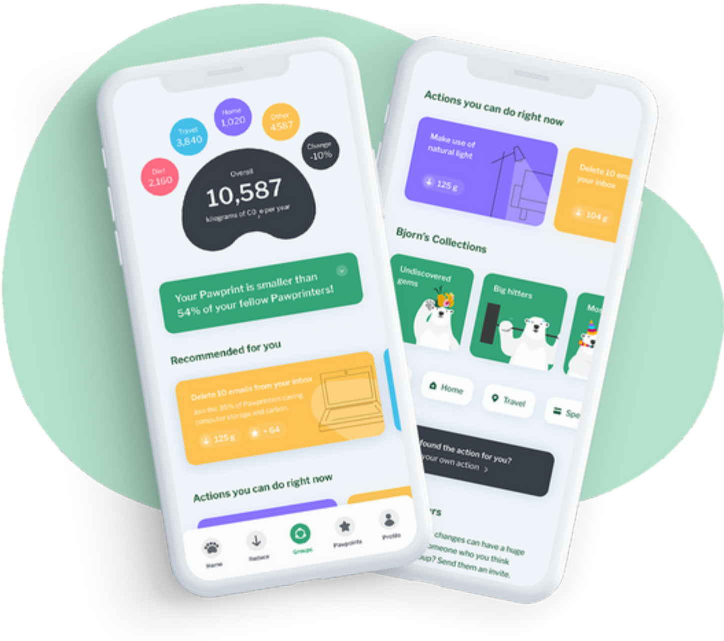
Pawprint
eco companion

## Carbon calculator methodology

The Pawprint Carbon Calculator expands on Small World Consulting's industry based carbon calculations. This takes the total emissions output of the UK, allocated by industries, and breaks this down for the average UK resident.




We split this footprint into four main buckets (Home, Travel, Diet and Spend) which are then subdivided into numerous individual data points. These data points form a tree as deep as needed to represent the data. Each data point in the hierarchy holds an average carbon emission score which can be summed to the data point above. The overall breakdown is displayed to the user one level deep.

Each user is allocated the default scores for each data point. Each survey question then modifies the users score away from that average. These are applied as multipliers to the average score to indicate using more or less carbon than the average resident. Multipliers can be combined when factors allow e.g. both the efficiency of your vehicle and the miles driven affect your car usage score (see example below). Answers to questions can affect multiple data points and data points can be affected by different questions.

A system of blacklists are used to hide irrelevant questions from users e.g. vegetarians will not get challenges on eating less meat.

## Calculation of multipliers

Multipliers are expressed as a deviation from the average: 2 indicates twice the average (all other factors being equal), 0.5 indicates half the average. This allows them to be combined - it is assumed the factors do not interact directly.

## Bottoms up!

The bottom-up model (or process based life cycle analysis/PBLCA) involves building a footprint with building blocks — like constructing a lego house. First, you gather information about every single piece (bricks, tiles, windows, doors, etc.). Then, you calculate the emissions of each of them, before adding it all up for an estimate carbon footprint.

### Pros

- Most used and widely understood
- Can be quite accurate, on the parts you manage to capture

### Cons

- Resource/time intensive and requires many questions to gather enough data
- Works well for a product but becomes complex if it's a service
- Complexity demands truncation error, damaging accuracy

## Top-down

Originally created to estimate the impact of economic activity, the top-down (or environmentally extended input output) model can be understood in the context of financial transactions. It essentially helps us recognise the impact of a pound spent in different industries, for example £1 spent in oil vs insurance.

### Pros

- Holistic view of impact of goods and services
- Useful assessing complex products or services
- Easy to derive emissions factors from financial transactions

### Cons

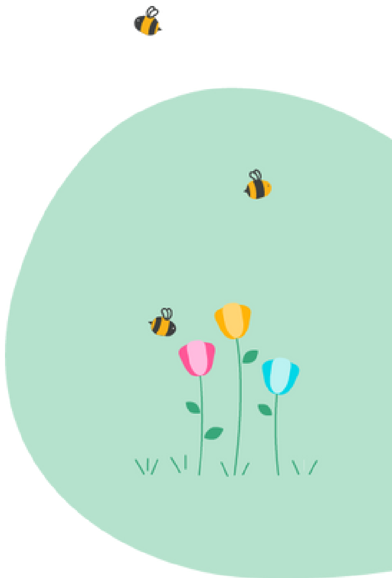
- Results are more general than PBLCA

*Example*

## Car usage

**How many miles do you travel in a vehicle per year?**

Average is 3,517 miles per year. Possible answers and multipliers are:



- 0-3,000 miles per year (assume 1,500) - multiplier is 1500/3717 = 0.43
- 3,000-6,000 miles per year (assume 4,500) - 1.28
- 6,000-9,000 miles per year (assume 7,500) - 2.13
- 9,000-12,000 miles per year (assume 10,500) - 2.98

**Example of combination of multipliers:**

- Average COe for car usage is 1,336 Kg
- I drive 6,000-9000 miles per year so my multiplier is 2.13. However my car is more efficient than average and has a multiplier of 0.80.
- Total CO2e is therefore 1,336 kg x 2.13 x 0.8 = 2,277 Kg CO2e

## Home

Ultimately, calculating the overall carbon impact of a home accurately is very easy given three key figures - total gas (or other fuel) usage, electric usage and water usage. Assuming standard mains connections, these figures are enough to calculate the carbon usage of any home, divided by the number of residents for a personal footprint. For off grid, eg heating oil/wood/coal then consumption can be calculated in the same way.
In this case we would bracket spend/usage deviations from the average and use these as multipliers for the various fuel types.

This does limit the level of detail under the top level 'electricity' or 'fuel' data points. We can ask additional questions but these will not generally affect the main data points - the modelling becomes too complex if we attempt to split out usage on heating within the electric data point for example. The answers will however be used to set blacklists and show suitable challenges to the user.

Not everyone has easy access to meter readings or estimated spend so we cannot rely on this data - we need to have two separate channels for users to go down. For non meter readings we need to ask further questions about the insulation types and general house characteristics to build an average figure.

This will be presented as a series of questions followed by the option to enter appropriate meter readings / spend if available.

## Data Tree

- Fuel usage - 1430 kg CO2e
  - Heating ~1200 kg CO2e
  - Hot Water ~230 kg CO2e
  - Metered value Gas 0.001kg - this approximates to zero but allows us to multiply as needed
  - Metered value LPG 0.001kg - this approximates to zero but allows us to multiply as needed
  - Metered value Oil 0.001kg - this approximates to zero but allows us to multiply as needed
  - Metered value Coal 0.001kg - this approximates to zero but allows us to multiply as needed
  - Metered value Wood 0.001kg - this approximates to zero but allows us to multiply as needed
- Electric usage - 650 kg CO2e
  - General Electric - 650 kg CO2e
  - Heating 0.001 kg CO2e
  - Hot Water 0.001 kg CO2e
  - Meter value 0.001 kg CO2e
- Water - 250 kg CO2e

The data tree assumes that the average user has mains gas for heating and hot water.

By having 0.001kg CO2e in some elements this gives us a value to multiply against when determining fuel usage. For example, selecting 'electric heating' will multiply 'gas' -> 'heating' by zero and 'electric' -> 'heating' by 1200 * 1000 * (actual modifier). This ensures values are stored under the correct data point.

This also allows us to override all the previous answers (set zero) and set the metered value to represent the users actual meter reading/spend.

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## Assumptions

Some assumptions to form the starting point of our 'typical home' need to be made here in order to sensibly separate out the carbon into areas we can usefully ask questions about. As most homes in our initial target areas should have access to mains gas, the following assumptions have been made:

- Mains gas central heating using a standard non-condensing gas boiler
- Hot water using storage cylinder heated on the same gas boiler
- Shower and bath water from the same hot water source
- Cooking is on an electric oven and hob. As the cooking impact is fairly small there will be no questions on this during the onboarding. This ensures that someone with no mains gas connection will not have a gas value at the end of the onboarding process.
- Electricity covers all usage aside from heating and hot water Modifiers can then be applied for the different power sources and appliance efficiencies.

**The typical home also has:**

- 2.7 bedrooms or 76m2
- 2.38 residents (as the majority of home items are shared between residents)
- Modern insulation resulting in a need for 160kWh of heating per m2 per year Again modifiers can be applied here to get a specific home's footprint.

### Space heating

- Approximately 12000 kWh on average for space heating. This tallies with the usage of a relatively modern gas boiler on full for 4 hours a day over 90 days a year.
- This is the input figure we are using rather than the heat output - this is discussed further down.

### Hot water

Hot water can be divided into three sub categories - showers, baths and other hot water usage. All is assumed per person rather than per household

- Showers - 4.4x per week, average duration 7.5mins, 8l/min flow rate and 27.6 degrees heating required - 442 kWh per person per year
- Bath - 1.3x per week, 80l hot water, 30.6 degrees heating required - 193 kWh per person per year
- Other hot water usage - 15l x 2 times per day, 30 degree heating - 382 kWh per person per year
- Assuming a standard gas boiler and storage cylinder, losses from the cylinder account for 178 kWh per year (per household)

In total this gives 2607 kWh for hot water per average household. $CO_2e$ will be allocated to just the usage with the losses shared proportionally.

Total 14607 kWh - which is roughly the value calculated by carbon scores. If we consider these approximations reasonable we can divide the total $CO_2e$ per person proportionally by these amounts:

- Heating - 1175 kg $CO_2e$ - this is subject to the household modifier
- Hot Water - 225 kg $CO_2e$ - this is per person

Electric accounts for 650 kg $CO_2e$ per person - this is subject to the household modifier.

## Questions

### Size of home

The average UK house is 2.7 bedrooms or approximately 76m2. Unfortunately not many people in the UK know the size of their house in m2 so we have to approximate using the number of bedrooms. These modifiers will affect both gas -> heating and electric -> heating data points in the same way.

### Insulation

Insulation has a huge impact on the energy needs for heating. This is generally expressed as a kWh/m2 per annum - so these can be compared directly between houses of different sizes. An old, poorly insulated house has 300 kWh/m2a while the 'Passivhaus' certification requires just 15 kWh/m2a. Average is 133 kWh/m2a

These will be provided to the user in terms of house characteristics rather than direct descriptors and potentially relate to home efficiency ratings. As with the house size, these will affect both gas -> heating and electric -> heating data points in the same way.

### Heating Type

Our average home runs on non-condensing gas boiler. To determine suitable multipliers we can simply multiply the efficiency of a heating method by the $CO_2e$ per kWh and compare this against the average. This assumes that the same amount of output heat is required.

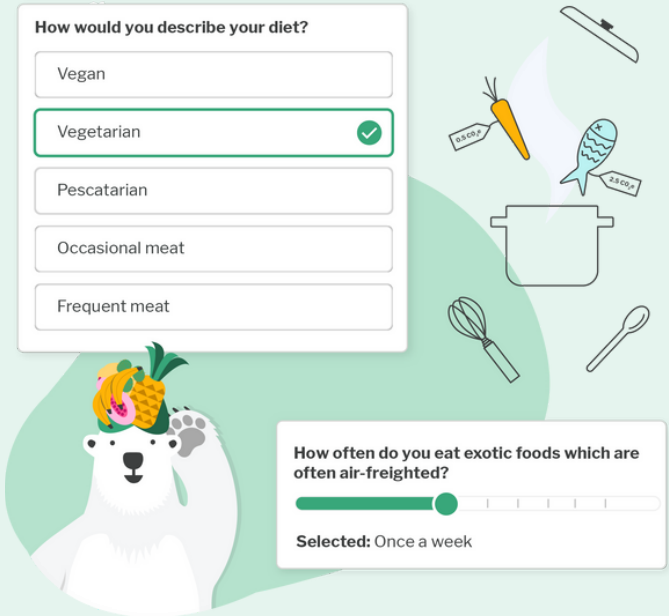
Some items are applied directly to the 'gas' -> 'heating' data point to represent deviation from the assumption. Electric based values are slightly more complex - firstly 'gas'->'heating' is multiplied by zero to remove this completely. The 'electric' -> 'heating' value is then multiplied by 1000 * 1175 to get to the base value, then by the modifier for the given heating type. This ensures that the impact of heating affects the expected column.

## Hot Water

We assume all hot water is by the same power source. As with heating types, electric types are applied to the electric data point with the relevant fuel one set to zero.

## Meter Readings/Fuel usage

These are optional and actually override all other questions. These can be phrased in terms of both spend and kWh. These apply a zero modifier to all other elements and sets the 'metered' value to 100 * 1430 * applied modifier (gas) or 100 * 650 * applied modifier (electric). A similar starting point is applied for all other fuel types.




## Fuel

### Gas

Default gas use per household is 1200kWh and contributes 1430 kg CO2e per person. This is per household so the household modifier must apply when calculating deviations here.

### LPG

1690l per year average to generate the same amount of heat
1.38x emissions of gas
1 973 400 total modifier applied to each answer

### Oil

1160 litres per year average
1.43x the emissions of gas
2 045 000 total modifier applied to each answer

### Wood

2850kg average
0.226x emissions
323 180 total modifier

### Coal

1500kg average
1.61x emissions
2 302 300 total modifier

### Electric

Default electric use is 3100 kWh and contributes 650 kg CO2e per person. This is per household so the household modifier must apply when calculating deviations here.

# Travel

## Air

Three data points here which belong to a main ‘flights’ datapoint:

- Short Haul (<2 hours) 56kg CO2e
- Medium Haul (2-4 hours) 334 kg CO2e
- Long Haul (4+ hours) 700 kg CO2e

Overall for air travel we can get quite complicated regarding the exact distances people travel. However we do have some good average values available that give a good approximation of air travel and will be much simpler for the end user. Averages per person are based on UK travel surveys regarding destinations and split by country/region.

Two major factors in air travel - number of flights and flying class (which we ignore on the basic survey).

### Short Haul flights

- Assumed to be any flight under 2 hours. This includes any domestic flights too.
- Average short haul flights per year - 0.15
- Average per person due to short haul flights - 56 kg CO2e

### Medium Haul flights

- Assumed to any flight between 2-4 hours - mainly Europe
- Average flights per year - 0.48
- Average per person - 334 kg CO2e

### Long Haul flights

- Assumed to any flight over 4 hours - rest of the world
- Average flights per year - 0.23
- Average per person - 700 kg CO2e

Questions are then simply the number of flights per year with the multiplier worked out relative to the average.

# Car

Two main data points here:
- Car usage - 1336 kg CO2e
- Car ownership - 450 kg CO2e

## Car Ownership
- CO2e per person 450 kg
- 31.842 million UK vehicles
- Population (million) - 66.4
- Households (million)- 27.8
- Average household size is therefore 2.388
- Cars per household = 31.842/27.8 = 1.145 cars per household
- 1.145/2.388 = 0.48 - approximately 1 per 2 people

We are apportioning this element to the whole household so the household factor is applied.

## Car usage
- Total CO2e including supply chain is 1336kg CO2e
- Miles driven - car (billion) 255
- Miles driven - van (billion) 51
- Percentage personal travel - car 0.88
- Percentage personal travel - van 0.18 This gives a total personal miles driven of 255 x 0.88 + 51 x 0.18 = 233.58 billion miles
- Divide by UK population => 3518 miles per person
- This includes everyone in the UK regardless if they can drive so is significantly less than an average vehicle usage which will be around twice this number.
- It is assumed that all driving CO2e is allocated to the driver rather than household at this stage
- Would be good to differentiate this and allocate less when car sharing but would need to take account for vehicles you travel in when you are not the driver too.

## Distance multipliers
We bracket the miles driven and assume the middle value each time, eg 0-3000 will be approximated to 1500. Multiplier is then simply 1500/3518 = 0.426

## Vehicle multipliers
A number of vehicle choices are picked out for the end user. Assumed default is an 'average diesel' - 0.34556 kg CO2e/mile. Multiplier is then simply the chosen value divided by the default. This uses the BEIS + SWC hybrid figures - the importance here is relative emissions not absolute values.

## Multiple Vehicles
As many users will have access to at least one vehicle we need to gain access to this information in an easy manner.

# Diet

Total allocation from food is 3210 kg CO2e per person. This includes supply chain losses and food waste as well as the food consumed. There are some important areas here that can modify the average footprint significantly - meat and other animal product consumption, air freighted/hot housed food and food waste - and it is important to separate these out and ask appropriate questions. Aside from food waste, everything will be dealt with in terms of consumption, ie portions per week of the various food types.

## Purchase figures

To get a baseline of figures we use the Family Food dataset to determine average purchase values per person. These are then uplifted by 20% to account for under reporting (which can be much higher is some cases). Additionally supply chain losses of 30% are used to get a final 'farm gate' weight. These are separated by food type as well as a general 'other food' section.

Total input carbon is then calculated using the farm gate and supply chain figures from both the SWC spreadsheet and Hoolohan et al. This total carbon figure is split into food and food waste with 20% initially going to food waste. An additional component is added to food waste to represent the decomposition of food. This assumes that food goes to landfill and could be modifiable for different disposal methods.

### Air freight / hot housed

The other large component is air freight/hot housed products. Not much data exists for these although the Hoolohan paper indicates that by removing these the total carbon can be reduced by 5%. Working backwards and assuming 'out of season' produce is flown 5000km and 'exotic' produce is flown 12000km, this is equivalent to 142g and 80g of fruit per week respectively. Carbon for these is allocated in the same way to food waste.

### Portion sizes

Portion sizes are drawn from BDA and uplifted by 25% to account for the common overestimating of portion sizes. The weekly purchase values are then divided by these numbers to give an average number of portions per week. We can then ask for real portions per week and multiply the CO2e emissions (both eaten and food waste) by this figure.

## Data points

There is a fairly complex data structure here to account for the food waste element in a manageable way. Due to the interrelated food waste and consumption figures, multiple data points will be affected by the same questions, hence the separation of food waste.

- Meat
  - Red Meat - 422.5
  - White Meat - 497.4
- Dairy/Eggs
  - Cheese - 123.3
  - Milk - 219.1
  - Eggs - 56.3
- Air Freighted Food
  - Out of Season - 78
  - Exotic - 50
  - Other Food - 1050.6
- Food Waste
  - Red Meat Waste - 105.6
  - White Meat Waste - 124.3
  - Cheese Waste - 30.8
  - Milk Waste - 54.8
  - Eggs Waste - 14.1
  - Seasonal Waste - 19.5
  - Exotic Waste - 12.5
  - Other Waste - 262.6
  - Landfill Emissions - 88.6

## Questions

The first question will be about dietary choices and doesn't have an impact on the data points. However this is used to set blacklists and hide subsequent questions from certain users.

*Frequency questions*

**How many times do you eat beef per week?**

Default is 1.84 portions per week, so actual multipliers are calculated by dividing the number of portions by 1.84 ie if 3 portions / week on average then 3 / 1.84 = 1.63 x beef element. These also affect the appropriate food waste sub point but not the decomposition sub point.

- Meat -> Beef sub point x 1.63
- Food Waste -> Production -> Beef sub point x 1.63 The same is true for all other main food groups. For high intensity foods we have separated into out of season (ie grown elsewhere and flown when not in season or hot housed) and exotic (never grown locally, always flown) in order to ask more relevant questions including examples of the most common types of food.

**Food waste**

Amount of food wasted?

This is fairly subjective and should include some examples of behaviour. As the default is 20% the extremes of this should be 10% for conscientious consumers and up to perhaps 40% for less engaged families with children. This will be a simple multiplier to both the production and disposal elements of the food waste.

## Spend

The areas in this section are all based on a simple multiplier of the user's spending compared with the UK average with the exception of clothing. Actual items purchased do have a major impact although it is difficult to get a deep sense of this with the questions we have available. This means we are using the top level economic carbon impact in each case, assuming every pound spent has the same impact. All averages come from the SWC calculator.

### Staying Away

- Total 540kg CO2e
- Assumed average is £120/month

### Newspapers Books and Paper

- Total 70kg CO2e
- Assumed average is £9/month

### Clothes

The assumption here is about volume purchased rather than spend - as for clothing higher cost is not related to proportionally increased CO2e emissions. This is also a much easier category to ask about volume of spend than the others.

- Total 190kg CO2e
- Assumed average is £90/every couple of weeks

### Electronics

- Total 450kg CO2e
- Assumed average is £150/month

### Everything Else

- Total 450kg CO2e
- Assumed average is £150/month

### Services

This is everything non physical including mortgage, insurance and other financial payments as well as broadband services, TV packages, phone contracts and anything else non-physical.

- Total 900kg CO2e
- Assumed average is £650/month

### National Services and Infrastructure

- Total 1690kg CO2e
- This cannot be modified at all

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## Emissions factor sources

**1**

**Ten years of carbon analysis**
Over the last decade, Small World's carbon analysis has spanned everything from supermarkets to clothing brands; construction companies to tech giants; national parks to local governments, and many more.

**2**

**A macro-economic carbon model**
Small World has refined and tested this model over a decade and used it with a range of clients, from some of the largest US tech giants to local micro businesses.

**3**

**Publicly available datasets**
Of course, only the most credible sources are used.

**4**

**Analysis of product life cycles**
Taken from academic papers and (less frequently) company reports.

**5**

**Our own tools**
Small World has developed its own tools for combining and enhancing all of the data into a methodologically coherent dataset.

## A bit about Mike

Mike is a professor, researcher and author of *There is No Planet B*, *How Bad are Bananas* and *The Burning Question*. He's Pawprint's Scientific Advisor and helps us ensure our numbers are as accurate as possible.