centre for sustainable energy

UNIVERSITY OF EXETER

Impact Tool Method Paper

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1. INTRODUCTION

This paper describes the methods and data sources used to estimate greenhouse gas (GHG) emissions in the Impact tool developed by the Centre for Sustainable Energy (CSE) and the Centre for Energy and the Environment at the University of Exeter. There are well established standards and/or tools for carbon accounting for countries, local authority areas, businesses, projects and individuals. The tool has been created in response to a perceived need for places smaller than local authority areas but larger than single households to estimate their "carbon footprint".

2. TYPES OF "CARBON FOOTPRINT"

The term *Carbon Footprint* is widely used to denote emissions associated with human activity. It lacks a clear scientific definition and variations may include a number of considerations [1]. The first

of these is the inclusion or omission of greenhouse gases other than carbon dioxide (CO_2). If included, greenhouse gases other than carbon dioxide are weighted by their global warming potential to produce a carbon dioxide equivalent (CO_2 eq) value. The approach taken here has been to include all greenhouse gases and present results as t CO_2 eq (tonnes of carbon dioxide equivalent).

When undertaking footprinting exercises for organisations, emissions are commonly categorised as one of three scopes: Scope 1 are direct emissions from fuel combustion, Scope 2 are indirect emissions implicit in the consumption of electricity and network supplied heating and cooling, and Scope 3 are indirect emissions arising as a consequence of consumption of other goods and services[*]. This type of footprinting is applicable to organisations, but not to places e.g. it could be applicable to Devon County Council the organisation (for example the vehicles it owns [normally Scope 1], the materials it purchases [Scope 3] etc.), but not to "Devon" the place. Therefore presenting emissions in terms of Scopes 1 to 3 are not applicable or necessarily suitable for the tool developed here.

A footprint for a geographic area (what this tool considers) may be produced on a strict **territorial** basis (all emissions occurring within the area) or on a **consumption** basis (all emissions caused by residents of the area, regardless of where geographically they occur). For example, territorial emissions would include those from all industry, agriculture and transport activity within the area (even if the agricultural output is consumed in a different place). Consumption-based emissions, on the other hand, would include upstream and downstream emissions from residents' consumption of manufactured goods, food and their own transport activity, regardless of where the emissions occur.

These types of footprints are typically used in different contexts as illustrated in Figure 1. At a global level, the territorial and consumption footprints will by definition be the same. Reporting at national and local authority tends to be undertaken using a territorial approach, though the UK does also produce a consumption based footprint (though the data is in arrears). At a national level, the UK consumption footprint is larger than the territorial footprint as in net terms we "import" more emissions than we "export" through the trade of goods and services. Individual and household footprints are produced on a consumption basis.

[*] For corporate carbon footprints the distinction between Scope 1/2 and Scope 3 becomes more nuanced, and typically considers ownership of the asset producing the emissions, e.g. emissions from vehicles owned or leased by the company are categorised as Scope 1 or 2, whereas emissions from employee's vehicles used for company business and bought-in logistics services are categorised as Scope 3.

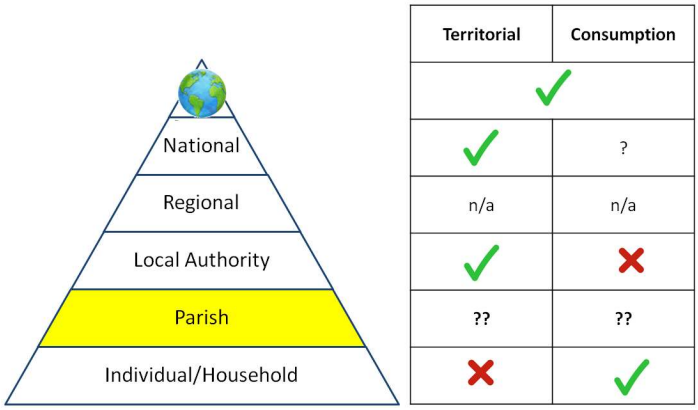


Figure 1: Typical application of Territorial and Consumption "carbon footprints"

Footprints for geographic areas smaller than a local authority but larger than an individual household represent a current gap in terms of what is routinely produced, and the approach undertaken here has been to produce footprints using both methods. It is important to understand that the two calculations are not directly comparable (the only exact overlap is emissions from dwellings, as these by definition only occur within the territory, and the consumption is by the population of the area) and intended to be used in a complementary way:

- Consumption Footprint: This indicates the impact of consumption of residents and should be used to highlight areas of individual behaviour that should be targeted to reduce emissions. It can be supplemented by and compared to individual consumption footprints of households within a territory (provided the methods used are similar).
- Territorial Footprint: This indicates the emissions occurring within a geographic area. Whilst there might be some overlap (e.g. territorial road transport emissions would arise from transport of both residents who live in the territory, and from those who don't and upstream freight), the intention of providing this information is to identify high carbon usage in the territory so that parishioners and local groups can constructively engage with those sectors. The territorial footprint has more diversity across the country than the consumption footprint e.g. the presence of a trunk road or large industry can significantly increase per household territorial emissions.

The results may be stated as the total absolute emissions for a municipality, individual or corporate entity, or normalised per unit land area, per head of population or per household. The approach undertaken here has been to provide results in absolute terms, and per household.

The principal data required to calculate a carbon footprint include the amount of consumption (on either a territorial or consumption basis) and emission factors for each fuel, good or service consumed. Consumption data is available from a range of public and private sources. Published sets of emission factors are available from a number of sources [2,3]. Established methodologies (and examples / resultant datasets) exist for carbon footprints at a variety of scales, for example PAS2070 [4] for city-level footprints on either a territorial or consumption basis, UK government local authority CO_2 emissions data [5]. Adopting an established methodology will help ensure the repeatability and reliability of results.

3. Requirements for Parish Resolution Footprinting

The following requirements were specified at the outset of the project to maximise the utility of the footprinting tool:

- **Ease of use:** Minimal user input (e.g. selection of the parish of interest, options to normalise the output per head of population or unit land area, selection of a territorial or consumption-based footprint and the inclusion or omission of non-CO_2 greenhouse gases).
- **Repeatability:** The underlying data should be consistent across the geographic extent of the model (to allow valid comparison of parishes) and updated following a fixed methodology at frequent intervals (preferably annually). The model should be documented sufficiently to allow others to understand and reproduce the calculation method.
- **Quick:** The project budget precludes primary data collection, so established data sources will be used. To make the tool accessible to a wide range of end users it should take the form of a website or app that will run on widely available IT platforms, and processing time should be minimal. This may imply pre-calculation of results.
- **Relevant:** Should include, and therefore discriminate based on, all major sources of GHG emissions including those that individual and local action groups would be able to influence, e.g. choice of travel mode, local renewable energy collective.
- **Reputable:** Source data (including emission factors) should be high quality and sourced from recognised organisations (governmental and international bodies) to minimise error margins in the results.
- **A driver for change:** A tool that is repeatable, relevant and reputable can inform local decision making processes and drive down the carbon footprint at a local level, allowing the community to take informed action ahead of the national trajectory that is reliant on centrally made (top-down) policy decisions.
- **Consistent with Local Authority footprinting:** Outputs should use (or include) a methodology that is consistent with the footprints already produced (or new footprints) at local authority level. This will allow valid comparisons to be made at a regional level.

4. Existing Data Sources

Following from Section 0, it is preferable to use data from primary sources or produced using established methodologies, for example National Statistics. The data should be updated at regular intervals, e.g. annually, and publically accessible.

4.1 Spatial Granularity

Source data should be as granular as possible (where this is very fine it can be aggregated to parish level). Where the geographic boundaries adopted in datasets differ from parish boundaries, estimation was required to convert between the two geographies. Parish, output area (OA, LSOA, MSOA[*]), district, county and region boundary systems are related to a certain extent, reducing the impact of such conversions (Figure 1). Postcode boundaries bear little relation to the aforementioned boundary systems, hence a greater level of conversion is required introducing more scope for inaccuracy (Figure 2). Source data may be aggregated in some cases where the sample size is small to preserve the anonymity of sample points (e.g. large consumers of fuels). This can create an added layer of complexity in the calculation of an accurate parish-level estimate.

[*] Output Areas (OA) were first introduced for the 2011 Census; Lower Layer Super Output Areas (LSOA) and Middle Layer Super Output Areas (MSOA) aggregate surrounding OAs. The system aims to create areas with similar populations, averaging 309 for OA, 1,500 for LSOA and 7,200 for MSOA.

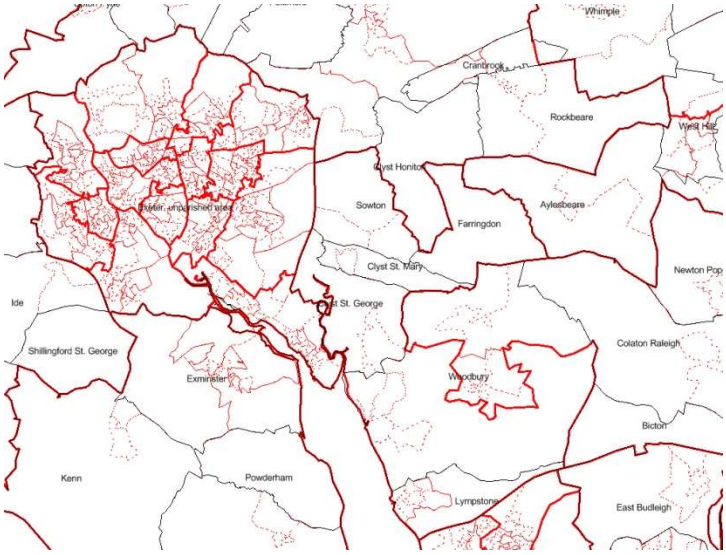


Figure 1: Plot comparing parish (black, named) and OA/LSOA/MSOA (red dotted/solid/bold) boundary systems.

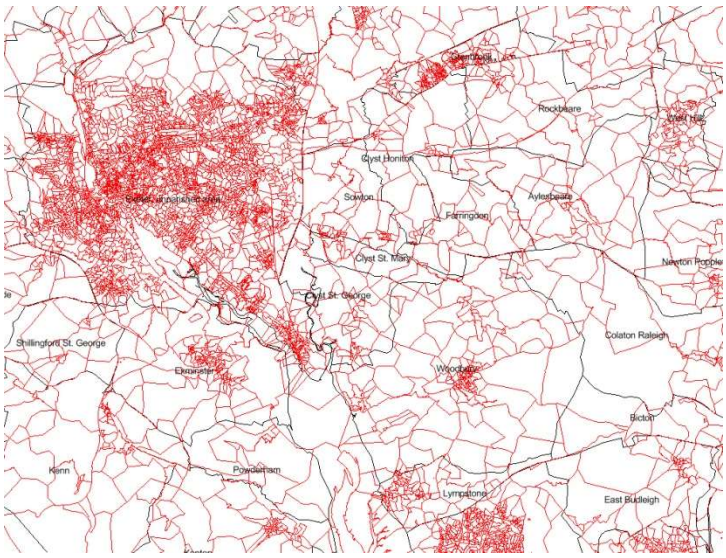


Figure 2: Plot comparing parish (black, named) and full postcode (red) boundaries.

Where the constituent parts of a parish that is split between, say, output areas, have relatively homogenous characteristics, it may be acceptable to aggregate the data on an area-weighted basis. For example, 40% of an output area is within the parish so the parish is allocated 40% of its energy consumption. In some cases a parish may contain a mix of urban and rural areas with a large difference in population density, in which case population-weighted apportionment is likely to be more representative. For example, the population of a parish is 800; it contains one output area with a population of 350, plus a portion of two further output areas with populations of 300 and 380 respectively. The contribution from the two partial output areas could be calculated as (800–350) ÷ (300+380) = 450 ÷ 680 = 0.66. For any statistics that are only available at national or regional level, disaggregation would be necessary to produce a parish-level estimate.

4.2 Characteristics of Data Sources

An initial search of potential data sources, primarily to assess territorial emissions, was undertaken in spring 2020 as shown in **Error! Reference source not found.**.

Sector					Name	Resolution								Latest Year Available	Update Frequency
General	Buildings	Transport	Consumption	Other		National	Regional	LA	MSOA	LSOA	OA	Postcode	Other		
x					**Population estimates** [6] By age; population density	x	x	x	x	x	x			2018	Annual
x	x	x		x	**UK local authority and regional carbon dioxide emissions** [7] CO_2 (not CO_2 eq) emissions by sector, including industrial/commercial, agriculture, domestic fuels, road transport by road type, diesel railways, land use change/forestry. Includes population data.			x						2017	Annual
x					**Nomis** [8] Labour market statistics; Census data download. Resolution options include parishes	x	x	x	x	x		x	x	2011	Census years
x	x	x			**Census/Data Shine** [9] All Census data Travel to work visualisations									2011	Census years
	x				**Sub-national electricity consumption data** [10] Domestic available to LSOA and postcode; non-domestic to MSOA				x	x		x		2018	Annual
	x				**Lower and Middle Super Output Areas gas consumption** [11] Domestic available to LSOA; non-domestic to MSOA				x	x				2018	Annual
x	x	x		x	**National Atmospheric Emissions Inventory** [12] Wide range of pollutants (inc. GHG) mapped by source (energy production, energy consumption(commercial / industrial, domestic), agriculture, industrial processes, road transport, other transport, waste). Mapped at 1 km resolution and point source data for large sources.								x	2017	Annual
		x			**Sub-national road transport fuel consumption statistics** [13] Road transport energy by vehicle type and road type			x						2017	Annual
		x			**Department for Transport Statistics** [14] Vehicles registered by body type and fuel. Local data available to postcode area (e.g. EX4)	x	x	x				x		2019	Annual
			x		**UK National Accounts, The Blue Book: 2019** [15] Large dataset of national financial accounts. Section 13 "Environmental Accounts" includes GHG emissions by broad sector	x								2017	Annual
			x		**Family Spending 2011: A report on the living costs and foods survey 2010** [16] Detailed regional sector based weekly household spend (excludes government expenditure).		x							2018	Annual
			x		**Income estimates for small areas, England and Wales** [17] Local level household income estimates				x					2018	Biennial

Sector					Name	Resolution								Latest Year Available	Update Frequency
General	Buildings	Transport	Consumption	Other		National	Regional	LA	MSOA	LSOA	OA	Postcode	Other		
			x		**Environmental Accounts: Atmospheric emissions: greenhouse gases by industry and gas** [18] GHG by sector on a "production basis" (emissions produced 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). International aviation and shipping emissions are allocated to countries based on the operator of the vessel.	x								2018	Annual
			x		**Input–output supply and use tables** [19] Spend by detailed economy sub sector by households, local govt. etc. including intermediate spend within supply chains and including imports and exports	x								2017	Annual
			x		**Detailed household expenditure by countries and regions: Table A35** [20] Spend by detailed economy sub sector by households, local govt. etc.		x							2017	Annual*
x			x		**UK's carbon footprint** [21] Detailed GHG emissions by SIC sector for UK, including supply chain emissions and kg CO_2/£. Based on spending of UK residents on goods and services, wherever in the world these emissions arise. Broken down by domestic and various non-domestic institutions. Electricity sector reported separately, not by end-user.	x								2017	Annual
				x	**Structure of the agricultural industry in England and the UK at June** [22] Livestock numbers and crop by area. High level data annual, detailed survey every 3 years corresponding to the EU Farm Structure Survey.	x	x	x						2018/ 2016	Annual / Triennial
x	x	x	x		**Government emission conversion factors for greenhouse gas company reporting** [2, 23] Greenhouse gas emission factors for fuel, electricity, refrigerant, transport, water, waste and hospitality consumption in the UK.	x								2019†	Annual
			x		**Environmental Reporting Guidelines: Including streamlined energy and carbon reporting guidance. March 2019** [24] Includes supply chain emissions (Annex E): CO_2 eq emitted per £ spent for Standard Industrial Classification categories of consumption.	x								2009‡	–

Table1: Potential sources of data.

5. Conversion of Datasets

Source datasets are available at varying spatial resolutions, e.g. parish, OA, LSOA, MSOA, local authority, NUTS 3, NUTS2 or regional, as described in Section 4.2. The tool needs to be able to

* 3-year rolling average.

† Note: the underlying data used to derive the factors lags behind the reporting year by two years; this can be particularly significant for the rapidly changing grid electricity emissions factor.

‡ Note advises to factor spend to take into account subsequent monetary inflation.

output results at the following spatial resolutions: parish, LSOA, MSOA, LAU1 (district authority), NUTS3 (unitary authority), NUTS2 (counties), NUTS1 (regions) and national (United Kingdom).

Conversion between resolutions has been conducted on the basis of land area and population, using a GIS-based approach.

Area-based conversions are achieved by splitting up the areas defined in one system (a) using the boundaries of a second system (b) and creating a list of the area of land common to objects in both systems. Values for system a are apportioned to system b by multiplying by the land area common to both system as a proportion of the total area of the object in system a, the resulting values are summed for all objects in system a that intersect the object in system b. This approach has been used to convert population data from 2011 parish boundaries (used as standard for the ONS parish population dataset for 2002 to 2017); however in a small number of cases the population has been estimated in a similar manner from OA-based data. The approach has also been used to apportion population from parishes to postcodes and 1 km grid squares; these population estimates could then used in population-weighted apportionment between datasets. It has, however, been found that discrepancies between different sources of population data (parish and OA) can lead to such an apportionment generating anomalies, in most cases area-based apportionment has therefore been adopted in the final dataset.

Population-based conversions are achieved by apportioning (or where the boundary systems align, by assigning), population from one boundary system on an area basis, i.e. the assigned population is determined by comparing the intersecting area to the total area of the object in the dataset being converted from.

Standard spreadsheet templates have been produced for each conversion that might be necessary from a more detailed to less detailed spatial resolution, and vice versa, i.e. between:

- parish and LSOA[*];
- LSOA and MSOA;
- MSOA and LAU1;
- LAU1 and NUTS3;
- NUTS3 and NUTS2;
- NUTS2 and NUTS1;
- NUTS1 and national.

Additional conversions have been provided from other spatial boundaries which source data might be based on:

- output area (OA) to parish[††];
- full postcode to parish[††];
- 1 km grid square[†] to parish[††];
- LAD (S12…) to LAU1 (S30…) (Scotland only).

[*] These conversions are between boundary systems that do not align therefore population apportionment is necessary as described in the text.

[†] Aligned to the British National Grid.

Many of the boundary systems are updated over time, e.g. as administrative areas change. The analysis has adopted a standardised set of boundaries for all years; source data may need to be converted to these boundaries. In many cases changes are minor, e.g. district or unitary authorities merging to form a larger entity, in which case adjustments could be carried out using a few simple summations; if the differences are more widespread and significant a bespoke conversion spreadsheet has been created based on comparing common areas and apportioning populations as described above. The standard boundaries adopted are:

- parishes: as at May 2020 (Ordnance Survey Boundaryline dataset; revised biannually) (not applicable for Scotland or Northern Ireland);
- OA / LSOA / MSOA: 2011 (revised every decade for the national census) (not applicable for Northern Ireland);
- LAU1: May 2020 for England and Wales (Ordnance Survey Boundaryline dataset; revised biannually); June 2019 for Scotland; 2014 for Northern Ireland.
- NUTS3 / NUTS2 / NUTS1*: 2018.

Tables of populations have been collated at each of the standard output resolutions (plus postcodes and 1 km grid squares); these are used in the above conversions, and also to convert CO_2e results between area totals and per capita figures.

Tables of average household size have also been collated at each of the standard output resolutions; these are used to convert CO_2e results between per capita and per household figures.

6. CONSUMPTION-BASED FOOTPRINT

6.1 SUMMARY

Consumption emissions are more closely linked with personal carbon foot printing calculations than territorial emissions, and could be considered an estimation of aggregating household carbon footprints to the parish level. In contrast to territorial emissions, consumption emissions associated with a given Parish will not all be emitted in geographical boundaries of that Parish. For example, a rural parish with no airport or airstrip but with a high proportion of frequent flyers will have high carbon emissions associated with flying behaviours. However, these emissions will not be directly produced in that parish.

Of course, it is not possible to conduct detailed household level carbon footprinting for all households in every parish across the country. Therefore, a variety of data sets providing information on household characteristics (e.g. social demographic information), building information and national statistics have been used to model and estimate energy and emissions associated with typical household consumption behaviours.

At the core of this analysis has been address level data, supplemented with data available at higher geographies and corroborated with national statistics wherever possible. Address level data has then been apportioned and aggregated up to the parish level.

Consumption emissions have been calculated for six separate sectors:

* The NUTS1 areas have remained static; NUTS2 and NUTS3 have experienced revisions in Scotland and Northern Ireland.

- Domestic housing emissions (heating fuels and electricity consumption)
- Transport
- Food
- Other goods and services
- Waste

Information on the sectors included in the analysis and the data sets used in the calculation of each consumption 'sector' are presented below. The full set of data sources used to estimate consumption emissions are presented in Table 2. Box 1 provides some additional information on the Mosaic data that was included in the estimation of consumption emissions.

Box 1: Summary explanation of Experian data used in the calculation of consumption emissions

Experian Mosaic and ConsumerView data

The spine of the datasets used Experian Mosaic household classification data. Mosaic is a geodemographic classification of households that is based on household and individual data collated from a number of government and commercial sources. Mosaic allocates every household (i.e. at address level) in to one of 15 'groups' and 66 detailed 'types'. Licencing Mosaic data also grants access to various online Experian tools which allow users to explore which household types best fit with certain socio-demographic indicators. In total there are approximately 250 different topics that can be explored to profile different Mosaic categories. These cover indicators such as values and attitudes (including toward environmental issues and technology), educational attainment, employment status, income levels, ethnicity, main forms of communication, internet usage, access to services, car ownership, regularity of visiting GPs and so on. Using Mosaics profiling tool allows users to explore of these variables and identify of specific types which best match a particular set of characteristics. These identified household types can then be mapped at address level or other levels of geography.

In addition to the Mosaic data, a number of other Experian household variables were used in the calculations. These included the following fields from Experian's ConsumerView data:

- Age of head of household
- Household composition (e.g. family type)
- Number of adults and children in household
- Number of bedrooms
- Residence/property type
- Tenure
- Property age
- Mains gas connection

6.2 Domestic Buildings

Carbon emissions from the use of energy in homes were estimated for each dwelling in the country. This used address level data – including household and building information from Experian data[25,26] (see Box 1), along with Energy Performance Certificate (EPC) certificate data[27] – to identify the different fuels used in each home, the size, type and energy efficiency of dwellings, plus household size. Typical energy consumption for these different combinations types of housing and households

was modelled using the English Housing Condition Survey (EHS)[28] and the National Household Model (NHM)[29], with the outputs assigned to different dwellings and household at address level. The consumption of mains gas and electricity from these calculations was aligned with postcode level data produced by the Department of Business Energy and Industrial Strategy (BEIS)[30,31] and calibrating total aggregated energy consumption to local authority inventories for each main domestic fuel. Where postcode level data was unavailable, data at LSOA level was used instead.

Parish level emissions for each fuel were obtained by aggregating emissions calculated for each fuel at dwelling level up to the Parish level. The data presented a Parish level includes the total emissions from all fuels consumed in the dwellings, plus emissions by mains gas, electricity, oil, LPG, coal and biomass fuels.

6.3 TRANSPORT

Detailed information on transport behaviour is captured in the Special License Access version of the National Travel Survey (NTS)[32], which represents the travel behaviours of all households in England. The data from the survey includes the number and different types of car owned by households, as well as the emissions rating of vehicles and the annual mileage driven by each household. It also records different trips taken by other modes of transport, including the origin, destination and total mileage and the number of domestic and international flights.

The data in the survey was used to calculate annual emissions for each household in the survey from different modes of transport (split by private vehicles, public transport and flying), and further location and social demographic information was used to segment the data to match to Experian address level data, including both Mosaic[25] and Experian ConsumerView[26] data which includes a range of other socio demographic fields. The rural/urban location of households was also considered in the analysis of the NTS data and when matching to address level data and determined using the ONS Postcode Directory[33].

The derived data at Parish level includes the total emissions from all forms of transport, and also a split by private vehicles, public transport and aviation.

6.4 EMISSIONS FOOD AND FROM CONSUMPTION OF OTHER GOODS AND SERVICES

Carbon emissions from consumption of food products, the purchase of other goods and the use of services were calculated using the Living Costs and Food survey (LCF)[34] which contains detailed information on the consumer spending habits of a representative set of households from across Great Britain. This enables the total spend on a detailed list of products to be calculated for each household in the survey. Carbon emissions conversion factors published by the UK Carbon Footprinting methodology[21] for calculating consumption emissions were then applied to these expenditures to calculate emissions related to consumer behaviour. This information was used to calculate annual emissions for each household in the survey. These emissions were split into two main categories: emissions from consumption of food (broken down by meat/fish and other food and drink products), and emissions associated from the purchase of goods, services, other consumption-related emissions. This second category included the following sub-categories:

Purchase of Goods: Purchase of all household goods, excluding food products, but including homeware, toiletries and medicines, furnishings, electricals and electronics, appliances, spare and replacement parts, and large purchases such as vehicles.

Services: Use of services including maintenance and repair of home, vehicles and other equipment, banking and insurance, medical services, treatments, education costs, communications (e.g. TV, internet and phone contracts), and other fees and subscriptions.

Other consumption-related emissions: These include other consumption related activities beyond the acquisition of goods and the use of services, and are predominantly leisure, entertainment, sporting or social activities.

Further location and social demographic information was used to segment different households in the data and to enable a match to Experian address level data (including both Mosaic[25] and other socio demographic fields from Experian ConsumerView[26]) and was used to estimate the typical consumption-related emissions for each household in a parish. The emissions were aggregated to parish level from address level estimates of emissions.

Food emissions data fields in the tool include the total emissions from food and diet, and also an split by emissions from meat/fish consumption and emissions from other food and drink.

Emissions from the consumption of goods and services emissions data fields includes total emissions and also the subcategories of emissions from purchase of goods, emissions from use of services and emissions other consumption-related emissions (see above).

6.5 Waste

Calculating carbon emissions associated from household waste used local authority statistics on the total volumes of waste and recycling streams and recycling rates at local authority level[35]. This included a breakdown of volumes of waste that was annually landfilled, incinerated (either via energy from waste or standard incineration processes), recycled and composted. UK government published carbon emissions factors for waste and recycling were then used to determine the total emissions and the per capita emissions in each local authority.

A lack of more detailed data on waste and recycling streams below local authority level meant that emissions associated with waste in a local authority had to be distributed out evenly across the population. At a household level, emissions were determined by the number of people in a dwelling multiplied by the per capita emissions in that local authority. Emissions were then aggregated to parish level.

6.6 Public Services and Other Categories

The UK Carbon Footprint includes emissions associated with households (separated into direct emissions from combustion of fuels, and indirect emissions associated with consumption of goods and services) which have been calculated as described in the sections above. In addition, the national footprint also includes a number of further categories which are: Non-profit institutions serving households, Central Government, Local Government, Gross fixed capital formation, Valuables, and Changes in inventories. In total, these account for 24% of the national consumption based carbon footprint. In order to allocate this to parish level, the nationally aggregated emissions from these additional categories were divided by the total population and then applied to parishes based on population and average household size. The underlying assumption is that provision of public services and capital formation provide value evenly across society.

Table 2: Sources of data and used for the consumption footprint.

Sector	Data source
Domestic housing	England and Wales Domestic Energy Performance Certificate data (2020)
	Experian Mosaic Public Sector
	Scotland Domestic Energy Performance Certificate data (2021)
	Experian ConsumerView
	English Housing Survey (2018)
	National Household Model
	BEIS sub-national electricity consumption statistics, postcode and LSOA level data 2018
	BEIS sub-national mains gas consumption statistics, postcode and LSOA level data 2018
	Sub-national total final energy consumption data 2018
	UK local authority and regional carbon dioxide emissions national statistics
	Greenhouse gas reporting - conversion factors 2020
Non-domestic buildings	Non domestic Energy Performance Certificate data (2020)
	Display Energy Certificate data (2020)
Transport	National Travel Survey 2002-2019
	Experian Mosaic Public Sector
	Experian ConsumerView
	ONSPD data (urban/rural identification of locations)
	Road transport energy consumption at regional and local authority level
	Greenhouse gas reporting: conversion factors 2020
Food/diet and Goods and services	Living Costs and Food (LCF) Survey 2014-2018
	Experian Mosaic Public Sector
	Experian ConsumerView
	Carbon Emissions Conversion Factors used in "UK's carbon footprint: annual greenhouse gas and carbon dioxide emissions relating to UK consumption":
Waste	England: Local authority collected waste management - annual results
	Wales: Annual management of waste by management method (tonnes) 2020-21
	Scotland: Household Waste Summary Data 2019
	Greenhouse gas reporting: conversion factors 2020

7. Territorial-Based Footprint

A territorial-based footprint considers emissions arising directly within a geographic area (or as a direct consequence of activity within the area, e.g. supply chain emissions arising from the consumption of electricity and other fuels). Carbon dioxide emissions reported by the government at local authority level [7] have been used as the basis of estimates of the territorial footprint. This

source reports CO_2 emissions for industrial/commercial, domestic, agriculture (fuel use), road transport, diesel railways, other transport, and land use/land use change / forestry (LULUCF).

Total CO_2e emissions have been estimated for most sectors by comparison of CO_2, N_2O and CH_4 emission factors for the most prevalent fuel type in the sector and factoring the CO_2 emissions accordingly. The exceptions are other transport and LULUCF due to the diverse nature of emission sources; in these cases the CO_2 figures have been used as-is.

Where possible, additional sources of information have been used to apportion emissions at local authority level more locally (e.g. to parish, LSOA and MSOA levels[*]). Emissions arising from dwellings have been calculated for the consumption based footprint and used in the territorial footprint as they should be the same.

For non-domestic energy consumption, government data are only available to MSOA level; furthermore a significant percentage of total consumption is not allocated geographically so as not to disclose the consumption of large isolated consumers. The geography of 80% of non-domestic electricity and 17% of non-domestic gas is concealed (compared to under 1% for domestic supplies). For non-domestic electricity, gas and other fuel the approach taken was to use the NOMIS[8] for "UK Business Counts - local units by industry and employment size band" to establish at MSOA level the number of businesses across a range of sectors. The number of people employed at each business unit was available within a banded category e.g. 20 to 49 people and so an average value was taken (i.e. for that example 34.5 people; for the category of 1,000+ employees this was taken to be 1,500). The number for each sector in each MSOA was then established by multiplying the number of sites by assumed number of employees. These numbers were then multiplied by derived factors of electricity, gas and other fuel use in the "Industry" and "Services" sectors from BEIS data[36]. The resultant estimated electricity, gas and other fuel use in each MSOA from non-domestic buildings was then used to apportion the known electricity, gas and other fuel consumption that was available at Local Authority level [7] to parish level via area apportionment. It should be stated that there is a high amount of uncertainty regarding non-domestic energy consumption as much of the source data was suppressed. The results should be treated with caution, and as a starting point for further local exploration.

For Large Industry (as reported at Local Authority level [7]), the approach taken was to allocate emissions on the basis of 1 km emissions data for industrial processes and all industrial point source data reported from modelling undertaken for the National Atmospheric Emissions Inventory (NAEI) [12]. This has been summed for the three greenhouse gases CO_2, CH_4 and N_2O with appropriate global warming potentials applied. Emissions from point and area sources have been summed within each 1 km grid square, and apportioned to parish level on an area basis.

Diesel railway emissions have been apportioned from local authority to local level by consideration of route mileage within the locality compared to the local authority as a whole.

[*] Conversion is initially to LSOA for the local authority data, and for the NAEI 1 km data to parish for England and Wales, and to LSOA for Scotland (spatial analysis has not been conducted in Northern Ireland below local authority level).

The NAEI data have also been similarly aggregated over all three reported greenhouse gases and for the point and area datasets for the reported sectors of agriculture, waste, road transport and power generation. Emissions reported at local authority level for agricultural fuel use and road transport have been apportioned. Waste, other transport and agricultural activity (e.g. livestock and crops) are not reported in the local authority data, and emissions are taken directly from the NAEI data (with the agricultural fuel dataset subtracted in the case of agriculture). Apportionment is based on land area. Emissions from power generation are included in sectoral electricity emissions, but have been assessed spatially at their source for information only. Apportionment from 1 km grid square to local level has been conducted on a land area basis.

Further emission sectors either only have reported data at national level or cannot be meaningfully reported on a territorial basis: f-gases (used as extinguishants and refrigerants, for example), aviation and international shipping (note: aviation and shipping have been included on this basis, though would not strictly be a territorial emission. It was felt that this would be the most helpful way of including these sectors). National emissions data from these sources are reported by the NAEI, and have been apportioned on a population basis (except for f-gases, which are apportioned commensurate with non-domestic electricity emissions, as systems utilising such gases are most prevalent in non-domestic buildings and electrically powered equipment).

The sources of data and apportionment techniques adopted are summarised in Table 3.

Table 3: Sources of data and data processing techniques for the territorial footprint.

Category	Primary Data Source	Processing and Apportionment to Smaller Geographies
Agricultural Activity	NAEI 1km and point source	Gridded data area apportioned, point data summed within area. Agricultural fuel subtracted.
Agricultural Fuel	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of agricultural activity data.
Aviation	NAEI national data	Population apportioned
Domestic Electricity	Local Authority CO_2 reporting	Consumption based footprint used
Domestic Mains Gas	Local Authority CO_2 reporting	Consumption based footprint used
Domestic Other Fuels	Local Authority CO_2 reporting	Consumption based footprint used
F-Gases	NAEI national data	Apportioned on the basis of industrial and commercial electricity consumption since emissions are predominantly from refrigeration systems including air conditioning.
Industrial & Commercial Electricity	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of NOMIS data on employment sites by size and sector at MSOA resolution.
Industrial & Commercial Mains Gas	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of NOMIS data on employment sites by size and sector at MSOA resolution.
Industrial & Commercial Other Fuels	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of NOMIS data on employment sites by size and sector at MSOA resolution.
Industrial & Commercial Large Users	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of NAEI 1km data for industrial processes and industrial point source data.
LULUCF	Local Authority CO_2 reporting	Apportioned by land area. Non-CO_2 emissions not considered.
Power Generation	NAEI 1km and point source	Gridded data area apportioned, point data summed within area. **Note: this category overlaps with electricity emissions and is provided for information only.**
Railways (Diesel) *	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned by route mileage of railway.
Road Transport	Local Authority CO_2 reporting	Local authority data adjusted to account for non-CO_2 greenhouse gas emissions. Apportioned on basis of NAEI 1km data for road transport.
Shipping	NAEI national data	Population apportioned
Transport Other *	Local Authority CO_2 reporting	Apportioned by land area. Non-CO_2 emissions not considered.
Waste	NAEI 1km and point source	Gridded data area apportioned, point data summed within area.

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