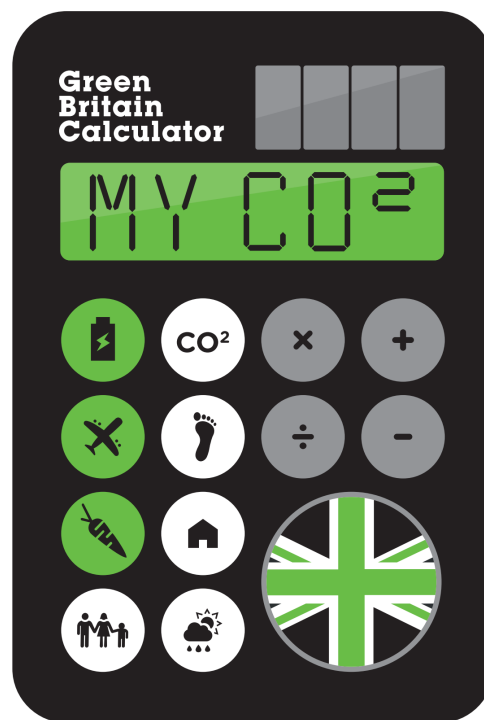




Final Report:
Carbon calculator

Independent analysis by:

Ximena Schmidt Rivera, and Gbemi Oluleye and Paul Balcombe
from Imperial College London

Date: 19 September 2021

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1. Background

The academic researchers from Imperia College London Consultants were commissioned by Ecotricity to produce a carbon calculator tool for the UK public. The aim of this project was to produce a simple carbon calculator that is robust and as accurate as possible, but simple for consumers in terms of number of questions and the simplicity of the questions. The carbon calculator tool is not intended to be an accurate portrayal of everything you do, but intended as a baseline to help consumers think about key aspects that can be changed to shrink their footprints.

This report lays out the questions being asked, how the calculation works, the underlying data sources and all the assumptions we made along the way. We also discuss a few key limitations of the calculator at the end of the report for further information.

2. Questions

The questions were designed and worded collaboratively between the investigators and Ecotricity and are described below.

Questions		Responses
Home energy (heat and electricity)	Is your home electricity on a dark green electricity tariff? It's a yes if you are with Ecotricity.	Yes/ No
	Is your heating carbon neutralised? It's a yes if you are with Ecotricity.	Yes/ No
	What type of fuel you use to heat your home?	Gas/ Oil/ Wood/ Electric
	What type of property do you live in?	Detached/ Semi-detached/ Mid-terrace/ End-terrace/ Bungalow/ Converted flat/ Purpose-built flat
	How many bedrooms?	1/ 2/ 3/ 4/ >4
	How many people do you live with who are over 18 years old (including you)?	1/ 2/ 3/ 4/ >4
	What energy saving measures do you have installed?	Condensing boiler/ loft insulation/ cavity wall insulation/ solid wall insulation/ solar PV
Transport	How many hours do you usually spend travelling in / using a car/motorcycle each week?	None/ up to 2/ 2 – 4/ 4 – 6/ 6 – 8/ 8 – 10/ over 10 hours
	What type of vehicle do you use for the majority of these hours?	<i>See list in the transport section.</i>
	How many adults do you normally travel with (including you) in a car/motorcycle?	1/ 2/ 3/ 4/ >4
	How many hours do you spend travelling on a bus each week?	None/ up to 2/ 2 – 4/ 4 – 6/ 6 – 8/ 8 – 10/ over 10 hours
	How many hours do you usually spend travelling on a train each week?	None/ up to 2/ 2 – 4/ 4 – 6/ 6 – 8/ 8 – 10/ over 10 hours
	How many hours do you usually spend flying domestically each year?	None/ up to 5/ 5 – 10/ 10 – 20/ 20 – 30/ 30 – 40/ 40 – 50/ over 50 hours
	How many hours do you usually spend flying short-haul (<5 hour journey) each year?	None/ up to 5/ 5 – 10/ 10 – 20/ 20 – 30/ 30 – 40/ 40 – 50/ over 50 hours
	Do you normally fly Economy or Business for short-haul flights?	Economy/ Business
	How many hours do you usually spend flying long-haul (>5 hour journey) each year?	None/ up to 5/ 5 – 10/ 10 – 20/ 20 – 30/ 30 – 40/ 40 – 50/ over 50 hours
	What type of ticket do you usually buy when you fly internationally?	Economy/ Premium economy/ business/ first

Questions		Responses
Food	How do you describe your diet?	Regular/ Pescatarian/ Vegetarian/ Vegan
	If you eat red meat (beef and lamb), how much red meat do you consume weekly?	None/ 1/ 2/ 3/ 4/ 5/ 6/ 7 days per week
	If you eat other meats (chicken, turkey, pork), how much other meat do you consume weekly?	None/ 1/ 2/ 3/ 4/ 5/ 6/ 7 days per week
	If you eat fish/seafood, how much fish/seafood do you consume weekly?	None/ 1/ 2/ 3/ 4/ 5/ 6/ 7 days per week
	If you eat eggs, how many eggs do you consume weekly?	None/ 1/ 2/ 3/ 4/ 5/ 6/ 7 days per week
	If you eat dairy products (milk, cheese, yoghurt), how many portions of dairy products you consume weekly?	None/ 1/ 2/ 3/ 4/ 5/ 6/ 7 days per week
	How much food is wasted a week?	10%/ 20%/ 30%/ 40%/ 50%
	How do you manage your food waste?	Compost/ General waste

Next step, methods and data- how to get from these questions to the results. The following sections are split into the main categories of a consumer footprint: home heating; home electricity; transport; and food.

3. Home heating

3.1 Calculation method

We ask consumers if their heating is carbon-neutralised with their energy tariff and if so, this section is set to zero. If not, a calculation is made based on the type of dwelling (e.g. mid terraced house or bungalow etc.), number of rooms, number of adults in the home and the heating fuel used. Gas usage statistics were sourced and converted into equivalent needs of heating per kWh for different fuels. The calculation to determine the GHG footprint of heat for a person in a dwelling was:

$$\begin{aligned}
 & \text{Heating footprint per adult} \left(\frac{kgCO_2 eq.}{yr} \right) \\
 &= \left[\text{gas use by dwelling type} \left(\frac{kWh of gas}{yr} \right) \right. \\
 &+ [\text{\#rooms} - \text{average \#rooms per dwelling type}] \\
 &\times \text{increase in gas demand by number of bedrooms} \left(\frac{kWh of gas}{room.yr} \right) \Bigg] \\
 &\times \left[\text{Efficeincy of fuel heating relative to gas} \times GHG fuel \left(\frac{kgCO_2 eq.}{kWh} \right) \right] \\
 &/ [\text{number of adults}]
 \end{aligned}$$

After this calculation, average energy savings are applied for energy saving measures applied, multiple check boxes can be selected and will result in adjustments for each energy saving measure:

- If condensing boiler is installed the total figure is multiplied by 0.96
- If cavity wall insulation is installed the total figure is multiplied by 0.92
- If loft insulation is installed the total figure is multiplied by 0.97
- If solid wall insulation is installed the total figure is multiplied by 0.83

This results in the final output:

$$\text{Heating footprint per adult} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{yr}} \right)$$

3.2 Data tables and assumptions

Average gas demand by property type

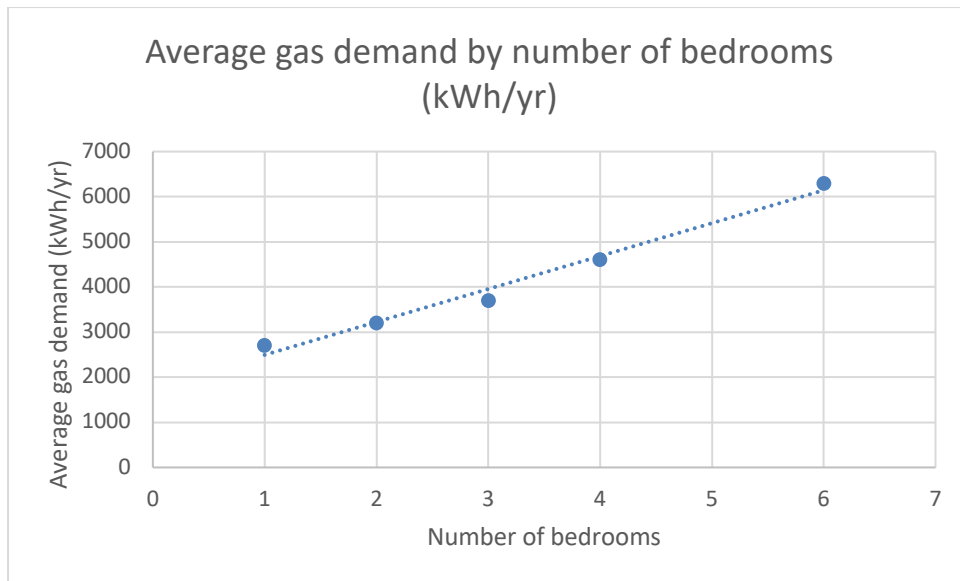
All of the data that we sourced could be scaled in some way. For example if you increase the number of bedrooms in a dwelling, the kWh of gas usage goes up. This is not true of dwelling type, which can be seen from the table below. This table for the average gas demand by property type was taken from the 2019 column of Table 5 in the National Energy Efficiency Data-Framework (NEED) energy consumption headlines for England and Walesⁱ.

Dwelling type	Average gas demand (kWh/yr)
Detached	18,300
Semi detached	14,000
End terraced	12,700
Mid terraced	12,000
Bungalow	13,700
Converted flat	10,200
Purpose built flat	7,600

Average gas demand by number of bedrooms

This table for the average gas demand by property type was taken from the 2019 column of Table 3 in the National Energy Efficiency Data-Framework (NEED)ⁱⁱ. An assumption was made that the value of “>4” was equal to 6. This is because the average gas usage for 1-4 bedrooms increased linearly and that this trend was still linear if this data point “>4” was equal to 6 as shown in the graph below.

Number of bedrooms	Average gas demand (kWh/yr)
1	7,100
2	10,600
3	13,800
4	18,100
>4	24,200



Increase in gas demand per number of bedrooms

The increase in gas demand by number of bedrooms was taken using the above graph fitted with a linear trendline. Again this assumes the value of ">4" is equal to 6. The gradient of this trendline was found, resulting in an increase of 3,455 kWh of gas demand for each bedroom added.

Average number of bedrooms by property type

In order to combine the data for the average gas demand by property type and the average gas demand by number of bedrooms it was necessary to know the average number of bedrooms by dwelling type. This data was taken from the English Housing Survey Home Report 2010, table AT1.17 (shown below)ⁱⁱⁱ.

Home type	1 bedroom	2 bedrooms	3 bedrooms	4 or more bedrooms	All dwellings (1000s)	Sample size
End terrace	46	648	1,257	300	2,251	1,729
Mid terrace	62	1,366	2,137	540	4,105	3,087
Semi detached	*	788	3,962	1,082	5,860	4,193
Detached	*	158	1,348	2,282	3,796	2,488
Bungalow	314	1,053	536	94	1,996	1,606
Converted flat	444	370	102	*	948	593
Purpose built flat, low rise	1,252	1,447	279	60	3,039	2,633
Purpose built flat, high rise	134	211	38	*	390	341

From this table the average number of bedrooms per dwelling type was calculated:

number of bed rooms by dwelling type =

$$\frac{(\text{Number of 1 bedrooms} + \text{number of 2 bedrooms} \times 2 + \text{number of 3 bedrooms} \times 3 + \text{number of 4 bedrooms} \times 4)}{\text{Number of all dwellings}}$$

To give the table below.

Dwelling type	# bedrooms
Detached	3.55
Semi detached	3.04
End terraced	2.80
Mid terraced	2.77
Bungalow	2.21
Converted flat	1.57
Purpose built flat	1.72

The “*” in table AT1.17 indicates that the sample size was too small for a reliable estimate. We therefore used these assumptions in working out the average number of bedrooms per dwelling type. There are no semi detached 1 bedroom houses no detached 1 bedroom houses, no converted flats with 4 or more bedrooms and no purpose built high rise flats of 4 or more bedrooms.

Conversion from gas to other fuel type

The carbon footprint of heating largely depends on which fuel is used to provide the heating. We ask consumers whether they have installed gas, oil, wood or electric heating. These different fuels vary in terms of their efficiency and to account for this, it was assumed that each fuel was utilised at the recommended minimum efficiencies for oil, wood and gas heating were taken from the domestic building services compliance guide 2013 edition, incorporating 2018 amendments, table 1^{iv}. Electric heating was assumed to be 100% efficient.

Heating type	Energy efficiency standard (%)	Conversion factor
Gas fired wet central heating: Non-condensing boiler (Natural gas)	78	1
Wood- Independent boiler: wood/pellets/chips (nominal load)	75	0.96
Oil-fired wet central heating: Non-condensing regular boilers	82	1.05
Electric	100	1.28

The conversion factor for efficiency between gas and other fuels was worked out as follows:

$$\frac{\text{Recommended energy efficiency standard for heating type}}{\text{Recommended energy efficiency for gas}}$$

Carbon intensity of heating type (kgCO₂eq./kWh)

These conversion factors were taken from the UK Government GHG Conversion Factors for Company Reporting^v from the fuels tab using the net calorific value and from the UK electricity tab.

Fuel type	kgCO ₂ eq./kWh
Gas	0.20374

Wood	0.01545
Oil	0.25964
Electric	0.23314

Energy savings are applied for energy saving measures applied

The data for energy savings for different energy saving measures taken was from the National Energy Efficiency Data Framework (NEED) impact of measures: England and Wales headline document table 1^{vi}.

Energy efficiency measure	Percentage saving	Adjustment for energy saving measure
Condensing boiler	3.8%	96.2%
Cavity wall Insulation	8.1%	91.9%
Loft insulation	2.6%	97.4%
Solid wall insulation	17.0%	83.0%

4. Home electricity (non heating)

4.1 calculation method

The first question is whether the consumer has a zero-carbon electricity tariff. If so, the calculation is set to zero for this section. If not, a calculation is made based on the type of dwelling (e.g. mid terraced house or bungalow etc.), number of rooms, number of adults in the home and the heating fuel used. The calculation to determine the GHG footprint of heat for a person in a dwelling was:

$$\text{Non heating electric footprint per adult without energy saving measures applied} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{yr}} \right)$$

=

$$\begin{aligned} & [\text{Average electric usage by dwelling type (kWh/yr)} \\ & + [\text{average electric usage by number of rooms (kWh /yr)} \\ & - \text{average number of bedroom per dwelling type(kWh/yr)}] \\ & \times \text{increase in electric demand by number of bedrooms}] \\ & \times \left[\text{carbon intensity of electric grid mix} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{kWh}} \right) \right] / [\text{number of adults}] \end{aligned}$$

After this calculation average energy savings are applied for solar PV installation:

- If solar PV is installed the total figure is multiplied by 0.9

4.2 Data tables and assumptions

Average electricity demand by property type

As was the case for the heating section, the data that we sourced could be scaled in some way. For example if you increase the number of bedrooms in a dwelling, the kWh of electric usage goes up.

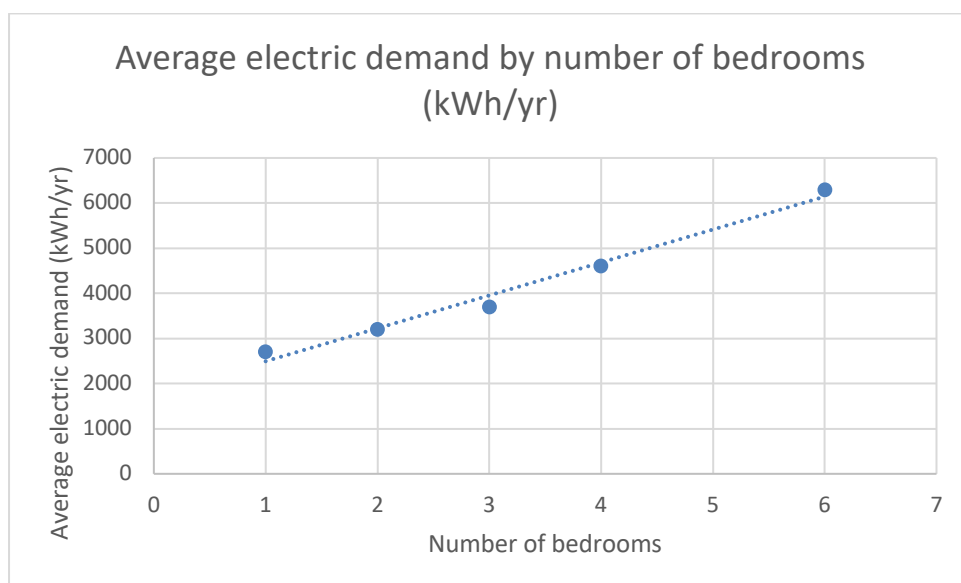
This is not true of dwelling type, which can be seen from the table below. This table for the average electric demand by property type was taken from the 2019 column of Table 6 in the National Energy Efficiency Data-Framework (NEED) energy consumption headlines for England and Wales^{vii}.

Dwelling type	Electricity demand (kWh/yr)
Detached	4,700
Semi detached	3,700
End terraced	3,500
Mid terraced	3,300
Bungalow	3,500
Converted flat	3,500
Purpose built flat	3,100

Average electric demand by number of bedrooms

This table for the average electric demand by property type was taken from the 2019 column of Table 4 in the National Energy Efficiency Data-Framework (NEED)^{viii}. An assumption was made that the value of “>4” was equal to 6. This is because the average electric usage for 1-4 bedrooms increased linearly and that this trend was still linear if this data point “>4” was equal to 6 as shown in the graph below.

# bedrooms	Average electric demand (kWh/yr)
1	2700
2	3200
3	3700
4	4600
>4	6300



Increase in electric demand per number of bedrooms

The increase in electric demand by number of bedrooms was taken using the above graph fitted with a linear trendline. Again, this assumes the value of “>4” is equal to 6. The gradient of this trendline was found, resulting in an increase of 730 kWh of electricity demand for each bedroom added.

Average number of bedrooms by property type

This was calculated using the same method above in the section for heating.

Carbon intensity of electric grid mix (kgCO₂eq./kWh)

These conversion factors were taken from the UK Government GHG Conversion Factors for Company Reporting^{ix} from the UK electricity tab.

Energy source	kgCO ₂ eq./kWh
Electric	0.23314

Energy savings are applied for Solar PV

The data for energy savings Solar PV installation was taken from the National Energy Efficiency Data Framework (NEED) impact of measures: England and Wales headline document table 1^x.

Energy efficiency measure	Percentage saving	Adjustment for energy saving measure
Solar PV	10%	90%

5. Transport

5.1 Calculation method

To estimate the carbon footprint of people’s transport habits, the calculator asks a set of questions that relate to the different modes of transport, which are:

- Personal transport via car or motorbike
- Bus
- Train
- Flights (split into domestic, short-haul and long-haul)

Essentially, the total carbon footprint of the consumer’s transport habits are the sum of all of these sub-categories. The calculation to determine the GHG footprint of all different modes of transport (car, bus, train, flight) was the same:

$$\begin{aligned} \text{Transport mode footprint} & \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{yr}} \right) \\ & = \text{GHG intensity} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{mile}} \right) \times \text{average speed} \left(\frac{\text{miles}}{\text{hr}} \right) \times \text{time spent} \left(\frac{\text{hr}}{\text{yr}} \right) \end{aligned}$$

For cars and motorbikes, we ask what kind of vehicle they use, how many hours per week do they use it and with how many adults do they ride. Where consumers typically drive with several adults, we divide the total footprint by the number of adults (to 'share' the footprint across the adults).

The calculation would be simpler by asking consumers how much distance they travel per year/week, but we gauged that it would be easier for consumers to estimate their time spent in a car rather than distance.

For short- and long-haul flights we ask which class they typically fly in and allocate a different GHG intensity to each class (business class has a higher carbon footprint, due to the larger space footprint that it takes up in the plane).

5.2 Transport data tables and assumptions

Average speeds

As knowing the distance of various transport methods can be challenging (e.g. knowing the return trip to Dubai or commuting by train), hours has been selected to simplify the calculator input questions. Consequently an average speed for each transport method was estimated, which could then be multiplied by the number of hours to give the miles travelled.

Transport type	Average speed (mph)
Bus	14.5
Car	22.4
Train	47.9
Domestic Flight	492
International Flight	492

Bus and car average speeds were obtained from the Department for Transport's Table SPE0111^{xi}, which contains free flow vehicle speeds by road and vehicle type in Great Britain in 2020. An average of the various speeds by road type was taken. To account for the fact that journey times reflect stationary time and traffic as well as free-flow, these free-flow speeds were divided by 2 to reflect a journey time average speed.

Average train speeds are also difficult to identify in the UK. In 2017 there was a report by the Press Association^{xii} that reviewed average speeds of different rail routes in the North/South of England and are detailed in the table below. TfL^{xiii} also publish their average speeds, which was added to the table in the bottom line. An average of these figures was taken to give an average train speed.

Route	Speed (mph)
London Paddington to Reading	93
London Euston to Milton Keynes	92
London to Ashford	65

Leeds to York	60
Liverpool Lime Street	56
Edinburgh to Dundee	34
Liverpool Lime Street to Preston	31
Cardiff Central to Bristol Temple Meads	30
Edinburgh to Perth	25
Liverpool Central to Chester	20
TfL	20.5
Average train speed in GB	47.9

Average flight speed varies by route and aircraft, so an average of several common aircraft average cruising speeds were taken^{xiv}:

Aircraft type	Average Speed (mph)
Boeing 747	575
Boeing 737	531
Boeing 777	566
Boeing 787 Dreamliner	567
Embraer 190	518
Embraer 175	498
Airbus A320	604
Airbus A330	594
Airbus A380	651
Average	492

Road transport emissions (private)

These were sourced from the UK Government GHG Conversion Factors for Company Reporting 2021^{xv}. These emissions cover the emissions from the combustion of the fuel for conventional cars,

and include the emissions from the power generation at the UK average grid carbon intensity level for electric vehicles.

It should be noted that there is a risk of double counting the emissions from electric vehicles if the car is charged at home and the annual energy consumption at home is reported.

Whilst average figures could have been taken to simplify, there are some large variations between size and powertrain which are key to understanding the true emissions.

Car type	kgCO ₂ e/mile
Motorcycle	0.16
Car - Petrol up to 1.4 litre engine	0.24
Car - Petrol from 1.4 litre to 2.0 litre engine	0.30
Car - Petrol above 2.0 litre engine	0.44
Car - Diesel up to 1.7 litre engine	0.22
Car - Diesel from 1.7 litre to 2.0 litre engine	0.26
Car - Diesel above 2.0 litre engine	0.33
Car - Hybrid - Small (e.g. Toyota Yaris)	0.16
Car - Hybrid - Medium (e.g. Ford Focus)	0.17
Car - Hybrid - Large (e.g. Lexus IS300h)	0.24
Car - Plug-in Hybrid - Small (e.g. BMW i3)	0.08
Car - Plug-in Hybrid - Medium (e.g. BMW 3-series)	0.14
Car - Plug-in Hybrid - Large (Mercedes E-class)	0.16
Car - Battery Electric Vehicle - Small (e.g. Renault Zoe)	0.077
Car - Battery Electric Vehicle - Medium (e.g. VW e-Golf)	0.085
Car - Battery Electric Vehicle - Large (e.g. Audi e-Tron)	0.092

Bus and train GHG intensities

These were sourced from the main data source of UK Government GHG Conversion Factors for Company Reporting 2021. An average local bus figure was used, rather than accounting for London busses separately to the rest of the UK for simplicity of calculator input.

Car type	kgCO ₂ eq./mile
Average bus	0.16
Standard national rail	0.056

Flight emissions

These were sourced from the main data source of UK Government GHG Conversion Factors for Company Reporting 2021. Domestic flight emissions were separated from other flights as there is typically no choice of class, and the average passenger emissions are far higher than economy on longer routes.

Class	kgCO ₂ eq./mile
Average passenger	0.39

For short-haul flights, business class is significantly higher than business class for long-haul/international, this is considered separately.

Class	kgCO ₂ eq./mile
Do not fly short-haul	0
Economy	0.24
Business	0.36

Long-haul and international are very similar, so an average is taken to simplify the calculator and have one question rather than two.

Class	kgCO ₂ e/mile
Do not fly	0
Economy	0.23
Premium Economy	0.38
Business	0.69
First	0.95

6. Food

6.1 Calculation method

The personal carbon footprint of your food consumption depends on your diet type, how much you eat, and much you waste. We split up the calculation into key food groups that typically contribute most too climate change, specifically:

- Red meat (beef and lamb)
- Other meat (pork and poultry)
- Fish
- Eggs
- Dairy
- All other food types.

We estimate a consumer carbon footprint for each of these food groups and the total food footprint is the sum of all these individual contributions. Generally we estimate each food group with the following method:

$$\begin{aligned} & \text{Food type footprint} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{yr}} \right) \\ &= \frac{\left(\text{GHG intensity} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{kg foodtype}} \right) \times \text{portion size} \left(\frac{\text{kg}}{\text{day}} \right) \times \text{consumption} \left(\frac{\text{days}}{\text{week}} \right) \times 52 \left(\frac{\text{weeks}}{\text{yr}} \right) \right)}{1 - \text{food waste} (\%)} \\ &+ \text{food waste} (\%) \times \text{GHG food waste} \left(\frac{\text{kgCO}_2 \text{ eq.}}{\text{kg waste}} \right) \end{aligned}$$

Each food group has a different GHG intensity and portion size, and consumers can select how frequently they eat each of these food groups (except the ‘all other food types’ category, which we assume for everyone). Consumers are also asked how much food they think they waste overall.

One complicating factor is that each food group may have a slightly different GHG intensity for different types of diets. For example, for a vegan, the GHG emissions from your ‘all other food’ category is likely to be a little higher, due to the different quantities of different foods consumed. To account for some of thing variation, we characterise the make-up of a set of 4 typical diets and ask the consumer to associate with one: ‘Regular’, which considered an omnivorous diet without food restrictions; ‘Pescatarian’ which does not contain any kind of meat, except fish and seafood; ‘Vegetarian’ which does not contain any meat, and finally ‘Vegan’ that only accounts for plant-based products.

The following sections explained each of these steps, including data sources and manipulation, and assumptions made.

6.2 Food data tables and assumptions

Food consumption across different diet types

The consumption patterns in the UK were characterized using data from the Food and Agriculture Organization (FAO) of the United Nations, specifically their food balance sheets (FBS). FBS present a comprehensive picture of the pattern of a country's food supply (in this case, the UK) during a

specified reference period. FBS provide estimates of per capita domestic food supplies after accounting for imports, exports, losses (where data are available), animal feed, and another non-food uses. The FBS shows different information for 92 items (primary commodities and several processed commodities for human consumption): the sources of supply and its utilization, as well as per capita annual food availability in weight, calories, and amount of protein^{xvi}. Data from FBS are available at FAOSTAT (<http://www.fao.org/faostat/en/#data/FBS>).

Each one of the elements retrieved from the FBS are used for a specific purpose: *food supply quantity (kg/capita/year)* is used to determine the quantities (mass) of each food item, then groups, which will enable the estimation of the greenhouse gas emissions associated to the diet; *food supply (kcal/capita/year)* and *protein food supply (g/capita/year)* is used to make the adjustment of calories and protein amount in different types of dietary patterns (more details below).

85 food items from the FAOSTAT Food Supply List were used (out of 92 which include other non-food items such as alcohol and cottonseed). These were classified into 13 different groups following the method in Bridle et al.^{xvii} A list of food and food groups are included in the appendix, and the food groups are listed below.

- Cereals, Starchy Vegetables
- Dairy
- Egg
- Fish, Seafood
- Miscellaneous
- Nuts, Seeds
- Other
- Other Meat
- Plant
- Pulses
- Ruminant Meat
- Sugar, Vegetable Oil
- Vegetables, Fruit

The next step was to estimate the quantity of food consumed per year within each food group for different diets (regular, pescatarian, vegetarian and vegan). The data source was again the FBS, but required some manipulation to make suitable for our purpose. The dietary pattern that comes from FBS provides 3300 kcal and 104 grams of protein per capita/day. This amount is clearly overestimated when considering recommended guidelines; this is because quantities reported in FBS reflect food availability and not food consumption. For example, bovine meat supplies are reported in dressed carcass weight, which includes bones and other parts typically considered inedible. Therefore, the consumption pattern was adjusted by scaling the diet to 2500 kcal, according to the energy requirements proposed by EAT-Lancet^{xviii} and Bridle et al.^{xix}. Each one of the 85 food items was reduced equally by 24% to preserve the relative proportions of the item within the diet. In this way, the share of protein to daily kcal was kept the same (12%), but the daily amount of protein was reduced to 78 g. The share of protein to daily calories falls within the range recommended by the World Health Organization - 10% to 15%^{xx}. This also followed typical protein consumption for middle-aged adults in the UK, estimated at 78 g of protein/day^{xxi}.

The resulting 'Regular diet' is used as a reference for consumers with no dietary restriction and is a starting point to derive the pescatarian, vegetarian and vegan dietary patterns described next. All the consumption patterns have similar caloric and protein intake (~2500 kcal and ~78 g of protein). The table below shows the adjustments made for the baseline and the definition of all the diets.

Groups	Regular (kg/capita/week)	Pescatarian (kg/capita/week)	Vegan (kg/capita/week)	Vegetarian (kg/capita/week)
Cereals, Starchy Vegetables	2.976	2.976	3.869	2.976
Dairy	3.084	3.084	0.000	3.084
Egg	0.164	0.164	0.000	0.164
Fish, Seafood	0.272	0.544	0.000	0.000
Miscellaneous	0.177	0.177	0.177	0.177
Nuts, Seeds	0.062	0.093	0.185	0.093
Other	1.461	1.441	1.441	1.441
Other Meat	0.834	0.000	0.000	0.000
Plant	0.000	0.000	0.000	0.000
Pulses	0.047	0.568	0.994	0.852
Ruminant Meat	0.321	0.000	0.000	0.000
Sugar, Vegetable Oil	0.758	0.758	0.758	0.758
Vegetables, Fruit	2.273	3.196	3.196	3.196
Total in Diet	12.429	13.001	10.621	12.741

The pescatarian consumption pattern was derived by:

- Removing all types of meat-based products, with exception of fish and seafood;
- Increasing fruits and vegetables uniformly up to 450 g/capita/day;
- Increasing pulses, nuts, seeds, and cereals, until 78 g/capita/day of protein and 2500 kcal/capita/day was achieved;
- The relative proportion of foods in the food groups was kept the same as in the baseline diet.
- No changes were applied to eggs and dairy products.
- Doubling the amount of fish and seafood. The adjusted amount of fish (78g/day) falls within the range suggested by EAT-Lancet (Willett W et al. 2019) (0-100 g/day).

The vegetarian consumption pattern was derived by:

- Removing all types of meat-based products;
- Increasing fruits and vegetables up to 450 g/capita/day;
- Increasing pulses, nuts, seeds, and cereals, until 78 g/capita/day of protein and 2500 kcal/capita/day was achieved;
- The relative proportion of foods in the food groups was kept the same as in the baseline diet.

- No changes were applied to eggs and dairy products. Although the EatWell UK Guide does not specify recommended amounts for dairy products or eggs, the EAT-Lancet (Willett W et al. 2019) recommends that dairy products and eggs should not exceed 500 g and 25 g per day, respectively. Both adjusted baseline and vegetarian consumption patterns provide 440 g of dairy and 23 g of eggs per day.

The vegan consumption pattern was derived by:

- Removing all animal-based products (animal meat, including fish and seafood, and dairy products);
- Increasing fruits and vegetables up to 450 g/capita/day.
- Increasing pulses, nuts, seeds, and cereals, until 78 g/capita/day of protein and 2500 kcal/capita/day was achieved.
- The relative proportion of foods in the food groups was kept the same as in the baseline diet.

Food portions per day

For the food groups that clearly differentiate between people's diets, we ask consumers how often they eat these types each week: red meat, other meat, fish, eggs and dairy. For all other food groups, we assume the rest of their diet is similar to their diet category (regular, pescatarian, vegetarian and vegan).

We ask consumers how many days per week that they eat each food group. To then calculate the footprint, we estimated how much of each food group might be eat per day. Calculations were based on average portion sizes in the UK using guidelines from the Department of Education^{xxii}. For all meat types, fish and seafood, the portion size corresponds to 80g; for eggs, the portion is equivalent to 1 egg or 50g. In the case of milk, 200ml correspond to a portion, while cream and butter, portions are equivalent to 50 and 30 g, respectively.

We estimated the aggregated food group portion sizes and then compared them to the average consumption across different diets. If number of portions per week average consumption is less than 7 (i.e. 1 portion per day), we assume that each daily consumption is one portion. But where average consumption is higher than one portion per day on average, we have assumed a higher consumption, as per the table below.

Food group	Regular (kg/day)	Pescatarian (kg/day)	Vegan (kg/day)	Vegetarian (kg/day)
Red meat	0.08	0	0	0
Other meat	0.16	0	0	0
Fish, Seafood	0.08	0.16	0	0
Egg	0.05	0.03	0	0.06
Dairy	0.58	0.58	0	1.25

GHG intensity of food

The GHG estimates for each food item, expressed in kg CO₂e / kg food, were sourced from Bridle et al.^{xxiii} who has adapted them from Poore and Nemecek^{xxiv}, consolidating data from 38,700 farms and 1,600 processors, globally, reflecting actual practices. The data is also homogenized to provide total

emissions up to the regional distribution centre. The choice to use this data instead of FAOSTAT Tier 1 methodology is that the latter is concerned with pre-farmgate emissions only, exclusively accounting for un-processed commodities, whereas, we are interested in the total emissions from food, including the processing phase.

Item	GHG [kg CO ₂ eq./kg]	Item	GHG [kg CO ₂ eq./kg]
Barley and products	1.84	Meat, Other	12.30
Cereals, Other	0.95	Offals, Edible	0.00
Maize and products	1.70	Pigmeat	12.30
Oats	1.84	Poultry Meat	9.90
Potatoes and products	0.50	Aquatic Plants	0.50
Rice and products	4.50	Beans	1.80
Roots, Other	0.40	Peas	1.00
Rye and products	1.84	Pulses, Other and products	1.80
Wheat and products	1.64	Soyabeans	1.80
Yams	1.30	Bovine Meat	70.50
Butter, Ghee	8.30	Mutton & Goat Meat	39.70
Cream	4.89	Coconut Oil	7.30
Milk - Excluding Butter	3.20	Cottonseed Oil	
Eggs	4.70	Groundnut Oil	6.30
Aquatic Animals, Others	10.70	Honey	1.46
Cephalopods	26.90	Maize Germ Oil	3.80
Crustaceans	26.90	Oilcrops Oil, Other	3.80
Demersal Fish	10.70	Oilcrops, Other	1.61
Fish, Body Oil		Olive Oil	5.40
Fish, Liver Oil		Palm Oil	7.30
Freshwater Fish	10.70	Palmkernel Oil	7.30
Marine Fish, Other	10.70	Rape and Mustard Oil	3.80
Molluscs, Other	26.90	Sesameseed Oil	3.80
Pelagic Fish	10.70	Soyabean Oil	6.30
Miscellaneous		Sugar (Raw Equivalent)	3.20
Coconuts - Incl Copra	0.40	Sunflowerseed Oil	3.60
Groundnuts	3.20	Sweeteners, Other	0.00
Nuts and products	0.40	Apples and products	0.40
Rape and Mustardseed	1.61	Bananas	0.90
Sesame seed	1.61	Citrus, Other	0.40
Beer	1.20	Dates	1.10
Beverages, Alcoholic	1.80	Fruits, Other	1.10
Beverages, Fermented	1.20	Grapefruit and products	0.40
Cloves	0.40	Grapes and products (excl wine)	1.50
Cocoa Beans and products	46.70	Lemons, Limes and products	0.40
Coffee and products	28.50	Olives (including preserved)	1.06
Fats, Animals, Raw	0.00	Onions	0.50

Item	GHG [kg CO ₂ eq./kg]	Item	GHG [kg CO ₂ eq./kg]
Infant food	16.40	Oranges, Mandarines	0.40
Pepper	1.61	Pimento	0.50
Spices, Other	1.61	Pineapples and products	1.10
Tea (including mate)	21.00	Plantains	0.90
Wine	1.80	Tomatoes and products	2.10
		Vegetables, Other	0.50

The impacts of food waste were accounted for in two ways; first as part of the life cycle of the product itself, which means that if for example 20% of the food is wasted, the system will require 120% of the food to provide 100% of the food item for the consumer requirements. Second, the impacts associated to the waste management practices of the food waste. In this case the following impact factors has been used: for industrial composting, 77.5 kg CO₂eq./t of food waste^{xxv}. Incineration and landfilling are the main practices for mix waste in the UK, which in this study we assumed a share of 70% and 30%, respectively. Slorach et al. (2019) has estimated at 31 kg CO₂eq./t food waste and 195 kg CO₂eq./t food waste the impacts of incineration and landfilling respectively.

7. Limitations of the work

As described in the previous sections, to produce this simple calculation several assumptions had to be made to simplify and produce an estimate. Some of these assumptions and their limitations are described below for further information.

Consumer variability/complexity

The objective of this calculator was to produce a simple calculation that focused on the key differentiators between consumer footprints. Whilst the calculator enables an extremely wide variety of footprint outputs, it is important to note that there is such a large range of variability and uncertainty within consumer footprints. This is simply due to the variability in how we live our lives, where we live, what products we purchase, the large range of products available to us, and the fact that very few products actually have a robust and accurate carbon footprint estimate associated with it.

Renewable tariffs

The discounting of emissions for different electricity tariffs is a complex topic. Here we simply have two options: are you on a renewable energy tariff or not? If consumers have selected a renewable tariff, their emissions associated with this electricity consumption is zero.

But in reality there are many more than two options for electricity tariffs, and currently no renewable tariff is truly 'zero carbon' in the UK with respect to a full lifecycle analysis. Renewable generation has embodied emissions associated with their manufacture, and consumers take electricity from the grid, where there is value associated with the flexibility of balancing mechanisms such as by natural gas thermal generation.

There are various ways that energy retailers label green tariffs, e.g. by purchasing REGOS, PPAs or actually investing in renewable capacity. Each have a different impact and their effect on reducing emissions has not yet been quantified to the researchers knowledge.

Carbon offsetting

Ecotricity requested that we include a carbon offsetting allowance if consumers are on a zero-carbon gas tariff. In reality, low carbon gas tariffs are made up of biogas purchases as well as offsetting substantial quantities of natural gas use with planting trees. For example, it is certainly not the case that the globe can simply carry on emitting as we do now and plant the equivalent number of trees to cancel it out. Examples of other carbon offsetting schemes supported by Ecotricity includes investing in reduction renewable energy schemes around the world.

Secondly the use of biomethane for heating in homes should not be considered zero carbon from a full life cycle perspective and emissions can vary substantially depending on where the biogas has come from (e.g., has it come from agricultural waste or dedicated energy crops?) Vatsanidou^{xxvii}.

Other impacts (products and infrastructure)

A UK citizen's carbon footprint is not only comprised of home energy, transport and food. Two other categories that are sometimes considered are other products that we consume such as electronics and clothes, and also an allocation of the infrastructural services that we use.

We have not included these aspects in our calculator, primarily because these would require several additional questions to the consumer and we prioritised the key aspects that consumers can change to reduce their footprint.

Electric cars on a zero carbon tariff

We ask consumers if they are on a zero carbon electricity tariff and what kind of car they drive. For electric vehicle transport, we have assumed that they are charged with electricity comprising the standard UK grid mix (e.g. reflecting charging at service stations), rather than a renewable tariff (e.g. if they charged at home).

The scope (1,2,3) of emissions across the report

In GHG emissions reporting it is recommended to be consistent in the 'scope' of emissions that are being reported^{xxvi}. Typically companies and products are reported as either scope 1 (direct emissions only), scope 2 (some energy-related emissions accounted for) or scope 3 (all materials and energy accounted for).

For this calculator, it was not possible to be consistent across all categories. For example, food footprints are always expressed in scope 3 life cycle emissions due to the large contribution from the upstream supply chain (e.g. methane emission from rearing cows to produce beef). Transport and home energy are typically scope 2 rather than scope 3. If we were to convert to scope 3 boundaries for home energy for example, renewable tariffs would no longer be zero-carbon in order to account for the embodied emissions associate with raw material extraction, equipment manufacture and transport, among other aspects.

Complex foods

Food consumption patterns were estimated using food supply data and by adjusting quantities to caloric and protein requirements only; this limits the understanding of large processed and ultra-processed products such as convenience food, and also limits the understanding of micronutrients and the rest of macronutrients, hence providing uncertainties about the overall health aspect of these diets.

Food cooking practices

This study does not account for food acquisition and home consumption practices, except for food waste, such as cooking, refrigeration, type of shopping outlets, etc. These practices, for example cooking, could affect the results depending on food items (Frankowska et al. 2020); however, it was impossible to account for them in this study as many assumptions will have to be made for each food items, which could generate larger uncertainties.

Food waste management

The impact of food composting reflects industrial practices only. Although it would be possible to estimate the impact of home composting, the uncertainties will be large as domestic composting practices vary from household to household.

8. Acknowledgements

The authors of the report and calculator would like to express thanks to several researchers who assisted in the task of collecting data and working out how to balance simplicity, accuracy and dealing with the reams of data!

- Alex Byford
- Patrick Cullen
- Jacqueline T Silva
- Lucas C Nahas

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