Living Witness Project
Quakers working for sustainability

Your contribution to climate change

Note by Laurie Michaelis to explain LWP leaflet, December 2009

This note is intended to accompany the leaflet *Your contribution to climate change*, which can be downloaded from www.livingwitness.org.uk.

The sheet is designed to allow individuals to estimate their personal contribution to climate change without needing access to utility bills or other precise information. The current update is based mainly on 2005 data.

In 2005 the UK had a population of 60.2 million, with 24 million households (on average 2.4 people per household) (National Statistics 2007).

1. Transport

Cars
There were 26.2 million cars registered in the UK in 2005 – 1.1 per household, 0.44 per person. The cars were driven a total of 397.2 billion vehicle-km or 15,000km per car. They used 17.9Mt of petrol and 4.27 Mt of diesel in 2005, emitting about 71 million tonnes of CO_2 – 1200kg per UK resident, 2700kg per car. On average, petrol cars (consuming 8.5 litres/100 km)produce about 180 grams per car-km; diesel cars (consuming 6.5 litres/100km) produce about 10% less at 160g/km.

In addition to this, oil refineries burn about 1 tonne of fuel for every 10 tonnes of transport fuels they produce. Car manufacture and road building also use energy and result in CO_2 emissions (manufacture accounts for 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%). Car exhausts include nitrous oxide which is a greenhouse gas contributing about 10g/km CO_2-equivalent. Hence the total GHG impact of driving a petrol car is likely to be nearer 260 g/km CO_2-equivalent or 416kg for 1000miles (IEA, 1993). This works out to 3500kg for a typical private car travelling 8500 miles per year. For a diesel car the total is about 240g/km.

In the sheet, emissions for cars driven 15,000 and 2,000 miles per year have been estimated on the basis of constant emissions per mile. Emissions in car manufacture and disposal are thus allocated on a constant

Larger and smaller cars
Fuel consumption is quite closely correlated with vehicle mass, and so with energy use and emissions in manufacture, so it should give a reasonable guide to the overall life-cycle emissions for the vehicle.

Fuel consumption of 4x4 vehicles is highly variable, depending on the engine type and power rating but can be as high as 16 litres/100km (e.g. for a 4.2 litre supercharged Range Rover, or a 4.7 litre Toyota Discovery). A 4.4 litre petrol-engined Landrover Discovery 3 produces about 354g/km of CO_2 on standard tests according to the Vehicle Certification Agency, corresponding to 15 litres/100km petrol consumption (VCA, 2007). However, cars in use typically use 10-20% more fuel than in the standard tests. Using air conditioning increases this by up to 20% more.

Some of the smallest, most efficient cars on the market have fuel consumption around 4 litres/100 km – e.g. the Honda Insight at 3.4 litres/100 km. Others include the Toyota Prius and the Peugot 107. CO_2 emissions from these cars are in the region of 100g/km and switching from a typical car saves around 1250 kg/year CO_2.

Alternative fuels

The sheet does 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. Does your trip result in additional services being run? In the case of air travel which has relatively elastic supply, it probably does contribute. For rail in the UK, service provision is near to capacity and additional passengers have very little impact on service provision. For buses, the effect is probably intermediate between air and rail. The question could be explored with an economic model. However, the figures here are based on the allocation of the overall emissions from the train or bus equally among its passengers.

Buses and railways in the UK produced about 10Mt of CO_2 in 2005 (based on DfT, 2006). This includes emissions from electricity generation for railways but it also includes rail freight which probably accounted for about 1.6Mt (estimate based on energy consumption of 1MJ/tonne-km).

Buses and coaches in 2005/6 travelled 3965 million vehicle-km, carrying 48 billion passenger-km. Average occupancy was thus 12.1 passengers. The energy consumption was estimated at 1.18 Mt of fuel which would produce 3.7Mt CO_2 or 77 grams per passenger-km.

Trains (including urban rail and tram systems) carried 52 billion passenger-km producing (my estimate) 5 Mt of CO_2 – an average of 100g/passenger-km.

Emissions per passenger-km depend heavily on occupancy and on the type of train. Older diesel powered intercity trains (High Speed Trains or 125s) in Britain emit about 100g/km per passenger of CO_2 if they are one-third full. The newer Adelante trains emit about 80g/km per passenger. Electric trains are better in CO_2 terms because the electricity generation mix in the UK contains a large proportion of new gas-fired stations and nuclear power. Very roughly emissions are likely to be around 40-50g/km per passenger for intercity trains. Local trains use about half as much energy as intercity trains per seat-km. On crowded, electric commuter routes CO_2 emissions may be as low as 20g/pass-km of CO_2 but energy consumption for the London Underground is higher because of air resistance in the tight-fitting tunnels.

Flying

Boeing 747 and Airbus A340 aircraft use about 50g fuel per passenger-km with airline typical seat occupancy of about 70%. This results in the emission of about 160g CO_2. Newer, more efficient aircraft have lower fuel consumption and emissions – estimated to be about 20% lower for the Boeing 777 (Boeing Website).

Calculating exact fuel use per passenger-km from statistics is complicated because aircraft carry both passengers and freight, and fuel use statistics do not differentiate between the two. A typical assumption for industry calculations is that the weight of a passenger plus baggage plus the associated seats, cabin equipment etc. amounts to about 200kg. So 5 passenger-km use about the same fuel as 1 tonne-km of freight. Applying this to USA aviation statistics shows that air travel energy intensity fell from 2.3 MJ/pass-km in 1995 to 1.73 MJ/pass-km in 2005.

UK statistics are hard to unravel. There are data a) for passenger numbers carried by UK and international flights by UK and other carriers to and from UK airports; b) for passenger-km and freight tonne-km carried by UK airlines; c) for total aviation fuel use in the UK. It is possible to estimate the overall energy intensity of air transport from UK airports based on the assumptions that: UK consumption of fuel for civil aviation equals the energy used for flights from UK airports; UK operators have the same average international flight length as non-UK operators; the freight share of aircraft load is the same for all international flights. On this basis, we can estimate that UK airports account for 253 billion passenger-km and 5.6 billion freight tonne-km. As the freight proportion of load carried is fairly small, the estimate of energy intensity of passenger travel is fairly insensitive to the weight assumed for passengers plus associated equipment etc. 150kg may be a better estimate for modern aircraft and travelling conditions, and gives an energy intensity of 288g of fuel per tonne-km or 43g/pass-km. CO_2 emissions then amount to 135g/pass-km.

Aircraft also emit nitrogen oxides and water vapour (resulting in contrails and cirrus cloud formation) which at high-altitude have a large contribution to global warming. The impact is very uncertain. In the Intergovernmental Panel on Climate Change report on Aviation and the Global Atmosphere, NO_x and linear contrails were each estimated to have an impact of a similar order of magnitude to that of the CO_2 – the impact of cirrus cloud formation was not estimated. More recent studies have found lower impacts for contrails, but have produced estimates of the cirrus impact that are comparable with the CO_2 impact. Hence in the sheet the impact of flying is treated as being about three times that of the CO_2 emissions, or about 405g/km overall.

As airliners fly at about 880km/hour, emissions amount to about 356kg CO_2-equivalent per hour. So a four-hour flight would result in the emission of about 1400kg CO_2-equivalent per passenger.

The UK national greenhouse gas inventory (official report to the UN Framework Convention on Climate Change) gives international aviation CO_2 in 2004 as 33 million tonnes, which is about 6% of UK domestic CO_2 emissions of 560 million tonnes (not including international aviation). Hence the overall UK aviation impact would add about 18% to UK domestic CO_2 emissions. The impact per person is about 1.65 tonnes CO_2 equivalent – but note that this includes air freight and any international bunker fuel used by the military.

Household energy

Household energy consumption in 2005 consisted mostly of oil (3.1 Mtoe), natural gas (32.8 Mtoe) and electricity (10.0 Mtoe) (from DTI, 2006).

1Mtoe (million tonnes of oil equivalent) = 41,868TJ = 11.6 billion kWh

So the average household consumed 1500 kWh as heating oil, 16,000 kWh as gas, and 4800 kWh as electricity. With the inclusion of coal, wood and other energy sources, the total was 22,700 kWh.

Of this energy, roughly 68% is used for heating, 17% for hot water, and 15% for electrical appliances, cooking and lights.

Estimating GHG emissions for your domestic electricity supply can seem quite complicated. Suppliers may either generate their own electricity or purchase it from other generating companies. The mix of coal, gas, nuclear and renewables is a key factor in emissions from the electricity provided.

CO_2 emissions in UK power generation amounted in 2006 to about 525g/kWh (based on DTI, 2007). Fugitive emissions of methane from coal supply add 25g/kWh . Emissions were higher than in previous years as high gas prices led to a shift to coal use in power stations. A more typical figure has been around 500g/kWh and this is used in the sheet. Burning 1kWh of gas produces 180g CO_2; burning 1kWh of oil produces 250g CO_2.

Hence the average UK household causes about 2400-2600kg CO_2 to be emitted in power generation. Burning gas in the home produces 2900kg CO_2. Burning oil produces 375kg CO_2. The total is 5800kg or 5.8t per household or 2400kg per person.

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

In a household using gas as its heating source, total CO_2 from heating amounts to about 2600kg. Turning down the thermostat from 21^{o}C to 20^{o}C reduces heating energy by about 10%. Turning it down to 15-16^{o}C halves the heating energy. Turning it down to 13^{o}C divides it by three, and to 11^{o}C by about five. (based on Building Research Establishment model of building energy use).

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 heating bills are often possible, with reductions in CO_2 emissions of around 800kg.

The government requires electricity suppliers to source a small proportion (5.5% in 2005/6; 6.7% in 2006/7) of electricity from renewables, but this obligation is not being met (the current level is about 4%). Compliance is regulated through Renewable Obligation Certificates (ROCs), which issued for units of power generated from renewables, and can be traded. Electricity suppliers have to hold sufficient ROCs to cover the electricity they sell, or pay what is effectively a fine.

Previous versions of the sheet assumed that switching to "renewable electricity" reduced emissions from electricity generation by at least 90%. Several companies offer green tariffs, supposedly using renewable electricity, but this is only meaningful if buying their electricity results in more renewable generation than would otherwise occur. This would entail holding ROCs for all of the electricity they supply. 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. It does retain 10% in excess of requirements so in 2006/7 it could be considered to supply 16.7% renewable electricity. A detailed discussion of the issues is available on the Quaker Green Action website (www.quiakergreenaction.org).

Installing solar panels might reduce energy use for hot water by one third or 1200kWh, cutting CO_2 emissions by about 300kg per household.

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. Electricity use is broken down roughly as follows:

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

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.

Food

Emissions included in the average UK diet are:

	Mt CO_2-equivalent	kg per capita	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 veg.	1.1	20	Estimated based on FAO food statistics
Total	114.85	1940	

About 840kg of this total is CO_2, the other 1100kg is methane and nitrous oxide.

Allocation of emissions to different diets

Dairy herd emissions allocated to omnivorous and lacto-vegetarian diets as specified in sheet. 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.

Details of calculations

The following tables detail background calculations.

CO_2 emissions in fertiliser manufacture.

	UK consum-ption	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)

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. I have not yet found good figures for typical European organic systems.

I have 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, I have used the IPCC standard time horizon of 100 years, 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. I spoke to the soil nutrient specialist at HDRA 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.

Waste

Landfill sites account for 25% of UK emissions of methane at 9660kt CO_2-equivalent (NAEI, 2005). CO_2 emissions from incineration are around 486kt. British households produce on average 1200kg/year per household of waste of which 176kg is recycled or composted (DEFRA, 2005b). 60-70% of household waste is organic matter including around 25% paper and card, and 30% putrescent material. Much of the paper and card decomposes very slowly in landfill sites, but the putrescent material decomposes rapidly and generates methane. On the basis of these data, households contribute about 9 million tonnes of food waste to landfill. DEFRA statistics show that the industrial and commercial sectors disposed of at least 630,000 tonnes of food waste (although there may be a further 1 million tonnes hidden in "general commercial" waste). 100,000 tonnes of sewage sludge also went to landfill in 1998. If it is assumed that at least 75% of the methane emissions are due to putrescent material in household waste, the average household would account for about 300kg of CO_2-equivalent emissions/year.

For most materials the main emissions are associated with production rather than waste disposal. In the leaflet emissions are calculated from waste but they could have been based on materials coming in to the home. The following table summarises emissions for various materials.

		For comparison		
Material	**GHG kg/year for each waste kg/week**	**UK typical kg per week**	**UK typical score**	**Reduction if recycled**
Paper & cardboard	**26**	5	130	**25%**
Plastic incl. film	**260**	1.7	440	**75%**
Metals	**240**	1	240	**50%**
Glass	**18**	2.5	45	**25%**
Textiles	**26**	0.6	15	**25%**
Kitchen & garden waste	**40**	7.6	300	**100% if composted**
Sanitary waste (eg nappies)	**30**	0.5	15	**n.a.**
DIY & other waste	**52**	4.3	220	**n.a.**
		23.2	1405	

Emission reductions for composting and recycling are calculated from these figures.

These data are based on household waste collections. Waste collected in skips is not included. If a typical skip contains about 5 cubic metres of waste at a density of 200kg/cubic metres – i.e. a total of one tonne – it will account for about 1000kg CO_2-equivalent.

Building your house is a major user of energy and materials, but it is hard to find good data. One widely quoted estimate is that it takes 90,000kWh of energy to build the average house, including manufacturing materials. House building also involves using cement and cement-making produces CO_2 (in the conversion of limestone or $CaCO_3$ to lime or CaO). The overall estimate here of 50,000kg CO_2 for a family house is very crude. Spreading that figure over 50 years is also a very crude way of allocating the emissions to successive inhabitants.

Everything else

The UK national GHG inventory for 2004 reports total domestic CO_2 emissions of 560.4Mt 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 2.47Mt (62 Mt CO_2-equivalent) of methane (mostly from fuel use, agriculture and waste) and 132kt of N_2O (39 Mt CO_2-equivalent) (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. The total is 771.4 Mt CO_2-equivalent.

The inventory does not allow GHGs "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_2 embodied in trade has grown rapidly in recent years to reach about 20% of UK domestic emissions or 112Mt in 2004. The total UK GHG footprint therefore amounts to about 883 Mt CO_2 equivalent or 14,400 kg/person CO_2-equivalent emissions.

In the footprint sheet, 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. However the 'everything else' and 'public sector', sections of the sheet need to make up the total figure to the UK average.

The emissions in the sections on transport, home energy, food, materials and waste account for nearly 7 tonnes per person of CO_2 – about 60% of the UK total – and the vast majority of the nitrous oxide, methane and aviation emissions (about 2.8 tonnes per person).

Remaining emissions amount to roughly 4.8 tonnes per person of CO_2-equivalent gases from sources including the supply chains for goods such as clothes, furniture and consumer electronics, the commercial/services sector, government offices, schools, hospitals, the military, etc.

The last section of the sheet seeks to allocate these emissions rather crudely based on consumption spending. Governments and non-profit organisations accounted for consumption nationally amounting to about £5,000 per capita in 2005 (National Statistics, 2006). Households spent directly about £12,600 per capita *on consumption* (i.e. excluding savings). Of this household consumption, the detailed sections of the sheet account for about 60%. Other items such as clothing, furniture, electrical appliances and entertainment account for about £5,000.

The sheet therefore takes roughly half of the remaining 4800kg of emissions to be allocated according to our personal expenditure relative to £5,000 per year or about £400 per month – i.e. 2400 x (monthly spending in £) / 400 = 6 x (monthly spending in £).

The rest is determined by government and non-profit organisation spending. 2400kg per person are not under our control except through voting and political action.

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