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Environment: treading lightly on the Earth



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Introduction 04/01/23

Introduction

This free course, *Environment: treading lightly on the Earth*, focuses on the problem of greenhouse gas emissions, especially carbon dioxide (CO₂), and explores what you can do to lighten those emissions to help reduce the rate of climate change. You will assess your 'carbon footprint' and see what actions you and, if relevant, other household members could take to lighten that footprint. You will also better understand which actions are more and less effective, and the scope and limits of what individuals can do at the personal and household level.

You'll explore the answers to questions such as:

- What is the effect on your carbon footprint of changing your eating habits, compared to driving fewer miles or flying less often?
- What are the limits of what you can do at the individual and household level to reduce carbon footprints?
- What is the individual's role in reducing carbon footprints, or is it mainly a problem for governments and business?



Figure 1 The greenhouse effect due to increasing concentrations of CO₂ and other greenhouse gases in the Earth's atmosphere

This OpenLearn course is an adapted extract from the Open University course U116 *Environment: journeys through a changing world*.

Learning Outcomes

After studying this course, you should be able to:

- explain the nature and extent of the carbon footprints of individuals and households within the national and global economy
- assess individual carbon footprints using a carbon calculator
- understand the main components of the carbon footprint of individuals and households, and the most effective actions for reducing the footprint
- explore options for reducing the carbon footprint.

1 What is the carbon footprint, and why is it important?

The carbon footprint is the annual amount of greenhouse gas emissions, mainly carbon dioxide, that result from the activities of an individual or a group of people, especially from their use of energy and transport and consumption of food, goods and services. It's measured as the mass, in kilograms or tonnes per year, either of carbon dioxide (CO₂) emissions alone, or of CO₂ plus the mass of other greenhouse gas (GHG) emissions converted into their carbon dioxide equivalent (CO₂e) global warming effect.

The carbon footprint can also be calculated for an event such as a music festival, or for making and distributing a product such as a car or computer.

The carbon footprint is an environmental indicator – a way of measuring impacts on the environment, in this case mainly climate change. This means that the carbon footprint doesn't measure other impacts, except sometimes indirectly. For example, driving a petrol or diesel car, as well as emitting CO_2 , results in air pollution from nitrogen oxides (NO_X) , especially the irritant gas nitrogen dioxide (NO_2) and other engine emissions; so the larger your carbon footprint from driving, the more air pollution you are creating.

There are many other environmental indicators that measure different impacts, including air and water pollution, loss of landscapes and biodiversity, and depletion of mineral and water resources. The UK Government, the European Union (EU) and the United Nations publish sets of 'sustainable development indicators' which – as well as measures such as economic growth, life expectancy and levels of inequality for different countries – include environmental indicators such as wildlife populations, pollution levels, recycling rates and annual GHG emissions. Another often used environmental indicator is the ecological footprint, which is based on the availability of land and sea to support a population (see Box 1).

Box 1 The ecological footprint

The ecological footprint (EF) is a measure of the environmental impact of a population (e.g. a household, city or nation) based on the area of land and sea theoretically required to indefinitely support its lifestyle at a given level of technology.

The ecological footprint measures the area of land and sea required to produce the population's food and accommodate its roads, buildings, etc., as well as the forested area required to absorb the population's CO_2 emissions. So the EF measures the carbon footprint component of a population's environmental impact using land and sea area. Sometimes 10% land area is added to the ecological footprint for biodiversity conservation. The EF is the indicator used to show that about three planet Earths would be needed if everyone in the world tried to live the current lifestyle of an average European in the long term, which is clearly unsustainable.

1.1 Carbon dioxide and other greenhouse gases

CO₂ emissions are used as the basis for the carbon footprint because it is by far the main contributor to the enhanced greenhouse effect from human activity (mainly burning fossil

fuels, clearing forests and making cement). Sometimes only the mass of CO_2 is counted in the carbon footprint. However, as noted earlier, for a complete carbon footprint the other human-generated greenhouse gases are converted into a CO_2 equivalent (in kilograms or tonnes CO_2 e) in terms of their global warming effect and added to the footprint. The complete footprint is then expressed as kilograms or tonnes CO_2 e per year.

The two main non- CO_2 greenhouse gases associated with human activity are methane (CH₄), mainly from cattle belching, manure spreading and decomposition, wet rice growing and decomposing waste, and nitrous oxide (N₂O), mainly from nitrogen fertilisers and industrial processes. One tonne of methane has the equivalent global warming potential of 21 tonnes of CO_2 , while one tonne of nitrous oxide is equivalent to 310 tonnes of CO_2 . But because the amounts of methane and nitrous oxide released are much smaller, their emissions together add about 16% to the UK's contribution, and about 25% globally, to the enhanced greenhouse effect (ONS, 2015; IPCC, 2015). This means that other greenhouse gases should not be ignored when measuring a carbon footprint, although to simplify calculations they often are.

In this course, you will use the total CO_2 equivalent (CO_2 e) effect of carbon dioxide plus other greenhouse gases whenever possible, but where only information on CO_2 is available, when discussing carbon footprints, only CO_2 emissions will be used.

1.2 The carbon footprint boundary

Depending on where you draw the boundary, the carbon footprint can apply to: an individual or household; an organisation, event or product; a city, region or country. In this course you will mainly be considering the footprints of individuals, households and the countries they inhabit.

But even then the boundary needs to be defined carefully. Sometimes the carbon footprint is taken to mean an individual's or household's *direct* CO₂ emissions, mainly from burning fossil fuels for home heating and car driving. But this leaves out their *indirect* CO₂ equivalent emissions arising from the production and distribution of the food, drink and other goods and services they consume, ranging from clothes and electronic products to banking, medical services and Open University modules.

Again depending on the boundary, these indirect emissions often include only those arising from the food, goods and services produced within the country where people live. But they may also include the emissions 'embedded' in imports; for example, the emissions produced by the 'supply chain' of mines, farms, factories, trucks and ships involved in making and transporting the food, cars and computers that Britain imports from the EU and China.

Whichever measure you choose, the 'footprint' image is used to suggest an individual or group treading on or occupying the Earth (Figure 2). It implies that the Earth can't indefinitely support the lifestyle of that individual or group, and if they are to live sustainably, they'll have to lighten their footprint.

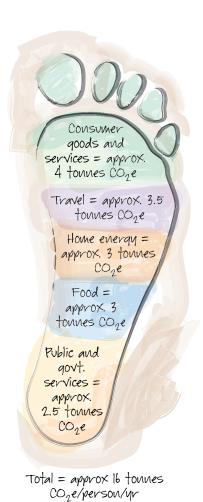


Figure 2 The footprint as a powerful image of treading on or occupying the Earth. A UK individual's carbon footprint arises mainly from home energy use and personal travel, including flights, and from consumption of food, goods and services. (adapted from Berners-Lee et al., 2011).

1.3 Individual and household carbon footprints

There are different ways of measuring the carbon footprint. The production perspective counts the greenhouse gas emissions produced by the power stations, factories, transport services, farms, buildings, etc., in different sectors of a country's economy – energy supply, manufacturing, transport, agriculture, construction, etc. From this perspective the producers of goods and services within each country are mainly responsible for that country's emissions, while households are responsible for only a relatively small percentage (about a fifth) of the total.

The consumption perspective, on the other hand, considers that the purpose of a modern economy is to provide individuals and households with the energy, transport, food and other goods and services they need and want. So individuals and households, as final consumers of all these things, are ultimately responsible for triggering the emissions involved in producing and distributing them, whether at home or imported.

As the focus of this course is on the carbon footprint of individuals and households, and that's what the carbon calculator, which you'll be using later, measures, we will be looking at the consumption perspective. While individuals and households may be ultimately

responsible for triggering most GHG emissions, they don't directly control how much of those emissions are produced and so can't be expected to reduce them unaided. There will be more about this later.

There are different ways in which this consumption-based carbon footprint is measured and broken down, which produce differing results. In this course it's not the exact numbers that are important, but the general principles.

The official convention is that only the CO₂ from home heating and car driving is counted as an individual's or household's *direct* emissions. Everything else, including emissions from domestic electricity use, car manufacture and maintenance, public transport and personal flights is *indirect* because it arises from systems not directly controlled by individual consumers. But from an individual's or householder's perspective, all home energy use, including electricity, and all transport, including travel by public transport and air, may more logically be viewed as emissions arising directly from their actions. Meanwhile emissions from the production and supply of food and all other goods and services may be viewed as arising indirectly from the actions of others. Viewed from this perspective, Figure 3 shows a breakdown of direct emissions (DTI, 2007).

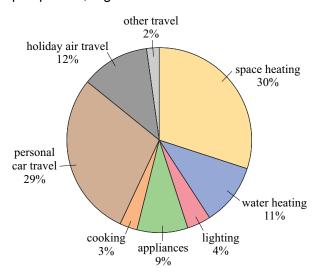


Figure 3 Breakdown of average direct *carbon* emissions of a UK inhabitant. Annual carbon emissions in 2005 = 1.16 tonnes carbon per person per year. (More recent studies (e.g. Preston et al., 2013) show a similar breakdown of direct emissions, although in less detail.) (DTI, 2007)

Study note: Pie charts

A pie chart shows different amounts as slices of a circular pie. The whole pie represents the total (100%) amount, so a pie chart is useful for displaying percentage breakdowns.

What does Figure 3 show?

• It is a pie chart and shows the percentage breakdown of the average annual direct carbon emissions of an individual living in the UK. Although this chart is based on 2004–5 data, recent studies show that this direct carbon footprint has not changed significantly.

- The emissions per person in the caption are given in tonnes of *carbon* (C) rather than carbon dioxide (CO₂). Carbon is just another unit for measuring GHG emissions. So always check whether emissions are given in kilograms or tonnes of C, CO₂ or CO₂e and convert if necessary (see *Study note: Converting carbon to CO₂ (or CO_e) emissions*).
- The pie chart is based on carbon dioxide emissions alone and doesn't include other greenhouse gases. But as the emissions involved arise from burning fossil fuels for energy and transport, they consist mainly of CO₂. The chart therefore provides a realistic footprint breakdown.

If you look closely at Figure 3 you can see that:

- space (i.e. room) and water heating (41%) and personal car travel (29%), account for the biggest part of an UK individual's average direct carbon footprint (70% of the total)
- other important carbon footprints arise from powering appliances, including electronic equipment, and lights (13%) and holiday air travel (12%) (25% of the total)
- cooking (3%) and other travel (public transport and motorcycles, 2%) create relatively minor average individual carbon footprints (5% of the total).

As you've seen, the *direct* carbon footprint given in Figure 3 (about 1.16 tonnes carbon or 4.25 tonnes CO₂ per person per year) covers only household energy use and personal travel. It doesn't include the *indirect* footprint from consumption of food and other goods and services. You will look at the total footprint in Section 1.4.

1.3.1 Converting carbon to CO₂ (or CO₂e) emissions

This study note will explain how to convert carbon to CO₂ (or CO₂e) emissions.

Study note: Converting carbon to CO₂ (or CO₂e) emissions

You have to be careful when looking at GHG emissions data to be clear on units. Emissions are sometimes expressed in tonnes of *carbon* rather than carbon dioxide or CO_2 equivalents (CO_2 e). This expresses emissions using just the mass of the carbon (C) *atom* rather than the whole carbon dioxide (CO_2) *molecule* or CO_2 and other GHG emissions converted into CO_2 equivalents (CO_2 e).

Each chemical element has an atomic mass associated with it, but these would be tiny numbers for individual atoms if expressed in grams or kilograms. So these are usually given as the *relative* atomic masses, taking the mass of a carbon atom to be exactly 12 units (usually abbreviated 'amu' for 'atomic mass units'). Using this convention, the relative atomic mass of hydrogen is close to 1, carbon 12, and oxygen about 16.

So a water molecule H_2O would have a mass of $(2 \times 1) + 16 = 18$ amu. A carbon dioxide molecule (CO_2) would have mass $12 + (2 \times 16) = 44$ amu.

As a carbon atom has a mass of 12 amu, whereas each CO_2 molecule has mass 44 amu, the form in which emissions totals are given makes a great difference to the amounts recorded. So always check whether emissions are given in units of C, CO_2 or CO_2 e, and convert if necessary (as shown below):

1 tonne carbon emissions = 1 tonne × 44/12 = 3.67 tonnes CO₂ (or CO₂e) emissions (the extra 2.67 tonnes came from the oxygen atoms in the molecule).

• 1 tonne CO₂ (or CO₂e) emissions = 1 tonne × 12/44 = 0.27 tonnes carbon emissions (the other 0.73 tonnes were oxygen).

OR

- 12 amu of carbon produces 44 amu of CO₂ emissions.
- So 12 tonnes of carbon produces 44 tonnes of CO₂ emissions.
- Therefore 1 tonne of carbon produces 44/12 × 1 = 3.67 tonnes of CO₂ emissions.

However, since the mass of carbon emissions is directly proportional to the mass of CO₂ or CO₂e emissions, the percentage breakdown (e.g. in Figure 3) is the same whether you measure the carbon footprint using C, CO₂ or CO₂e.

1.4 Total footprint

The UK Government publishes information on the country's carbon footprint, covering both direct and indirect annual GHG emissions, including the emissions embedded in imports. This provides a comprehensive picture of the UK's total carbon footprint from the consumption perspective (Figure 4).

You'll notice that, where possible, for UK data publications from government departments such as DEFRA (Department for Environment, Food & Rural Affairs) and DECC (Department of Energy & Climate Change) have been used. The names and responsibilities of these departments can change in government reorganisations (e.g. in 2016, DECC became part of the Department for Business, Energy & Industrial Strategy) but remain an invaluable source of information and statistics.

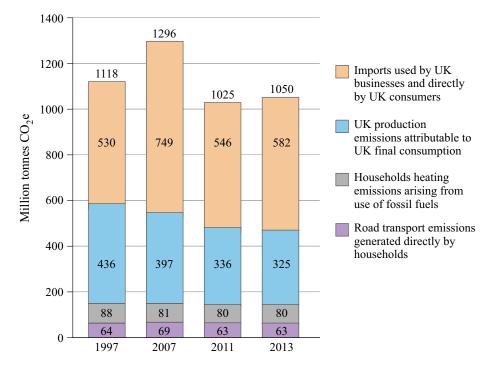


Figure 4 The UK carbon footprint: GHG emissions associated with consumption 1997 to 2013, including emissions embedded in imports but not exports (total = 1050 million tonnes CO_2e in 2013) (*DEFRA*, 2016)

Study note: Stacked bar charts

Figure 4 is a bar chart, another way of showing the breakdown of numerical information. This is a 'stacked' bar chart, in which the components that make up the total are shown within each bar.

Notice that in Figure 4 the direct carbon footprint of households (the purple and grey sections of each bar) is relatively small. This is because (unlike in Figure 3) this breakdown uses the official convention, mentioned earlier, in which household electricity for lighting and appliances, travel by public transport and holiday flights are considered as *indirect* sources of emissions. The total indirect carbon footprint (the blue and brown sections) includes these emissions plus the emissions arising from food, goods and services both produced in the UK and embedded in imports.

This and other studies have shown that about half the UK carbon footprint is the result of the GHG emissions embedded in imports, notably electronic products, clothing and motor vehicles from the EU and Asia. This means that the emissions from an individual's consumption of imported goods and services have become a major part of their carbon footprint. This proportion is expected to increase, at the same time as the emissions arising from their consumption of energy, goods and services produced within the UK decrease (Barrett et al., 2011; Committee on Climate Change (CCC), 2013).

Also included in the total carbon footprint in Figure 4 are emissions from government activities, including public administration, health, education, defence and capital investment, for example, in railways. This residue, which arguably can't be allocated to households, amounts to 10% to 20% of the total UK carbon footprint.

This means that consumption decisions by individuals and households are responsible for creating or triggering 80% to 90% of the UK's carbon footprint (Barrett et al., 2011). This proportion is not unusual for a developed country where final consumption of energy, food, and other goods and services by individuals and households accounts for most economic output.

Now complete Activity 1 to test your understanding of the carbon footprint.

Activity 1 The carbon footprint



a. What is the carbon footprint?

Provide your answer...

Answer

The carbon footprint is the total annual mass of 'carbon' emissions which result directly or indirectly from the activities of an individual or a group of people, from an event, or from providing a product or service.

b. Give three different ways of measuring the carbon footprint (in terms of how the mass of emissions is calculated).

Provide your answer...

Answer

'Carbon' emissions can be measured as the annual mass in kilograms or tonnes of either:

- carbon dioxide (CO₂) gas; or
- total GHGs converted to carbon dioxide equivalents (CO₂e) in terms of their global warming potential; or
- the carbon (C) content of CO₂ (or CO₂ converted to CO₂e).
- c. Look at the caption for <u>Figure 3</u> in Section 1.3. The average UK individual's direct carbon (C) emissions are given as 1.16 tonnes per person per year. What is this mass expressed as CO₂ emissions?

Provide your answer...

Answer

Based on 2005 government information, the average direct carbon footprint of an individual living in the UK was $1.16 \times 44/12 = 4.25$ tonnes CO_2 per person per year. This footprint was unchanged in more recent studies (e.g. Preston et al., 2013).

C.

d. What are the main components of an average carbon footprint of an individual living in the UK?

Provide your answer...

Answer

The main components of a UK individual's or household's average carbon footprint are:

- home energy use, especially for room and water heating and running lights, electronics and appliances
- · transport, especially driving and flying
- consumption of goods and services, produced at home and imported
- government activities and public services.

1.4.1 Percentages and parts per million (ppm)

This study note will look at how to calculate percentages and percentage change, as well as parts per million (ppm).

Study note: Percentages and parts per million (ppm)

Percentages (%) indicate proportions and show the number of parts out of 100. For example, 30% is 30 out of 100 and 65.2% is 65.2 out of 100.

To find out the percentage of something, first convert the figures into a fraction and then multiply by 100. For example, if 42 people in a group of 70 vote for a political party, the percentage voting for that party is

42 divided by 70 multiplied by 100, or $42/70 \times 100 = 60\%$.

If you already have a fraction and want to change it to a percentage, you multiply by 100. So three-quarters expressed as a percentage is $3/4 \times 100$ or 300/4 = 75%.

Similarly, to change a decimal to a percentage, you multiply by 100. For example, the decimal number 0.25 expressed as a percentage is $0.25 \times 100 = 25\%$.

To change a percentage to a fraction, or to a decimal, the percentage is divided by 100. So for example, 30% expressed as a fraction is 30/100, or 0.30 as a decimal; and 65.2% is 65.2/100 or 0.652. Thus for example,

```
20\% of 350 people = 20/100 \times 350 (or 0.2 \times 350)
= 70 people.
```

Percentage changes

Repeated measurement of an environmental indicator makes it possible to assess change over time. Change between two given dates is often expressed as *percentage change* in which the figure at the later date is expressed as a percentage of the earlier one.

Calculation of percentage change is best done in stages. For example, if you wish to calculate the percentage increase of atmospheric CO₂ levels, which were 360 parts per million (ppm) in 1995 rising to 378 ppm in 2005, then:

- The increase is (378 360) ppm = 18 ppm.
- As a fraction of the original value, this is 18 ppm/360 ppm = 1/20 (or 0.05).
- As a percentage change, this becomes 0.05 (or 1/20th) × 100 = 5% increase.

Note that you always divide by the original (earlier) value regardless of it being numerically larger or smaller than the later one. If it is larger than the later value, then this would be a percentage decrease, which is sometimes written using a minus sign before the number e.g. -5%.

You can also use percentage change the other way round. Suppose you plan to reduce carbon emissions of 350 kg by 20%. What would the new value of emissions be?

There are two ways of tackling this question. Either:

- A 20% reduction leaves 80% of 350 kg of emissions to remain.
- 80% of 350 kg is $80/100 \times 350$ kg = 280 kg as the new reduced value.

Or:

- 20% of 350 kg is $20/100 \times 350 = 70$ kg.
- Subtract 70 from the original 350 to give the new reduced value of 280 kg.

Parts per million

Parts per million (ppm) is an alternative to percentages that can be useful for very small proportions. As the name implies, ppm represent the number of parts out of a million (1 000 000) instead of 100. For even smaller proportions, parts per billion (ppb) may be used.

Like percentages, ppm can be converted into a fraction or a decimal. For example, an atmospheric CO_2 level of 400 ppm can be written as 400/1 000 000. This can also be expressed as a decimal as 0.0004. The following sequence shows this conversion step by step.

$$\frac{400}{1\,000\,000} = \frac{40}{100\,000} = \frac{4}{10\,000} = \frac{0.4}{10\,000} = \frac{0.04}{100} = \frac{0.004}{100} = 0.0004$$

At each step, the top and bottom terms of the fraction are both divided by 10 so the overall value of the fraction does not change.

The fraction 400/1 000 000 that you started with has been simplified by dividing the top and bottom terms by the same number. This is called *cancelling out*. When you are working through a calculation by hand this is shown by crossing through the numbers that cancel each other out, like this:

$$\frac{490}{1000090}$$

Conventionally, fractions are written in their simplest form. In this case, you can simplify further because both top and bottom are divisible by 4 so this fraction can also be written as 1/2500. You can also see from the term 0.04/100 in the sequence above that this is equal to 0.04%.

Activity 2 Calculating percentages



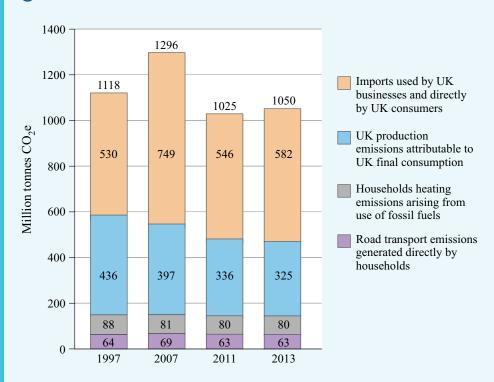


Figure 4 (repeated) The UK carbon footprint: GHG emissions associated with consumption 1997 to 2013, including emissions embedded in imports but not exports (total = 1050 million tonnes CO_2e in 2013) (*DEFRA*, 2016)

Look at Figure 4 from Section 1.4 repeated again above.

a. What percentage of the total UK carbon footprint of 1050 million tonnes CO₂e in 2013 is represented by household road transport emissions?

Provide your answer...

Answer

In Figure 4, household road transport emissions are 63 million tonnes (Mt) CO_2e . As a percentage this is $63/1050 \times 100 = 6\%$.

b. What is the percentage change in the total UK carbon footprint between 1997 and 2013?

Provide your answer...

Answer

The difference in emissions between 1997 and 2013 is a reduction of $1118 - 1050 = 68 \text{ Mt CO}_2\text{e}$.

As a fraction of the 1997 footprint this is a reduction of 68/1118.

As a percentage, this is a reduction of $68/1118 \times 100 = 6.0829 = 6.1\%$ (rounded to one decimal place). You will look in more detail at rounding numbers in Section 2.

c. If the UK managed to reduce its 1997 carbon footprint of 1118 Mt CO₂e by 35% by 2020, what would be the resulting footprint?

Provide your answer...

Answer

A reduction of 35% means that 100 - 35 = 65% of the 1997 footprint remains in 2020.

65% of 1118 Mt CO_2e is 65/100 × 1118 = 726.7 Mt CO_2e .

1.5 Summary of Section 1

The main learning points from Section 1 are:

- The carbon footprint is the annual mass of 'carbon' emissions that result from the activities of an individual or a group, from an event or providing a product or service. To be complete, the carbon footprint should include the direct and indirect emissions of CO₂ and CO₂ equivalent including other GHGs (mainly methane and nitrous oxide). However, for simplicity, carbon footprints based on CO₂ emissions alone are often used.
- The carbon footprint is an environmental indicator that is concerned mainly with climate change. It measures other environmental impacts, such as water pollution, biodiversity and resource depletion, indirectly or not at all.
- Emissions embedded in imported food, goods and services are a major part of the carbon footprint of individuals and households in many developed countries, notably the UK where this proportion is expected to increase.
- From a consumption perspective, individuals and households are directly or indirectly responsible for creating or triggering 80% to 90% of the total carbon footprint of developed countries. Hence, reducing the carbon footprint arising from individual and household activities and consumption is very important in addressing climate change.

Next you will look at the variations in carbon footprints depending on factors such as where you live, the type of home you live in, income, values and lifestyle.

2 Not all footprints are equally heavy

You've just read some information about the average carbon footprint of a UK individual or household. But the footprint of a particular individual or household depends on the amounts and types of energy, food, and other goods and services they consume. This means that their carbon footprint depends on where they live, the type of home they live in, their income, values and lifestyle. Thus, carbon footprints of individuals and households vary widely within a country and also between different countries, but especially between rich, developed countries (e.g. the UK), newly industrialised countries (e.g. China), and poor developing countries (e.g. Uganda).

For individual or household carbon footprints, the average (or more correctly, the mean) footprint within a country is usually given (see <u>Study note: Averages – mean and median</u>). These average (mean) values show the variations in carbon footprints between different countries, but conceal the wide variations within each country.

2.1 The carbon footprint of UK individuals and households

The average (mean) carbon footprint of an individual living in the UK can be calculated by dividing total UK annual CO_2 equivalent emissions by the number of people in the country. Using the official government information in Figure 4, this produces a mean footprint of 16.4 tonnes CO_2 equivalent per person per year in 2013.

This provides a realistic mean footprint of a UK inhabitant on a consumption basis because it includes CO_2 and other GHG emissions, and takes the data on emissions embedded in imports into account. Before 2013, embedded emissions were undercounted, but with improved data on international trade, global deforestation, etc., more reliable information is available. The estimated mean UK carbon footprint (updated to 2016) is 14.6 tonnes CO_2 e per person, per year – this is the figure used in the carbon calculator that you'll be using later.

Several studies have attempted to provide a more detailed breakdown of this carbon footprint than given in Section 1 (e.g. Druckman and Jackson, 2010). Unfortunately, as they produce different results depending on the data sources, the methods used and how the breakdown is categorised, when writing this course a decision had to be made as to what to present from a number of studies and reports.

One useful study, which was drawn upon to develop the carbon calculator, breaks down an individual's mean CO₂ equivalent emissions into a few high-level categories (Table 1).

Table 1 High-level breakdown of the mean UK carbon footprint per person

Sector	GHG emissions per person per year (tonnes CO ₂ e)	Percentage
Domestic energy and housing	3.98	26.2
Transport	3.78	24.9
Food	2.07	13.6
Consumables (i.e. goods)	1.83	12.1

Private services (e.g. banking)	1.68	11.1
Public services	1.78	11.7
Total emissions (incl. other)	15.18	100.0

(Gough et al., 2012; Dawkins et al., 2010)

More detailed footprint breakdowns for the whole of the UK are difficult to find. But there are detailed studies at local authority level, such as a study of the carbon footprint of Greater Manchester residents (Figure 5).

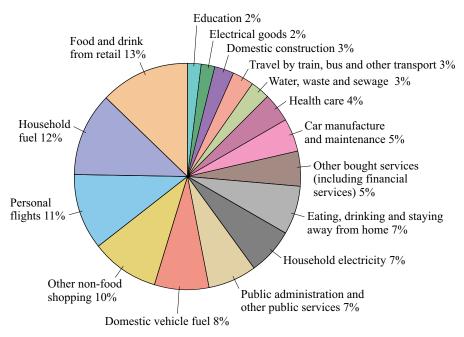


Figure 5 The carbon footprint of Greater Manchester residents, broken down by consumption category (CO_2 e per person per year) (*Berners-Lee et al., 2011*). Note: the percentages add up to over 100% due to rounding (see Study Note: *Rounding numbers, decimal places and significant figures*).

The annual carbon footprint of Greater Manchester residents is estimated at 41.2 million tonnes CO_2e . This makes a Manchester resident's mean footprint 15.7 tonnes. Just over a quarter (27%) of the Manchester footprint is for personal transport (car fuel, flights, public transport and the carbon embedded in cars themselves). Fuel use in homes adds a further 19%. This means that household energy and transport make up almost half (46%) of the total carbon footprint. The rest of the footprint is a mixture of embedded carbon in food and other goods, a wide range of services (from hotel accommodation to financial services) and public services such as education, healthcare, defence and government. This is similar to the breakdown in Table 1 where domestic construction (housing) is combined with household energy use.

2.1.1 Averages - mean and median

In this study note you will look at two different types of averages – the mean and the median.

Study note: Averages mean and median

An average value is often used to provide a 'typical' value for a set of data. There are several ways of expressing a typical value, but the most common are the mean and the median.

Mean values

The *mean* value (commonly called the 'average', although it is just one type of average) is obtained by adding up all the values of a set of data and dividing by the number of items in the set. For example, if three individuals have carbon footprints of 13, 9 and 17 tonnes CO_2e per year, their total footprint is 13 + 9 + 17 = 39 tonnes CO_2e per year. Their *mean* footprint is the total divided by the number of individuals, i.e. 39/3 = 13 tonnes CO_2e per person per year.

The mean is also used when several values contribute to an overall value, as in the case of assignment marks. If you had the assignment marks 67%, 82%, 45%, 75%, 77%, 68%, and they all counted equally towards your final score, you could work out your overall mean percentage score by adding the six scores together and dividing by that number of scores, i.e.

$$(67 + 82 + 45 + 75 + 77 + 68)/6 = 69\%.$$

To calculate the mean carbon footprint of a UK inhabitant (in 2013) using the information in <u>Figure 4</u>, you divide the total UK emissions of 1050 million tonnes CO₂e by the 2013 UK population of 64.1 million. The result is 16.380655. Rounded to one decimal place this is 16.4 tonnes CO₂e per person per year. (See Study Note: Rounding numbers, decimal places and significant figures at the end of this section.)

Median values

Although the example above gave a value for the amount of CO_2 e emissions that could be attributed to each person on an equal basis, this may not represent a 'typical' person. This is because there may be a group of heavy emitters that have a larger effect on the total (and hence the mean) than the majority of more modest emitters. In this case the *median* is a better indication of a typical individual's footprint.

So, if the carbon footprints of a sample of 11 individuals were 21, 6, 15, 16, 10, 9, 13, 25, 12, 11, 27 tonnes CO_2e per year, the mean footprint is 165/11 = 15 tonnes CO_2e per year.

The median footprint is obtained by arranging the data into ascending order, as follows:

6, 9, 10, 11, 12, **13**, 15, 16, 21, 25, 27 tonnes CO_2e per year the median footprint is the *middle* value in the set = 13 tonnes CO_2e per year, i.e. the sixth value in the set, with five below and five above it.

If there are an even number in the sample, say 10 individuals with footprints of

9, 10, 11, 12, **13, 15**, 16, 21, 25, 27 tonnes CO₂e per year

then the median is halfway between the two middle numbers (13 and 15), i.e. 14 tonnes CO₂e per year, again with five values below and five above.

Consider another example, the UK's income distribution. Some people have very high incomes and some have low incomes, with the majority spread between the extremes. Figure 6 shows the official distribution of the UK population by *household* incomes (after tax and before deduction of mortgages and rents) in 2014–15. The *mean* household income in 2014–15 is £581 per week (£30 212 per year), calculated

by adding up all the incomes and dividing by the number of individuals living in households whose incomes were measured.

The *median* income is the amount which divides the income distribution into two equal groups, half having an income above that amount, and half having an income below that amount. The median household income in 2014–15 is £473 per week (£24 596 per year), which is less than the mean and more representative of an 'average' or 'typical' household.

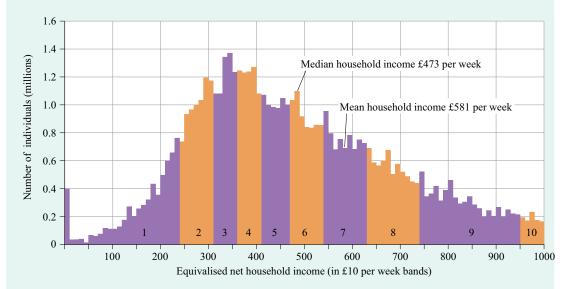


Figure 6 Distribution of the UK population by household incomes in 2014–15. Group 1 is the distribution of household incomes for the 10% of individuals living in the poorest households. Group 10 is the household incomes for the 10% of individuals living in the richest households (excluding 5.3 million individuals with a household income above £1000 per week). Equivalised means the incomes are adjusted to take account of the numbers of adults and children in a household (adapted from DWP, 2016).

2.1.2 The effect of incomes and household types

The carbon footprints given in Section 2.1 are averages (means) for a UK inhabitant. But, as mentioned earlier, footprints differ considerably for different individuals and households.

A factor which has a major effect on the footprint is individual or household *income* (a distribution of which was shown in Figure 6). In general, the higher a person's or household's income is, the higher their carbon footprint will be. This is not just because wealthier people generally consume and travel more, but because, even if they save a lot, their savings will be invested to produce products and services for consumption, which indirectly adds to their footprint.

For example, the study that provided the Table 1 breakdown also showed how the footprint per person differed for ten groups, from households with the lowest 10% to households with the highest 10% of UK incomes (Figure 7).

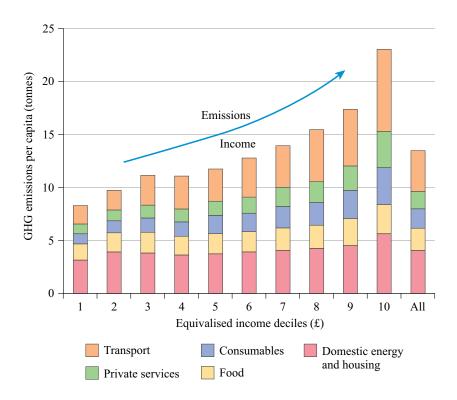


Figure 7 Mean carbon footprints (tonnes CO₂e per person per year) by emission categories for ten household income groups, excluding public services. (The income groups are categorised as in Figure 6.) (Gough et al., 2012)

Look carefully at Figure 7. Can you see that the carbon footprint per person for households with the highest 10% of incomes is about three times that of people living in households with the lowest 10%? This is true for all categories, but especially for consumables (goods), private services and transport.

A similar income-related pattern has been shown for the direct carbon footprint that just includes energy use and transport. The richest 10% of households have three times the footprint (including the emissions from energy use in the home and all personal travel by car, public transport and air) of the poorest 10% (Preston et al., 2013).

Thus wealthier people generally have a greater environmental impact than poorer people and so arguably have a greater responsibility for reducing their footprints.

The carbon footprint per person also varies with household size and composition. The Table 1 study also showed how the carbon footprint per person varied for different sizes and types of household (Figure 8).

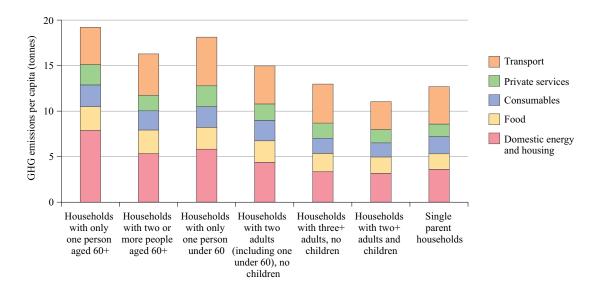


Figure 8 Mean carbon footprints (tonnes CO₂e per person per year) by household type (Gough et al., 2012)

Figure 8 shows that one-person households (bars one and three) generally have heavier footprints per person than those with two or more members, including children (especially bars five and six). This is because people living alone usually occupy and heat a bigger space per person and don't share as many goods and services as larger households. So, one of the barriers to reducing carbon footprints is the growing number of one-person households (now nearly a third of all UK households). Sharing your home, therefore, can be one of the most effective ways of reducing your individual footprint.

2.2 Household carbon footprints in other developed countries

Although the mean carbon footprints per person vary in different European and other developed countries, depending on their energy supply system and economy, the footprint breakdown is generally similar to that for the UK. You will now look at two major economies for a brief comparison: Germany and the USA.

A study of the carbon footprint of German households found that the mean footprint was 14.3 tonnes CO_2e per person per year. Housing (which in this study covered domestic fuel use, purchase of appliances and furniture, water use and rent) was responsible for the highest share of emissions (34%); followed by personal transport (24%), including car manufacture, fuel and maintenance, public transport and air travel; then food and drink (18%); goods such as clothing and shoes (15%); and services such as health and education (9%). As for the UK, the study found heavier carbon footprints were associated with higher household incomes and smaller household sizes (Miehe et al., 2015).

A US study (Weber and Matthews, 2008, updated by Hubacek, n.d.) found that the mean American carbon footprint was about 23.5 tonnes CO_2e per person per year. This is considerably heavier than mean European footprints, but its breakdown is similar, with the largest components again being personal transport, home energy use, food, and consumption of goods and services and, especially in the US context, private health services.

One difference in the carbon footprint breakdown is the result of the amounts of room heating and cooling required in different climates. In the USA, for example, 87% of homes

had air conditioning in 2009, which used over 6% of all household energy (US EIA, 2013). In Britain, by comparison, few homes at present need or have air conditioning.

Earlier it was mentioned that the carbon footprint measures only ${\rm CO_2}$ and other GHG emissions while other environmental impacts are included only indirectly or not at all. This was highlighted by an earlier American study (Brower and Leon, 1999) which showed that personal transport, food production and home energy use, as well as emitting large amounts of GHGs, were also major sources of toxic air and water pollution and damage to wildlife habitats.

2.2.1 Carbon footprint components

Now you have found out about the main components of the mean carbon footprint per person per year for the UK, USA and Germany, as well as more detailed components for a resident of Greater Manchester in the UK, complete Activity 3 which asks you to consider and compare these mean footprints.

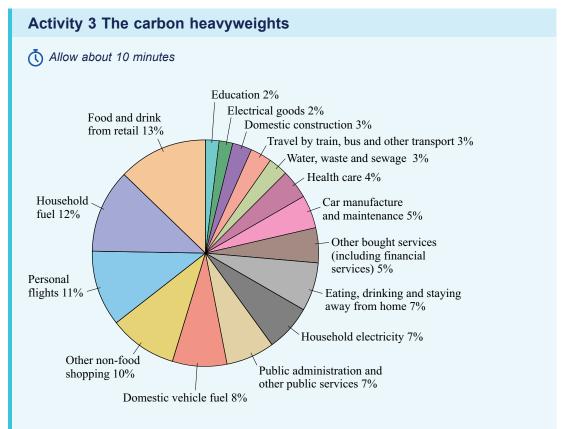


Figure 5 (repeated) The carbon footprint of Greater Manchester residents, broken down by consumption category (CO₂e per person per year) (Berners-Lee et al., 2011). Note: the percentages add up to over 100% due to rounding (see Study note: Rounding numbers, decimal places and significant figures).

a. Look at Figure 5, repeated above. What are the components of the carbon footprint of a Greater Manchester resident broken down into high-level categories (e.g. travel, food, home energy, goods and services)?

Provide your answer...

Answer

From Figure 5, the mean carbon footprint of a Greater Manchester resident is made up of:

- travel by car, air, bus and train (vehicle fuel + car manufacture/maintenance + flights + public transport = 27%)
- food consumption (retail food and drink + eating, drinking and staying away from home = 20%)
- gas, electricity, etc. use (household fuel + electricity = 19%)
- consumption of goods (electrical goods + other non-food shopping + domestic construction = 15%)
- private and public services (financial, water, waste, health and education services, public administration, etc. = 21%).

(The percentages add up to over 100% due to rounding.)

b. Look at <u>Table 1</u> and this section. Is the personal footprint breakdown for the UK as a whole similar to that for other developed countries, such as Germany and the USA?

Provide your answer...

Answer

The breakdown for the UK as a whole is similar to that for most other developed countries.

2.3 International comparisons of carbon footprints

You've seen that the carbon footprint is a simple idea, but calculating it can be complicated. It depends on whether you count only CO₂ or all GHGs and whether you include the emissions embedded in imports and exports. It also depends on whether you include the emissions associated with changes in land use and forests and from international aviation and shipping which have not been mentioned until now.

This complexity means that international comparisons are usually based on the most widely available data, namely emissions of CO₂ alone arising within a country's borders (so-called territorial CO₂ emissions).

2.3.1 Carbon footprints per person

The statistics clearly show huge differences between countries in carbon footprints per person. Table 2 shows the mean annual footprint per person for selected countries in 2011, when the latest reliable data for all countries were published by the United Nations (UN), plus estimated footprints for 2015 from another source. These footprints are for *territorial* emissions of CO_2 and so do not include imports and exports. Hence in Table 2 the mean carbon footprint for a UK inhabitant is 7.2 tonnes of CO_2 alone rather than 14 to

over 16 tonnes of CO_2 equivalent GHG emissions discussed in previous sections. That's because about half of the UK footprint is emissions embedded in imports.

Table 2 Mean annual territorial carbon footprint per person for selected countries (CDIAC, 2015; Global Carbon Atlas, 2016)

Country	CO ₂ per person, tonnes per year (for 2011, rounded)	CO ₂ per person, tonnes per year (estimates for 2015, rounded)
Saudi Arabia	18.7	19
United States	16.8	17
Australia	16.2	17
Russian Federation	12.6	11
Japan	9.3	9.8
Israel	9.2	8.9
South Africa	9.2	8.5
Germany	8.8	9.9
Ireland	8.0	7.9
United Kingdom	7.2	6.4
China	6.6	7.5
Sweden	5.5	4.3
France	5.3	5.3
Thailand	4.6	4.6
Turkey	4.4	4.9
Romania	3.9	3.8
Egypt	2.8	2.4
Brazil	2.2	2.5
India	1.7	1.7
Pakistan	0.9	0.9
Nigeria	0.5	0.6
Uganda	0.1	0.1
World average (mean)	4.8	4.9

Figure 9 shows estimated footprints for more countries presented in graphical form for the year 2015.

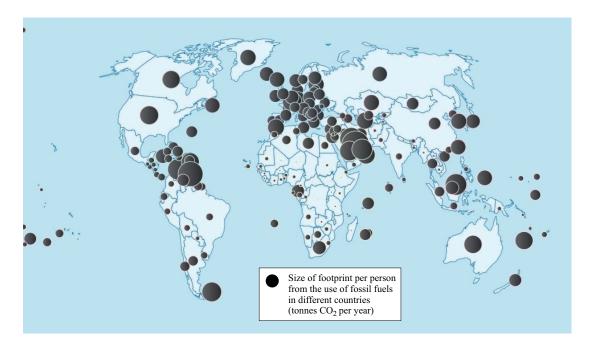


Figure 9 Estimated territorial CO₂ emissions per person in 2015. The bigger the black bubble, the bigger the footprint per person for the country indicated. (Global Carbon Atlas, 2016)

Having reviewed Table 2 and Figure 9, now complete Activity 4.

Activity 4 International comparisons



(1) Allow about 15 minutes

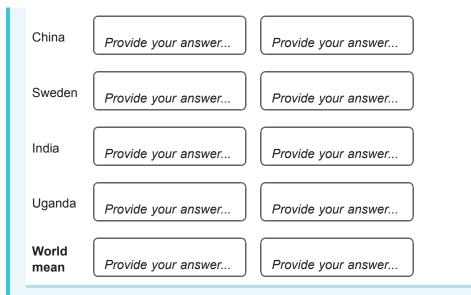
Look at the data for 2015 in Table 2.

How heavy is the mean territorial carbon footprint of a UK inhabitant (in tonnes CO₂ per person per year) compared to the mean footprints of inhabitants of the USA, China, Sweden, India, Uganda and the world mean? Round your answers to the most appropriate number of significant figures (see Study note: Rounding numbers, decimal places and significant figures).

Here's an example. UK divided by Brazilian CO_2 emissions = 6.4/2.5 = 2.56 = 2.6rounded to two significant figures. Thus, the mean carbon footprint of a UK inhabitant is over two and a half times heavier than the mean for a Brazilian.

Table 3 The carbon footprint of a UK inhabitant in 2015 relative to that of other countries

Country	Mean footprint per person (tonnes CO ₂ per year)	UK mean footprint per person relative to other country's mean footprint per person
UK	Provide your answer	Provide your answer
USA	Provide your answer	Provide your answer



Discussion

The mean carbon footprint of a UK inhabitant in 2015 relative to that of other countries was:

Table 3 The carbon footprint of a UK inhabitant in 2015 relative to that of other countries (completed)

Country	Mean footprint per person (tonnes CO ₂ per year)	UK mean footprint per person relative to other country's mean footprint per person
UK	6.4	_
USA	17	0.38
China	7.5	0.85
Sweden	4.3	1.5
India	1.7	3.8
Uganda	0.1	60*
World mean	4.9	1.3

* to 1 significant figure

How realistic are these comparisons? They show clearly that, because people in rich countries generally consume more and have more energy-intensive lifestyles than people in poorer countries, they have heavier mean carbon footprints. But it doesn't mean that the inhabitants of a rich country inevitably have heavy footprints. The inhabitants of Sweden, for example, have only about a quarter of the mean footprint of Americans. This is at least partly because of the low-carbon electricity supplies in Sweden.

But remember that these are figures for *territorial* CO₂ emissions. This is because few countries publish *consumption* emissions that include imports and exports. On a consumption basis, the emissions embedded in Chinese exports to the UK, for instance, are counted as belonging to UK *consumers* rather than Chinese *producers*. So, more realistically, the mean footprint of a UK inhabitant is about twice that of an inhabitant of China, rather than a bit smaller (CCC, 2013).

2.3.2 Total carbon footprints

The picture of carbon footprints changes again when you consider total CO_2 emissions for different countries rather than emissions per person. Table 4 shows that by 2011 China had become by far the greatest total emitter of CO_2 , followed by the USA and India. In terms of consumption-based emissions too, the three greatest CO_2 emitters were China, the USA and India (CCC, 2013).

Table 4 Total territorial carbon dioxide emissions for selected countries (CDIAC, 2015; Global Carbon Atlas, 2016)

Country	Total CO ₂ (2011), million tonnes per year (rounded)	Total CO ₂ (2015 est.), million tonnes per year (rounded)
China	9020	9680
United States	5306	5561
India	2074	2597
Russian Federation	1808	1595
Japan	1188	1232
Germany	730	789
Saudi Arabia	520	602
South Africa	477	476
United Kingdom	448	428
Brazil	439	507
Australia	369	382
France	339	331
Turkey	321	573
Thailand	303	337
Egypt	221	237
Pakistan	164	168

World average (mean)	150.8	(World total 36 292)
Uganda	3.8	4.3
Ireland	36.1	35.9
Sweden	52.1	44.3
Israel	69.5	67.2
Romania	84.8	72.6
Nigeria	88.0	93.6

Note: the CO_2 emissions shown in Tables 2 and 4 are based on from burning fossil fuels, cement manufacture and gas flaring.

(CDIAC, 2015; Global Carbon Atlas, 2016)

Figure 10 shows more of the same information updated using estimations to 2015, when China, USA and India emitted half of the world's CO₂.

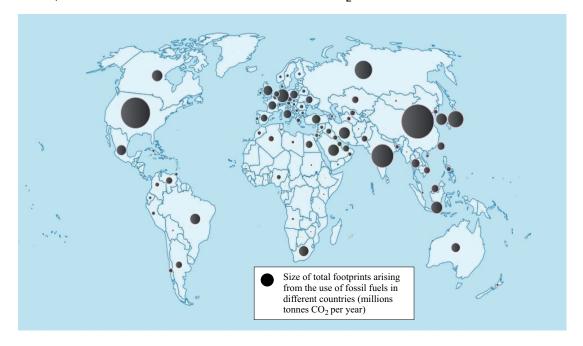


Figure 10 Estimated total territorial CO₂ emissions in 2015 (Global Carbon Atlas, 2016)

2.3.3 Differences between people and places

Mean individual and household carbon footprints for a country conceal the differences *within* that country. As you saw for the UK, these differences in carbon footprints are strongly related to income and can be very great.

For example:

 in India the 2015 mean carbon footprint of 1.7 tonnes CO₂ per person per year hides the differences between middle-class Indian households living in air-conditioned apartments and owning a television, refrigerator and motor scooter, or perhaps a car

(e)

- (Figure 11(a)), and the household of a subsistence farmer, whose only fuel is dried cow dung for cooking, and perhaps kerosene for a lamp (Figure 11(b))
- in Africa, the contrast between the elite, who may have a private swimming pool, and villagers who have to collect water for cooking and washing (Figures 11(c) and (d)) is not shown
- in China, where the lifestyles of the wealthier members of the very rapidly growing urban population still contrast with those of people living in China's villages and rural areas (Figures 11(e) and (f)).



Figure 11 (a) Apartments, New Town, Kolkata, India, built for India's fast-growing middle class; (b) Indian cattle farmer living on less than £1 per day; (c) government official's house, Libreville, Gabon; (d) villager's house, Jinja, Uganda; (e) typical apartment block, China; (f) village alley, near Yangshuo, China

(f)

2.3.4 Rounding numbers, decimal places and significant figures

In this study note you will look at decimal places, significant figures and rounding numbers, as well as how to choose what precision to give an answer.

Study note: Rounding numbers, decimal places and significant figures

Rounding numbers

Numbers are often 'rounded up' or 'rounded down' depending on how precise they need to be. Often a good approximation of a number is adequate, and this process is called 'rounding'.

When rounding a number up or down you need to look at the digit immediately to the right of the digit you are rounding to. If this right-hand figure is between 0 and 4 (i.e. less than 5), then the digit you are rounding to stays the same, and if it is between 5 and 9 (i.e. 5 or greater), then it is raised to the next whole number. For example:

62 to the nearest 10 is 60, as the digit to the right of the 6 is 2, which is between 0 and 4, so the 6 remains the same;

2932 to the nearest 1000 is 3000, as the digit to the right of the 2 is 9, which is between 5 and 9, so the 2 is rounded up to a 3.

Decimal places and significant figures are two commonly used ways of rounding.

Decimal places

Decimals are often rounded to a given number of decimal places. Decimal places are those to the right of the decimal point, e.g. 5.368 has three decimal places. To round this to two decimal places: find the second decimal place (6) and look at the number to its right (8). As that number is between 5 and 9, the second decimal place is rounded up to the next whole number, which is 7. So 5.368 rounded to two decimal places is 5.37.

To round 5.3634 to two decimal places: the second decimal place is 6 and the figure to its right (3) is less than 5, so the 6 remains as it is. So, 5.3634 rounded to two decimal places is 5.36.

Significant figures

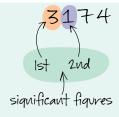
If you are dealing with very large or very small numbers, rounding to a number of decimal places is not convenient. Instead you need a way of rounding numbers that just considers the most important digits in each number. These are called significant figures and tell you roughly how big or how small the number is. The first significant figure in a number is the first *non-zero* digit on, or starting from, the left (ignoring the location of any decimal point).

For example, the first significant figure in 3 246 485 is the 3. It tells you that the number is between 3 and 4 million. The first significant figure in 0.00245 is 2, which tells you that the number is between 2 and 3 thousandths. You can round a value to any number of significant figures in a similar way to decimal places.

Here are two examples:

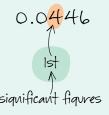
• Rounding 3174 to 2 significant figures (the abbreviation 'sig. fig.' or 's.f.' is often used).

The first s.f. is 3 and the second is 1. The digit to the right of the 1 is 7; this is between 5 and 9, so the second s.f. is rounded up to 2, giving the answer: 3174 = 3200 (to 2 s.f.).



• Rounding 0.0446 to 1 s.f.

The first s.f. is 4. The digit to the right is 4; this is between 0 and 4, so the first s. f. remains as 4, giving the answer: 0.0446 = 0.04 (to 1 s.f.).



Choosing appropriate precision

When using data or measurements in a calculation, you may need to decide how much to round off the final result, especially if you use a calculator that shows many digits. The rule is that the final result shouldn't be more precise than the data used to produce it, and this should be the number of significant figures in the answer.

For instance, in Activity 4 you compared UK mean carbon footprints with those of other countries. For India, the calculation was (6.4/1.7) = 3.764705882 tonnes on a calculator. The original data were given to 2 s.f., so it is appropriate to round the final result to 3.8 tonnes (to 2 s.f.).

If the original data are not all given to the same number of significant figures, then the least precise item limits the final precision. For instance, in Table 2, the ratio for UK/Uganda emissions is 6.4/0.1 = 64 tonnes. The Uganda value of 0.1 is given to only 1 s.f., so the answer should be 60 tonnes (to 1 s.f.).

2.3.5 Viewing and listening for a purpose

Videos can be a powerful medium for showing and explaining complex subjects. They can help you move away from static words to show the dynamics of events, interactions and processes. This study note will give advice on how to view a video effectively.

Study note: Viewing and listening for a purpose

To view video effectively, make sure you can watch without distractions, as when learning from text. Before you view, think about why you are watching a video. Is it to help you gain deeper understanding of a topic or to provide illustrative background material? Will you need to incorporate ideas from the video into an assignment? To learn effectively from viewing, read any notes supplied or the relevant sections of the course beforehand.

When viewing a video there's a lot of information to take in at once. So after viewing, write down the main points. Don't write down everything – key points reflecting the video's purpose are most useful in triggering your memory and understanding. You may want to note down questions or links to things you've seen before. You can, of course, stop viewing to take notes or go through to the end – do what works best for you. Sometimes the material may be very rich, and you may feel it is worth viewing several times, but consider whether you have time for this.

If you use these techniques you should be able to use the many environmental TV, radio and online programmes more effectively to enhance your knowledge and understanding. A word of caution – words and images on video and TV are very engaging and may easily convince you. But they give only a version of events and, as with written materials, you should ask questions about the reasons behind the programme and whether alternative views may be just as valid.

Now watch the following video by statistician Professor Hans Rosling who explains why it is important to compare carbon dioxide emissions *per person* for different countries (as in Table 2 and Figure 9), rather than total emissions, in order to develop policies for tackling climate change on a fair basis. Then complete Activity 5.

Video content is not available in this format.



Video 1 Hans Rosling on carbon emissions

Activity 5 Hans Rosling on carbon emissions

Allow about 10 minutes

a. Why does Rosling say it is necessary to compare countries on emissions per person rather than total emissions?

Provide your answer...

Answer

Measuring mean emissions per person of rich countries is fairer, and so more likely to be politically acceptable, to middle-income and poor countries.

b. From which groups of countries does Rosling say the main growth in emissions will come in the future?

Provide your answer...

Answer

The main growth in emissions will be from newly industrialised countries (e.g. China) and other developing countries (e.g. Thailand) whose inhabitants earn between \$10 and \$100 per day on average.

c. What level does Rosling suggest different groups of countries aim for in reducing their emissions?

Provide your answer...

Answer

Rich countries with high carbon emissions per person, like the USA and Australia, should reduce their emissions to the lower level of other rich countries like France and Sweden. Rapidly developing countries like China and Thailand should try to avoid the path of countries like the USA, the UK and Germany by preventing their emissions per person from growing as much.

d. What does Rosling leave out of his analysis?

Provide your answer...

Answer

Rosling does not include non-CO₂ GHG emissions or the emissions embedded in imports and exports in his analysis.

2.3.6 Carbon footprint at home

The carbon footprint, as an indicator of how heavily people are 'treading on the Earth' and affecting the climate, is a rather abstract idea. Videos 2 and 3 are a collection of extracts from a BBC/OU TV programme, *Can we save planet Earth?*, which provides striking images of a household's footprint as black blocks of carbon coming out of a house, car and power station. Although the programme was made in 2006, the issues it discusses are still relevant today, even though some of the information it presents has changed. For example, as you've seen, China has now overtaken the USA to become by far the world's largest CO_2 emitter. Video 2 examines the carbon emissions of a fictional average suburban family – the Carbons – who live in a rich country, like the USA.

Video content is not available in this format.

Video 2 The Carbons



Now watch Video 3 which looks at the Tans, a fictional and upwardly mobile couple who are about to move into a new apartment block in a suburb of a Chinese city, mainly fuelled by carbon-heavy electricity from China's coal-fired power stations.

Video content is not available in this format.

Video 3 The Tans



Activity 6 The Carbons and the Tans



a. According to the video, what are the main sources of CO₂ and other GHG emissions created by the Carbons' and the Tans' households?

Provide your answer...

Answer

The Carbons' main GHG emission sources shown on the video are: electricity for household electronics and appliances; their cars; food distribution and consumption; decomposing waste; and flights. The Tans' main emission sources are not detailed, but focus on building construction and electricity from coal-fired power stations.

b. What major source of emissions does the video not mention explicitly?

Provide your answer...

Answer

The direct emissions from the fuel (probably gas or oil) used for heating the Carbons' house and providing hot water, and the indirect emissions from the production and consumption of the goods and services to support the Carbons' and Tans' lifestyles, are not explicitly mentioned.

2.4 Summary of Section 2

The main learning points from Section 2 are:

- There are different ways of calculating the carbon footprints of individuals and households. Excluding the emissions embedded in imports and exports, the mean territorial UK footprint is about 7 tonnes of CO₂ per person per year. But more realistically, including imports and exports and other GHGs, the mean consumptionbased UK footprint is about 14 to 16 tonnes of CO₂ equivalent per person per year.
- The main components of individual and household carbon footprints in developed countries are: car and air travel; household gas and electricity use; the consumption of food and other goods; and the use of private and public services.
- The carbon footprints of individuals and households vary widely within countries, related especially to people's incomes, household sizes and lifestyles. For example, the carbon footprint per person of people living in UK households with the highest 10% of incomes is about three times that of those with the lowest 10%.
- The carbon footprint also varies between countries, by amounts depending on how it
 is calculated. For example, the mean territorial carbon footprint of an inhabitant of
 China is now similar to that of someone living in the UK, but if the emissions

- embedded in imports and exports are included, then the mean UK footprint is about three times that of a Chinese person.
- There are wide variations in carbon footprints, especially between wealthy, middleincome and poorer people and countries.
- It is fairer to compare countries on mean carbon footprints per person than on total emissions, although this obscures the differences between the footprints of rich and poor people within each country.

Next you will measure your own carbon footprint.

3 How heavy is your footprint?

You've seen that individual and household carbon footprints vary widely both within and between countries. So, in this section you'll be measuring your individual (i.e. personal) carbon footprint using a computer-based calculator.

The carbon calculator was specially developed for the Open University by drawing upon some of the studies and reports discussed in previous sections. The data from these were then updated using the latest available statistics.

In Section 2, you saw that household income and the number of people occupying the household usually have a big effect on individual carbon footprints. That's why these questions are included in the carbon calculator.

The calculator will show you which consumption activities make large and small contributions to your carbon footprint. But because the calculator is a model of reality, a simplified representation of the real world, it can give you only an approximate measure of your carbon footprint and how it is broken down into: emissions arising from the energy you use for room and water heating; your travel by car and air; your typical diet, usual spending habits, and so on.

The results the calculator produces are only as good as the accuracy of the data, assumptions, equations and options within the model and the information you enter into it. For example, if you drive a medium-sized petrol-engine car, the calculator works out the carbon footprint of your personal car travel by multiplying your approximate annual car mileage (chosen from a drop-down list of options) by the mean CO_2 emissions per kilometre for medium (1.4 to 2 litre) petrol engines from official statistics adjusted for the number of people who typically occupy a household car when in use. The accuracy of the car footprint depends on how close your actual car mileage is to the options offered by the calculator, how close your actual car emissions are to the mean for 1.4 to 2 litre petrolengine cars, and how typical your car occupancy actually is.

The calculator could, of course, provide a more accurate car travel footprint if it asked you for more detailed information, such as the make and model of your car, how many people usually travel in the car and your typical annual car mileage. But it could be time-consuming and laborious if this amount of detail were required for all the questions in the calculator. Carbon calculators therefore make compromises between the time and effort required to use them and their accuracy. This one tries to make the process fairly quick and easy, and focuses on the information that has the biggest effects, in order to provide an approximate, but realistic, individual carbon footprint.

The carbon calculator also enables you to try out the effects on your footprint of making changes; for example, to your home's energy efficiency. Testing different changes without having to make them in reality is a form of computer modelling. In Section 4 you'll be asked to reduce your footprint by modelling the effects of changes allowed by the calculator – such as driving or flying less or more, or changing your car, diet or spending behaviour. Because it uses the consumption-based perspective, the calculator assumes that most of the nation's footprint arises from consumer demand and behaviour. The emissions generated by public services, business and non-governmental organisations are allowed for to some extent, but the main responsibility for reducing the footprint is given to individuals and households. However, in Section 5 you can try out the effects on your footprint of making changes beyond the household level, such as spending some of your income on 'voluntary carbon offsets' for carbon-saving projects overseas or agreeing to tax increases for national investments in low-carbon technologies.

3.1 Calculating your carbon footprint

How big is your carbon footprint? And what are the main contributors to your carbon footprint? You will now use the OU carbon calculator to work out an approximation of your individual footprint and identify your actions which contribute to it.

Activity 7 Your carbon footprint



(Allow about 1 hour

- a. Following the steps below, use the OU carbon calculator to work out your individual carbon footprint.
- Click on the following link to view the carbon calculator. Open the link in a new window or tab so you can easily find your way back to the course: OU carbon calculator.
- Select 'Next' on the Welcome screen to start.
- Answer the questions on the calculator's tabs from 'Your Household' to 'Goods' for your existing situation. You'll find that some questions are fairly general and don't exactly fit your personal situation and there are options that require estimates (or even 'guestimates'). So you'll have to choose answers or values that fit your situation as closely as possible.
- Note that some questions refer to the whole household and some to you personally. If the question asks what do 'you' do (e.g. How many minutes do you spend in the shower?) it generally means you personally, unless it's clear that all household members are involved (e.g. What main fuel do you use to heat your hot water?).
- Additional guidance and FAQs can be found here

As you answer the questions, the changes to your footprint will be shown on the 'You' bar chart and on the Summary screen, together with the UK Average individual footprint for comparison.

When you are satisfied that you have the best estimate of your existing footprint; go to the **Summary** tab. Then name (e.g. ExistingFootprint1) and save a record of your footprint. You can make changes to your answers as many times as you like until you are satisfied you have the best estimate of your footprint.

Figure 12 below shows the OU carbon calculator 'Summary' footprint screen, with an example existing carbon footprint from a hypothetical student (in the left-hand column of the table and the left-hand bar chart) and the UK average (mean) carbon footprint (in the right-hand column of the table and the right-hand bar chart).

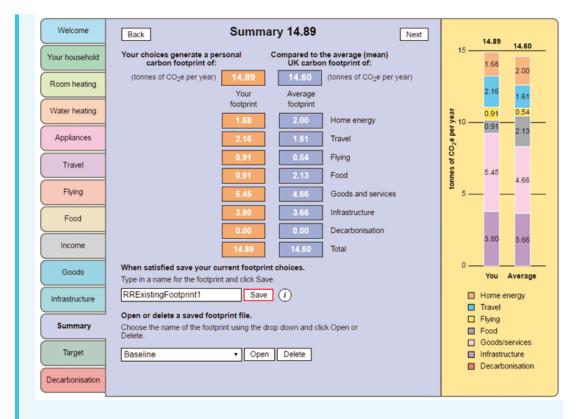


Figure 12 An example of the OU carbon calculator 'Summary' footprint screen. The student's existing footprint is 14.89 tonnes CO_2e per year; this is greater than the UK national average of 14.60 tonnes CO_2e per person per year.

b. The carbon calculator is a simplified computer model of the real world. Why is such a model useful, and what is the implication of it being based on the consumption perspective for measuring carbon footprints?

Provide your answer...

Answer

The carbon calculator is a useful model because it allows individuals to calculate their carbon footprint and explore options for changing it.

Being a consumption-based model, the calculator assumes that individual and household consumption is ultimately responsible for triggering most GHG emissions, so decisions by individuals could significantly reduce the nation's footprint.

3.2 Summary of Section 3

The main learning points from Section 3 are:

Individual and household carbon calculators are models that use data, mathematical
equations and assumptions to convert information that you provide about your home,
travel, etc. into an approximate figure for your carbon footprint.

- The results provided by a carbon calculator can only be as good as the accuracy of the data, assumptions, equations and options within the model and the information entered into it. Carbon calculators have to make compromises between usability and accuracy.
- Carbon calculators allow you to model the effects on your carbon footprint of making changes (e.g. to your home's energy efficiency, travel choices or diet), and so explore how best to reduce your footprint.

Now you know the extent of your carbon footprint, next you will look at ways of reducing it.

4 Reducing your carbon footprint

Calculating your individual carbon footprint using the OU carbon calculator gives you a good idea of the contribution to the total footprint made by your choices regarding energy, food, travel, etc. You'll also know how your carbon footprint compares to that of the mean footprint per person for the UK or another country.

Unless you already live a very 'green' lifestyle, it's unlikely that your footprint will be light enough (at 2 to 3 tonnes CO: warning! inherit not supported 2e) to be compatible with long-term environmental sustainability, or at least to help avoid dangerous climate change in the coming decades.

This section, therefore, discusses targets for reducing carbon footprints towards an environmentally sustainable level. At the end of the section, you'll then use the carbon calculator again to explore options for reducing your footprint towards such targets.

4.1 Carbon reduction targets

The first international agreement to set carbon reduction targets was the 1997 United Nations Kyoto Protocol. This came into force in 2005 and required developed countries to reduce their human-generated GHG emissions by an average of just over 5% on 1990 levels between 2008 and 2012. The developing countries that signed up, including India and China, were not required to meet any reduction targets, and the USA never ratified the treaty to make it legally binding. The Kyoto Protocol was a modest first step and known to be inadequate to meet the challenges of climate change.

Since Kyoto, a series of UN climate change conferences have come into force, which have attempted to get international agreements on limiting GHG concentrations in the atmosphere to a 'safe' level. This level has been interpreted as the concentration that gives better than a two-thirds chance that the mean global temperature will not rise by more than 2 °C (and ideally no more than 1.5 °C) above pre-industrial levels this century (IPCC, 2015).

A sustainable carbon footprint, likely to avoid the worst effects of climate change (and other adverse environmental impacts), is calculated to be about 2 to 2.5 tonnes CO_2 equivalent for every person on the planet. This requires today's total global GHG emissions to be at the very least halved by 2050 (IPCC, 2015). And for the UK to achieve a sustainable footprint, each inhabitant's mean consumption-based carbon footprint of 14 to 16 tonnes CO_2 e per year would have to be reduced by over 80% by 2050 (CCC, 2015). This level of cuts had been anticipated by the authoritative Stern Review (HM Treasury, 2006). Importantly, Stern calculated that the cost of taking the actions to achieve these reductions would be much less than the costs of not doing so; for example, dealing with storms, floods, and food and water shortages.

After very slow progress, the most successful UN climate conference to date was the one held in Paris in December 2015. It agreed on the need for drastic cuts in GHG emissions and was signed by most countries in April 2016.

For its part, the UK Government has exceeded its Kyoto target and in 2008 passed a pioneering Climate Change Act.

Under this Act the Committee on Climate Change was set up to advise the government on carbon budgets and associated emission reduction targets. The Committee recommended a cut of 35% in UK GHG emissions by 2020, 50% by 2025 and 57% by 2030 on the way to a reduction of at least 80% in the nation's emissions by 2050, all compared to 1990 levels. These targets are legally binding, and by 2016 the UK had already exceeded its 2020 target. But in line with the UN's Climate Convention, these targets are based on *territorial* GHG emissions and so don't include the other half of the UK's carbon footprint

embedded in imports, which you learned about in Sections 1 and 2. Also, the reductions were mainly due to more electricity generated by renewables and less use of coal, while reductions from other sectors such as transport and housing had stalled. And the Paris Agreement would require even greater reductions in the UK's emissions by 2050 than the current 80% target (CCC, 2016).

What might these targets mean for your individual carbon footprint?

Activity 8 Carbon footprint targets



(1) Allow about 30 minutes

The mean territorial carbon footprint of a UK inhabitant in 1990 was 14.2 tonnes CO₂e per person per year (UNFCCC, 2015).

- What should be the mean carbon footprint of a UK inhabitant given the following targets?
 - The UK Government's target of a 35% reduction in territorial GHG emissions on 1990 levels by 2020.
 - The government's target of a 50% reduction by 2025.
 - The government's target of an 80% reduction by 2050.
- On a consumption basis, including imports and exports, the 1990 UK footprint was approximately 15.7 tonnes CO₂e per person per year (CCC, 2013). What would be the footprints for the above reduction targets?

Spend 10–20 minutes on this first part of the activity before looking at the discussion below. See Percentages and parts per million (ppm) in Section 1 for how to calculate percentage reductions.

Provide your answer...

Discussion

- Considering only *territorial* emissions:
 - By 2020 the mean UK footprint should have fallen to 100% 35% = 65%of the 1990 figure of 14.2 tonnes, namely $65/100 \times 14.2 = 9.2$ tonnes CO₂e per person per year (rounded to one decimal place).
 - By 2025 the mean UK footprint should have fallen to 100% 50% = 50%of the 1990 figure of 14.2 tonnes, namely $50/100 \times 14.2 = 7.1$ tonnes CO₂e per person per year.
 - By 2050 the mean UK footprint should have fallen to 100% 80% = 20%of the 1990 figure of 14.2 tonnes, namely $20/100 \times 14.2 = 2.8$ tonnes CO_2 equivalent per person per year (rounded, i.e. near to the sustainable level).
- 2. Considering *consumption* emissions, including imports and exports:
 - By 2020 the mean UK footprint should have fallen to $0.65 \times 15.7 = approx$. 10 tonnes CO₂e per person per year (rounded).
 - b. By 2025: $0.5 \times 15.7 = \text{approx}$. 8 tonnes CO_2e per person per year.
 - C. By 2050: $0.2 \times 15.7 = \text{approx}$. 3 tonnes CO_2e per person per year.

For a UK inhabitant with a mean consumption-based carbon footprint of 14 to 16 tonnes per year, a 10 tonne (and even an 8 tonne) CO₂e per person footprint should be achievable by actions at the individual or household level, such as those that you can explore with the carbon calculator. A lighter footprint than these is likely to require actions by government (and business), and the calculator allows you to try the effect of some of these actions in Activity 11 in Section 5.

If you live outside the UK, find the mean CO_2 emissions per person for your country using the sources for <u>Table 2</u> and <u>Figure 9</u>. Then work out your individual target footprint (e.g. using the EU countries' target of 40% reduction by 2030 or by searching for 'emissions reduction pledges, Paris 2015').

4.2 Actions for lighter living

Nobody made a greater mistake than he who did nothing because he could only do little. (Edmund Burke, 1729–97)

In this section, you will look at those actions or changes which are likely to have a big effect on your footprint and those with only a small effect. You will also look at some of the complexities in calculating these effects. This should help prepare you for Activity 11 at the end of this section.

Tables 5a-d provide examples of how different actions affect your carbon footprint and so what you could do or change to reduce it. But be aware that the effects of these actions depend on the assumptions and data sources used. For example, the CO_2 savings from filling cavity walls with insulation depend on: the house type and size (detached, terraced, etc.); its heating system (gas, electric, etc.); how the house is occupied; and more. So in Table 5a, instead of providing different savings for different types of household, an overall average of $240 \text{ kg } CO_2e$ per year from a government survey of a large sample of UK homes on the actual savings from such energy efficiency measures (DECC, 2015a) has been used. You should therefore regard the information in Tables 5a-d as 'ballpark' figures rather than exact numbers. It also means that effects of changes you might make in the calculator may not exactly match those in the tables.

You can view Tables 5a–d in their full size by clicking on 'View larger image' beneath each table.

Carbon footprint category	Technical or lifestyle action	Effect on mean carbon footprint (CO ₂ e)	Source
Energy	Install solar PV system (mean for all UK properties that installed in 2012)	375 kg/year saving	DECC (2015a), p. 6; DEFRA (2015)
	Replace a 60 W halogen light bulb with an 11 W compact fluorescent OR a 50 W halogen spotlight with a 6 W LED (used 400 hours per year)	9 to 10 kg/year saving per lamp	Goodall (2007), p. 127; DEFRA (2015)
	Replace pre-2005 gas central heating boiler with modern condensing gas boiler	280 kg/year saving	DECC (2015a), p. 22; DEFRA (2015)
	Install solar water heating: gas boiler system electric immersion heater	270 kg/year saving 500 kg/year saving	EST (2014)
	Reduce winter room thermostat temperature by 1 °C (gas heated properties)	250 to 300 kg/year saving	Goodall (2007), p. 84
	Line dry washing instead of using tumble drier twice per week (100 times per year)	170 kg/year saving	Berners-Lee (2010), p. 84
	Replace old (c. 2000) fridge-freezer with A++ rated one	150 kg/year saving	White (2008), p. 116
	Fix external or internal insulation to solid walls (gas heated properties)	390 kg/year saving	DECC (2015a), p. 22; DEFRA (2015)
	Fill cavity walls with insulation (gas heated properties)	240 kg/year saving	DECC (2015a), p. 22; DEFRA (2015)
	Top up loft insulation to recommended 270–300 mm (gas heated properties)	75 kg/year saving	DECC (2015a), p. 22; DEFRA (2015)

 Table 5a
 Effects of individual or household actions on carbon footprint (Energy)

Carbon footprint category	Technical or lifestyle action	Effect on mean carbon footprint (CO ₂ e)	Source
Transport	Long haul flight (e.g. London to New York return, 11 000 km)	2180 kg incl. radiative forcing	All DEFRA (2015)
	Medium haul flight (e.g. Manchester to Barcelona return, 2750 km)	468 kg incl. radiative forcing	
	Domestic flight (e.g. London to Glasgow return, 1000 km)	300 kg incl. radiative forcing	
	Short haul flight (e.g. London to Paris return, 700 km)	119 kg incl. radiative forcing	
	Drive 1600 km (1000 miles) with one person in car:		All DEFRA (2015), except hybrid; Davis (2011)
	Small petrol car (<1.4 l)	253 kg	
	Medium petrol car (1.4-2 l)	318 kg	
A PAR	Large petrol car (>2 l)	466 kg	
	Small diesel car (<1.4 l)	230 kg	
	Medium diesel car (1.4-2 l)	282 kg	
	Large diesel car (>2 l)	360 kg	
	Medium hybrid car (1.4-2 l)	184 kg	
	Medium electric car	120 kg	
	16.2 km (10 mile) car journey	Divide above emissions by 100	
	Share car with one or more passengers	Divide by number of people in the car (average occupancy = 1.6)	
	International rail journey (e.g. Milton Keynes to Paris return, 1000 km or 620 miles)	12.1 kg	
	100 km (62 mile) UK rail journey	4.5 kg	All DEFRA (2015)
	100 km (62 mile) long-distance coach journey	2.9 kg	
	10 km (6.2 mile) local bus journey	1.0 kg	

 Table 5b
 Effects of individual or household actions on carbon footprint (Transport)

Carbon footprint category	Technical or lifestyle action	Effect on mean carbon footprint (CO ₂ e)	Source
Food	Minimise waste of edible food (from average 20% thrown away)	275 kg saving/year	Based on WRAP (2013), p. 10
Diet	1 kg beef or lamb	17 to 18 kg	Berners-Lee (2010), pp. 95, 111
	1 kg hard cheese	12 kg	Berners-Lee (2010), p. 106
	1 kg pork	6.3 kg	DEFRA (2006), p. 88
	1 kg chicken	5.6 kg	DEFRA (2006), p. 93
	1 kg Kenyan green beans (airfreighted to UK)	4.4 kg	Terry (2011), p. 109
	1 kg fish fingers	4.0 kg	DEFRA (2006), p. 101
	1 kg frozen cod	3.3 kg	Berners-Lee (2010), p. 99
	1 kg rice	2.5 to 6 kg	Berners-Lee (2010), p. 216
	1 kg frozen carrots	1.1 kg	DEFRA (2006), p. 49
	1 litre milk	1.0 kg	DEFRA (2006), p. 68
	1 kg bananas	0.5 kg	Berners-Lee (2010), p. 27
	1 kg fresh carrots	0.4 kg	DEFRA (2006), p. 49
	1 kg organic potatoes	0.3 kg	DEFRA (2006), p. 38
Drink	750 ml bottle wine	1.0 kg	Berners-Lee (2010), p. 78
	587 ml (1 pint) beer	0.5 kg	Berners-Lee (2010), p. 49
	500 ml plastic bottle of water	0.2 kg	Berners-Lee (2010), p. 43

 Table 5c
 Effects of individual or household actions on carbon footprint (Food)

Carbon footprint category	Technical or lifestyle action	Effect on mean carbon footprint (CO ₂ e)	Source
Goods	A new medium-sized petrol car (e.g. VW Golf, Ford Focus) over a 10-year life	660 kg/year embedded emissions	PE International (2013), p. 4
	A new computer kept for 4 years before replacing or scrapping	145 kg/year embedded emissions	Based on Berners-Lee (2010), p. 124
	A new mobile phone, used for 2 years before replacing or scrapping	24 kg/year	Based on Berners-Lee (2010), p. 114
	A new pair of shoes A new pair of trousers	11.5 kg 6.0 kg	Berners-Lee (2010), pp. 105, 93
Waste and recycling	Recycle all household waste rather than about half	230 kg saving/year	Based on Berners-Lee (2010), p. 61
	Reusable bags instead of 5 supermarket disposable plastic carrier bags per week	2.5 kg saving/year	Berners-Lee (2010), p. 18

Table 5d Effects of individual or household actions on carbon footprint (Goods; waste

and recycling)

Activity 9 Light carbon living



Allow about 10 minutes

Looking at Table 5a-d, what actions are most likely to substantially reduce your carbon footprint? And which seem to make only a small difference?

The actions fall into two broad groups – technical and lifestyle. For example, installing energy-saving lamps in your home is a 'technical' action, while switching lights off is a 'lifestyle' (or sometimes referred to as behavioural) action. Sort your list into technical (T) and lifestyle (L) actions.

Provide your answer...

Discussion

The following actions in Table 5a-d are more likely than others to significantly reduce your carbon footprint:

- avoiding air travel as much as possible (L)
- reducing long car journeys (especially regular ones like commuting); car sharing and/or replacing driving with travel by bus, coach or train (L)
- improving home insulation (especially of older properties) (T) and, if possible, lowering room temperatures (L)
- installing a solar PV system (T)
- reducing consumption of meat (especially beef and lamb), dairy products, and air-freighted fruit and vegetables (L)
- keeping products rather than rapidly replacing or scrapping them (L) (unless a different product is much more efficient, e.g. a hybrid or electric car (T))
- not wasting edible food, and recycling household waste (L).

The following actions are likely to have only a relatively minor effect on your carbon footprint, but may address other important environmental impacts:

- not buying just one new pair of shoes or trousers (L)
- upgrading your mobile phone (L)
- avoiding bottled water and disposable plastic carrier bags (L).

4.2.1 Deciding what action to take

Although there are uncertainties involved in calculating the effects of different actions on your carbon footprint, some information is readily available. For example, you can check the CO₂ emissions per kilometre of different car models on government websites (VCA, 2016). But emissions from air travel depend on whether the additional radiative forcing effect on the upper atmosphere of the nitrogen oxides and water vapour in aircraft emissions is counted. Based on current science, the UK Government recommends multiplying CO₂ emissions from flights by 1.9 then adding the CO₂ equivalent emissions of other GHGs. This has been done for the flight emissions in Table 5b and also in the carbon calculator (DEFRA, 2015).

The CO_2e savings from changing diets or recycling materials are also difficult to calculate. Many of the figures quoted depend on life-cycle analysis, the results of which vary widely. For example, while cows and sheep produce large amounts of the powerful greenhouse gas methane when digesting their food, the effects of reducing meat and dairy consumption depend on what is substituted. If out-of-season, imported vegetables and rice are substituted, the footprint could be greater than for a diet with small amounts of locally produced beef and lamb fed on grass rather than imported grains.

Buying locally produced food can help to reduce emissions and food miles, especially if the food is imported by air. However, for most foods the main impacts arise from production and processing, and reducing food miles may not be the best option. For example, imported tomatoes grown outdoors in Spain have a lower carbon footprint than tomatoes grown in a heated greenhouse in the UK.

Table 5a–d showed the impacts of selected actions in terms of 'ballpark' GHG emissions. But other environmental impacts may be as, or more, important. A dramatic example was the scandal in 2015 when a major car manufacturer was shown to be concealing the amounts of unhealthy NO_X air pollution from its diesel cars, which previously had been considered 'greener' due to their lower CO_2 emissions than petrol cars (Porter, 2016).

There are many other cases where choosing between alternative environmental actions involves trade-offs and compromises. For instance, chickens reared indoors in cramped conditions are more efficient at converting their feed to meat than free-range birds. Intensively reared chicken therefore has a lower carbon footprint than free range, but at the cost of poorer animal welfare. While the carbon savings from avoiding plastic carrier bags may be negligible, the 150 million tonnes of plastic waste (mostly packaging) now in the oceans has become a major threat to marine life (World Economic Forum, 2016), a more important reason for reducing plastic waste.

Remember from Section 2 that household income and size also have a very big effect on individual carbon footprints. There may be little you can, or want to, do about your income, but you may have some control over how you spend it; for example, you could spend spare income on insulating your home, on holiday flights, or on 'offsetting' your emissions (see Section 5). The number of people in your household may also not be something you can change, but if you have spare room it is usually carbon efficient to occupy it.

That raises the highly sensitive issue of children. Having a child probably adds more to your carbon footprint than any other decision you might make (even if the child increases your household's size). Berners-Lee (2010, p. 151) has calculated that the mean footprint of an extra child born in the UK is about 373 tonnes CO_2e over an average 79-year life. And that doesn't take into account the fact that the child is likely to have children too. One estimate of the total effect of each extra female child born in the USA, including their offspring, is nearly 9500 tonnes CO_2 (Murtaugh and Schlax, 2009).

4.3 Lighter living costs and constraints

The costs of 'light living' actions need, of course, also to be considered. Some actions involve no cost or save money – for example, less flying, shopping or meat eating – or can even make money, such as letting out a spare room. Others are low cost with a rapid <code>payback</code> time. For example, replacing a halogen incandescent light bulb with a low-energy compact fluorescent lamp (CFL) or light emitting diode (LED) lamp should pay back the new lamp's cost in lower electricity bills in about 6 to 12 months. Other measures may involve extra cost, for example taking the train instead of driving, or considerable investment, such as installing a rooftop solar photovoltaic system, which may take ten

years to pay back. The big carbon-reduction benefits of such actions have to be weighed against affordability, cost and return.

Apart from cost, there are many other factors that may attract or deter you from acting. Travel behaviour is well known as one of the most difficult things to change. You may have little choice about using a car for commuting, shopping or ferrying children about. Looking forward to that foreign holiday may be the one thing that keeps you going.

As noted in Section 2, your needs, wants and social values are important too. For example, some people feel that travelling by bicycle or bus is only for people who can't afford a car, and that flying to exotic destinations gives them social status. On the other hand, others find the idea of cutting their travel footprint in half, or making their home really 'green', exciting and challenging.

Most people's lifestyles are only partly under their control or are what is considered 'normal' in society. So freedom to change is constrained by circumstances and the wider society. Even so, it's important not to fall into the trap of thinking that only making changes with minor environmental benefits is enough. As the former government chief scientific advisor, Professor David McKay, observed, 'If everyone does a little, we'll achieve only a little' (McKay, 2008, p. 3).

4.4 Moving towards a sustainable carbon footprint

In Section 4.1 it was noted that a globally sustainable carbon footprint was about 2 to 2.5 tonnes CO_2e per person per year, to be achieved by 2050. That would require the mean footprints per person in rich countries like Britain and Germany to be reduced by over 80%, while allowing the footprints of poorer developing countries to increase to give their growing populations a reasonable standard of living. On the way to an 80% reduction, the UK Government set a target of a 35% reduction in the country's territorial carbon footprint by 2020 and 50% by 2025. In Activity 8, you calculated that that would be a mean annual footprint of, respectively, about 9 and 7 tonnes CO_2e per person (or 10 and 8 tonnes CO_2e per person, including imports and exports).

Such personal carbon footprint reductions should be achievable by individual and household actions. Next you will look at how one environmentally pioneering household has tried to do it.

4.4.1 Low-carbon living

This section considers how one couple, Mark and Alice, have significantly reduced their carbon footprints by 'eco-renovating' their three-bedroom mid-terraced house in Oxford, England, without losing the benefits of a normal developed society's lifestyle.

As you study this section, consider the questions in Activity 10 and think about the technical and lifestyle changes this couple have made to reduce their carbon footprint, as well as addressing some other environmental impacts. Think about which (if any) of these changes you might consider yourself.

Box 2 Eco-renovating

Mark and Alice's philosophy

Mark and Alice's aim is to show how a modern family can make serious reductions in their environmental impact, while still having a standard of living most of us would recognise. Above everything their aim is to be practical, rather than offer solutions that few people are likely to adopt.

Energy

Mark and Alice started by commissioning an energy audit of their house. This showed that their house was built to pre-1982 UK Building Regulations standards. Their plan of action included:

- 1. Replacing the ancient boiler with a modern condensing boiler and installing new heating controls and radiator valves.
- 2. Because of its cost, the case for installing solar water heating is usually marginal, but as they were having the central heating upgraded they decided to go for it.
- 3. Insulation is key in any eco-renovation. Mark and Alice noticed the biggest change when they had the cavity walls filled with mineral fibre. They put sheep's wool insulation in the loft, 100 mm on top of the 70 mm of fibreglass, and insulated the walls and ceiling of the internal garage to stop heat leaking into the cold space.
- 4. Mark and Alice's house had single-glazed windows plus secondary glazing. They decided to install the best double-glazed windows, and then refit the secondary glazing triple glazing for a fraction of the price.
- 5. Building a conservatory, which helps to heat the house in spring and autumn and acts as a heat buffer in winter. The conservatory was the largest investment Mark and Alice made. It's a great space for relaxing and growing plants, and also improves the environmental performance of the house.
- 6. Building an insulated front porch to stop cold air entering in winter.
- 7. Mark and Alice cook, heat and provide hot water from gas, which has half the emissions per kWh of electricity. Gas and electricity consumption is about 50% lower than when they first moved in.

Water

Mark and Alice try to save water. Lower hot water consumption also reduces energy use. Nationally, slightly more than a third of all domestic water is flushed down the toilet. A new UK toilet can use up to 9 litres a flush. They chose a Swedish design, which uses 2 or 4 litres a flush, but is indistinguishable from any other toilet.

Transport

Mark and Alice replaced their two cars with a (second-generation) Toyota Prius hybrid car. It cost little more than an average saloon, at the time about £17 500 minus a £1000 government grant, yet uses less than half the fuel of their previous cars. It has two engines, one petrol, the other electric, whose battery is charged when the petrol engine is running and by recovering energy when going downhill or braking. They get around 55 to 63 miles per gallon (5 to 4.5 litres per 100 km) of petrol, and it didn't mean driving a really small car, or trading in comfort or safety.

They also decided to live close to the city centre and to public transport. They decided there was no point having an eco-house while having to travel long distances to and from work. They also got a couple of old bikes. These allow them to get around without always jumping into the car.

Mark and Alice have several relatives living in Canada and know that air travel produces very high emissions. If they travel to Canada about once every one to two years they know this can more than outweigh the CO₂ savings they've made from eco-renovating the house.

Food

Mark and Alice try to reduce their food impacts by: shopping in the local covered market for fresh, unpackaged food; using a box delivery of locally grown vegetables; growing fruit and vegetables on their allotment; buying local, ethically produced meat and eating it sparingly; and reducing consumption of imported and out-of-season fruit and vegetables.

Goods and services

Their house is small with no unoccupied rooms, which uses the available space and heating efficiently. Mark and Alice also like to keep the house uncluttered, which means not buying more goods than they really need or want and recycling unwanted items. As Mark says, 'reduce first, reuse second, and recycle third'.

Beyond the household

Mark and Alice try to reduce their carbon footprint as much as they can, but recognise that there are limits to what people can do individually. They therefore help others to follow their example by providing information, if asked by friends or colleagues, and by contributing to eco-renovation open days and websites.

At the community level, Mark was chair of the Board of Westmill Wind Farm Cooperative from 2006 to 2015, which generates more than enough electricity to supply the demand of all the co-op's 2500 members.

Mark and Alice also recognise that there are environmental issues that can be tackled only at government levels, such as local and regional planning and national energy, and transport policies. (Government responsibility for reducing emissions is discussed further in Section 5)

(Mark and Alice, personal communication and interviews, March/April 2008, updated 2016)

Figure 13 shows some images of Mark and Alice's property and vehicle.



Figure 13 (a) The front of the house; (b) the rear conservatory; (c) the boiler and solar heat store; (d) Toyota Prius hybrid petrol–electric car

Activity 10 Low-carbon living

Allow about 10 minutes

- a. What approaches to saving energy for heating etc. were adopted by Mark and Alice in their Oxford house?
- b. What transport dilemmas have Mark and Alice faced in trying to live their low-carbon lifestyle?

Provide your answer...

Answer

- a. The approaches to direct energy saving made by Mark and Alice include:
 - o insulation as much as possible
 - o draught-proofing, secondary plus double glazing
 - installing an efficient gas condensing boiler and controls
 - building a solar conservatory and porch
 - low-energy lighting
 - solar water heating
 - efficient appliances and cooking with gas
 - a small house with no unoccupied rooms.

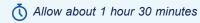
- b. Mark and Alice's main transport dilemmas are:
 - wishing to visit their relatives in Canada about once every one to two years, which involves flights that more than outweigh the carbon savings they've made from improving the energy performance of their house
 - choosing low carbon transport for commuting, as the locations and requirements of their jobs change.

Mark and Alice are better off than many families in Britain and so could afford some of the more costly changes to their home, travel and lifestyle. But many of the changes they made cost little and often save money. There are many websites that provide information and inspiration for home eco-refurbishment, lower carbon transport options and other green technologies and lifestyle changes. Some give the cost of different actions, available subsidies and the time to pay back any expenditure involved.

4.4.2 How can you reduce your carbon footprint?

Having seen how one couple managed to reduce their carbon footprint, you will now return to the carbon calculator to explore how you might be able to reduce your carbon footprint to a target level.

Activity 11 Reducing your carbon footprint



Use the carbon calculator to explore how to reduce your carbon footprint to your chosen target by following the steps below.

- Open the carbon calculator.
- With the calculator running and set on your existing footprint, which you made in Activity 7, select a footprint reduction target (you can open your existing footprint by selecting the Summary tab and open your existing footprint file).
- On the Target screen, select either a Personal OR a Government reduction target.
 - Personal target: first select the 'Accept footprint' button to set Your existing footprint value. Your footprint on the bar chart and Summary screen will appear in the box. Then in the box below type in a percentage reduction target on Your footprint.
 - Government targets: select a percentage reduction (30%, 46% or 54%) on the UK Average consumption-based footprint (approximately equivalent to reductions of 35%, 50% and 57% in the territorial footprint in 1990 on which UK carbon budgets are based).
- Use the calculator to explore how your existing footprint might be reduced to your chosen target level. Do this by selecting the calculator's tabs and changing answers to the questions.
- When you are satisfied that you have reached or done your best to reach your target, save your reduced footprint using a different name (e.g. 30GovtFootprint1)
- Additional guidance and FAQs can be <u>found here</u>.

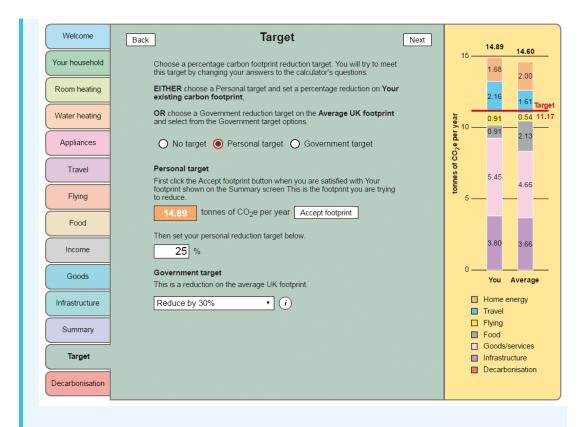


Figure 14 Target screen: My Existing Footprint 1 saved and a Personal target of a 25% reduction on that existing footprint set

If you haven't managed to reach your target, you have the option of further reducing your footprint via non-household emission reduction measures paid towards by you but undertaken by government or others in Activity 13 in Section 5.

4.5 Summary of Section 4

The main learning points from Section 4 are:

- There are many national and international targets for reducing GHG emissions, especially CO₂.
- Increasingly, these targets are based on reductions in emissions necessary to give a
 reasonable chance of preventing the mean global temperature rising by more than 2
 °C (and preferably 1.5 °C) compared to pre-industrial levels, in order to avoid
 dangerous climate change.
- A sustainable carbon footprint is likely to involve an eventual reduction of at least 80% in the mean carbon footprint of people living in rich, developed countries.
 Shorter-term individual or household footprint reductions of 35% to 50% should be possible without losing the benefits of a developed society's lifestyle.
- Different technical and lifestyle changes have different effects on individual or household carbon footprints. The effects depend on personal circumstances, but the most cost-effective usually include:
 - reducing, or replacing, air and car travel; car sharing
 - upgrading home insulation

- installing an efficient heating and hot water system
- fully occupying homes, but keeping family size small
- reducing consumption of meat and dairy products and air-freighted fruit and vegetables
- reducing unnecessary purchases of high-carbon goods (e.g. new vehicles)
- spending spare income on low-carbon or carbon-saving goods and services.
- People's ability to radically reduce their footprint is constrained by their circumstances, such as their jobs, family, social pressures and willingness to change.
- A carbon footprint calculator is one way of exploring how to reduce individual or household footprints. However, it can provide only an approximate calculation of the effects of different technical and lifestyle actions.

The final section of this course will look at the role of individuals, households, communities and governments in reducing carbon footprints.

5 Who's responsible for reducing carbon footprints?

We must abandon the conceit that individual, isolated, private actions are the answer. They can and do help. But they will not take us far enough without collective action. (Gore, 2007)

There are some things that we can do as individuals: making this an energy-efficient house and making smart transport choices. Then there are things that we can do in our community ... I'm chair of a local community wind farm ... and work with Low Carbon West Oxford, a group of local residents ... And then there's a third strand where it's really much more to do with government.

(Mark and Alice (2008), former owners of the eco-renovated house, Oxford)

As mentioned earlier, viewed from the consumption perspective, individuals and households directly or indirectly generate the demand for most of the goods and services produced by the economy.

Does this mean that individuals and households are responsible for reducing the CO_2 and other GHG emissions from all their *consumption*? Or are the businesses and industries that *produce* the goods and services at home and abroad mainly responsible? In this section you'll be considering who is responsible: 'I' (as an individual consumer or citizen), 'we' (my household, workgroup, community) or 'they' (the government, business, other countries, and so on).

5.1 The role of individuals and households

You've been considering how to reduce your carbon footprint to help tackle climate change and, to some extent, other environmental changes. To that extent, 'I' as an individual consumer has a role to play.

But unless you live alone, you share your household with other people, a group that could be called 'we'. Within a household, there may be different views and priorities about what, if anything, should be done about reducing carbon footprints. Saving energy and other resources can involve some inconvenience or loss of comfort and often involves advance planning or careful thought. It may involve spending money on carbon-saving products or cutting down on some pleasurable activities. There may be social or cultural issues, or deep-rooted beliefs and habits, which differ. Not everyone in the household may agree that the actions are necessary or desirable, or worth even minor inconveniences. Others may be driven by their environmental or other values to live as sustainably as possible (see Box 3 for an example).

Box 3 My household

Here's an example of how members of a household can have differing views and priorities when thinking about their carbon footprint:

Using the carbon calculator to explore how to reduce my carbon footprint reminded me that some of these issues occur in my own household. Regarding energy use, my partner and her daughter like the house kept nice and warm in winter and often turn up the thermostat or thermostatic radiator valves.

On transport, my partner and I run a small car. I try to car-share or cycle to work and usually take a train or coach for longer journeys. But my partner's daughter likes driving her own, fairly powerful, car and rarely uses public transport. And while my partner and I have avoided flying in the past year (having flown three times for leisure in the previous year), my partner's daughter has already enjoyed two holiday flights and is looking forward to a trip to Australia.

I would happily become a vegetarian, but my partner likes to eat meat at least once or twice a week.

Regarding consumption, while I prefer buying a few long-lasting goods, my partner's daughter, and to some extent my partner too, like shopping for new things.

So while my own carbon footprint may be fairly light and could be lighter, the total household footprint is heavier than it could be. To lighten our footprint involves tradeoffs and choices, and requires give and take among the household members.

You may be able to think of similar issues in your household. Does this mean that each member of the household has to be responsible for their own carbon footprint? Or are there shared activities about which compromises have to be made in order to reduce the household's total footprint?

Of course, you may not be just part of a shared household: you are also a member of society. Even if you agree within your household about what to do, many others in society aren't concerned about reducing carbon footprints. Is there any point in trying to reduce your footprint when others aren't interested or willing to change? In economics this is an aspect of the 'free rider' problem in which others benefit from a public good – a reduced risk of dangerous climate change – without paying for it.

One view, argued by businessman and green politician Chris Goodall in *How to Live a Low-carbon Life* (2007), is that pioneering individuals should take responsibility for reducing their carbon footprints in an attempt to galvanise governments, businesses and other members of society into action. He admits that even a million individuals cannot tackle climate change alone, but if governments, businesses and others are unwilling to make the necessary changes, they have to be persuaded by being shown examples of low-carbon living (such as the Oxford couple in Section 4.4.1). His model is that of the abolition of slavery and votes for women, in which radical change was brought about by the actions of small groups of highly committed people.

5.2 The role of active citizens and communities

UK Government policy is that individuals and households have a role to play in reducing emissions, especially from home energy use and transport. However, policies have shifted over the past decade, with less emphasis on supporting individual and household action (e.g. with grants and subsidies for home insulation) and more on voluntary initiatives and what business and governments can do.

Part of the reason for this shift is that governments have become increasingly reluctant to try to change the lifestyles and consumption of millions of people, focusing instead on influencing business and other major decision-makers. So, for example, as noted earlier (Section 4.1), most of the UK's recent reductions in GHG emissions are the result of shifts from coal to wind and solar electricity generation, while emissions from people driving and flying have increased.



Figure 15 Solar panels

As George Marshall (2014) has argued, from a psychological viewpoint, asking people to reduce their carbon footprint to help tackle climate change is a very difficult message to get across, as it may require immediate sacrifices in order to address an invisible long-term problem. Also, individuals don't control many of the decisions that affect their carbon footprint, such as national energy and transport policies, town planning, food processing and retailing practices, overseas farming and manufacturing, and so on. In other words, while individuals and households are directly or indirectly responsible for most of the consumption of goods and services, they do not control their production and distribution. So it is now recognised that while individuals and households can do much to reduce their

carbon footprints, they can't make the over 80% reductions needed to reach a sustainable footprint. That requires actions by communities, businesses, local and national governments, for example in developing a low-carbon energy supply system, improving the energy and materials efficiency of industry, and contributing to international efforts on climate change.

Another reason why people argue that others are responsible for environmental problems is that they often feel powerless in the face of all the complex decisions and big changes that seem necessary. However, even if they don't directly control many economic activities and policy decisions, in a democracy at least, individual citizens can exert influence by voting in elections and political involvement.

Another way 'we' can help reduce carbon footprints is by joining with others in a pressure group such as WWF (World Wide Fund for Nature) or one of the voluntary groups that get together to help each other reduce their individual and household impacts. Such voluntary groups include: those set up through a charity called Global Action Plan; local groups in the Transition Network; and some 5000 community energy groups that have formed in Britain since 2010 to install renewable energy technologies and improve home energy efficiency (DECC, 2015b). The UK Government considers such community initiatives to be as – or more – effective, than individual action.

In the workplace, individuals can switch off lights and computers, recycle waste paper, and so on. But surveys show that individuals are less likely to save energy at work than at home, as they don't have to pay the bills. However, by working with their colleagues, they can help each other to adopt green practices and also encourage their employer to adopt environmental policies, for example switching to a green electricity supplier, setting up recycling facilities, and establishing staff travel plans.

5.2.1 Voluntary carbon offsets

One of the ways that individuals can shift the responsibility for emission reductions from 'l' and 'we' to 'they' is by paying for so-called voluntary carbon offsets. A carbon offset is a reduction in emissions resulting from a carbon-saving project undertaken elsewhere — often in a developing country — voluntarily paid for by individuals to compensate for (offset) the carbon footprint arising from their activities. (Organisations, such as businesses, can also buy offsets.) For example, many airlines and other companies offer carbon offsets to compensate for the emissions from personal or business flights. One energy supply company is offering 'green' gas to consumers by including some methane biogas generated from waste and offsetting the remaining emissions by paying into carbon-saving projects such as efficient cooking stoves and biogas plants in developing countries.

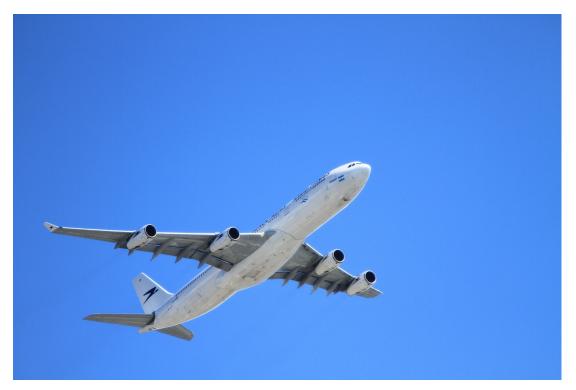


Figure 16 The carbon emissions from air travel are often offset by airlines

However, the benefits of carbon offset schemes have been questioned. The small amount charged by airlines for offsetting the emissions of a flight, for example, bears little relationship to the actual cost of totally eliminating that amount of GHGs from the atmosphere. For example, delegates to the 2015 Paris Climate Change Conference were invited to offset their flights through UN certified carbon reduction schemes, costing from 50 US cents to \$5 per tonne of carbon. It meant that a delegate flying return from New York to Paris could consider their flight 'climate neutral' for a mere 40 cents to \$4.

Tree planting schemes have also been criticised, not least because it takes years for the trees to absorb the CO_2 emissions from, say, a flight made today. However, there are now some schemes that promise more worthwhile carbon offsets, as they approve only offsets which fund renewable energy and energy efficiency projects, and promote sustainable development for the local community where they take place. But whatever the type of project, a carbon offset is a payment to transfer the responsibility for reducing emissions from the person or organisation creating the emissions to someone else.

Despite such reservations, the carbon calculator allows you to offset some of your emissions, especially if you can't reduce your footprint by individual or household actions. The amount you (theoretically) have to pay for this is based on a realistic price for eliminating each tonne of carbon emissions, not the unrealistically low offset prices charged by airlines, etc.

5.3 The role of governments and business

Despite all the possibilities for individual and group action to reduce carbon footprints, there will still be people, groups and organisations who won't, or can't, do much. Many individuals limit themselves to 'every little bit helps', with small effects on their carbon footprint, such as reusing plastic bags or recycling paper. This avoids having to consider more significant changes in car and air travel, home energy use, diet or shopping. Others will simply carry on producing and consuming to maximise their own personal or organisational benefit, even if they know this is to the detriment of everyone else and future generations.

This behaviour is what has been called the tragedy of the commons, a term popularised by an American ecologist Garrett Hardin (1968). The 'tragedy' is that for a time, each person, organisation or nation can gain an additional benefit by using or consuming a bit more of the commons (the Earth) until a resource is used up, or an irreversible environmental change has occurred. Then everyone suffers.

That's where government support, taxation and regulation, business initiatives and international agreements to tackle climate change and other environmental problems come in. It's what 'I' and 'we' can't achieve unaided and only 'they' have the power to do.

5.3.1 Government taxation and subsidies

One of the things that governments can do is to tax fossil fuels, goods and services that create GHG emissions to encourage households or businesses to reduce those emissions. Or governments can provide grants and subsidies to encourage industry to develop low-carbon products and consumers to adopt them.

An example is transport taxation, in which cars with higher CO_2 emissions per kilometre pay a higher road tax than those with lower emissions. Another is the tax on petrol or diesel fuel intended at least partly to encourage people to change their travel behaviour. Examples of grants and subsidies for emissions reduction include grants to low-income consumers for home insulation or to all consumers for buying electric cars, and the payments by energy companies to householders who have installed solar PV for the electricity generated, paid for through everyone's electricity bills.



Figure 17 Low-carbon products, such as electric cars, have been incentivised through government grants and subsidies.

Taxes on emissions, such as a carbon tax on fossil fuels, are often not popular and they can hit poorer members of society harder than better-off ones. But by careful design to reduce undesirable consequences, such taxes and subsidies can be a very effective way of encouraging businesses, individuals and households to reduce their carbon footprint through financial penalties and incentives (Feng et al., 2010).

The carbon calculator allows you to decide whether to support an increase in taxes to fund national investments in decarbonising the economy and so reduce everyone's personal, individual footprint.

5.3.2 Government, business and international actions

Other government, business and international actions to address climate change include, in no particular order:

- international treaties on reducing greenhouse gas emissions, perhaps even to negative emissions (i.e. absorbing more GHGs than are produced through, for example, replanting or creating new forests, or carbon capture and storage)
- national and international policies on increasing renewable and/or nuclear energy supply
- regulations on energy labelling of refrigerators, washing machines, etc.
- · regulations on the energy performance of buildings
- urban and regional planning polices to encourage people to use public transport
- local authority home insulation and heating improvement schemes
- company programmes to save energy, avoid waste and reduce car commuting
- environmental education and information programmes.

Having now considered what the individual, household, community and government can do to help reduce the carbon footprint complete Activity 12 as a summary exercise.

Activity 12 I, we or they?



(1) Allow about 15 minutes

List five activities that 'I' could do as an active citizen, and what 'we' could do as a household, workgroup or community, to reduce your own and others' carbon footprints.

What 'I' as an active citizen could do, or what 'we' as a household, community or workgroup could do to reduce our own and others' carbon footprints:

- 1.
- 2.
- 3.
- 4.
- 5.

Answer

You may have suggested some of the following:

What 'I' as an active citizen could do to reduce others' carbon footprints:

- try to educate or persuade other household members, including children, to adopt more environmentally responsible behaviour
- 2. join an environmental pressure or support group, or community energy group
- lobby local or national politicians on environmental issues 3.
- vote for a political party with the best environmental policies.

What 'we' as a community or workgroup could do to reduce our and others' carbon footprints:

- 1. try to save energy and resources at work
- avoid unnecessary commuting and business travel (e.g. by telephone or online communications)
- 3. work with local schools etc. to adopt environmental teaching and policies
- 4. work with our employer to adopt environmental policies.
- List five activities that are beyond the control of individual consumers, citizens, community and social groups.

What 'they' as governments, etc. can do to reduce carbon footprints of the nation, region or world:

- 1.
- 2.
- 3.
- 4.

Answer

You may have suggested some of the following:

What 'they' as governments, etc. can do to reduce carbon footprints of the nation, region or world:

- adopt policies to increase supplies of renewable and/or nuclear energy
- 2. implement national, regional and international agreements and targets to reduce GHG emissions
- 3. develop and implement plans to reduce a business organisation's carbon footprint
- adopt and implement regulations to improve the energy performance of buildings and the fuel economy of vehicles
- 5. introduce or increase carbon taxes, and/or grants and subsidies to individuals, communities and businesses, to help reduce emissions.

5.3.3 Further reducing your carbon footprint

You have now assessed your existing individual carbon footprint and considered how changing your actions, such as changing eating habits, driving fewer miles or flying less, can reduce your footprint. You are almost at the end of this course and the final activity asks you to return to the carbon calculator to see what can be done to further reduce your footprint with some actions beyond the household.

Activity 13 Decarbonising your footprint



Allow about 45 minutes

This activity assumes that you have completed Activity 11 and have tried to reach a Government and/or Personal footprint reduction target.

If you haven't managed to reach your target through individual or household ('1' or 'we') actions, there are some non-household ('they') actions by government or others on the carbon calculator's 'Decarbonisation' screen that can contribute towards reducing your personal footprint by decarbonising the national or global economy. This is done via carbon dioxide emission reduction measures paid for through your taxes or voluntary carbon offset payments, but undertaken by government or others.

Even if you've reached your target, you can set a more challenging target to explore the effect of these actions, such as supporting taxes to fund investments in decarbonising the economy or paying for voluntary carbon offsets.

First open the Carbon calculator.

If you've reached your target in Activity 11:

- On the Target screen, starting from your reduced footprint file, set a more challenging target (as in Activity 11 above).
- Select the Decarbonisation tab. Try out the tax and offset options, which will produce emission reductions that subtract from your reduced footprint lowering it further. When you enter one or more decarbonisation option to reach a target already set, the red target line splits to show the target compared to the 'You' result, while the 'Average' bar shows the target line and its value in its pre-Decarbonisation position.
- You'll find that, depending on your income, increased income tax or regular voluntary carbon offset payments, can produce quite large emission reductions.

If you haven't reached your target in Activity 11:

• Starting from the footprint file which hasn't reached your target, use the Decarbonisation tab (as above) to reach it.

In either case:

- When you have reached your target, save the new reduced footprint file using a different name (e.g. DecarbonisationFootprint1).
- Additional guidance and FAQs can be found here.

This final activity has helped you explore the impact on your carbon footprint of carbon dioxide emission reduction measures paid for through your taxes or voluntary carbon offset payments, but undertaken by government or others. Such measures can be difficult to implement in practice and are often politically sensitive.

5.4 Summary of Section 5

The main learning points from Section 5 are:

- There are limits to the ability of individuals and households to reduce their carbon footprints, because they don't directly control decisions about the production and distribution of the goods and services they consume.
- Even so, individuals can take actions to help reduce emissions as citizens and/or as active members of community organisations, pressure groups or workgroups.
- There are still many actions concerning the environment and climate change beyond the control of individuals, households and communities ('1' and 'we'). These require action by governments and business at local, national and international levels ('they').

Conclusion 04/01/23

Conclusion

This free course, *Environment: treading lightly on the Earth*, has shown you that much of the carbon footprint of an economy is due to use of energy and transport, and consumption of food, goods and services by individuals and households. Hence, what you can do as an individual consumer, citizen and/or household member to reduce your carbon footprint can be significant. But communities, business and governments also have a crucial role in tackling GHG emissions and climate change.

This OpenLearn course is an adapted extract from the Open University course U116 *Environment: journeys through a changing world*.

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