Calculating your carbon emissions

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Background

This note accompanies the *Climate impact calculator for individuals* and *Climate impact calculator for Quaker meetings*, which were developed over a period of time by the Quaker 'Living Witness' project, and revised in association with Quaker Peace and Social Witness (QPSW) in 2011. The calculators can be downloaded from www.livingwitness.org.uk, or filled in online at ww.quaker.org.uk/climate-impact-calculators.

The *individual* calculator is designed to allow people to estimate their personal contribution to climate change without needing access to utility bills or other precise information. The *Quaker meeting* calculator allows Quaker meetings (or other groups) to assess the climate impact of their buildings and activities. Both calculators have sections on Travel, Energy in the home, Materials and waste, Building construction, and Other goods and services. The individual calculator includes extra sections on Food and Public/Non-profit services.

The sections in this note follow the same order as in the calculators. Appendices at the end give a quick review of terminology and units; explain how Renewable Obligation Certificates work; and give more detail of the background calculations on food.

The calculators are intended to show the approximate scale of these different sections of your climate impact. As far as possible, each section tries to account for your full impact (sometimes termed 'all scopes' or 'lifecycle') – for instance, including the emissions associated with refining and distributing a fuel, and not just those associated with its final use. Thus the numbers may be a bit different from those in other calculators.

We have done our best to draw on reputable data sources, but the calculators are not precise, and for some sections (particularly Building construction and Other goods and services) they are very approximate indeed. From our perspective, what is important is to gain a clearer overview of how your personal or community life might be impacting our precious climate, to think about it, talk about it, and then **do something about it** - rather than become too focused on exact numerical values.

Section 1: Transport

Cars

Burning petrol and diesel in car engines directly produces large amounts of carbon dioxide, as well as small amounts of nitrous oxide and methane. Further emissions are produced indirectly from the refining of primary petroleum products into finished fuels, and the storage, distribution and retail of these fuels. The total of these direct and indirect emissions ('all scopes' column in Annex 6 of the 2010 DEFRA/DECC guide) is 2.73 kg CO_2e per litre of petrol and 3.18 kg CO_2e per litre of diesel. The indirect emissions account for about 13% of these values.

Car manufacture and road building also use energy and thus result in emissions. Manufacture accounts for about 10% of total lifecycle GHG emissions; road building is hard to allocate among road users but some estimates suggest that it contributes a further 10-15%. Hence to estimate the broader impact of your car, it is reasonable to add 20% to the 'all scopes' fuel values, giving an overall contribution of 3.28 kg CO_2e per litre for petrol and 3.81 kg CO_2e per litre for diesel.

The amount of fuel used in a year obviously depends on the distance that you drive. It also depends on the size of your vehicle and the way that you drive. Keeping a record of fuel use is the most reliable way to calculate your car-related emissions, but an estimate can be made using average ‘all scopes’ CO_2e per mile, which the DEFRA/DECC guide has estimated for different classes of vehicle. These values, with an additional 20% for car manufacture and road building, are used in the Climate impact calculators

Alternative fuels

The calculators do not include information about alternative transport fuels. Lifecycle GHG emissions using LPG are about 24% below those for petrol - provided the engine is optimised for LPG, not just a converted petrol engine (IEA, 1993). Small additions of bio-ethanol to petrol result in marginally lower emissions but this depends heavily on the energy use in ethanol manufacture. Using rapeseed methyl ester (bio-diesel) results in lifecycle emissions about 20-30% below those from diesel (IEA, 1994).

Rail and bus

Calculating the impact of public transport is complicated by the fact that the train or bus was going anyway. So does your trip result in additional services being run? In the case of air travel where the number of planes changes in response to passenger demand, your trip probably does contribute. For rail in the UK, service provision is near to capacity, and additional passengers have very little impact on it. For buses, the effect is probably intermediate between air and rail.

For simplicity, the climate impact calculators allocate the overall emissions from the train or bus equally among its passengers, using the ‘all scopes’ figures per passenger-mile from the 2010 DEFRA/DECC Annex 6. The value for trains is a weighted average for UK journeys: in practice diesel trains produce higher emissions per passenger-mile than electric trains, and short commuting journeys more than inter-city journeys. The emissions for Eurostar are based on the UK mix of grid electricity: the low value reflects the high efficiency that can be achieved with modern, high-speed electric trains.

Flying

Calculating fuel use and emissions per passenger-km of airline flight is complicated, for several reasons. Firstly, aircraft carry both passengers and freight, and fuel use statistics do not differentiate between the two. Secondly, long flights are usually more efficient than short ones, because the planes reach higher altitudes where air resistance is lower, but aircraft type and route have a significant impact too. And finally, an average first-class passenger accounts for about four times as much of the overall weight (and thus the overall emissions) as an economy passenger.

‘All scopes’ emissions for domestic, short-haul international, and long-haul international flights, are given in Annex 6 of the DEFRA/DECC guide. AW weighted these in the ratio 5%:15%:80% to account for the relative distance travelled by different modes, giving an overall average of 0.14 kg CO_2e per passenger-km (or 0.22 kg CO_2e per passenger-mile).

This value includes the direct greenhouse gas emissions from burning the aviation fuel, and the indirect emissions from processing and transporting that fuel. However, there are other climate change effects of aviation (including increased cirrus cloud, condensation trails and the effect of NOx at high levels in the atmosphere) that are not included. The magnitude of these effects is very uncertain, but the best current scientific evidence cited by DEFRA/DECC suggests that they can be represented by a multiplier of 1.9.

For the calculator, this means an overall (0.14 x 1.9) or 0.26 kg CO_2e per passenger-km. And since airliners fly at about 880 km/hour, this equates to about 230 kg CO_2e per passenger-hour, the value which is used in the calculator.

Section 2: Energy in the home (or Meeting House)

The ‘UK Energy in brief’ booklet published by DECC (2011) showed that most of the energy used by the 26.5 million UK homes in 2010 was natural gas (390 billion kWh); electricity (120 billion kWh) and oil (39 billion kWh), along with about 16 billion kWh of other fuels – coal, wood and other renewables. So the average home uses 14,700 kWh as natural gas, 4500 kWh as electricity,1500 kWh as oil, and 600 kWh as other fuels – a total per home of just over 21,000 kWh per year. Of this energy, roughly 68% is used for heating, 17% for hot water, and 15% for electrical appliances, cooking and lights.

The table below gives the CO_2e emission factors associated with the different household fuels, in terms of kWh and also in terms of other common units which you might find on your fuel bills. The average household produces about 6.5 tonnes (6,500 kg) of CO_2e each year.

The CO_2e emission factor for electricity needs a bit of explanation. In the UK, electricity is generated from natural gas, coal, nuclear power, renewables and oil, and also imported from France (mainly nuclear-generated). The relative proportion of these fuels is obviously important in determining the emission factor. The factor used in the table represents the average for the mix of supply to the UK grid in 2008.

Previous versions of the calculator assumed that you could reduce your household emissions from electricity generation by switching to a ‘renewable electricity’ or ‘green electricity’ tariff. This assumption has not been made in the current calculators because electricity companies are not meeting their government-set obligation for supplying renewable electricity. This means that electricity sold as ‘green’ is just part of what suppliers should be producing anyway. Appendix 2 has more detail on how the ‘green electricity market’ works.

However, if you generate renewable electricity yourself, for instance using a photovoltaic (PV) array on your home or Meeting House, then this renewable electricity is not part of any supplier’s obligation. If you use this electricity yourself, then the CO2 emission is just the small amount ‘embodied’ in the manufacture of the generating equipment. If you export to the grid, then you negate or ‘offset’ emissions associated with grid electricity.

‘All scopes’ emission factors for different fuels

Energy source	**units**	**kg CO_2e per unit**
Gas:	kWh	0.20
new meters	m^3	2.2
old meters	$100\ ft^3$	6.3
Fuel oil	kWh	0.32
	litres	3.5
Coal	tonnes	3300
Wood: chip	tonnes	61
pellets	tonnes	180
Electricity from the grid	kWh	0.62
Renewable electricity generated and used on-site	kWh	0.05
Renewable electricity generated on-site and exported	kWh	-0.57

Source: DEFRA/DECC 2010, Annexes 1, 3 and 9

The most reliable way to work out the climate impact of your home energy use is to regularly note down meter readings for the different fuels that you use, then multiply the annual use by the emission factors above. But if you don’t keep this information, then the estimates in the calculator will give you a good indication. These estimated also give you a feel for the potential impact of changes that you could make.

Heating
The figures in the calculator for home heating are based on Building Research Establishment (BRE) tables of energy use depending on house type and indoor temperature.

Turning down the thermostat is a zero-cost and effective way of cutting carbon and bills. A BRE model suggest that turning down from 21ºC to 15ºC cuts heating energy by about 10% per degree. Turning it down to 13ºC cuts energy by two thirds (although there is a health risk to the elderly at this temperature.)

In an uninsulated house, a third of the energy loss is through the roof and a third through the walls. Exact savings from insulation depend on a) the type of house – cavity insulation savings are greatest for a detached house and smallest for a flat and b) the level of pre-existing insulation. However, savings of 30% on energy use and heating bills are often possible.

Hot water
Installing a solar water heater might reduce energy use for hot water by one third. But more significant savings are possible by switching from a daily bath to a quick shower or flannel wash.

Appliances
Emissions from appliances are based on older survey-based data. In 2000 the average UK household is estimated to have used 325 kWh of gas per year for cooking, and 2900 kWh of electricity per year for cooking, lighting and appliances. In 2005 this was about 6% higher. The typical house has a fridge-freezer or separate fridge and freezer; runs a dishwasher or washing machine every day; and has a TV, video player and other equipment permanently on standby, and watches 3 hours/day of TV. Electricity use is broken down roughly as follows:

Use	**Typical kWh per year**
Fridges and freezers	700
Lighting	700
Cooking	500
Clothes/dishwashers	500
TVs & other electronic equipment	650
Other	150
Total	3200

Section 3: Food

Emissions included in the average UK diet are calculated from the following:

	Mt CO_2e	kg CO_2e per person	Source/basis
Fertiliser manufacture	5.0	80	DEFRA fertiliser statistics, energy inputs from IEA study
Agricultural energy	3.3	60	DTI statistics
Dairy herds methane and nitrous oxide	8.6	150	Estimated based on national GHG inventory and FAO food statistics
Methane and nitrous oxide from livestock kept for meat	35.5	600	
Other nitrous oxide from agriculture (food and feed production)	16.9	290	National GHG inventory
Food transport (domestic and imports)	18.0	300	DEFRA study
Energy use in food manufacturing	9.0	150	DTI statistics
Energy use in retail	15.0	250	DTI survey
Methane from crop waste	2.5	40	Estimated based on DEFRA waste survey
Emissions associated with production of imported fruit and vegetables	1.1	20	Estimated based on FAO food statistics
Total	114.85	1940	

About 840kg of this total is CO2, the other 1100kg is methane and nitrous oxide. Further details are given in the appendix. Using the DEFRA/DECC 2010 ‘all scopes’ emissions from fossil fuels increases the total in the above table to about 2,000 kg/year CO_2e per person.

Allocation of emissions to different diets
Dairy herd emissions are allocated to omnivorous and lacto-vegetarian diets. Meat-related emissions allocated to omnivorous diets only. Grain imports and exports are roughly in balance, so UK emissions for arable farming are allocated to UK consumption of food and feed. Roughly half of UK grain production is fed to animals, so half of N_2O and CH_4 from arable is allocated to animals. Of this, 20% is allocated to dairy. Other emissions are assumed to be shared equally across different diets.

Organic agriculture
Organic agriculture avoids emissions associated with fertiliser manufacture and breakdown of nitrogen fertiliser to N_2O, but has higher emissions of N_2O from ploughed-in crops, legumes grown on leys and animal manures. However, the size of these impacts may be swamped by the effects of organic production on soil carbon.

Several studies have found that organic agriculture results in higher levels of carbon in the soil than intensive chemical-based agriculture. Increases are in the region of one quarter, raising soil carbon from around 1.5 to 2%. These increases are one-off (i.e. the carbon content increases on organic conversion and levels out over time). They amount to somewhere in the realm of 100 tonnes of carbon per hectare, or the absorption of 370 tonnes of CO_2. However, these figures are associated with ‘no-till’ agriculture which does not apply to the majority of commercial organic production. LM has not yet found good figures for typical European organic systems.

LM applied a fairly arbitrary credit for organic diets for notional carbon sequestration, on the basis that the average UK diet requires 0.25ha of arable land and the long-term increase in soil carbon is about half of the reported figure. Ignoring any increased land use under organic production, 50,000kg of CO_2 is sequestered per organic eater. As this is a one-off change, the IPCC standard time horizon of 100 years was used, and spread it over that period. Hence an organic omnivorous diet gets a credit of 500kg (25%). Vegan and lacto-vegetarian diets require less land and so are allocated proportionate credits.

Other issues
Questions have been raised about emissions from different livestock and manure management systems. Anaerobic cattle slurry systems are almost completely confined to the dairy sector where they handle about 30% of manure, and account for a large proportion of the methane in the inventory.

Extensive livestock management produces more methane per kg of meat produced because productivity (meat out divided by food in) is lower, and hence emissions from enteric fermentation are higher per unit of meat produced.

Questions have also been raised about the viability of an organic, vegan diet. LM spoke to the soil nutrient specialist at HDRA (now Garden Organic) and looked at a number of technical support documents on the Soil Association website. The view from both is clearly that the primary means of maintaining soil fertility should be through growing legumes in leys. A significant proportion of organic production in the UK is stockless and it is financially viable. Some organic producers do feel that including livestock is necessary but the HDRA specialist saw this as being more to do with their idea of what is ‘natural’ than any ecological, technical or economic need. He also mentioned a study of farms in conversion, where several introduced livestock because they thought it would be necessary for the economics, but in fact found that they did better without and are now stockless. The main argument for including stock is to provide an income stream from leys – but of course, keeping stock also involves additional costs and the economics depends on a whole range of factors. They do not add to soil nutrients – rather the point is that they do not take much away. Producers do bring in manure when they are trying to build up the soil (mostly during conversion) and it can help especially when soil is short of phosphorous and potassium, but there is actually more concern to limit the amount of manure applied. HDRA is encouraging the use of municipal compost instead – and availability of this is growing rapidly as councils try to meet landfill reduction targets.

Section 4: Household waste

British households produce on average about 23 kg or two black rubbish bags of household waste each week (1200 kg/year) of which 3.4 kg/week (176 kg/year) is recycled or composted (DEFRA, 2005b). The table below shows how this waste is divided between different materials: note that about 60-70% is organic matter including around 25% paper and card, and 30% putrescent material.

Household waste is a source of greenhouse gases. The major contributor is the CO_2e that is ‘embodied’ in the discarded materials through the energy used in their production. Excluding food waste (which is counted in the food section of the calculator) this amounts to about 2.3 tonnes/year CO_2e per household.

Sending waste to landfill increases GHG emissions, by around 0.3 tonnes/year CO_2e per household. The major source is the CO_2 and methane produced from the decomposition of the organic waste. In addition, all waste requires energy to transport it to a landfill site.

Recycling and composting cut the emissions associated with landfill, and also ‘pay back’ some of the embodied emissions, by reducing the need for virgin material. This can be very significant for paper, metal, garden waste and plastic. But even with a major effort to recycle, the typical household still throws out around 1.5 tonnes/year CO_2e. Cutting waste production is the most effective way to cut waste emissions.

Material	**UK typical kg per week per household**	**kg CO2e embodied per kg virgin material**	**Net kg CO_2e per kg waste if all landfilled**	**Net kg CO_2e per kg waste if recycled**
Paper and cardboard	5	0.95	1.5	0.24
Plastic including film	1.7	2.8	2.8	1.55
Metals	1	7.1	7.1	1.9
Glass	2.5	0.84	0.85	0.53
Textiles	0.6	19.3	19.6	15.4
Kitchen (k) and garden (g) waste	7.6	4.0(k) 0.09(g)	0.37*	0.09*
Sanitary waste (eg nappies)	0.5	0.10	0.41	n.a.
DIY and other waste	4.3	2.9	2.9	2.6
Total	23.2			
Equivalent GHG emission for typical household (tonnes/year CO_2e)		2.3*	2.6*	1.5*

Sources: waste kg - DEFRA 2005b; emission factors - DEFRA/DECC 2010, Annex 9, Table 9d
*these values exclude the CO_2e embodied in food production, because this has already been taken into account in the food section of the calculator.

The information above is for household waste collections. Waste collected in skips is not included. A typical skip holding about one tonne (5 m^3) of material will account for a further 1000 kg CO_2e.

Section 5: Housebuilding

Building or extending your home or Meeting House requires a significant amount of energy, both directly and also indirectly in the production of the required material. In addition, it requires cement, which is manufactured using a process that releases CO_2 (in the conversion of limestone or $CaCO_3$ to lime or CaO). Thus constructing and extending buildings is a significant source of GHG emissions.

However, it is difficult to find reliable data on the amounts involved. A 1999 guide to 'Embodied energy in residential property developments' suggests between 500 and 1000 kg CO_2e per m^2 floor area for houses, and 800 to 1200 kg per m^2 for flats, so AW has assumed a value of 800 kg per m^2 in the calculators. Floor areas range from about 13 m^2 (so 10 tonnes CO_2e) for a single room extension to 115 m^2 (90 tonnes CO_2e) for a 4-5 bedroom house.

Even more problematic is how to share these greenhouse gas emissions over the lifetime of a building? There is no 'right' way. One approach is that all the emissions should be counted in the first year of the life of the building – since they are physically emitted at that time. But that perhaps unfairly penalises the owner of a brand new building, compared with a owner of a two-year old building who 'pays' nothing in GHG emissions. Another view is to share the emissions uniformly over the total life of the building – but that seems harsh on the residents who 'pay' the carbon emissions of an old building that is perhaps in rather poor condition. AW therefore decided to use a sliding scale in the calculators, in which the share of the total emissions decreases linearly over the first 50 years of the building's use, and is zero after that.

Sections 6&7: Other goods and services: spending by individuals and the public/not-for-profit sectors

(Note: LM worked on sections 6 and 7 in 2009. AW reviewed in 2011, but recognised that she does not have the expertise in macroeconomics to take this further. The numbers in sections 6 and 7 therefore relate to the previous version of the calculators. As you will see, they are very approximate, so this does not matter too much: what is important is to recognise the significant GHG impact of our personal consumption of 'stuff', and also the contribution of the public and non-profit services on our behalf.)

The UK national greenhouse gas inventory for 2004 reports total domestic CO_2 emissions of 560 Mt plus emissions from international bunkers (aviation and shipping) of 40 Mt. The latter is not part of the UK's Kyoto commitment but it is included as a 'memo item' in the inventory. The inventory also includes 2.47 Mt (62 Mt CO_2e) of methane, mostly from fuel use, agriculture and waste; and 132 kt (39 Mt CO_2e) of N_2O, mostly from transport and agriculture. Aviation emissions of NO_x and water vapour (contributing to contrails and cirrus formation) add a further contribution of the order of 70 Mt CO_2e. The total is about 770 Mt CO_2e.

The inventory does not include greenhouse gases 'embodied' in trade – i.e. the emissions involved in producing the goods we import or export. A recent study (Wiedmann et al., 2008) found that the balance of CO_2e embodied in trade has grown rapidly in recent years to reach about 20% of UK domestic emissions or 112 Mt CO_2e in 2004. The total emissions for which the UK is responsible therefore amount to about 883 Mt CO_2e, or 14,400 kg/year CO_2e per person.

In the calculators, trade-embodied emissions are included in the specified sectors (food, transport etc.) where the calculations are based on physical consumption of goods and services including imports. The emissions in the sections on transport, home energy, food, materials and waste account for about 6,800 kg/year CO_2 per person (60% of the UK total) and the vast majority of the nitrous oxide, methane and aviation emissions (about 2,800 kg/year CO_2e per person).

Thus roughly 4,800 kg/year CO_2e per person remain. These emissions come from all the other goods and services that we use, both as individual consumers (clothes, furniture, consumer electronics, entertainment, insurance etc) and through the public and non-profit services to society as a whole (government offices, schools, hospitals, the military, Quaker meetings, guide dogs and much more).

LM suggests that the simplest way to divide these emissions between 'individuals' and 'government and non-profits' is in proportion to their share of national spending. Households spent directly about £12,600/year per person *on consumption* (i.e. excluding savings) in 2005 (National Statistics, 2006). The previous sections of the calculator account for about £7,600 of this, so the individual items above (clothes, entertainments etc), account for the remaining £5,000/year per person. Governments and non-profit organisations spent nationally about the same amount, £5,000/year per person in 2005. The calculator therefore divides the remaining emissions equally between individual and government/non-profit spending.

For individuals, the average spend of £5,000/year per person corresponds to an emission of 2,400 kg/year CO_2e per person, or roughly 0.5 kg CO_2e per £ spent (section 6). The other 2,400 kg/year CO_2e per person is used on our behalf for public and non-profit services (section 7). This is not under our control except through voting, other political action, and engagement with the non-profit sector.

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Embodied energy in building booklet

Appendix 1: Greenhouse gases and units used.

The main contributors to climate change (known as 'greenhouse gases' or GHGs) are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Per kg, the climate impact of methane is around 25 times greater than CO_2, and nitrous oxide around 298 times greater. To put all three GHGs on the same basis, emissions are expressed in kg of CO_2equivalent or CO_2e. This is the mass of CO_2 alone that would have the same impact as the actual mix of GHGs.

There are many other GHGs that are generally less significant than the three mentioned above. Dust, smoke and clouds also have an effect on climate. These other factors are not covered in the calculator, except in the section on flying, where the significant impact of aircraft emissions on the upper atmosphere is taken into account.

Amounts of CO_2e are given in kilogrammes (kg), tonnes (t), thousand tonnes (kt) and million tonnes (Mt) depending on the amount in question.

Appendix 2: Renewable obligations certificates and ‘green’ electricity

The government requires licensed electricity suppliers to source an increasing proportion of their electricity from renewables (5.5% in 2005/06, increased yearly up to 9.7% in 2009/10). Compliance is regulated through Renewable Obligation Certificates (ROCs), which are issued for units of electricity generated from renewables, and can be traded. Electricity suppliers have to hold sufficient ROCs to cover the electricity they sell, or else pay what is effectively a fine.

However, the UK electricity industry has not met its targets. In 2009/10 only 6.9% of electricity came from renewable sources, compared with the 9.7% target.

Several companies offer green tariffs, supposedly supplying renewable electricity, but this is meaningful only if buying their electricity results in more renewable generation than would otherwise occur. This would entail the company holding ROCs for all of the electricity they supply, rather than selling its excess ROCS to other suppliers. At present, we are not aware of any company that does this. Good Energy, which is probably the best, is a small company that buys all of its electricity from renewable sources but it then sells most of the ROCs to other companies. According to a letter to its customers in 2009, it does retain some ROCs in excess of its requirements, but the proportion is less than 5%.

Appendix 3: Background calculations for 2005 food-related emissions table

CO_2 emissions in fertiliser manufacture.

	UK consumption	Energy intensity	UK energy input	CO2 emissions
	Kt	MJ/kg	PJ	Mt CO2
N	1030	60	61.8	4.499
P	286	10	2.86	0.208
K	378	7	2.646	0.193
Pesticide	4.339	190	0.82441	0.060
Total				4.96

Emissions from livestock husbandry
(enteric fermentation and fermentation and decomposition of manure)

	UK emissions from national GHG inventory		UK prod^n as share of consumption	Emissions associated with UK consumption		Total GHG, CO_2-equivalent
	N_2O kt	CH_4 kt	%	N_2O kt	CH_4 kt	kt
Dairy	9.95	224	94	10.6	238.3	8614.0
Beef	11	476	60	18.6	793.3	23747.3
Pig	2.3	36	52	4.5	69.2	2924.3
Sheep	7.6	200	87	8.7	229.9	7873.1
Poultry	2	11	87	2.3	12.6	971.3
	32.85	947		44.7	1343.4	44130.1

(CO_2 equivalents based on GWP of 310 for N_2O, 21 for methane – need updating to latest figures of 298 for N_2O and 25 for methane)