'
UK intermediate demand from rest of the world	Domestic use table			UK final demand of rest of the world	All rest of the world final demand of rest of the world	D'
UK value added	Rest of the world value added					
A'	B'	C	D			

Figure 8: Pre-balanced MRIO table

To balance the table, we know that:

- $A' = A$ (the row sum of the UK supply table)
- $B' = B$ (the row sum of the rest of the world supply table)
- $C' = C$ (the column sum of the UK supply table)
- $D' = D$ (the row sum of the rest of the world supply table)

The RAS balancing procedure is then used to re-proportion this section to ensure that the MRIO table balances.

3 Accuracy, uncertainty, effects of methodological changes and comparisons with other databases

3.1 The UK territorial, production and consumption-based accounts, 1990 to 2023

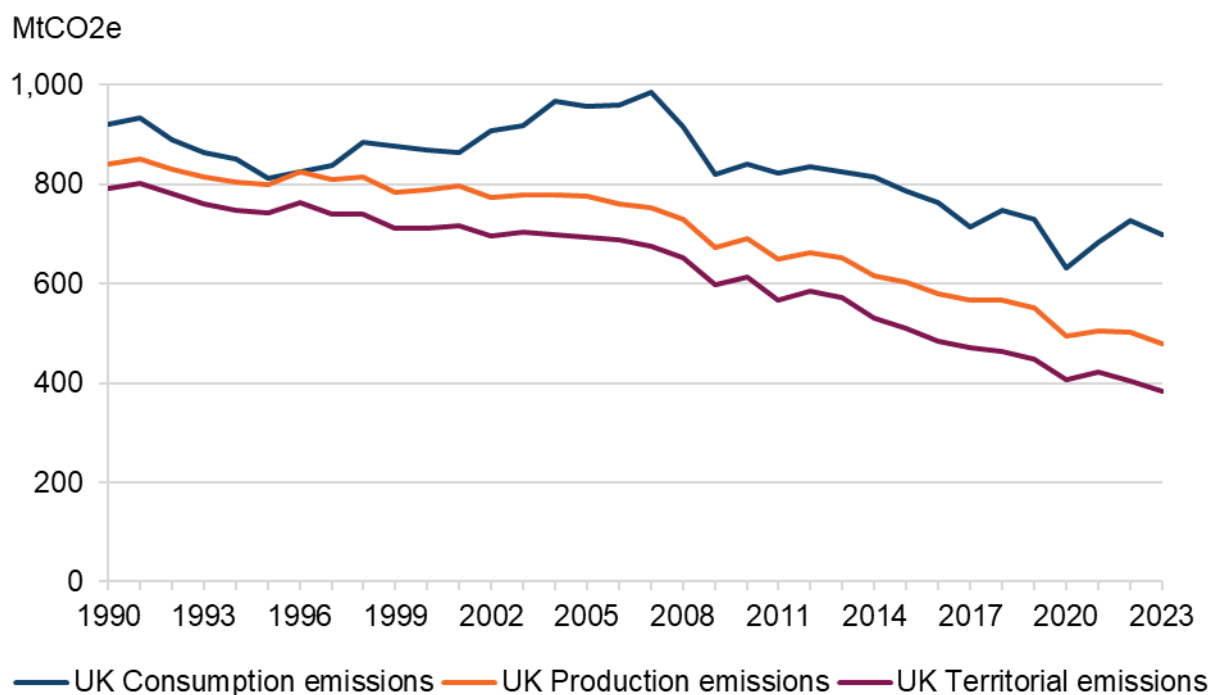


Figure 9: UKMRIO carbon footprint (all GHGs) results 1990 to 2023 alongside UK production and territorial and accounts

Source: University of Leeds; [DESNZ, Final UK greenhouse gas emissions statistics: 1990 to 2024 - GOV.UK](#); [ONS, Atmospheric emissions: greenhouse gases by industry and gas](#)

Figure 9 shows that where the territorial and production accounts show steady decreases between 1990 and 2024, the UK's consumption account initially increased to 2007 before reducing. Between 1990 and 2023, the territorial, production and consumption accounts, reduced by 53%, 43% and 24% respectively.

Figure 9 shows that the UK's consumption-based account for GHGs decreased by 12% between 1990 and 1995, before climbing to a maximum of 984 million tonnes (Mt) CO₂e in 2007 (an increase of 21%). The financial crisis saw a reduction of 17% to 2009, followed by a further 11% reduction between the years 2009 and 2019. The COVID-19 pandemic in 2020 saw a reduction of 14% in a single year, followed by a post pandemic increase of 15% to 2022. Between 2020 and 2022, the GHG emissions associated with UK consumption increased by 96 MtCO₂e. Of this 96

MtCO₂e, increases in household spend on transport services, restaurants and hotels and personal transport contributed the most. In 2023, the UK's consumption-based GHG emissions have fallen by 4% to 699 MtCO₂e.

3.2 The evolution of the UK consumption-based account

Calculating consumption-based accounts, which accurately cover emissions, energy, materials and water embodied in imports, has only been possible in the last decade and a half and the datasets and techniques are continually improving. Figure 10 shows the evolution of the UK's carbon footprint measured in MtCO₂e as calculated by the UKMRIO database. The overall pattern is very similar throughout the model versions. The new 2026 release estimates very similar footprint compared to the 2025 release between 1990 and 2010 but data improvements in the 2026 released have increased estimates between 2010 and 2015 and reduced estimates between 2015 and the latest year. The reasons for these differences are due to an improvement in the way we calculate the imports proportion. We have switched to using FIGARO v2025 for post 2010 imports. In the 2025 release we used an older version of FIGARO and only made the switch in 2014 due to data quality concerns. These methodological improvements are explained further in section 3.5.

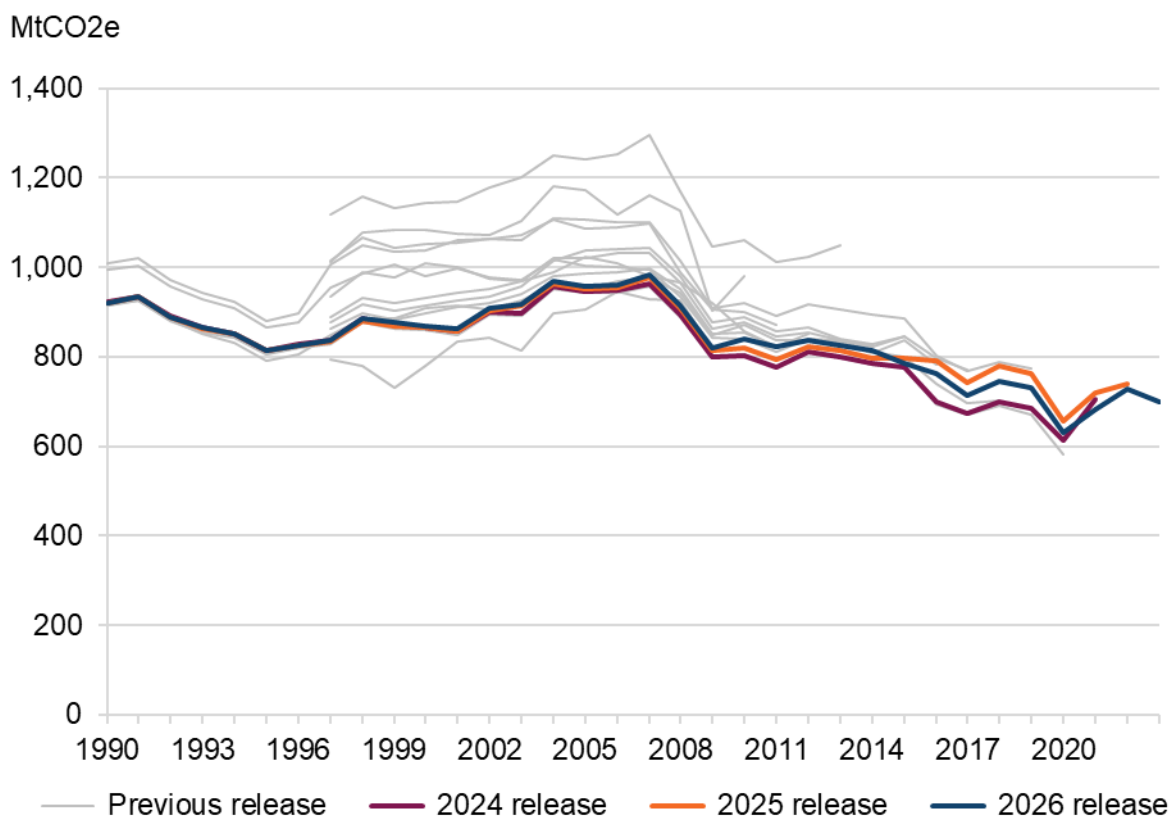


Figure 10: UKMRIO carbon footprint (all GHGs) results from 2011 release to 2026 release, 1990 to 2023

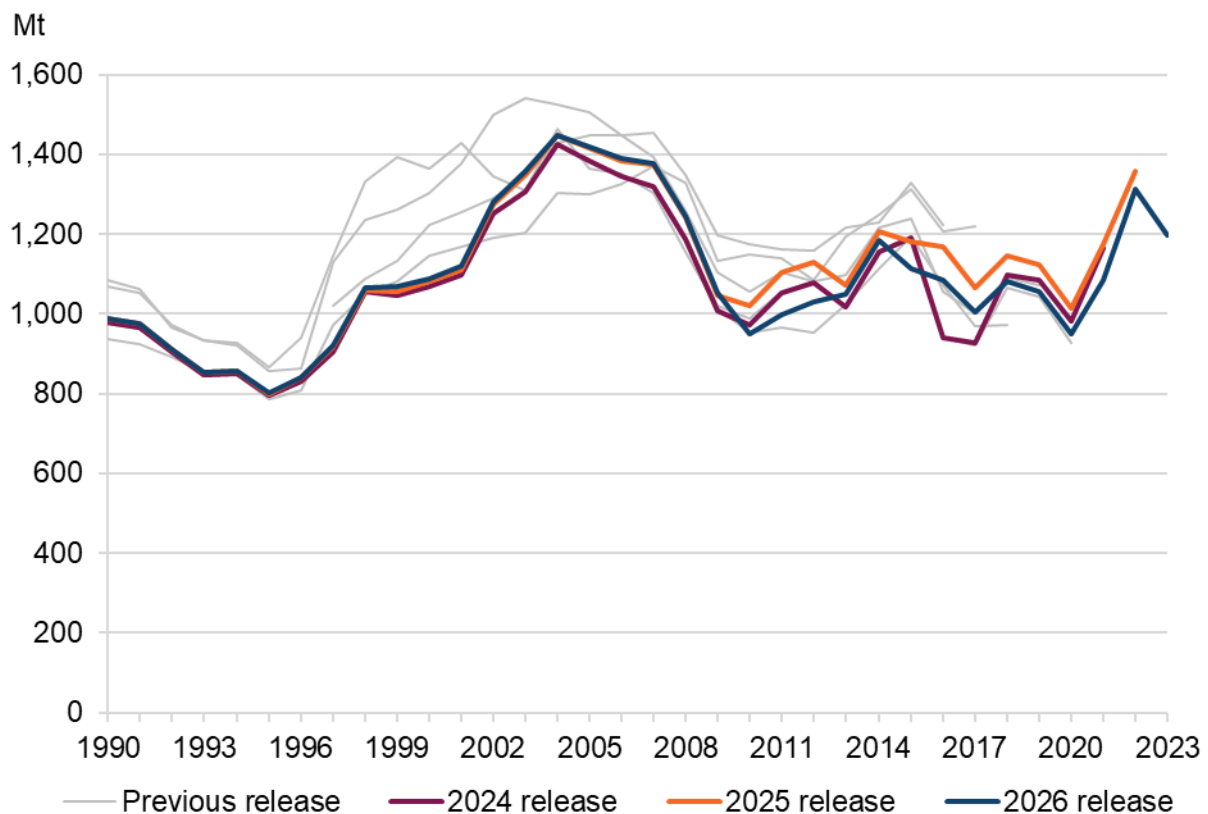


Figure 11: UKMRIO material footprint results from 2019 release to 2026 release, 1990 to 2023

Material footprint estimates have been calculated for the UK from 2019, meaning that we have eight versions to compare, and we see consistency in the estimates (see Figure 11). A major change in the material footprint occurred in the 2025 release with the move from EXIOBASE to FIGARO for traded data from 2015 onwards. This is documented in the [‘UK consumption account methodology 2025’](#).

3.3 Comparing UK consumption-based account with results from other multi-regional input-output databases

Prior macro-level analyses of the UK consumption-based account are available using various global MRIO databases. Examples include Steen-Olsen et al. (2012); Moran and Wood (2014); Tukker et al. (2014); Hertwich and Peters (2009); Wood et al. (2018); and Barrett et al. (2013). Other studies have employed other UKMRIO models (for example, Wiedmann et al., 2010; Druckman and Jackson, 2009). Figure 12 summarises the UK GHG footprint data provided by the most commonly used global MRIO databases. The UKMRIO model estimates slightly lower than other models to 2007 but post 2007, the results are strikingly similar to the Eora and EXIOBASE 3.9.6 models where we do not draw data from. We believe this to be important evidence that our methodology is producing results that are accurate and in-line with other work.

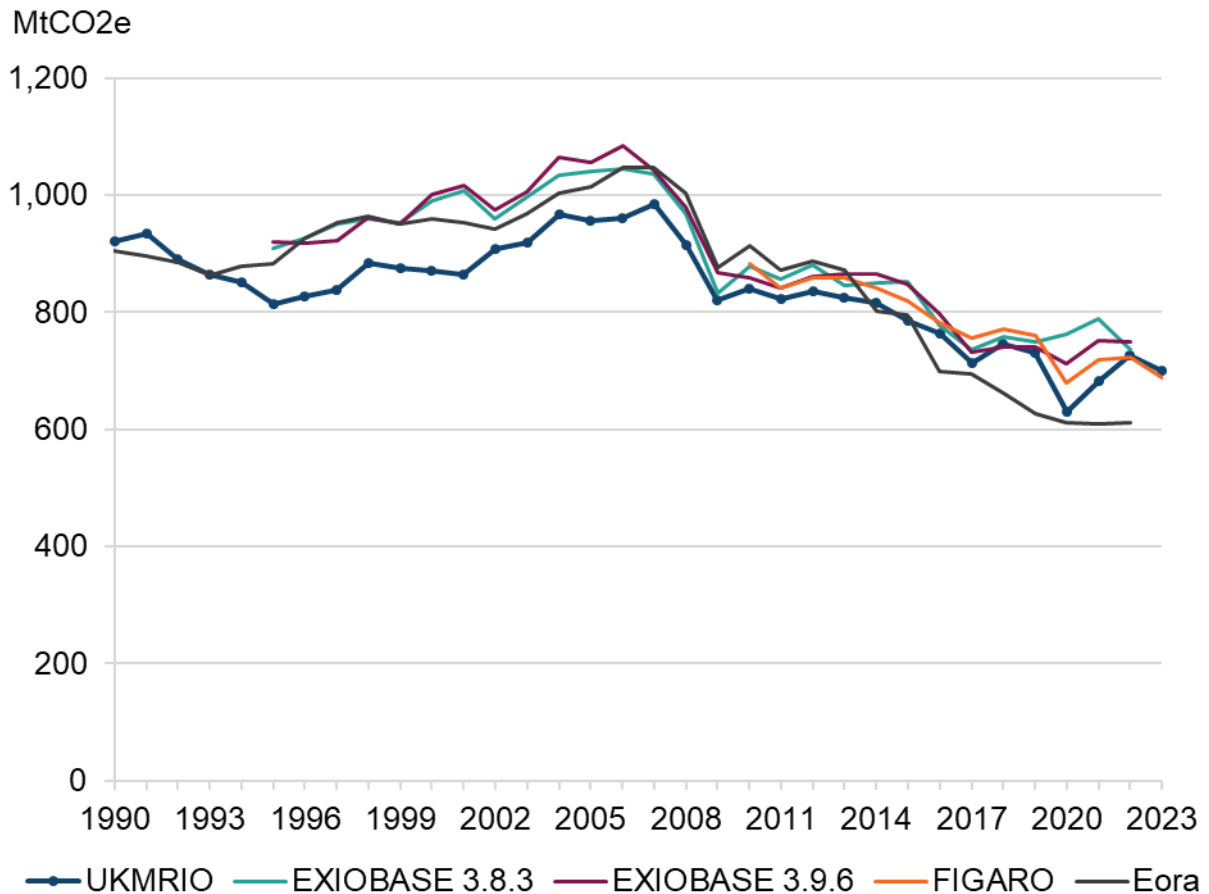


Figure 12: UK carbon footprint calculated by the UKMRIO database and four other global MRIO databases, 1990 to 2023

We have concerns, however, about the accuracy of EXIOBASE v3.8.3 in 2020 and 2021. EXIOBASE v3.8.3 was finalised in the year before the COVID-19 pandemic and its estimates for 2020 to 2022 are ‘nowcasted’ based on trend data and some global totals. We know that global emissions reduced in 2020, but this is not evident in the EXIOBASE data. This is the reason why we used project funding from the Economic Statistics Centre of Excellence (ESCoE) to explore the adoption of an alternative global MRIO to draw trade data from. Based on advice from the ONS and our own explorations (see Killian et al., 2026 [FORTHCOMING]) we chose to switch to using FIGARO for trade data post 2009. FIGARO is the only dataset that uses real data to estimate MRIO tables for 2023 (rather than nowcasting). We are also confident that because FIGARO is produced by Eurostat, there will be a commitment to maintain the model. Models produced by universities are often reliant on grant funding to maintain them.

3.4 Uncertainties involved in extending the database back to 1990

We use data from the National Archives to extend the dataset back to 1990. This data is not consistent with the UKMRIO database used to calculate the consumption-

based account. Sometimes the data uses a different classification system for the sectors, and it has to be transformed to the 112 sectors used in the national accounts. In other cases, data does not exist for a particular year, and assumptions have to be made using proxy data, for example, using data from a different year and adjusting the totals to match known changes in GDP.

The most accurate footprint estimates will be for the years 2010 and 2013 to 2015. For the earlier years, 1995 to 1996 are reasonable estimates of the footprint. 1992 to 1994 do not have accurate information on the character of trade into the UK. 1990 to 1991 are the least accurate estimates and use previous years tables as a large part of the model construction.

3.5 Effects of methodological and data changes for the 2026 release

In the 2026 update, there was a switch to using FIGARO v2025 for the traded data from 2010. In the 2025 update, we used an older version of FIGARO and only included it post 2014. This was the only major change for the 2026 release.

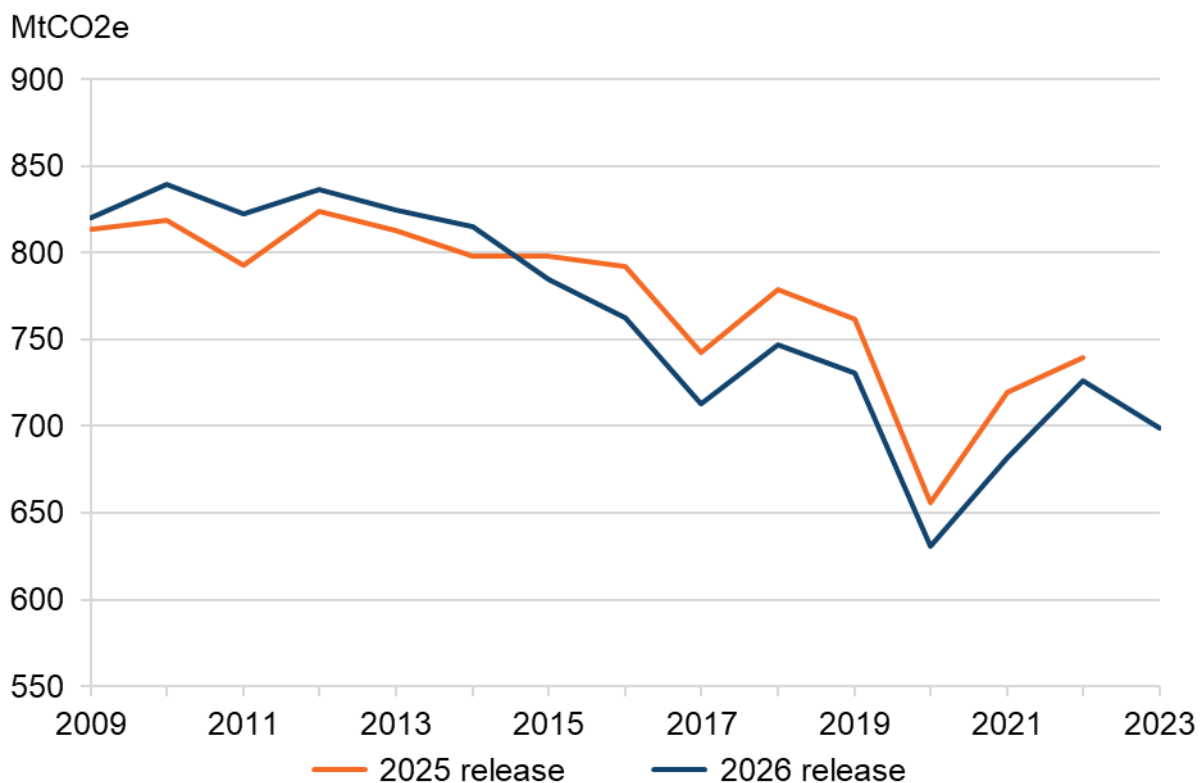


Figure 13: Comparison of the 2025 UK GHG release and the 2026 UK GHG release, 2009 to 2023

EXIOBASE v3.8.3 uses casting methods rather than real data for year post 2019 and therefore does not estimate consumption-based emissions between 2020 and 2023 accurately (see Figure 12). University of Leeds secured funding from ESCoE for 18

months to investigate the effects of sourcing import data from different source global MRIO databases. We ultimately made the decision to use FIGARO as a replacement. FIGARO has MRIO tables from 2010 to 2023 meaning that we needed to decide on which year to switch from using EXIOBASE v3.8.3 to FIGARO. Last year, we made the switch in 2015. However, there has been a new version of FIGARO released, and our investigations show that the data appears to have been improved between 2010 and 2014. So, for this year's release we switched to FIGARO v2025 from the earliest possible year: 2010. Figure 13 shows the UK carbon footprint results from 2009 to 2023 using the combination of EXIOBASE v3.8.3 and the older FIGARO in the 2025 release compared to using FIGARO v2025 in the 2026 release. The new FIGARO has the effect of making the post 2009 consumption emissions decrease slightly steeper.

Figure 13 shows the effect of changing the source of trade data for the GHG consumption emissions account, but we also need to consider the effect on the material footprint. As Figure 14 shows, the results for the UK material footprint show a slightly reduced figure for materials but the general pattern is preserved.

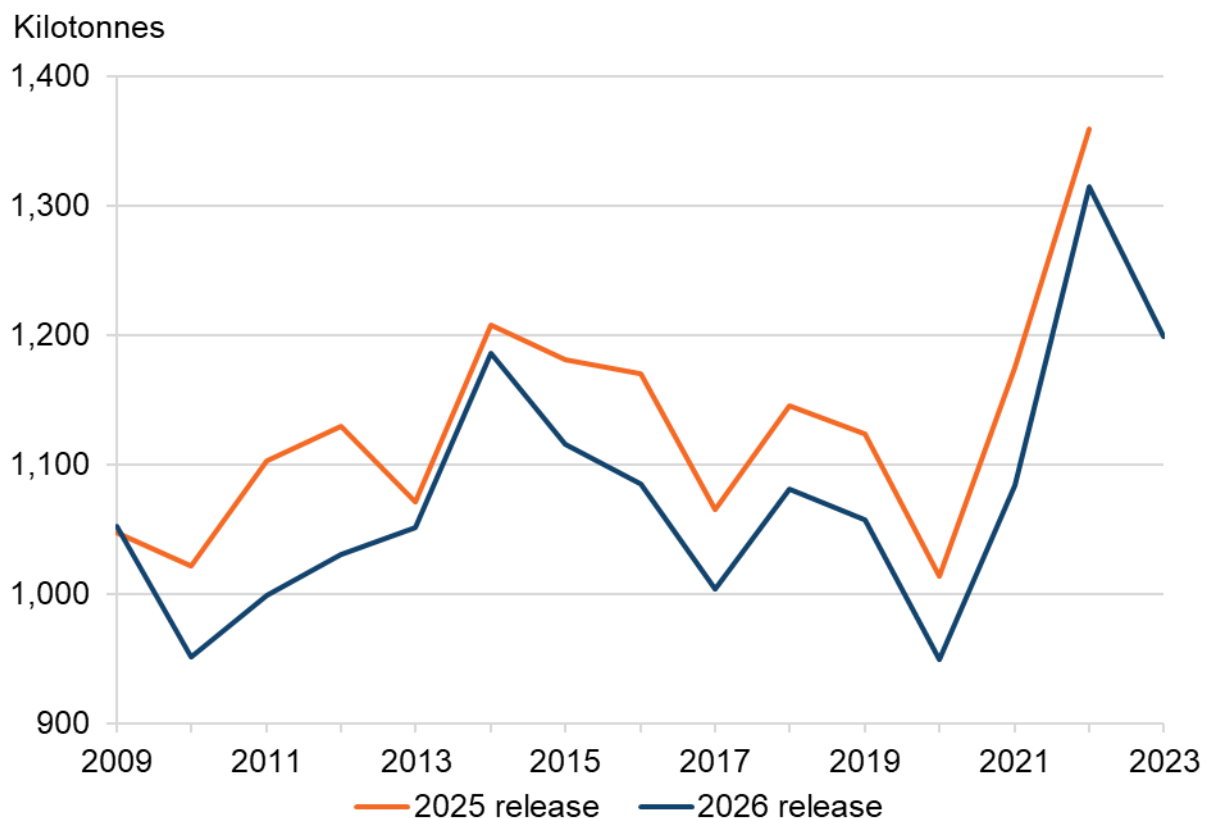


Figure 14: Comparison of the 2025 UK material footprint release and the 2026 UK material footprint release, 2009 to 2023

4 Results for the devolved regions

In 2026's release we are also able to report the consumption-based account for the devolved regions: England, Northern Ireland, Scotland and Wales.

We use a hierarchical hybrid methodology for estimating final consumption of each of the devolved regions (Minx et al., 2013). Essentially, we need to calculate what proportion of the total UK spend is each of the devolved regions is responsible for, for each consumption item contained in the database. For example, if England spends 85% of the total UK spend on Clothing, it receives 85% of the total UK footprint associated with clothing demand. To understand the portion of UK spend attributed to England, for example, we would either need to know total consumption of each good or service for each of England, Scotland, Northern Ireland and Wales or we would need an average expenditure profile for the devolved region and multiply this up by the number of residents.

For domestic consumption of gas and electricity we use the 'Regional and local authority consumption statistics' produced by DESNZ which give estimates of gas and electricity consumption at the regional (NUTS1) and local authority levels for Great Britain for the years 2005 to 2023. Separate data is available for Northern Ireland, but the time series is shorter. We convert the data into proportions and use trend projections to project the data back to 2001 for all regions.

We use estimates of household spend profiles from the Living Costs and Food Survey (LCFS) for all other spends on goods and services. Since 1957, the ONS has annually surveyed UK households on their weekly expenditure (UK Data Service, 2024). In 2008, this survey became known as the Living Costs and Food Survey; prior to this it was known as the Expenditure and Food Survey. The LCFS achieves a sample of around 5,000 UK households and is used to provide information on retail price indices, National Account estimates of household expenditure, the effect of taxes and benefits, and trends in nutrition. In addition to providing information on household spend on over 300 different product types (coded by the European Standard Classification of Individual Consumption by Purpose (COICOP)). Additional information is collected such as the age, sex and occupation of members of the household, the total household income, taxes paid, and the location, tenure, dwelling type. The characteristics of each sampled households can then be compared to the characteristics of all UK households using the UK census. The survey strives to produce a representative sample of the 28 million UK households. For each of the 4,000 plus household surveys in the 2023/24 release, a weight is supplied to indicate the proportion of UK households that are represented by this profile. For example, the first household in the 2023/24 survey has a weight of 9,636 and the sum of every weight is 28,461,497. In all calculations for this study, we use the weights to convert

the sample into a set of data that is representative of all 28 million households in the UK.

The LCFS is available in a format that is comparable for the financial years 2001/02 to 2023/24. This means that our results for the devolved regions start at 2001 rather than 1990.

The UK is unusual because the supply and use tables constructed by the ONS include final demand by UK households that is split by both product sectors in the input-output structure and 42 aggregated sectors found in the LCFS. This means that we can be confident in linking these datasets and exploring household energy footprints by groupings formed from the household survey. The UK is unique in providing this bridge table between the two formats of recording spend by products. In other studies much work has gone into the construction and evaluation of these bridge tables (Steen-Olsen et al., 2016; Min and Rao, 2017) but because the LCFS is an input to the national accounts, the ONS can supply this mapping at an aggregate scale.

3 Household final consumption expenditure 2016					
Contents		01.1	01.2	02.1	02.2
Product		Food	Non-alcoholic beverages	Alcoholic beverages	Tobacco
01	Products of agriculture, hunting and related services	15 808	-	-	-
02	Products of forestry, logging and related services	-	-	-	-
03	Fish and other fishing products; aquaculture products; support services to fish	699	-	-	-
05	Coal and lignite	-	-	-	-
06 & 07	Extraction Of Crude Petroleum And Natural Gas & Mining Of Metal Ores	-	-	-	-
08	Other mining and quarrying products	-	-	-	-
09	Mining support services	-	-	-	-
10.1	Preserved meat and meat products	19 190	-	-	-
10.2-3	Processed and preserved fish, crustaceans, molluscs, fruit and vegetables	12 200	1 908	-	-
10.4	Vegetable and animal oils and fats	1 193	-	-	-
10.5	Dairy products	11 772	-	-	-
10.6	Grain mill products, starches and starch products	2 926	-	-	-
10.7	Bakery and farinaceous products	8 719	-	-	-
10.8	Other food products	14 527	3 144	-	-
10.9	Prepared animal feeds	-	-	-	-
11.01-6 & 12	Alcoholic beverages & Tobacco products	-	-	18 520	19 640
11.07	Soft drinks	-	6 731	-	-
13	Textiles	-	-	-	-
..	...	-	-	-	-

Figure 15: A screenshot of ‘Table 3: Household final consumption expenditure 2016’ from the supply and use tables, 1997 to 2016 (ONS, 2018)

The LCFS collects information on the Government Office Region that each surveyed household is found in. We construct an average spend profile for households in each of the four devolved regions, multiply this by the households in the regions and calculate the portion of spend by each product that each region is responsible for in order to disaggregate the total UK footprint. This method ensures that the sum of the regions equals the total footprint.

4.1 Accuracy of devolved region results

This method assumes that each region consumes domestic and imported products in the same proportions. For example, we assume that households in England consume the same proportion of Brazilian beef products as households in Wales. This is because we assume the same production structure for products regardless of where the household is located. For many products, this is a reasonable assumption. However, we are unable to demonstrate the fact that electricity generation in Scotland may be made up of a greater proportion of renewable fuel compared to the rest of the country.

The ideal approach would necessitate the construction of a MRIO model where England, Northern Ireland, Scotland and Wales are individual regions, each with their own use tables detailing their unique production recipes. However, this type of data is not currently collected and the approach we use with the four estimated final demand vectors is the best available.

Obviously, the final demand vectors generated for each of the devolved regions are built on survey data. Even though the LCFS surveys over 4,000 households each year, these are not equally distributed by region. Table shows the number of households surveyed in the four devolved regions of the UK in the 2023/24 financial year. It is possible that one household with particularly unusual spend in the week surveyed could skew the results when small numbers of surveyed homes are used and where this happens, those surveyed results are smoothed.

Table 3: Number of surveyed households in the 2023/24 LCFS

Devolved region	Number of surveys in the LCFS, 2023/24
England	2,909
Scotland	523
Wales	366
Northern Ireland	407

The Welsh Government publish the [carbon footprint of Wales](#) in their Wellbeing of Wales statistics, and the Department for the Economy publish the [carbon footprint of Northern Ireland](#) as one of their indicators to monitor decarbonisation and the circular economy.

4.2 Scotland data

The Scottish Government publishes their own estimates for the [carbon footprint of Scotland](#) which takes the final demand vector from Scottish specific input-output tables and uses this with the UKMRIO. The results differ slightly to the estimate produced using the LCFS.

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