Carbon footprints of low income households; does addressing fuel poverty conflict with carbon saving?

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Abstract

Carbon footprinting has become a popular way of communicating climate change issues and the need to change behaviour. The UK government has developed an on-line system called Act On CO_2, whereby people can input their fuel usage, house and appliance characteristics and travel activity, to produce a carbon footprint partitioned into household, appliance and travel use.

A study of thirty households in the eastern region of the UK sought to establish the carbon footprint of people in lower income brackets, who had received energy efficiency measures under local authority funding schemes, using the Act On CO_2 system. The aim was to provide information on whether local authority funding for low income housing supports their aim to reduce carbon emissions, or whether rebound effects mean that their efforts are negated. This is important in the argument for maintaining fuel poverty programmes compared with programmes directed to the better off.

The paper presents the footprints of the thirty households and considers whether they are significantly different from other interested parties. It considers lifestyle changes using case studies of five households and compares what is included in currently circulating carbon footprints.

It concludes that programmes for low income families are probably as effective in reducing carbon footprint as for any other social group and that cost savings to the household have been eroded by rising costs of fuel and other necessities including water and food. Furthermore, reducing the carbon emissions for households in fuel poverty through energy efficiency schemes is unlikely to lead to indirect rebound effects.

Introduction

This paper considers the effect of having different policies relating to energy efficiency, fuel poverty and climate change mitigation all being delivered through the same or similar schemes. For those developing these programmes at the local level, there is uncertainty as to whether focus on one will also bring benefits in another, or whether they will conflict. The paper introduces the range of policies and their recent developments, then provides an overview of previous research on rebound effects especially in low income or fuel poor households. An overview of carbon footprinting and the reasons for choosing the Act On CO_2 calculator are presented in the next section. This is followed by a description of the project, the survey and interviews, which leads into the results and their significance for programmes at local level, and the rebound effects particularly referencing the case studies. The final part of the paper discusses the use of carbon footprinting and concludes with a summary of the findings. The aim of the paper is to communicate some of the issues surrounding carbon footprinting as a policy tool and to determine whether the specific programmes to alleviate fuel poverty conflict with carbon saving programmes.

BACKGROUND

Climate change has become the major driver of energy efficiency policies in the UK. Legislation has been introduced to require, among other things, a carbon budget to be set in stages to 2050. Policies in place since the 1990s have been reviewed; the Home Energy Conservation Act was repealed in

England so that local authorities no longer have a target for energy conservation in domestic properties. Instead, National Indicators have been developed to promote good performance in a wide range of local issues, three of which relate to energy efficiency – No 185 relates to targets for carbon emissions from public buildings, 186 to carbon emissions from households in the area, and 187 to the reduction of fuel poverty (Defra, 2008a). Household emissions reductions have become a community issue, generating projects and programmes from a wide range of independent organisations. Many projects are supported by government funds such as the Low Carbon Buildings Programme. The energy suppliers obligation, the Energy Efficiency Commitment that measured savings in tWh ended in March 2008. It was replaced by the Carbon Emissions Reduction Target (CERT), which runs from April 2008 to March 2011, measuring savings in tCO_2 (lifetime) as well as tCO_2/year. Although carbon emissions were the new focus the UK's concern for fuel poverty was not entirely forgotten; energy suppliers still have to apply 40% of their carbon emissions reduction effort to people in the 'Priority Group', defined as people receiving certain benefits and those over 70 years of age. This benefits group had been used as a proxy for people in fuel poverty for some years, in spite of concern that this may address as few as 20% of those actually in fuel poverty (Sefton 2004). Despite the effort to eliminate fuel poverty under a range of programmes since 1997, the effects of energy price rises had halted the reduction of the number of fuel poor, with Government departments estimating that for every 1% rise in energy prices, 40,000 more people would be brought into fuel poverty in England alone. With energy prices rising by 20% and more each time a supplier made an announcement, the estimated number in fuel poverty in England had risen to 3.9 million by the middle of 2008 (NEA, 2008).

National programmes for carbon emissions reduction and reducing fuel poverty are highly reliant on local authority officers for delivery, especially to lower income households. WarmFront is a scheme funded by national government that provides standard measures (loft insulation, cavity wall insulation, gas condensing boilers and draught-proofing) to households in England that qualify by means of receipt of certain income benefits. Although WarmFront is marketed directly, it relies heavily on local authorities to receive referrals to the scheme. Energy suppliers market their CERT schemes directly and through retailers, but schemes run in conjunction with local authorities, especially for more costly measures such as lower carbon emissions heating systems and insulation, are often the best way of reaching householders. In many instances, householders lack trust in anything relating to household improvements that is not supported by the local authority (Dodd & Dobson, 2008).

There is pressure on local authority officers to develop programmes that maximise the amount of carbon emissions that can be saved for every pound of public money invested. However, due to their statutory powers on social well-being, authorities still need to address fuel poverty. Some concerns arose about a conflict of interest between the two types of programmes, mainly on the magnitude of rebound effects. Councillors (elected representatives) were cited by officers as saying things like "if we make the fuel poor able to heat their homes more cheaply, they'll go out and spend the money on flights to Ibiza, or other high carbon things". With information provided on rebound effects of fuel poverty programmes (using modelled data) but little available on actual expenditure patterns, officers felt unsupported in their efforts to maintain their fuel poverty programmes.

The question arose as to what the carbon footprint of these people was, before and after fuel poverty programmes. Interest in carbon footprinting has grown, especially since the launch of the Government's Act On CO_2 calculator, part of the strategy for communicating climate change and carbon emissions reduction. A range of carbon footprint calculators is available on the internet as discussed later in this paper. In response research was carried out into the carbon footprints of a small group of households in the East of England who were considered (by policy definition) to be eligible for fuel poverty measures. The research aimed to establish the typical carbon footprints of this group compared with the general public and to consider whether rebound effects did mean that fuel poverty programmes conflicted with carbon emissions reduction programmes. It also explored other issues of concern: internal temperatures and comfort, what to include in carbon footprints, whether personal carbon allowances would be acceptable. The results of this research are the subject of this paper.

Rebound effects

Evaluation of rebound effects have in the main been carried out on a macro-economic basis, i.e. to evaluate or illustrate the 'true' cost to the economy of efficiency programmes. Rebound effects were described as early as 1864: the more efficiently a machine uses energy, the more people use it, and therefore the total energy used increases (Jevons, 1998).

Rebound effects can be classified in two main types: direct and indirect. Direct effects are those whereby the increased affordability of an option enable the user to use more at the same price. Indirect effects switch the purchasing power away from the original item (fuel) into something else, which may consume fuel, or may use other resources (Berkhout et al, 2000).

Assessment of carbon savings from insulation measures for the design of the CERT scheme has embedded a 15% comfort factor for all insulation measures based on analysis of insulation performance in the home (Defra, 2008b). Sorrell argues that rebound effects are notoriously hard to estimate, are hotly disputed, and are likely to be less than 30% of the claimed energy efficiency savings for household heating, cooling and personal transport (Sorrell, 2007). However it is acknowledged that there are gaps in the assessment, an important one of which is the relationship between household income levels and rebound effects. This can be emphasised when looking at the actual cost savings generated by consumer products, in their study Chalkley et al (2001) calculated that an efficient gas condensing boiler would save a household £/Euro 703 over its lifetime, taken to be ten years. At higher prices currently experienced, this amount could be double, but an additional £70 per year, or £1.40 a week makes a difference to someone on a low income (£180 a week is the expected minimum income) especially after paying housing costs and taxes, but is easily absorbed into general spending of a more affluent consumer.

One of the few empirical studies that measured household fuel use before and after installation of energy efficiency meas-

ures was carried out in Canada in 2000-2 (Parker et al, 2005). The results gave rise to a classification of three household types, conservers, consumers and the middle, steady type. However, looking at characteristics of these groups, they found that conservers were typically lower income with higher initial bills, consumers (who used much more fuel) generally were higher income groups and had already invested to have more efficient homes in the first place. However they also emphasised the need for local support, and recognised one flaw in their methodology that they did not measure electricity use, which may have influenced the result for 'consumers' as many changed their water heating from electricity to gas.

The problem is that little is known about what people who receive measures to reduce their fuel costs under a fuel poverty scheme do with the money they save, if any. The assumptions are:

1. They take the benefit in higher standards of warmth throughout the house, i.e. the programme may allow them the standard of comfort defined by the WHO, that is 21˚C in the living room and 18˚C in other habitable rooms in the house. Calculations of the benefits of UK government programmes assume that they are heating their home to this new standard. They may have a cash surplus, or this may be illusory, i.e. they only spend as much as they can afford anyway.
2. They take this benefit too far i.e. they heat it to a warmer standard than the WHO one. The new cost of fuel allows them to do this within the same level of expenditure as before.
3. They heat their home to a lower, but comfortable temperature (possibly the same temperature as before) and have a cash surplus.
4. They spend the cash surplus on other things that have been carefully budgeted before, including food, clothes, and minor luxuries (small scale entertainment, leisure activities and children's or grandchildren's treats).
5. They spend the cash surplus on major consumer items that they would not have been able to afford before. The most (cynically) cited examples are foreign holidays and plasma TVs.

It is this last assumption that is the most damaging one from the point of view of resource expenditure on fuel poverty programmes. If people who were spending more than 10% of their income of energy costs are now spending less, what will they do with that money? Would they spend more on products and services that have a high level of associated carbon emissions? How would this be measured? One method of measuring the household impact on the environment from heating and other fuel use is carbon footprinting.

Carbon footprinting

Carbon footprinting is a way of measuring the amount of carbon emissions from a household or a person and can be applied in many contexts. In this paper we are concerned with household footprint, which may include direct emissions from all fuel use in the home including private vehicle use, but may also consider secondary emissions from public transport, waste, water and food.

Current carbon footprinting methodologies vary from simplistic to complex, and tend to make different assumptions about the carbon content of (or emissions from) product and services, how to measure them and where to set the boundaries in terms of lifecycle analysis.

The simplest way to determine a carbon footprint is to take direct fuel use for heating and other household use, plus motoring use, and to calculate the carbon emissions based on the carbon content/intensity. This is the basis of the Government's Act On CO_2 calculator[1]. To make the web tool user-friendly, various short-cuts and proxies have been introduced, such as the facility to make a simple calculation of the expected emissions (if a person using the online tool does not have their fuel bills handy) using standard modelling tools embedded in the system. The report on their footprint (i.e. number of tonnes of CO_2 emitted) is compared with the UK average, and the user is given a target (a 10% reduction on their existing footprint) to encourage reduction. The database engine is open to use by different actors through the organisation AMEE[2], with the carbon emissions factors gathered together in one authoritative source, that can be centrally updated as knowledge improves.

The RSA carbon footprint project Carbon Limited[3] was originally independent, but is now linked to AMEE, and aims to test the concept of domestic tradable quotas (DTQs) through a 'virtual' trading system. Google adopted the same calculator. Erase my Footprint[4] uses a trimmed down version of the calculator and offers to offset emissions through verified schemes. GO East, the government office for the East of England, has launched a community footprint calculator. The Penrhos Permaculture holding[5] have a very personal approach to their carbon footprint in which they compare the results from different tools, but also factor in disposal of items like batteries, launderette use and so on. Carbon Footprint Ltd[6] have a more detailed approach to secondary emissions by asking about attitudes to recycling, packaging, etc. to estimate secondary impacts.

An important feature of these tools, especially in the context of local authority carbon reduction, is that they are 'bottom-up', i.e. they take details of energy use and calculate it for the household/individual. Government statistics, including the average UK footprint against which it compares individuals in the Act On CO_2 tool, are top-down, taking the estimated carbon emissions from UK households, based on end-use fuel figures and dividing them by the number of households/population. This includes emissions from industry, commerce, and transport excluding air travel. The same approach is taken to allocate regional and local emissions. This creates problems of apportionment when considering top-down versus bottom-up. Just one question to be answered is how should public transport

1. http://actonco2.direct.gov.uk/index.html
2. AMEE – Avoiding Mass Extinction Engine, now with the tagline 'The World's Energy Meter'. http://blog.co2.dgen.net/
3. http://www.rsacarbonlimited.org/
4. http://erasemyfootprint.com/
5. http://www.konsk.co.uk/design/energy2.html
6. http://www.carbonfootprint.com/calculator.aspx

emissions be apportioned? What about other services, including those investigated under a wider ecological footprint?

For local policy decision making carbon footprinting provides a useful tool that is relatively easily communicated. And if one wishes to reduce a carbon footprint, it makes sense, to address those people with large footprints, where efficiencies are likely to produce larger results. Do fuel poor households have large carbon footprints? Or is this limited to the more affluent in society?

Research on carbon footprints of people in fuel poverty

Just as Parker et al (op.cit.) described, the greatest reductions in emissions are likely to come from those with most to save. However what Parker et al found is that those with most to save are often not in the highest income brackets. Ekins & Dresner (2004) also pointed out that some 30% of those in fuel poverty have very high energy bills, and potentially could be badly hit by carbon taxes. Modelling the impact of personal carbon allowances on low income households (Roberts, 2008) found that carbon footprint increases slightly with income until the highest income levels, when there is a rapid increase. However, in the lowest income brackets, the variation in carbon footprints is very wide, due in part to the variation in quality of the housing, i.e. its energy performance. So there is a more complex issue for local authority officers to consider when they are negotiating resources for their core energy efficiency programmes. Fuel Poverty is a social issue as much as an environmental issue, and some of those in fuel poverty may have high carbon footprints which can be reduced through either programme, provided that capital (investment) costs can be supported in a programme addressed to the 'fuel rich'. What is not clear, because it does not appear in published research so far, is whether people who have received measures under a fuel poverty programme have a smaller carbon footprint than other households, and whether rebound effects lead to spending on other high carbon goods and services. Does addressing fuel poverty negate efforts to reduce the local carbon footprint?

This question was addressed by the project Fuel Poverty Carbon Footprint, funded by the Eaga Partnership Charitable Trust and undertaken in 2008. The hypotheses are twofold: that people who have received measures under a fuel poverty programme have lower carbon footprints than the general public, and that receipt of measures under a fuel poverty programme does not lead to direct rebound effects of the switching kind to any marked effect. The size of the subject group being interviewed in this survey is too low to prove the hypotheses, the results provide an indication of whether further study is warranted.

CARBON EMISSIONS AND FUEL POVERTY IN THE EAST OF ENGLAND

The counties of eastern England (the East of England Government region) provide a contrast of wealth and poverty. Largely rural in nature, there are pockets of industry such as the Cambridge computer and research area, areas of former wealth hit by change in methods and fashion such as the ports of Kings Lynn and Great Yarmouth, areas of development such as southern Essex, and an area of almost obscene wealth coupled with rural poverty centred on the racehorse capital of the world at Newmarket. It provides a substantial hinterland for commuting to London, and also holiday areas for both rich and poor. Transport connections are not highly rated except in the Cambridge – London corridor; the only motorway in the area links Cambridge, Stansted airport and London, and there are only a few dual carriageways, mainly linking ports such as Felixstowe and Harwich to London and the industrial Midlands.

In the more rural parts the majority of housing is relatively old, especially in the northern parts of the region, and when the gas pipelines were installed in the nineteenth century, only the major cities and the routes to them were connected, leaving the region the second lowest in terms of houses connected to mains gas in England. The carbon footprint of the region is third highest (of twelve regions), at 22.7 $MtCO_2$ per year (EST, 2007). In 2006 there were 2.3 million households in the region, 9.2% of whom were in fuel poverty (BERR, 2008). By the middle of 2008, the number was estimated to have risen to 17.2% due to change in prices of electricity and heating fuels (NEA op.cit).

PROJECT METHODOLOGY

Local authorities in the East of England were invited to participate if they had undertaken an Affordable Warmth programme (providing measures for energy efficiency in homes where there was risk of fuel poverty) in the previous three years. Five authorities contacted a total of 156 participants in those programmes explaining the research and asking them if they were willing to take part. 42 were willing to be contacted, and 31 interviews carried out. It is not known how representative the group were of those contacted although the general profile is thought to be typical of those receiving measures under other such schemes in non-urban areas. Failed interviews were mainly due to changes in circumstances, clashes of appointments, illness, and three were out when visited of which only 1 was successfully rearranged.

Interviews took place in the participants' homes in the period February to May 2008. After the introduction and gathering of household composition for classification purposes, the Act On CO_2 questions were administered. As internet access was not anticipated during the visits, a copy of the engine had previously been devised and tested to run on an excel spreadsheet. This ensured that the interviewees could be given instant feedback about their footprint and any questions they had about it answered. At the time the interview was arranged the householder was asked to take meter readings from their gas or electricity meters, or to look for their oil or solid fuel bills in order to get real data to use in the footprint calculator. Second readings were made at the time of the interview to calculate how much had been used. This enabled a reasonably accurate picture of fuel use to be input to the calculator. The carbon footprint was explained, and compared with the local and national footprints. Some high footprints were explored further and possible reasons discussed and the interviewees referred to the Energy Advice providers where appropriate.

Following the use of the calculator, the subjects were asked how their fuel bills compare now to before the measures were installed. This was complicated by recent fuel price rises and the use of direct debits which may or may not have been adjusted by the energy supplier. A range of typical statements about comfort, easing of finances and health were asked using a standardised questionnaire, following which the subjects'

Table 1: Characteristics of households interviewed

Age group	***25–34***	***35–44***	***45–54***	***55–64***	***65–74***	***75+***
Number	1	4	2	2	12	10
Income decile	***A***	***B***	***C***	***D***	***E***	***Prefer not say***
Number	11	7	3	6	3	1
Number in Household	***1***	***2***	***3***	***4***	***5***	
Number	10	14	5	1	1	
Occupation (head)	***Retired***	***Full-time employed***	***Part-time employed***	***Long-term sick/disabled***	***Self-employed***	
Number	21	2	5	2	1	
Children	***Households with children***	***Child age***	***3–***	***4–11***	***12–18***	
Number	8		1	4	8	(n=31)

income range and age range were established. Income was established in deciles: a decile represents the ten ranges into which the incomes of the UK's households can be divided on an equal basis i.e. 10% of households are in each range. The lowest range (A) represents an annual income range of up to £9,393 in 2007. The highest range in this survey (E) represents £17,230 to £20,002. Following the interview, the household data for the carbon footprint was cross checked with the online Act On CO_2 calculator and a report produced and sent to the interviewee with thanks and information on who to contact for further help on any issues raised in the interview.

A control group was established through working with the providers of the Act On CO_2 engine, AMEE. The project manager for Herefordshire produced a control group of 325 people who had used a similar survey on the council's website. Both research group and control group could be criticised for being self-select surveys and therefore likely to be biased.

CHARACTERISTICS OF THE SURVEY GROUP

There were thirty-one subjects from five local authorities. The majority (22) were retired, and those with families were spread across age groups. Table 1 shows the main characteristics of the survey group.

The most common house type was detached bungalow (single storey house) – 10 households. 8 were semi-detached houses, 5 mid-terrace houses, 3 detached houses, 2 semi-detached bungalows, 2 end-terrace houses and 1 maisonette (upstairs flat). All but five homes were on the gas network when interviewed; of the oil-fired homes, 2 were 2 bedroom bungalows, 1 a 3-bedroom bungalow, and the other 2 were three bedroom semi-detached. Four dwellings were solid wall – 9 inch brick, and one was traditional timber frame with weatherboard. One of the solid walls dwellings was also off the gas network. These types of houses do not take the standard measures offered by government programmes. The measures installed tended to be all those available to the property where not already fitted, e.g. cavity wall and loft insulation, gas or oil condensing boilers (some with full central heating).

Whether the occupants had experienced reduction in fuel bills was masked to a great extent by the fuel price rises over the previous twelve months, some suppliers having increased prices twice in that period. Nevertheless, reductions in prices had been noticed by 14 in response to the question "Have you noticed any change in your fuel bills since the work was done" with a further 3 saying down then up after recent price rises. It was decided to explore this question further when analysing the data when the effects of price rises could be applied to the data obtained in the interviews.

This question was followed by a list of possible changes to their lifestyle since the work was done. The list was drawn up from typical statements made in previous surveys and suggestions from the Steering Group. The responses are shown in Table 2. The responses about 'feeling better' and 'not so worried about bills' as well as 'easier to keep warm' are important feedback about the success of the programmes. One person preferred not to give answers on these ancillary questions, only to those directly related to the carbon footprint.

The survey sample is biased towards white, lower middle class households of pension age. It is true that ethnic minorities and urban households are under-represented in this survey, as a result of the focus on the east of England, and in particular on some of the more rural counties. The survey appears to represent these areas reasonably well; it may not be directly transferable across all regions, especially not to highly urbanised areas. There is a range of those managing easily on their pensions and those experiencing hardship and even privation.

CARBON FOOTPRINTS OF THE SURVEY GROUP

The range of carbon footprints, based on the Act On CO_2 calculator and showing emissions due to household, appliance and car and air transport, are shown in Figure 1. Most of these are below the UK average of 10.2 tonnes CO_2, shown by the dotted line, and they are also mostly below their respective LA averages. The range is from 1.14 to 16.64, mean 6.12, median 5.75 all tonnes CO_2 per year. The codes used are prefixed with a local authority indicator.

It is noticeable that the chart shows an extremely low carbon footprint on the left and a very high one, by these standards, on the right. KL03 on the left is a single person, retired, living in a small modern terraced house, who believes in low resource use and keeping fit. He has a low emissions car, runs and cycles. He saves on hot water costs (and water charges) as he swims three times a week, so showers at the local pool. By contrast, BD03 on the right lives with his extended family in a large house with good public transport which he uses, as he doesn't drive for health reasons. He likes a warm house, and generally uses electric fires for warmth in specific rooms late at night rather than using the central heating. He has a plasma TV which is

Table 2: Lifestyle statements

Statement (n=30)	Agree	Disagree
It's been easier to keep warm	24	
The temperature indoors has been quite variable	4	5
It's been difficult to keep a comfortable temperature	3	13
I've been able to afford things like food and clothing more easily	8	3
I've bought some thing(s) I've been saving up for	3	2
I've been feeling better in myself	11	
I've treated myself/my family to some thing(s)	8	1
I've not been so worried about bills	16	
I've been more worried about bills	3	4
There are some problems relating to the work which haven't been fixed	5	6
I've been getting out and about more	4	2
I'm planning to do something I wouldn't have done before	2	1

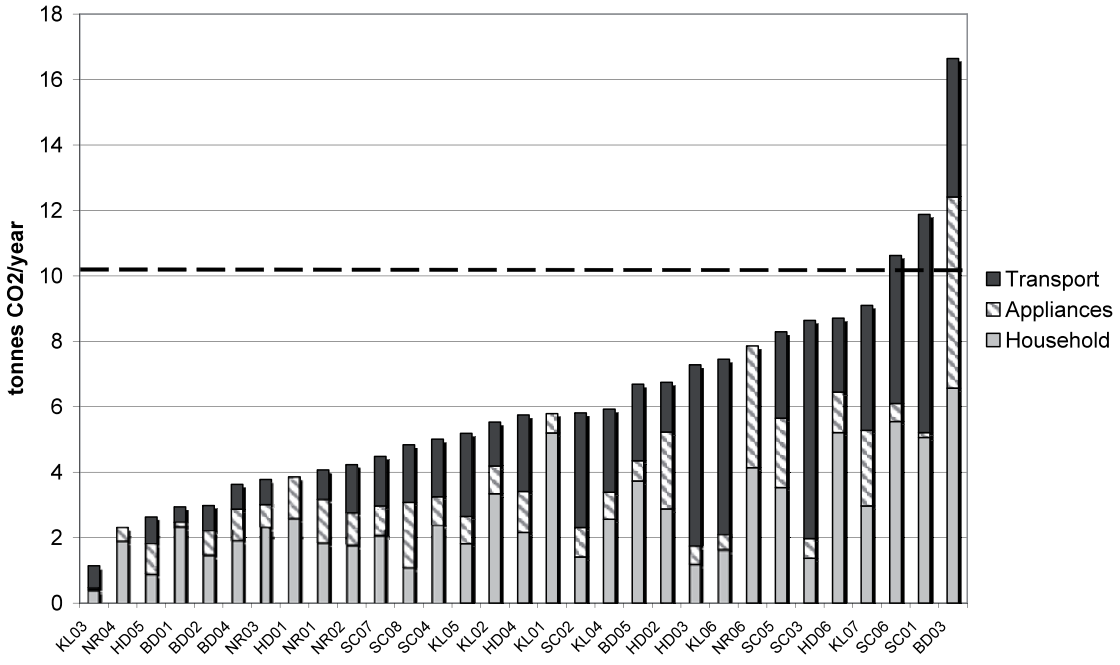

Figure 1: Carbon footprints, low to high

often left on stand-by, contributing to the very high heating and appliance footprint, which is topped off by a high travel footprint as he and his wife take long-haul flights twice a year to visit relatives.

The carbon footprints of this group were compared with their local area averages, shown in Figure 2, and with a control group. The footprints are grouped by local authority and with the averages drawn from the Green Barometer report (EST, op.cit.). This shows the variation in the averages for the areas with Norwich City (NR0x, second group in black), at 6.8, very much lower than the others, which are closer to the UK average. It could be speculated that the compact nature of the urban area and the availability of public transport might be factors in this. The chart also demonstrates the range of footprints within the group in each area. In a large sample some trends might be discernable but not within this survey. The footprints generally fall below the local authority averages, with exceptions and outliers.

Using the population of 156 letters sent out with a sample size of 31 yields a 15.8% confidence interval at the 95% confidence level, i.e. 95% confidence that the mean lies between 5.15 and 7.09. Taking as a proxy the number of vulnerable households improved under EEC2 as the population (approx 4 million in the Priority Group), the confidence interval rises to 17.6% at the 95% confidence level. The mean carbon footprint would be expected to lie within 5.04 and 7.20. The distribution of the footprints from this survey is shown in Figure 3, with the confidence interval indicated in grey.

The control group from the Herefordshire project which is a similarly mixed rural/market town/ small city region, was part of a climate change project. Both samples are biased in that both have an element of self-selection, i.e. people chose to take part. The mean and median of the survey group was lower than the control group, but the calculation of Student's t-test comparing the two groups indicated that the survey sample was not significantly different from the Herefordshire control

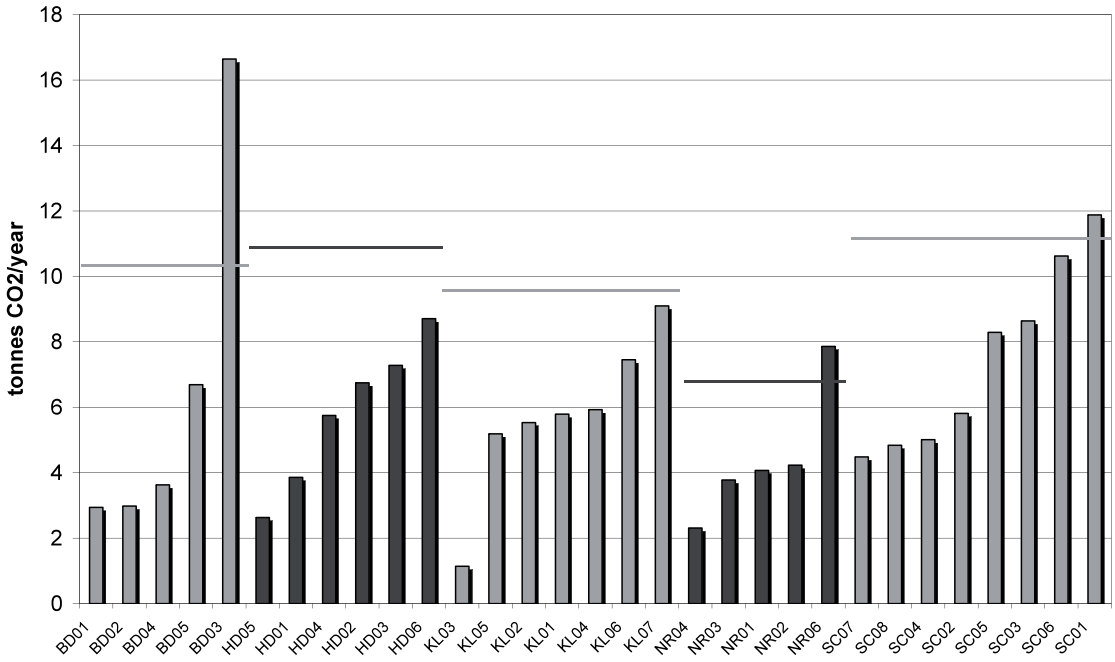

Figure 2: Footprints by local authority, with average lines

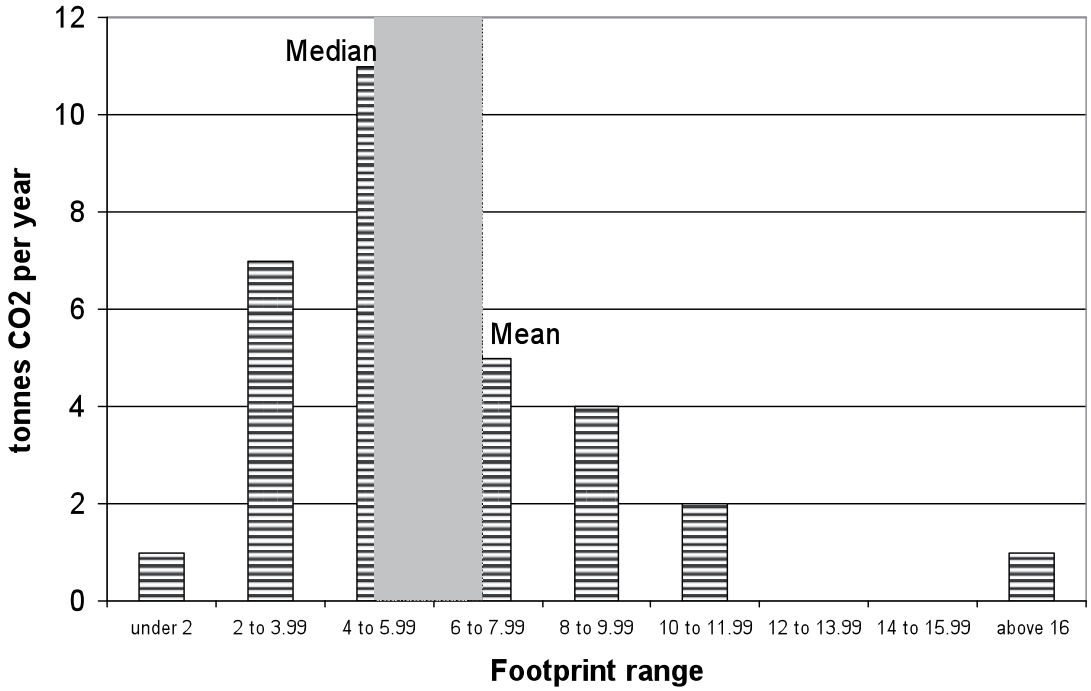

Figure 3: Distribution of carbon footprints in the survey

group. Nothing is known about this control group other than they opted in to the online survey. However, it shows that the range of footprints found in this small survey is not particularly different from a much wider sample across a broader range of incomes and household types.

Because the number of interviews is small it is important not to place too much emphasis on the trends encountered in the analysis. The main findings were:

- no significant difference between urban and rural footprints of households surveyed, although rural footprints, especially in transport, tend to be larger
- a slight tendency for lower footprints after pension age, especially in reduced transport footprint, but small numbers make this unreliable
- a suggestion of increased footprint with increasing income, although the results in the lowest income decile supports the modelling on footprints distribution by income (Rob-

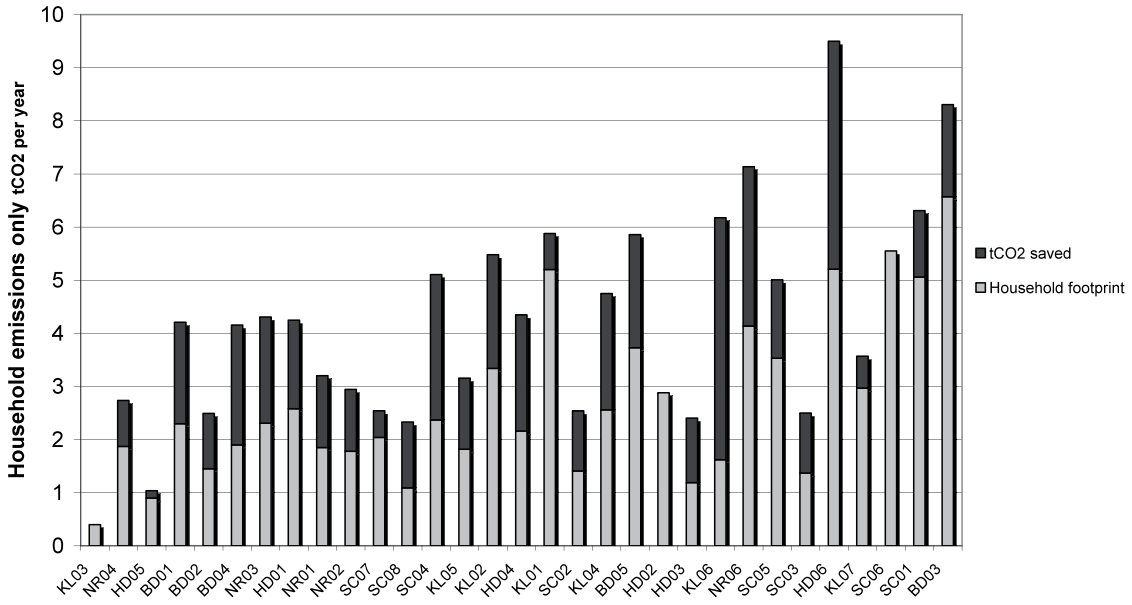

Figure 4: Household carbon footprint before and after measures

erts, op.cit.) of a wide range of footprints at the lowest decile linked to poor housing. This particularly seems the case after pension age but may be due to the greater number of people in that age range in this survey.

- the footprint by the number in the household supports earlier research such as the DECADE reports (Boardman et al, 1997). The survey suggests that more people in the household leads to higher energy use and therefore an increase in footprint. However, looking at the footprint per capita, it emphasises generally that single person households have a higher per capita footprint.
- some general theories could be drawn from the type of house occupied, such as people in bungalows have lower footprints, or that 3 or 4 bedroom houses tend to lead to higher footprints unless they are mid terrace, but in these cases it is difficult to distinguish between the inherent energy efficiency characteristics of the buildings, and the lifestyles of those who occupy them, or who choose to occupy them because of their lifestyles (older people retiring to bungalows).

This research may not have been sufficiently wide ranging to draw conclusions about actual footprints, however the change in carbon footprint, and the potential switch of emissions between heating and other lifestyle changes is sufficiently reliable to examine further.

CHANGE IN CARBON FOOTPRINTS

The degree to which carbon emissions (and thus carbon footprint due to household use) have been reduced has been deduced from modelled data where the 'before' data were not available, using the ACE Fuel Prophet tool (ACE 2006). The fuel saving from each household has been allocated to gas, electricity, oil or solid fuel, depending on the main heating system in use before and the measures applied. This has then been allocated a carbon saving in $tCO_2\ yr^{-1}$ based on the figures used for the CERT programme 2008-2011 (Defra, 2008b). The resulting savings in carbon emissions (modelled or actual) are shown in Figure 4. They have been added to the carbon emissions from household energy use from the carbon footprint, to give a total *household* carbon footprint 'before'. This gives an indication of the degree to which the measures installed under an Affordable Warmth programme have contributed to a (hypothetical) carbon emissions reduction programme. This figure is in the same order as overall footprint and shows quite a contrast without the emissions due to appliance use and transport.

The average household footprint 'after' measures was 2.68 $tCO_2\ yr^{-1}$, and that 'before' was 4.39, giving an average reduction of 1.71 $tCO_2\ yr^{-1}$, or 39% (of household emissions only). Taking account of the overall carbon footprint, the reduction is 22% (1.71 on an average 7.83 before measures).

Three households are not shown as having a reduction. SC06 is discussed in case study C; overall fuel cost is up, and the net carbon dioxide emissions are about the same. KL03 uses so little fuel as part of his lifestyle that it is impossible to estimate the extent of reduction without his previous figures. HD02 has an anomalous winter reading not explained by his lifestyle and heating regime.

IMPLICATIONS FOR LOCAL PROGRAMMES

By this calculation the investment of the five local authorities in these 31 households has given a carbon emissions reduction of 47.9 tCO_2 each year. The measures installed in these dwellings can be compared with the standard costs and savings assumed for similar properties and the same measures under the CERT scheme. Note that the CERT figures assume that low income households have a higher level of comfort taking than standard, so the carbon savings assumed are lower. But the calculations using the survey data estimate CO_2 savings for actual use in lower income groups are *similar to or greater than* the calculated savings for standard groups under CERT. This suggests that, provided the costs to the local authority are not significantly more than assumed in CERT, the value of delivering these types of measures to households at risk of fuel poverty (in terms of

fuel costs or carbon emissions) is *the same or better* than delivering them to supposedly 'fuel-rich' households.

It follows that if the local authority is focusing on carbon reduction programmes it is no disadvantage to focus on fuel poor households as the same or better carbon savings are likely to accrue. Whether it is more expensive to deliver the measures depends on how poor is the quality of the house (and therefore the measures needed) in the first place. This is a major issue – the cost of the measures for low quality households. However it also supports Sefton's view (op.cit) that instead of fuel poverty programmes being addressed to households on benefits they should be directed to poorer quality housing regardless of income.

The question was whether indirect rebound effects in lower income families offset the carbon emissions gains. The suggestion from the dialogue surrounding the benefits of the measures, as outlined in Table 2, is that comfort-taking aside, there has been no change in what the subjects do with their lifestyles, although they may feel a lot more comfortable about doing it. The case studies in the next section will elaborate on lifestyle issues in more detail.

Case studies

Five case studies were selected from the survey group. The aim was to gain more understanding of the implications of affordable warmth programmes in the context of local authority carbon reduction targets, and to understand the impacts on different types of households, especially those who are classed as vulnerable. The case study approach also considered other aspects of carbon footprinting – namely from water, waste and food, which are sources of carbon emissions not included in the Act On CO_2 calculator. The case study participants were asked to keep records of their food purchase and waste arisings for their month, and either their monthly meter reading for water, if on a meter, or a water usage diary.

The case studies were:

- Mrs A, an 80-year old widow living in a rented three bedroom mid-terrace house in Norwich City. Since the work has been done it has been much easier to keep warm and lovely to come into a warm hall on a cold day, instead of into a cold house and then turn on a gas fire. She has not been so worried about bills since the work was done, partly as she fixed her prices with her supplier till 2010, and now pays two-thirds of what she did before. She has also treated herself to some things including a warm winter jacket she got in the sales and has been getting out and about more. She saves money on cooking fuel by making major use of her combination microwave & conventional oven, which is more energy efficient than her old stove. Mrs A has a modest requirement for food and chooses fresh fish and occasional small cuts of meat rather than processed food. Mrs A doesn't travel very far these days, mostly into the city approximately once a week (by bus), and a treat might be going out to lunch at a garden centre on the outskirts of the city. She was treated to a trip to India last year, but doesn't expect to do anything like that again.
- Rebound effects: as the whole house is now warmer there is an element of comfort taking, but the temperature is also now likely to meet the guidelines.
- Ms B, a lady in the 35-44 age group with three children, one is 'special needs' and the youngest is under 3 years old. They live in a traditional wooden (weatherboard) house in a seaside village in Suffolk, and her partner is self-employed mainly working away from home and has a fluctuating income. The house did not qualify for the standard energy efficiency measures but the council determined that an equivalent grant could be given to enable Ms B and her partner to insulate between the timber frame with insulating board. Since the insulation has been installed it is much easier to keep warm, and easier to afford the bills, not thinking there's a bill due and someone needs shoes, and how can she afford them. Her partner is visibly better, less stressed and even with the recent price rises they are still quite relaxed. The children sleep better at night which has a positive effect on all aspects of their lives. Both Ms B and her partner have cars, but the family also use their bicycles for outings, and use the Park & Ride scheme into the nearest city about twice a year. The children can't use the school bus as the eldest has Down's syndrome and needs supervision on a bus, which is not available. So Ms B cycles with them to school unless it's very wet. Half term and holiday outings might include a train trip, just for fun, as the eldest son likes them. She said that if money became a problem again they would probably have to give up one car and her partner would commute to London, but this would not be ideal due to his irregular hours.
- Rebound effects: Insulation between the wooden walls has made a huge difference to the house but they still use a secondary wood/coal burner as a point source to alleviate asthma problems among the children. The internal temperatures are probably only just reaching the recommended guidelines. Any theoretical savings are swallowed up by the needs of a growing family. The modelled data for this house is particularly suspect as the type and construction is very different from the base building used in the model, and also Ms B still needs to keep a wood or coal burning stove in the winter months to ensure the special needs son in particular has a warm enough environment. However the drop actual fuel use compared with the drop in the modelled figures suggests that Ms B has saved substantially through the application of the insulation boards, and that the grant to do this has had a greater carbon saving than that calculated by the model.
- Mrs C and her son who is her full time carer. Mrs C is in her eighties and had a stroke which left her with impaired mobility and memory loss. They live in a 3 bedroom semi-detached house in a large Suffolk market town. She spends much of her time in her sitting room, which has a single-glazed window onto her garden. She needs a warm room. The old coal-fired boiler was replaced with an A rated gas condensing boiler under the council scheme but they decided to keep the open coal fire. Loft and cavity wall insulation were done about ten years ago. The coal fire provides one nice warm room with a focal point and radiant, more

comforting heat, while the rest of the house is cooler (but not so cold as previously). A floor level draught to allow the chimney to draw and a cool downdraught from the window balances the heat. They are not sure whether it would help to have the window double glazed if they could find the money to do so. The central heating hasn't saved money overall (coal plus gas is more than previous coal alone) but it's made living easier. When moving about the house the heat from the radiators is good and it makes the house comfortable. Previously getting up in the winter, especially if Mrs C needed attention in the night, it was very cold and Mrs C risked catching a chill. They are using the same company for gas and electricity and have fixed their price till 2009. The prices after that and how they will afford them are already of some concern. They notice the prices going up – the money they used to have for a cup of tea and a bun when they went out is now being used on petrol, and they take a flask instead. All their travel is in the car, which is spacious enough for Mrs C and her wheelchair plus one or two of her friends. They know that the car they have is large and old, but can't afford a new one and if they could they don't think a compact one would suit their needs.

- Rebound effects: comfort taking in the rest of the house probably brings the temperature to recommended levels. Warmth in the living room needs to be higher due to Mrs C's sedentary lifestyle, but is only just reaching the guidelines for an able person, not an elderly one, although it is real radiant heat, not convection from radiators. Their preference use an open fire to provide the necessary warmth and comfort factor makes the cost of dual fuels exceed the original cost of coal alone but the carbon footprint is about the same.

- Mr & Mrs D are recently retired, living in a 1960s three bedroom house in a small market town in Suffolk. They use one electricity and gas supplier and have capped their bills to 2010, so they can't tell whether the recent changes have made any difference to their bills. The house is warmer now, although Mr D finds it gets too warm before the thermostat goes off and Mrs D finds it gets too cold before the thermostat switches back on again, but they try to find a happy medium and put on and take off clothes as necessary! Upstairs it is warm enough to have only the landing radiator on, turning the TRVs off in the other rooms, unless using them to dry clothes. In particular Mrs D likes to have a cool bedroom as she finds it gives her arthritis relief to keep her legs cool when in bed. Mr & Mrs D enjoy an active lifestyle, with holidays and trips to the nearby towns, by bus when possible.

- Rebound effects: given that this is a house very close to the base building of the model, it is surprising that the modelled fuel costs should be so much below the actual, unless their recent building work has affected fuel use or there is more comfort taking than suggested by the living room temperature.

- Miss E, aged 25-34, lives with her daughter aged 4 in a semi-detached house in a rural village in Norfolk, off the gas network. The house has a good sized garden in which Miss Y grows a range of vegetables. Cavity wall insulation had been done before Miss E moved in, and additional loft insulation was put in at the end of 2006, with the new boiler being installed outside in May 2007, the previous boiler having been in the kitchen. Although Miss E is not so worried about fuel bills as before, as she is using about two-thirds of the oil she did previously, she is worried about bills generally. She finds all costs increasing while she is on a tight budget, and as she earns slightly more than the benefits limit she gets no additional help. Since the work has been done it is much warmer upstairs, but colder downstairs, as the new boiler was put outside and so the kitchen does not benefit from its heat, and there is no radiator there. The installers said there was no need for TRVs to be fitted, although Miss E is certain that these were quoted on the original specification, and she feels she is wasting fuel to get it too warm upstairs when she could do with it cooler there and warmer downstairs. Miss E is too far from the main road to have a public transport option available. Her car is a Xsara, which has good fuel consumption figures and suits the needs of her family and friends.

- Rebound effects: Fuel bills have gone down since the work was done, which means that Miss E finds it slightly easier to meet the everyday bills which are rising. The heating system does not give a balanced comfort.

The range of carbon footprints split into their various components are shown side by side in Table 3. As might be expected, the household with the most occupants (B) has the highest overall footprint, which also has the highest food footprint, although according to the food footprinting calculator, this is only average for the population as a whole. All five case studies appeared to have low water consumption compared with the industry averages of 160 litres per household per day in unmetered properties, or in case studies C & D, which are metered, 150 litres per household per day.

One difficulty in addressing footprints is illustrated by the last line of table 3 which shows the footprints per capita. Case studies B & C have high transport and fuel footprints which can be clearly explained by their lifestyle factors. These dominate the overall footprints, and they are both above the average UK household footprint of 10.2 tCO_2/year, however on a per capita basis B is extremely small, and C is not excessive. For both B & C, both of whom have vulnerable occupants, the additional emissions from heating their homes can be explained from the need for additional warmth and for specialist transport requirements.

What evidence is there that saving money on fuel bills leads to a more carbon intensive lifestyle, using other products? Although the case studies are a self select group, they clearly live moderately, and are concerned about the cost of many items, not just fuels. The recent rise in fuel prices has meant that many of them are concerned about how they will continue to afford to heat their homes, and other cost increases are digging deep into limited incomes. Mr C has recognised the need to switch from "having tea and a bun" when out for the day to taking a flask and sandwiches, due to the cost of petrol. Ms B notices that they don't have to worry "so much" about being able to afford new shoes, and her partner is not so stressed about costs.

Table 3: Summary of case study footprints

Case study	*A*	*B*	*C*	*D*	*E*
Urban/rural	urban	rural	urban	rural	Rural
Income decile	a	c-e	a	e	e
Age	75+	35-44	75+	65-74	25-34
No in Household	1	5	2	2	2
House: number of bedrooms, type, age, heating fuel	3 bed mid-terrace, <1930, gas	3 bed semi-detach. <1930, gas	3 bed semi-detach. <1930, gas	3 bed semi-detach, 1960s, gas	3 bed semi-detach, 1950s, oil
Household	2.37	5.06	5.55	3.53	3.73
Appliances	0.77	0.15	0.55	2.12	0.62
Transport	3.78	6.67	4.52	2.64	2.34
Total Act On CO_2	**6.92**	**11.88**	**10.62**	**8.29**	**6.69**
Food	1.66	2.28	1.44	1.60	0.86
Waste	0.013	0.027	0.020	0.013	0.006
Water	0.053	0.042	0.047	0.054	0.041
Public transport	0.025	0.08	0	0.036	0
Total	8.67	14.31	12.13	9.99	7.60
Less Air travel	0	0	0	0	0
Total	**8.67**	**14.31**	**12.13**	**9.99**	**7.60**
Per person footprint	**8.67**	**2.86**	**6.07**	**5.00**	**3.80**

But money is still tight. Even had prices remained stable, the actual additional income for most of these householders would not have led to any wild extravagances – it merely eases the way for the time being.

What do the Case Studies think about Carbon Footprint as a concept? Ms B and Mr C were well informed in this area – which both put down to an interest in current affairs. All commented about the usefulness of knowing how much their footprint was, but what to do about it was more uncertain. Miss E was one of those not so sure about whether climate change was an important link, but agreed with saving energy as it saved money, and recycling was just a good use of things. Mrs A took a similar view and was very concerned at the general wastefulness of others, she hoped that knowing one's carbon footprint would help everyone to save more. The other three all said it had focused their attention on it, and may have caused them to make small changes, but couldn't see that it would affect their lifestyles.

The principal value of this part of the research was to raise and understand better the policy issues arising from these qualitative interviews and additional measures:

- catering for the needs of vulnerable members of society; ensuring that those with special needs, the sick and elderly can be assured of appropriate heat (and water) for their physical and psychological needs
- catering for the different perspectives of different age groups – those who remember rationing may have a different set of skills and attitudes to resources (and possibly to the community) than those brought up in the consumer era. Role of peer group/role models on individual approaches to resources may affect this also.

Using carbon footprinting

The comparison with national and local averages has been discussed in the main results section. Most of the survey subjects were below local and national averages. Are these measuring the same set of carbon emissions?

The Act On CO_2 calculator uses the national figure in its internally generated reports. That figure, 10.2 tCO_2 yr^{-1}, is derived from the total UK emissions including all secondary carbon emissions and excluding air transport, divided by the total number of UK households. The Green Barometer report calculations were carried out by SEI using their REAP methodology[7] for Defra; it aims to cover all secondary emissions including a share of that necessary for commerce and governance, as a citizen and consumer drives these, and also air travel. When the total emissions in that report are summed, and divided by the total number of households, this gives a total UK emissions per household of 10.05 tCO_2 yr^{-1}. Neither of these is what the Act On CO_2 calculator measures through its engine. Where the individual household puts in actual fuel use, the engine calculates emissions based on standard emissions factors for those fuels (as derived by BERR). It uses modelling to estimate the split of electricity use into household and appliance use. It then estimates emissions from motor fuel consumptions, which may be very accurate where individuals know what their own fuel consumption and mileage per year are, but are otherwise estimated from the car type and mileage. This means that Act On CO_2 approximates the carbon footprint but only based on direct emissions. The case study total footprints should be a closer representation of the household footprints of all carbon emissions included in the Government's own figures as they include estimates emissions due to water, waste and food. The Herefordshire control group attempts to include food footprint on a per capita basis (rather than a household one), but does

7. http://www.resource-accounting.org.uk/

not recognise a contribution from water use and waste. An evaluation of the first year of the Act On CO_2 project is known to be in preparation and it will be interesting to read their comments on the differences.

Although carbon footprints are a tool for helping people to manage their carbon emissions, the range of tools available can be highly confusing. They do not all count the same thing, and even within tools, they may not be comparing like with like. Whilst a single number may be easy for people to refer to, it makes no greater sense than kWh – what does 10.2 tonnes of carbon dioxide look like? It is also not clear whether we should measure footprints for a household, a person or for the number of adults within a household. Yet people are grappling with this probably more easily than kWh, which is a positive step.

Summary and conclusions

This research aimed to explore whether people who had received measures under fuel poverty programmes provided by their local authorities showed, through an assessment of their carbon footprints and interviews, whether rebound effects negated carbon savings. The number interviewed was small, but gave a reasonably reliable indication that the amount of carbon saved through the measures (using actual fuel expenditure) was at least as good as that assumed for non-fuel poor households from the Government calculations for the energy suppliers' Carbon Emissions Reduction Target programme. It would be useful to compare the footprints before and after measures, and to compare households receiving energy measures that are classified as 'able to pay' or not fuel poor. However, from the questions asked in the interviews, from temperatures recorded and from the case studies, it would appear that comfort-taking might be lower than generally modelled and that indirect rebound effects are very low. This may partly be due to the economic situation, with high fuel prices and increased cost of staples including food and water, so that meeting day-to-day costs on a low income is becoming even more difficult.

This group seemed generally interested in their carbon footprints but were not likely to be able to do anything to reduce them further. The number of carbon footprinting tools on the market could lead to confusion amongst the public, especially if the measurement for an individual or household is compared with a stated average based on a different set of emissions. However, the development of a generally available database in AMEE that has the latest knowledge of carbon emissions due to specific products, services and activities is a step in the right direction. The use of carbon footprints for personal carbon allowances would need to overcome shortcomings in footprinting techniques so that calculations are straightforward and accurate for all, which may be more challenging than it sounds. It would be unwise to rely on modelled data when dealing with issues at the personal level, as the modelled data for some of the case studies show. The five responses on personal carbon allowances also show the need for equity to be taken into account. The needs of the vulnerable and elderly have to be delivered in a way that does not further marginalise them.

The conclusion is that reducing the carbon emissions for households in fuel poverty through energy efficiency schemes is unlikely to lead to indirect rebound effects. The question that then should be addressed is: does addressing carbon savings among the 'fuel rich' produce greater indirect rebound effects than it does among the fuel poor?

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