Fuel Poverty Carbon Footprint

Final Report

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Fuel Poverty Carbon Footprint is a research project looking at the carbon footprints of private householders who have received energy saving measures under a local authority scheme in the East of England. The survey was carried out in the period February to June 2008 by

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Fuel Poverty Carbon Footprint

Executive Summary

- A survey of 31 households in the east of England that had received measures under LA fuel poverty programmes
- Majority retired, some families and vulnerable households
- Data collected through interviews and case studies to establish carbon footprint using Act On CO_2 calculator
- Five case studies explored other source of emissions and lifestyle issues
- Lowest carbon footprint 1.14; largest 16.64 ($tCO_2\ yr^{-1}$)
- Mean of group 6.12, median was 5.75 ($tCO_2\ yr^{-1}$)
- Carbon footprint lower than control group but not statistically significant
- Four may be in fuel poverty still (June 2008 prices); this does not take account of household temperature regime as included in fuel poverty definition, and income is not precisely measured
- **No evidence of indirect rebound effects; savings in fuel costs do not lead to expenditure on carbon emitting activities or appliances**
- **Amount of carbon savings from measures delivered to this group the same or better than to a higher income group**
- **Hard to treat dwellings (solid wall and/or off the gas network) provide greater carbon emissions reduction on a dwelling for dwelling basis but the cost is higher**

The Fuel Poverty Carbon Footprint project carried out a survey of 31 households in the East of England, all of which had received measures under a fuel poverty programme, although there was no assessment of whether they were in fuel poverty or not before the measures were installed. The majority (21) of the people involved were retired, but some families were involved (8) and many households included vulnerable people (two with long-term sick or disabled, one with children under 3 years old, 18 in the Priority Group based on benefits, 7 more due to age).

The objective was to collect data to establish the carbon footprint using the Government's Act On CO_2 calculator, and to compare these with national and local averages, in order to determine whether their footprints were any different from the average. The purpose was to add information to the debate on whether fuel poverty programmes run by local authorities conflicted with carbon emissions reduction programmes. At issue was the use of any cost savings from measures, and whether they were used in a way that increased the carbon footprint rather than decreasing it. In policy terms, the project relates to National Indicators 186 and 187 and to research about direct and indirect rebound effects.

The range of carbon footprints discovered was from a very small 1.14 $tCO_2\ yr^{-1}$, to a fairly large 16.64 $tCO_2\ yr^{-1}$ compared with the national average at 10.2 $tCO_2\ yr^{-1}$. The mean footprint for this group was 6.12 and the median was 5.75 $tCO_2\ yr^{-1}$. The majority of households surveyed had footprints around or below the average for their local authority. Compared to a control group from Herefordshire, the mean was lower than the control group but it was not significantly different. The control group was self-selected by response to an on-line project by the unitary authority in Herefordshire and the survey group was self-selected in that they responded to an invitation to take part. Bias in both groups exists, but may be complementary.

From this small sample, no conclusions can be drawn whether their footprints are significantly lower than the general population, nor whether the benefits of energy efficiency measures have contributed to a low footprint. However it was identified that the footprint would have been larger had the measures not been installed. This was achieved by analysing the change in fuel bills and calculating the total CO_2 savings attributable to measures installed in this group of dwellings.

Carbon footprints under Act On CO_2 can be divided into three parts: household (heating, lighting and hot water), appliances (including washing, cooking, communication and entertainment appliances) and transport (air travel and personal car use). 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 each year, or 39% (of household only). Taking account of the overall carbon footprint, the reduction is 22% (1.71 on an average 7.83 before measures). There was no evidence to show that these householders had increased their emissions of carbon dioxide through additional air travel or high energy using appliances such as plasma TVs. Due to the rise in energy bills and costs in general, the lower fuel requirement for heating meant that most households were able to afford to heat and eat, with some but not much ease in worry about bills.

Although much of the data has been drawn from modelling, as detailed fuel bills before the measures were applied were not generally available, there has been a decrease in the number of people at risk of fuel poverty among this group. Income was obtained using a self-select income decile scale so the income used in these calculations is not exact.

For 12 households where actual fuel bills were available 3 were probably in fuel poverty before the measures were applied, one was still in fuel poverty afterwards. Had the measures not been applied a further one of the 12 would have been in fuel poverty now. One would have been paying more than a quarter of her income on fuel, this was a vulnerable person.

Based on current fuel use and costs, 4 out of 30 may be in fuel poverty now, and a further 3 are very close. Of these, 3 are in hard to treat homes and may not be heating them to the standard stated in the fuel poverty definition, and one prefers his home to be kept warmer than the standard, so may technically not be in fuel poverty although he is spending more than 10% of his income on fuel. All but one of these would qualify as Priority Group customers under the energy suppliers obligation (CERT) programme.

Using modelling on all 31 homes to fill in the gaps, 3 households would have been at risk of fuel poverty plus a further 5 would have been borderline before the measures were installed. Had the measures not been installed, 9 would have been in fuel poverty plus one more borderline. According to the modelling, none of the households are technically now in fuel poverty.

Based on both actual fuel costs and modelled data, the amount of carbon savings that can be attributed to these 31 households is 47.9 $tCO_2\ yr^{-1}$. By assessing the measures installed against the Defra assumptions for the CERT programme, the assumed CO_2 savings for the survey households are similar to or greater than the calculated savings under CERT for the same set of measures and cost. This suggests that, provided the costs to the LA are not significantly more than under CERT, the value of delivering these types of measures to households at risk of fuel poverty is the same or better than delivering them to supposedly ‘fuel-rich’ households. However there is awareness that some of this difference may be due to differences in modelling assumptions.

If, therefore, carbon reduction programmes are a priority to the LA, 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.

Five case studies provided detailed information on other aspects of carbon footprints: water, waste, food and public transport. Resource use was generally low amongst all these subjects. A common theme about social justice may be partly attributable to selection bias.

Comfort-taking aside, there has been no change in what the subjects do with their lifestyles, although they feel more comfortable about doing it. Although most (80%) respond positively to the statement 'It's been easier to keep warm', at least 20% do not maintain their homes at the recommended temperatures, therefore direct rebound effects may be lower than generally assumed through modelling. More than half agreed that they are 'not so worried about bills'. There is no evidence of indirect rebound effects, i.e. spending the money saved on high-emissions activities or appliances.

The main conclusions from this study are:

- There is no evidence that people who receive measures under a fuel poverty programme are likely to use any money saved to spend on high-carbon emissions products and services. So the rebound effect, if any, does not lead to an increase in carbon footprint.
- Whether this is the case for all types of households requires further study. A robust study using kWh measurements before and after as well as fuel costs could ease the decision making of local authority policy-makers when deciding the focus and funds allocation for housing improvement, fuel poverty eradication or climate change mitigation programmes.
- Further exploration of the value of programmes that improve so-called hard to treat properties – off the gas network and/or with walls that cannot be filled using cavity wall insulation – would be beneficial. The carbon savings and social benefits for vulnerable people in these homes suggest there may be a double benefit and comparatively greater carbon savings than hitherto calculated.

Contents

Abbreviations

AFP	ACE Fuel Prophet tool
AWI	Affordable Warmth Index
BERR	Department for Business Enterprise and Regulatory Reform
CB	Condensing boiler (distinguishing: CGB, gas-fired, OCB, oil-fired)
CERT	Carbon Emissions Reduction Target
CFL	Compact fluorescent (energy-saving) light
CH	Central heating
CO_2	Carbon dioxide
CWI	Cavity wall insulation
DEFRA	Department for Environment Food and Rural Affairs
DTI	Department for Trade and Industry
DTQ	Domestic Tradable Quota
EST	Energy Saving Trust
HECA	Home Energy Conservation Act
HTT	Hard to Treat (home or property)
LA	Local Authority
LI	Loft insulation
LTU	Loft insulation top-up
NI	National Indicator
ONS	Office of National Statistics
PCA	Personal Carbon Allowance
tCO_2	Tonnes of carbon dioxide
$tCO_2\ yr^{-1}$	Tonnes of carbon dioxide per year

Company names are left as acronyms.

Introduction

'Fuel Poverty Carbon Footprint' aims to compare the carbon footprints of selected fuel poor and/or formerly fuel poor households with the national average.

Households in fuel poverty spend ten percent or more of their household income on energy in the home, but it is not known whether this represents also a high level of carbon emissions compared with the UK average. Does solving the high cost of household heating lead to what might be termed a "carbon rebound effect", where the households spend the money previously dedicated to heating on other, higher, sources of carbon emissions. This is an important issue as increasingly the targets for climate change mitigation and fuel poverty eradication are seen as being in conflict. In the ideal situation, one would study householders both before and after interventions aimed to bring them out of fuel poverty. This has a number of difficulties, among them the changes in the households themselves over time, particularly with vulnerable groups. In addition, there is an ethical issue of studying people rather than fixing their problem. Yet organisations including local authorities and Warm Front are affected by the diversion of resources from fuel poverty programmes (taking account of vulnerability and social aspects) to highly targeted programmes to reduce carbon emissions. In the absence of proper data on the lifestyle choices of fuel poor households and their carbon implications, assumptions are made that can favour programmes for the fuel rich, where the potential for carbon emission savings are perceived to be greater.

This study attempts an initial quantification of the carbon emissions of a number of households that have received measures through fuel poverty programmes. By using a publicly available carbon footprint calculator, the emissions of the group that have received measures can be compared with the UK average and a control group using the same calculator. This will provide information as to whether the "post-fuel poverty programme footprint" is detrimental to carbon saving programmes, or whether, in general, solving fuel poverty is an equitable step towards lower UK carbon emissions. It aims to provide information about the carbon benefits of fuel poverty programmes looking at household, appliance and transport use, in order to demonstrate that tackling fuel poverty is consistent with, or at least not a threat to, tackling climate change.

Main aims of the project

The aim is to provide policy makers with information about the carbon impact from the lifestyles of households in fuel poverty and those which have been removed from it through fuel poverty programmes. This in turn aims to assist those making decisions on priorities for funding and delivering programmes to understand the potential conflict between climate change (carbon reduction) programmes and fuel poverty (social equity and energy efficiency).

Main objectives of the project

The objectives are:

- to carry out a quantitative survey of the carbon emissions of a number of households that meet the criteria of the research (the subject group). These are categorised, in general terms, as having qualified for fuel poverty programmes by being in or near fuel poverty or in receipt of triggering benefits.
- to carry out a case study of the lifestyles of at least five of the subject group to provide information about the changes in lifestyle and carbon implications of removal from fuel poverty
- to report on the research to key organisations and individuals that influence the policy agenda for fuel poverty and climate change

Report structure

The report begins with the background to the research, showing the reasons for the study and exploring some of the problems of definition and measurement. There follows a chapter on the methodology, which is in turn followed by the results. These are analysed first in descriptive terms, i.e. the households and their responses to the questions, then in terms of the carbon footprints and the relationships with household characteristics. The next chapter looks at the difference the measures made to the affordability of warm winter homes to the householders. It uses both recorded and modelled data to assess the impact of the measures on the risk of the householder being in fuel poverty, and considers the effects of price rises on these results. The last chapter of results describes the case studies and their responses to the key questions asked of them.

A discussion follows on the problems of using carbon footprints as a method, and compares the results with other surveys, including a survey using ecological footprint, research on personal carbon allowances and also the Family Spending report 2006.

The implications of this research are then discussed, before considering lines of future research, and the report closes with a summary and conclusions.

First, some background to why the study was thought to be worthwhile.

Background to the research

The Home Energy Conservation Act (1995) placed a duty on local authorities (LAs) to improve household energy efficiency in their area by at least 30% over the 15-year period from 1996 to 2011, and appoint an officer with responsibility for this target. The Warm Homes and Energy Conservation Act (2000) placed further obligation on Government to address fuel poverty, which was devolved to LAs. As LAs could not affect the price of fuel or, generally, incomes other than through information campaigns, they were really left with no option but to address fuel poverty through energy efficiency programmes, thus resources for the one purpose became combined or aligned with the other.

The shift to a focus on climate change mitigation, and carbon saving, has produced a further tension. The Energy Saving Trust switched its focus from energy saving to carbon reduction, and this was followed by the more recent regime for LAs, where Climate Change strategies were developed and implemented in many local authorities, sometimes in harmony or partnership with a regional strategy. The most recent development is for LAs to adopt a series of National Indicators (NI), selecting from a menu suggested by central government, which include the three energy related options, energy performance in public buildings, carbon reduction and eradication of fuel poverty. This is a negotiable area, with LA officers being involved in the discussion of the 'best' approaches for their area. The concern of some HECA officers is that focus on climate change mitigation could reduce or remove resources for addressing fuel poverty. The most difficult issue for them to argue on is that of rebound effects, where research has shown that a percentage, often quoted as high as 30%, of energy efficiency gains are wiped out by people using more energy to keep warmer, or switching to other high-energy using products and services, or finding such services affordable and using them when they did not formerly. This means that the value of fuel poverty alleviation programmes in a council with a carbon reduction target is questioned, with no real information available as to how much fuel poverty programmes contribute (if at all) to carbon emissions reduction.

Three issues within this problem require exploration in order to address the arguments satisfactorily:

- Measurement /definition of fuel poverty including actual versus modelled energy use before and after
- Rebound effects and assumptions/modelling
- Carbon footprints and (cost-effective) potential for saving carbon (bangs for bucks)

Measurement and definition of fuel poverty

The original definition of a fuel poor household was "one that needs to spend in excess of 10% of household income on all fuel use in order to maintain a satisfactory heating regime"[1]. However, when the UK Fuel Poverty Strategy was published there was division over the definition of income, as the energy community who had campaigned for the eradication of fuel poverty argued that the definition should consider only disposable income, i.e. after necessary housing costs such as mortgage and rent, and excluding benefit payments because of need, whereas the government wished to include benefits and exclude items such as tax relief on housing costs. Consequently two 'definitions' were used in the Fuel Poverty Strategy. This issue has remained a sticking point, with the Government gradually dropping the use of the wider definition, and campaigners continuing to use it, arguing that disposable income was the critical issue.

[1] DTI (2001) UK Fuel Poverty Strategy

The second issue that has been less widely discussed is the definition of the satisfactory heating regime, and how it affects the way the number of households in fuel poverty is measured. An 'adequate' temperature is assumed to be the World Health Organisation standard of 21˚C in the living area and 18˚C in other habitable rooms. So simply taking a household's fuel bills and seeing whether this is more or less than 10% of their income (by whatever definition) does not necessarily produce a 'correct' result in terms of categorising fuel poverty – it depends on what the household *would need to spend* in order to maintain the standard heating regime.

The consequence of this is that a household that receives measures under a fuel poverty programme may not be spending 10% of their income on fuel before the programme takes place; they may just be heating one room, or none, spending what they can afford from a limited household budget. Afterwards, they may spend the same amount, but be warm throughout the house. Tragically, there are instances when, after receiving central heating systems and insulation measures, some individuals keep the heating off as they don't use all their rooms, and revert to inefficient heating of one or two rooms, as they believe this will be cheaper[2]. This can also lead to health problems induced by condensation and mould growth in unheated rooms.

The difference between actual and presumed (or modelled) energy use or behaviour has a major bearing on the discussion of rebound effects when considering the fuel poverty issue, but is under-researched.

This difficulty in measuring whether individual households are or were in fuel poverty is one of the particular problems for LA and other fuel poverty programmes, and most resort to proxy indicators, led by the Government's own proxy – people in receipt of a certain 'qualifying' benefits. Most do not then go further in establishing whether people are actually in fuel poverty, even on a simple definition of how much is spent on fuel compared with their income. The issue is thought too sensitive, and smacks of means testing. In addition, there is a widely held view amongst the energy efficiency professionals, as shown at conferences such as that of Energy Action Scotland (EAS) when such questions are asked in open forum, that it is better to treat all the houses where there is risk of fuel poverty, despite fuel poverty being a problem of the specific occupants. If the energy performance of the house is improved, the family living in it will be at lower risk of fuel poverty. If the occupants change, the new occupants will still be at a lower risk of fuel poverty: the benefits persist. Finally, people move in and out of fuel poverty if their income changes e.g. through unemployment, or through fuel price changes. Perversely, people can go into fuel poverty when they come off benefits, which means they are no longer eligible for fuel poverty programmes. There are, and continue to be, efforts made by government and energy companies to address income and prices, but the energy efficiency of the household is the only aspect on which the LA can have direct impact.

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[3].

[2] Pett & Guertler (2004) User Behaviour in Energy Efficient Homes, ACE London
[3] Jevons in Ko et al (1998) Resource rates and efficiency as indicators of regional sustainability. Env. Monitor Assess 51/1-2 571pp

Rebound effects can be classified as 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[4]. Berkhout also identifies second order effects, where the effects of these indirect effects can shift the market, suggesting that potentially large rebound effects can have "severe repercussions on the effectiveness of policy aimed at the penetration of energy efficiency".

In recently published research for the UKERC, Sorrell argues that rebound effects are notoriously hard to estimate, are hotly disputed, and are likely to be less than 30% for household heating, cooling and personal transport[5]. 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.

One of the few empirical studies that measured household fuel use before and after installation of energy efficiency measures was carried out in Canada in 2000-2[6]. 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.

However, this recognition of lower income groups as conservers is also an issue for green consumption in the UK. Research in the 1990s by the National Consumer Council[7] identified five classifications of consumers whom they termed Affluent Greens, Recyclers, Careful Spenders, Young Greens, and Sceptics. The first and fourth are probably self-explanatory, although Young Greens tend to have relatively low incomes for their age group. Recyclers tended to be older and more affluent, Careful Spenders tend to be middle-income range and older age groups, particularly sparing in their use of gas, electricity and water, and Sceptics tend to be on fairly low incomes and doubt what they can do for the environment. This type of segmentation was echoed by subsequent research sponsored by the Co-operative Bank into ethical consumption[8] although they identified a 5% Global Watchdog group which was as likely to be low-income, or council tenant, as any more affluent indicator. However, this research also identified a large group of people on lower incomes they called the Conscientious Consumers, who are concerned with value for money, product quality and service, plus ethical issues rather than purely environmental.

The problem therefore remains 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:

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[4] Berkhout et al (2000) Defining the rebound effect. Energy Policy 28 pp425- 432

[5] Sorrell (2007) The Rebound Effect: an assessment of the evidence for economy-wide savings from improved energy efficiency. UKERC, London

[6] Parker et al (2005) Who changes consumption following residential energy evaluations? Local Environment Vol. 10, No. 2, 173–187

[7] NCC (1997) Consumers and the Environment: can consumers save the planet? National Consumer Council, London

[8] Cowe & Williams (2000) Who are the ethical consumers? The Co-operative Bank, Manchester

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. Calculations of the benefit of the programme 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 up to their available limit.
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. This is a cultural issue that brings forward value judgements.
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 (both of which have high carbon emissions implications).

Research by ACE (op.cit.) analysed the way heating was used by 118 people who had received measures under a housing association energy efficiency scheme. They found that only 23% used their systems in the way that corresponded to policy expectations, whereas 50% used them in a way that seemed reasonable (i.e. efficient) to the researchers given the statements about lifestyle, but did not follow the model used to assess energy use in the home. The remainder did not use the systems effectively and did not get good value for their lifestyle. However, only 61% got the results they wanted from their heating systems, many finding them difficult to set to a consistent level of comfort. No assessment was made of possible post-measures purchasing decisions, although numbers of appliances were noted (there were on average 2 TVs per household). In terms of costs, there was no significant shift to paying less even over a period when prices were relatively stable (or falling). More stated they were paying less than those who said 'more', but nearly a quarter were paying much the same. However, most had met or improved their expectations of cost reduction.

Sorrell (op cit) suggests that rebound effects can be managed on a policy basis by a mix of measures. For energy efficiency measures these could include policies such as carbon pricing, labelling, education and advice. There is a reasonably large body of research available on the value of advice, and this tends to show that one to one advice is best (particularly when delivered in the home), especially combined with education, and that where effort has been put into this area, energy savings persist[9] (see Appendix 1 of Pett & Guertler 2004).

Carbon footprints and (cost-effective) energy saving

One of the policy options debated recently is the concept of carbon counting, as a precursor to Domestic Tradeable Quotas or Personal Carbon Allowances, or carbon footprinting. DTQs/PCAs have a particularly favourable profile because they seem to have the potential to have low impact on those in fuel poverty[10] (depending on the detail of the application of such a policy). Current carbon footprinting methodologies vary from simplistic to complex, and tend to suffer from 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.

[9] Harrigan & Gregory (1994) 'Do Savings from Energy Education Persist?'; ACEEE Summer Study Proceedings 1994:1.65

[10] Ekins & Dresner (2004) Green Taxes and Charges. PSI, London and JRF, York

One of the simplest ways of determining 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[11], although 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. The person using the tool gets a report on their footprint (i.e. number of tonnes of CO_2 emitted) compared with the UK average, and is given a target (a reduction on their existing footprint) to help contribute to reduction in line with the Kyoto targets.

For someone who has their annual fuel bills at hand, this can give an accurate view of their footprint, but there are concerns over the treatment of monthly or quarterly bills at present, and the assumptions based on the type of house and its insulation are woefully inadequate as a measure, albeit user friendly. For example, if someone installed cavity wall insulation between one use and another, that would create a reduction in the footprint, but most other energy efficiency measures, and particularly in hard to heat homes, would show no difference. Yet as a first step the tool is well presented, and the database is open to use by a myriad of applications by different actors through the organisation AMEE[12], with the carbon emissions factors gathered together in one authoritative source, that can be centrally updated as knowledge improves.

Other carbon footprint calculators exist which may take a more detailed view of a person's (or household's) lifestyle, and may or may not use the same emissions data as the AMEE database. The RSA carbon footprint project Carbon Limited[13] was originally independent, but is now linked to AMEE, and aims to test the concept of DTQs through a 'virtual' trading system. Google adopted the same calculator. Erase my Footprint[14] uses a trimmed down version of the calculator and offers to offset emissions through verified schemes. The Penrhos Permaculture holding[15] 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[16] have a more detailed approach to secondary emissions by asking about attitudes to recycling, packaging, etc. to estimate secondary impacts. The Centre for Alternative Technology have an information sheet[17] comparing carbon calculators and ecological footprints and have launched their Carbon Gym[18]. However, a wider approach using the Ecological Footprint approach, EcoCal[19], takes a comprehensive looks at lifestyle and purchasing and calculates the amount of land needed to produce the resources and absorb the carbon dioxide emissions.

An important feature of these tools, especially in the context of LA 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 domestic fuel figures from BERR (formerly DTI) and Defra, and dividing them

[11] http://actonco2.direct.gov.uk/index.html
[12] AMEE – Avoiding Mass Extinction Engine, now with the tagline 'The World's Energy Meter'. http://blog.co2.dgen.net/
[13] http://www.rsacarbonlimited.org/
[14] http://erasemyfootprint.com/
[15] http://www.konsk.co.uk/design/energy2.html
[16] http://www.carbonfootprint.com/calculator.aspx
[17] http://www.cat.org.uk/information/info_content.tmpl?sku=info_is_az
[18] http://carbongym.cat.org.uk/carbongym/
[19] http://www.bestfootforward.com/ecocal.htm

by the number of households/population. 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 emissions be apportioned? However in terms of local policy decisions it makes sense, if one is trying to reduce the carbon footprint, to address those people with large footprints, where efficiencies are likely to produce larger results. The same issue is at the heart of EST's targeting of energy saving measures and advice.

Carbon footprint reduction versus 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. The Ekins & Dresner (op.cit.) 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. So there is a more complex issue for the LA 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 one addressed to the 'fuel rich'. A number of research reports analyse the demographics of carbon or ecological footprints, such as Barrett et al[20], Caird and Roy[21] and Haq et al[22].

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 is the topic that is being addressed by this research. The hypotheses are twofold: that people who have received measures under a fuel poverty programme have lower (or at least, no higher) carbon footprints than others of their demographic groups, 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, but it should provide an indication of whether further study is warranted.

[20] Barrett et al (2006) Environmental impacts of UK consumption – exploring links to Wealth, inequality and lifestyle. Paper presented at IABSE Henderson Colloquium, Cambridge, 10-12 July 2006

[21] Caird & Roy (2006) Household Ecological Footprints - Demographics And Sustainability. JEAPM Vol. 8, No. 4 (December 2006) pp. 407–429

[22] Haq et al (2007) Greening the Greys - Climate change and the over 50s. SEI, York

Methodology

Synopsis

Householders that have had energy efficiency measures (any) installed as a result of their authorities' fuel poverty programme were interviewed to establish their carbon footprint according to the Government's Act On CO_2 calculator. They received feedback on the result, both at the end of the interview and a follow-up report based on the Act On CO_2 report tailored to their situation. Five households were selected for a second, more in depth interview, about their lifestyles, what has changed since measures, and their carbon footprints, to provide narrative case studies. They were asked to monitor their food, public transport, waste and water usage in a four week period prior to the second interview. These will be compared with other footprint case studies and studies such as family expenditure surveys.

Subjects' carbon footprints are compared with:

- Their LA averages
- Households of similar composition within the interview group (e.g. all pensioners, all one adult families with children etc)
- National averages
- A control group who have used the Act On CO_2 calculator or one of the clones from the engine provider d-gen.

Conclusions are drawn about the carbon footprint of the sample leading to theories or hypotheses about footprints of households in or near fuel poverty and the interaction of fuel poverty programmes and climate change (carbon reduction) programmes.

Target group

The subjects were recruited from a request for participation from five local authorities. The local authorities involved are those in the East of England Region who have expressed willingness to take part and who have recently instituted a programme of energy efficiency improvements for the purpose of reducing fuel poverty in their areas. The subjects therefore qualified for and benefited from these programmes (the criterion for selection), whether or not they were in fuel poverty beforehand. The only other requirement was that the householders had recent (post-programme) meter readings so that actual use was known. This was supplemented by a set of meter readings when they committed to the interview and at the interview itself.

The target group provided a range of categories such as pensioner household, single occupant, two parent and single parent families. In addition, there are differences in situation e.g. type of house, construction type, gas, electric, oil or other heating fuel.

The five local authorities that participated were Suffolk Coastal, Norwich City, Huntingdon, Kings Lynn and West Norfolk, and Broadland. Suffolk Coastal were the first to commit to the project and their interviews commenced in February 2008, although the final lists of participants had been delayed till Easter. This meant that the interviews for Suffolk and Norwich took place in the winter heating season, and the internal temperature was recorded during the interviews. The other three all took place in the spring, and unluckily many during the few hot weeks experienced, and no temperature record was made as the heating had been turned off. Interviews were arranged mainly by phone, although in some cases a number was not available so a letter sent instead.

The breakdown of interviews is shown in Table 1:

Table 1: Interviews secured from LA contacts

LA area	Contacts supplied	Interviews arranged	Interviews done
Suffolk Coastal	10	9	8
Norwich City	8	7	5
Kings Lynn & W Norfolk	12	11	7
Huntingdon	6	6	6
Broadland	6	5	5
Totals	42	38	31

There was a comparatively large drop-out from the West Norfolk applicants, undoubtedly influenced by missing telephone numbers so letters had been sent; many of these had hospital appointments that were coincident with the survey arrangements – some of those interviewed managed to juggle appointments successfully. Six appointments were rearranged, three of the Huntingdon and three Kings Lynn to the same day, although one was aborted when it emerged that the householder had not taken or kept any meter readings that could be used in the interview. Those who gave reasons for withdrawing either changed their minds (at least two in Norwich and Suffolk were influenced by the loss of personal data by government departments in that period) or for health reasons although one offered to take part later in the year when she had recovered. Three interviewees were out when first visited as arranged. A message was left for one (as no phone number was held) which elicited no response and the other two were rearranged by phone. One of those was still unavailable on the second visit, so the interview aborted.

The one Broadland resident who was not interviewed was unavailable till the end of the interview period. He occupied a park home which would have been interesting but difficult to analyse in the context of the rest of the study, so was not pursued.

The degree of failure of interviews is on a par with previous interviews of this type (Pett & Guertler op.cit).

Control Group

A number of attempts were made to secure a control group for comparison, i.e. the footprints from other groups who had used the Act On CO_2 calculator drawn from the general public rather than from a group with specific characteristics. In particular the mean footprint and the number in the population could be used for a statistical test of significance (Student's t-test). It was not possible at the time the project was started to obtain this data from the Act On CO_2 owners, but the agreement of Herefordshire Unitary Authority was obtained to share data from their Climate Change on-line project, which used the same questionnaire and engine. Although this was a self-select group, i.e. they had opted to take part in response to publicity, and was therefore likely to be biased towards those with an interest in the subject, it was the largest dataset that was available, and had the advantage of being drawn from an area with a similar type of demographic profile as the eastern counties involved in this project. The data were not obtained until the majority of interviews had been completed, for technical reasons. At one stage it appeared that this control group would not be available and an attempt was made to build a separate control group for the project by requesting members of the HEON-E network and their friends and colleagues to complete the questionnaire. Plans were made to obtain more footprints from attendees at the HEON-E conference. It was recognised that there might be a bias introduced due to the number employed in energy conservation, but the negotiations with Herefordshire meant that this plan could be dropped.

Interviews

Interviews took place in the participants' homes, using the questions for the Act on CO_2 calculator on the interviewee's laptop for later checking against the official calculator and production of the report. After the introduction and gathering of household composition for classification purposes, the Act On CO_2 questions were asked and the carbon footprint produced using a spreadsheet version of the calculator which had been tested for accuracy with the project's steering group. The carbon footprint was explained, and compared with the local and national footprints. It was important that elderly or vulnerable households realised that they do not need to make further savings by setting the heating at an unreasonably low level as this would counteract the purpose of the fuel poverty programme. Some high footprints were explored further and possible reasons explored, and the subject referred to the Energy Advice providers where appropriate.

Following the use of the calculator, the subjects were asked how their fuel bills compare now the 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, following which the subjects income range and age range were established. Income ranges were divided into deciles based on ONS income data, and subjects were asked to make these inclusive of benefits. One subject was happy to complete the carbon footprint part of the interview but declined to answer the questions on fuel costs or income.

At the conclusion of the interview, householders were asked whether they would be willing to take part in a more detailed study that includes a review of food buying habits, waste & recycling, and further discussion of the differences that the measures have made to their lifestyles.

The interview plan is included in Appendix 1.

Data management and analysis

Data held comprises:

- Reference number of interview
- Household type; age and adult etc composition
- House type and construction type (cavity or solid wall)
- House details as required for Govt calculator
- Fuel/heating types and usage
- Appliance types and usage
- Transport types and usage
- Carbon Footprint
- Income bracket
- Willingness to take part in second interview for case study

And for case studies:

- Water usage for the period or actual meter readings
- Waste arisings for the period
- Food purchases by receipts plus specified packaging for analysis of provenance
- A public transport diary (private transport is included in Act On CO_2)

Carbon footprints were analysed by household type, by fuel type, income bracket and age bracket. The actual fuel costs provided are used to identify degree of fuel poverty (Affordable Warmth Index) before and after measures, and the house type and measures modelled using the ACE Fuel Prophet tool to estimate Affordable Warmth Indices for before measures at current prices, before at previous prices, and after and current prices (March-May 2008 prices). This

allows the comparison of footprints of those who have moved in and out of fuel poverty.

Case studies

Five case studies were carried out with people willing to discuss the changes in their lifestyle because of the energy efficiency measures and to monitor their use of other resources with a secondary carbon impact.

The objective was to discover what the energy efficiency measures have meant to them in terms of:

- Warmth
- Health
- Disposable income
- Changes in type of carbon emissions

The aim was to secure additional interviews representing the following groups:

- Family with young children
- Pensioner
- Long-term sick or disabled
- Rural
- Hard to Treat homes (probably an off-gas network rather than sold walls due to the type of schemes under consideration).

Because of the delay in carrying out the second batch of interviews, the majority of the case studies came from the first round, i.e. from Norwich City and Suffolk Coastal. The LAs involved in the project were consulted on this list and requested a single young mother in rented accommodation to be included if possible.

Six candidates were invited to take part with profiles as follows:

- disabled pensioner with full time carer (son), market town (SC06)
- family with disabled son in hard to treat home, rural town (SC01)
- single mother with two near-teenage boys, city area (NR06)
- pensioner couple with reasonable level of income, active, rural town (SC05)
- pensioner lady in rented accommodation, city area (NR03)
- single (25-34) mother with young child, off gas, rural village (BD05)

The six were sent a letter with instructions on data and items to save during the period, with an example (see appendix), and an appointment was made for a date close to the end of the monitoring period. Four of the interviews took place in the first week of June, and the other 2 weeks later (BD05 was the last to be interviewed in the original round). The interview looked at the information they had collected, noting any difficulties experienced; reviewed information they gave in their first interview about the changes that the measures installed made to their lifestyle, this time collecting narrative detail, and checking where any information subsequently realised to be important (e.g. energy supplier) had not been collected initially. The were also asked about their understanding of the term ‘carbon footprint’, and due to recent publicity about personal carbon allowances and acceptability, a question about how they would feel about these. Unfortunately the single mother with two teenage boys experienced a health problem during the monitoring period and withdrew.

The results of the case study monitoring were used to estimate secondary carbon footprints for food, waste, water and public transport, to add to the Act On CO_2 breakdowns and create a footprint more closely aligned to the average figures quoted for comparison by Act On CO_2. The case studies were written up and a draft sent to the individuals for approval and amendment, together with a permission form. Stamped addressed envelopes were included for their use to reply.

Results of the interviews

The survey group characteristics and measures installed

There were thirty-one subjects from five local authorities. The majority (22) were retired, and those with families were spread across age groups. Table 2 shows the base characteristics of the survey group.

Table 2: Characteristics of households interviewed

Age group	25-34	35-44	45-54	55- p.a	p.a – 74	75+
Number	1	4	2	2	12	10
Income decile[23]	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	H'holds with children	Child age	3 -	4 -11	12-18	
Number	8		1	4	8	
Priority group	PG (Bens)	PG (age)	nonPG			
(estimated)	18	7	6			(n=31)

p.a. = pension age

The house types are shown in the matrix below. 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.

Table 3: House types of interview group

(n=31)	2 bedroom	3 bedroom	4 bedroom
Maisonette	1		
Mid-terrace House		4	1
End-terrace House	2		
Semi-detached house		7	1
Semi-detached bungalow	2		
Detached house		2	1
Detached bungalow	6	4	

The carbon footprinting questionnaire required the classification of urban or rural. Many of the households were in small market towns or large villages, and the decision to classify them as rural depended on whether there was farmland or similar within 200 yards and whether there was good local public transport. So a house in the centre of a small town might be 400 yards away from farmland; if no

[23] Where A is the lowest and E the 5th of 10 deciles. For the actual ranges see Appendix table A2

bus service was available, it was classed as rural, but with good transport links, as urban. On this basis, 19 were classed as urban and 12 as rural.

Measures installed were the usual mix of cavity wall and loft insulation or loft top-up and gas condensing boilers. Fuel switching was a measure applied in ten homes, from electric storage or warm air systems, or coal open fires or back boilers. The following table shows the measures installed before the most recent energy efficiency intervention, and the installation afterwards.

Table 4: Measures installed, before and after recent intervention

Before	Number	After	Number
LI, CWI, gas ch	6	Plus LTU & Gas CB	3
		Gas CB	3
LI, CWI, electric	4	Gas CB + ch	2
		Oil CB + ch	2
LI, CWI, open or solid fuel fire	2	Plus Gas CB & open fire	1
		Plus oil CB and open fire	1
LI, CWI, oil boiler	1	Oil CB	1
LI & gas fire	2	Plus CWI	1
		Plus LTU, Gas CB + ch	1
LI & gas or oil ch	8	Plus internal wall insulation	1
		Plus CWI	2
		Plus CWI & gas CB	4
		Plus LTU & gas CB	1
LI & electric	2	Plus LTU, gas CB	1
		Plus CWI, gas CB	1
Gas ch	5	Plus LI, CWI	3
		Plus LI, gas CB	1
		Plus LI	1
Gas fire	1	Plus LI, CWI, Gas CB + ch	1

LI=loft insulation, LTU= Loft (insulation) top-up, CWI=cavity wall insulation, CB= condensing boiler, ch = central heating. (n=31)

Most of the dwellings received all appropriate cost-effective measures, but some did not. The maisonette only received loft insulation as it was an upper dwelling in a block of four where it was the only non-social one. The owner expressed an interest in CWI if the housing association was planning to do the rest of the block, depending on how much he would have to pay; this message was passed on via the LA officer.

A number of residents who had received central heating continued to use a point source such as an open fire or coal/wood stove. Three did so because of a specific need to keep one room exceptionally warm for health reasons and they used them regularly, others because of the pleasing nature of an open fire, but one of these said she hadn't used it in the last winter.

Table 5: Changes to fuel bills

Answer		Number (n=31)
Yes	Up	1
	Down	14
	Down then up after price rises	3
No		3
No change to direct debits		4
Don't know		5
Don't wish to answer		1

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 bills had been noticed by some, as shown in Table 5 which reports the responses to the question "Have you noticed any change in your fuel bills since the work was done" with prescribed answers as shown.

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 6. It was interesting to hear comments about the statements from some people to whom they seemed absurd, particularly 'I've been feeling better in myself', even though it might be a commonly heard expression and one which other subjects agreed with whole-heartedly.

Table 6: 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

A number of interesting findings about appliances were recorded as part of the carbon footprinting questions. All subjects had a washing machine, most did not own a tumble drier and many always dried their clothes outside, good weather or not, when the best answer allowed in the system was 'often, in good weather'! Digital television was present in nearly all the households, mostly through Freeview boxes, with Sky and digital-ready TVs vying for second choice. Only one plasma screen was recorded; most had more than one TV, although usually it was an old one relegated to a spare room used when guests were visiting.

Most of the survey group had plenty of low energy light bulbs. Figure 1 shows the number of low energy lights stated compared with the total number of light bulbs in the house, the remainder being labelled as incandescent, although they include halogen. Each individual light bulb was counted, even in clusters of five or six in a luminaire. Discussion of this question led to an impression that for those who already have around 50% of their lamps changed to CFLs, the need is for low energy replacements for halogens and for small candle types that fit narrow fittings.

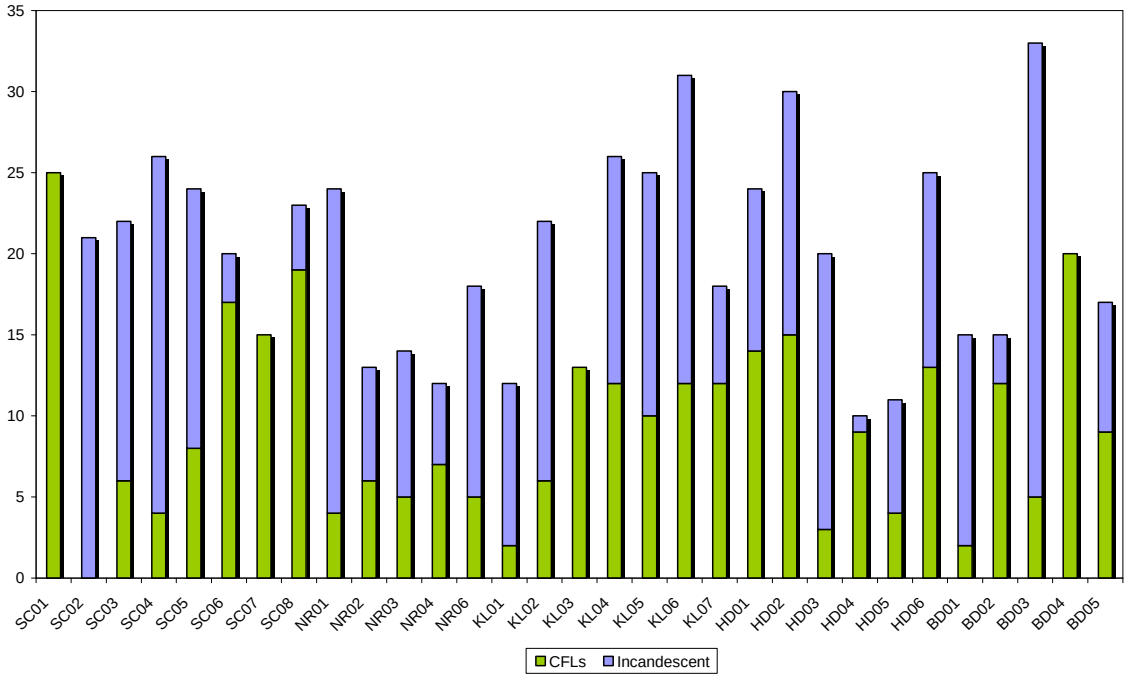

Figure 1: Prevalence of CFLs within survey households

Carbon Footprints of the survey group

The full analysis of the carbon footprints of the survey group is shown in Appendix 2, which includes exploration of a range of issues relating the carbon footprints measured again demographic data.

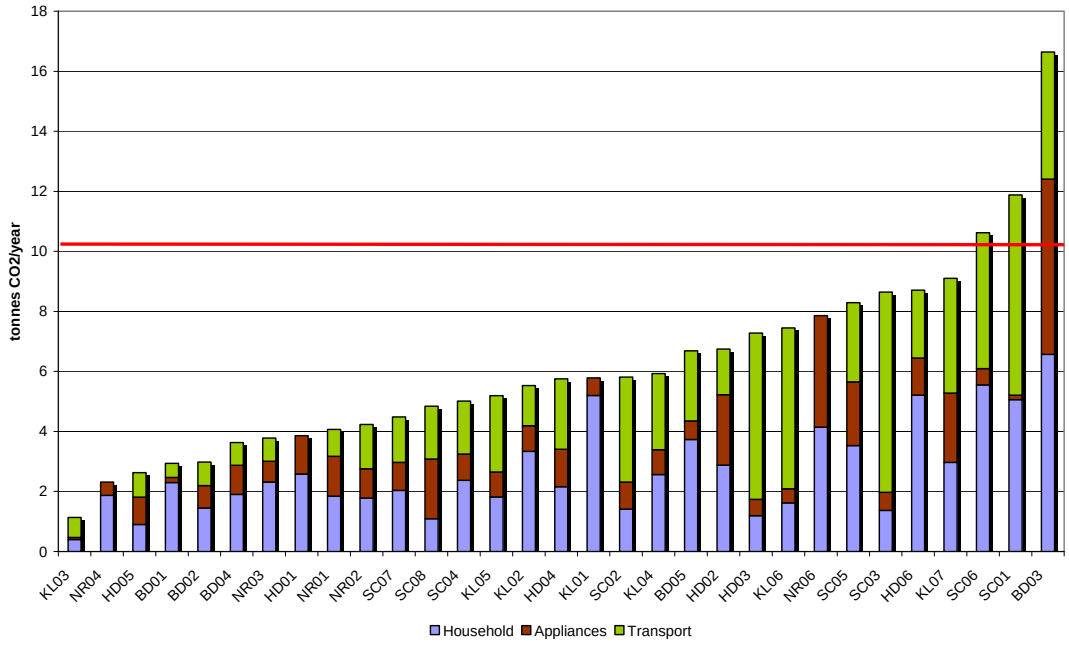

Figure 2: Carbon footprints, low to high

The range of carbon footprints, based on the Act On CO_2 calculator, are shown in Figure 2 above. Most of these are below the UK average of 10.2 tonnes CO_2, shown in red, and they are also mostly below their respective LA averages.

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 is a single person,

retired, living in a small modern terraced house, who believes in low resource use and keeping fit. He is proud of his low emissions car which he spent some time researching to get the best to suit his purposes, but he doesn't use it very much, and apologised to me for driving to nearby countryside to go running, but he found it a bit too far to cycle. He also saves on hot water costs (and water charges) as he swims three times a week, so showers at the local pool. By contrast, BD03 lives in a large house with good public transport access which he uses, as he doesn't drive for health reasons. He likes a warm house, and particularly at night if he is up late or his niece is studying, they will use electric fires for warmth rather than using the central heating. This, plus the ownership of the plasma TV which is often left on stand-by, explains 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. These may not appear to be typical lifestyles of people in fuel poverty, but the individuals qualified for the LA programmes, and are lifestyle choices for the individuals.

Because the number of interviews is small it is important not to place too much emphasis on the trends encountered in the analysis. The following points are explored further in the appendix, but the main findings appear to be:

- no clear differences between footprint ranges in mainly urban and mainly rural LAs
- 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 work done by CSE for Defra on footprints distribution by income[24] 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[25]. 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, the impact on fuel poverty and the potential switch of emissions between heating and other lifestyle changes is sufficiently reliable to examine in the next section.

[24] Roberts S (2008) Carbon rationing: feasible and fair? Energy Efficiency Partnership for Homes workshop 30 April 2008

[25] Boardman B, K Lane & M Hinnells (1997) DECADE domestic equipment and carbon dioxide emissions: transforming the UK cold market. ECI, Oxford

Affordable Warmth and carbon emissions reduction

The figures in this chapter have been derived in two ways. The first, from fuel bills recorded by the subjects, to give actual before and after heating fuel and electricity expenditure, and the second from modelled data.

The analysis covers:

- percentage of income spent on fuels (actual costs), before and after measures (affordable warmth index)
- the same based on modelled costs
- carbon emissions reductions based on modelled changes
- a comparison of these figures for where actual costs are available

The complication in both is the price increases that took place in 2007-8. On average these were 15% across gas and electricity. The analysis of cost saving is carried out both in terms of what has been saved (or not) based on prices 15% different between before and after, and on a current price basis. This enables consideration of what the householder *would* have been paying had the measures not been installed. Oil prices have increased by more than 60% between summer 2007 and spring 2008, but the price paid varies depending on the actual date of delivery. When calculating the fuel saving from switching from electric or solid fuel heating to oil, a 15% increase in the electricity price is assumed. When calculating between oil boiler upgrades, a 50% price increase is assumed.

The subjects were invited to select their income decile rather than asking exact figures for income. This leads to a problems for calculating an affordable warmth index (AWI). Using the maximum of the decile range potentially gives a low AWI, but most of those in the lowest range were at the maximum of the range as they had claimed all the benefits to get them to that level. Using the mid-point of the range might be more appropriate for the rest of the subjects. One subject had a fluctuating income because of self–employment. So income has been estimated at the maximum for the lowest decile (category A), the average of the minimum and maximum for the self-employed household and mid-point for the rest. The 'before' income is adjusted to 95.5% of the current income, based on the 4.7% cost-of living increase in January 2008. (£100 in 2007 is £104.70 in 2008).

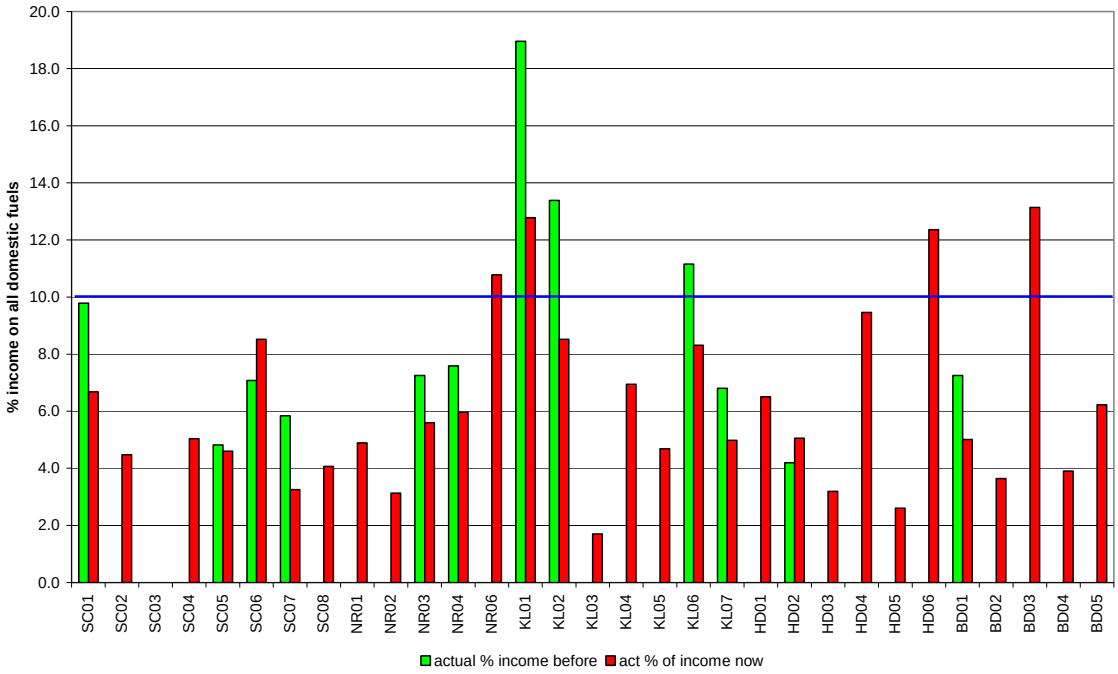

Figure 3: Actual fuel expenditure % of income (actual AWI)

Actual expenditure and affordable warmth

The first graph (Figure 3) shows the actual expenditure on fuels before measures were carried out (where known) as a percentage of the estimated income (adjusted for cost-of-living), compared with the expenditure afterwards on current income. The 10% line for fuel poverty is also shown. It can be seen that four appear to be in fuel poverty, NR06, KL01, HD06 and BD03. KL01 is off gas and now has an oil condensing boiler, and reports buying two-thirds of the oil they did last year. The rest are on gas. NR06 is in a solid wall home, BD03 is the very high carbon footprint household. HD06 had no comparison with the previous year and was using gas focal point as well as gas central heating (new condensing boiler) without awareness of the cost. SC06 and HD02 have total expenditure on fuels greater than last year. HD02 has an anomalous electricity reading which is being investigated. SC06 is discussed in the case study.

KL06 has been brought out of fuel poverty by the replacement of electric warm air heating with a gas condensing boiler, and SC01 (who is the subject of a case study) is less at risk of going in and out of fuel poverty on an irregular basis.

Table 7: Fuel spend and affordable warmth index before and after measures

	fuel spend % of income (AWI)			actual £ change in fuel spend	Fuel spend increase if had no measures
Code	Actual before	Now if no measures	*Actual now*		
SC01	9.8	10.8	*6.7*	-400	610
SC02			*4.5*		
SC03					
SC04			*5.0*		
SC05	4.8	5.3	*4.6*	0	128
SC06	7.1	7.8	*8.5*	165	70
SC07	5.8	6.4	*3.3*	-500	680
SC08			*4.1*		
NR01			*4.9*		
NR02			*3.1*		
NR03	7.2	8.0	*5.6*	-124	222
NR04	7.6	8.3	*6.0*	-120	222
NR06			*10.8*		
KL01	19.0	27.2	*12.8*	-500	1350
KL02	13.4	19.2	*8.5*	-400	1000
KL03			*1.7*		
KL04			*6.9*		
KL05			*4.7*		
KL06	11.2	12.2	*8.3*	-220	370
KL07	6.8	7.5	*5.0*	-280	460
HD01			*6.5*		
HD02	4.2	4.6	*5.1*	168	72
HD03			*3.2*		
HD04			*9.5*		
HD05			*2.6*		
HD06			*12.4*		
BD01	7.2	8.0	*5.0*	-180	278
BD02			*3.6*		
BD03			*13.1*		
BD04			*3.9*		
BD05			*6.2*		

Table 7 details the fuel spend as % of income (affordable warmth index) based on reported fuel expenditure, including supplementary fuels such as coal and wood. The first and third columns were represented in Figure 3. If no measures had been carried out, SC01 would have been in fuel poverty (family in hard to treat home, see case study), KL01 (a housebound elderly lady) would have been in dire straits, and KL02 in great difficulty. SC01 has a relatively high carbon footprint, largely due to the nature of the house, but the other two have small footprints.

The last two columns show the actual change in fuel expenditure reported, and a calculation of their fuel bills now had they not had the measures installed. Most of those who reported fuel savings have saved between £120 and £500 a year, if they had not had measures installed, they would have been spending up to £1350 more than the previous year, or more likely, they would not have been heating the house to a reasonable standard – or at least to the standard to which they were accustomed.

Modelled expenditure and affordable warmth

These figures have also been modelled using the ACE Fuel Prophet, in order to get an indication of the situation for those who did not have or were not able to provide information on the previous year's fuel expenditure. Details of the approach to the modelling is shown in appendix 2.

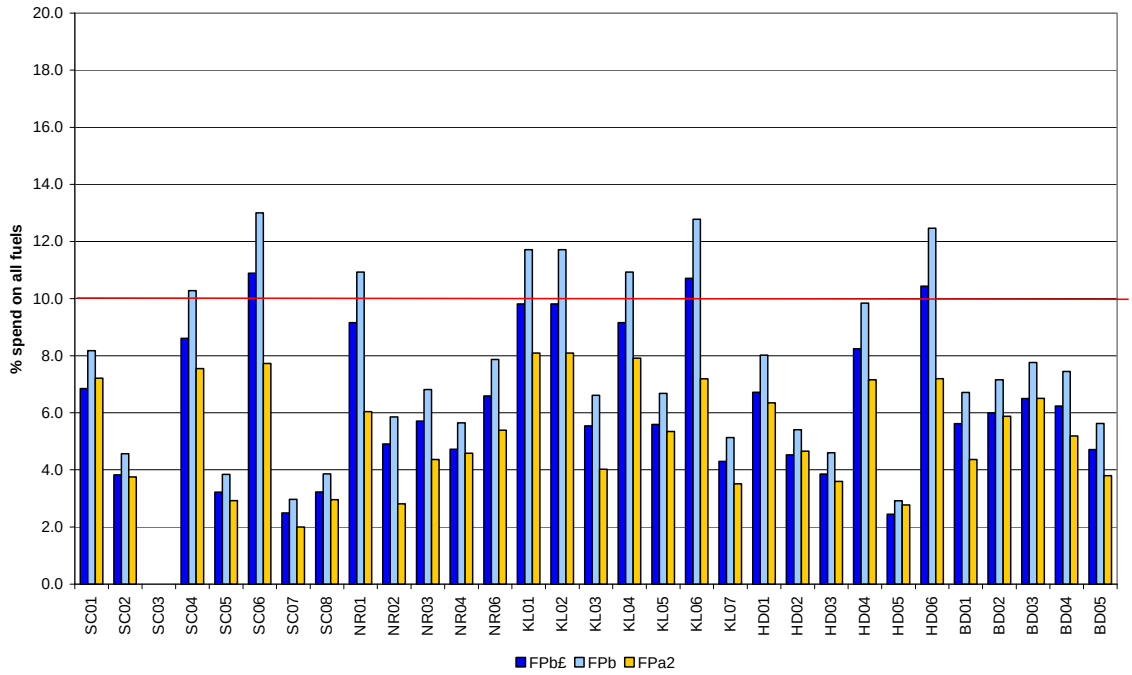

Figure 4: Modelled fuel expenditure % of income (modelled AWI)

In Figure 4 FPb£ represents the fuel expenditure based on previous prices and previous income (i.e. compares with 'actual before') according to the Fuel Prophet tool, FPb represents 'before measures on current prices and current income' i.e. what they would have been paying now if no measures had been done and FPa2 represents current expenditure on current income. The actual and modelled figures are shown alongside each other in Table 8.

Notice that according to Fuel Prophet, none of the households should be in fuel poverty now. This suggests that the homes are requiring more energy to raise them to a suitable temperature or there is an element of comfort taking, or the model's base buildings (with an adjustment for size differences) are not a suitable

description of the actual dwellings. However there is a reasonable fit between the 'actual after' and the 'modelled after', and also the 'actual before' figures where known, which is important for the estimation of carbon savings and hence reduction in carbon footprint that can be attributed to the measures.

Table 8 shows the data alongside each other for comparison.

Table 8: Comparison of actual and modelled AWI figures

	Actual AWI			Modelled (AFP) AWI			Note
Code	Before	Now if no measures	*Now*	Before	Now if no measures	*Now*	
SC01	9.8	10.8	*6.7*	6.8	8.2	7.2	HTT wall
SC02			*4.5*	3.8	4.6	3.8	
SC03							Declined response
SC04			*5.0*	8.6	10.3	7.5	
SC05	4.8	5.3	*4.6*	3.2	3.8	2.9	
SC06	7.1	7.8	*8.5*	10.9	13.0	7.7	Ex solid fuel
SC07	5.8	6.4	*3.3*	2.5	3.0	2.0	Ex electric
SC08			*4.1*	3.2	3.9	3.0	
NR01			*4.9*	9.2	10.9	6.0	Ex electric
NR02			*3.1*	4.9	5.9	2.8	HTT wall ex electric
NR03	7.2	8.0	*5.6*	5.7	6.8	4.4	
NR04	7.6	8.3	*6.0*	4.7	5.6	4.6	
NR06			*10.8*	6.6	7.9	5.4	HTT wall
KL01	19.0	27.2	*12.8*	9.8	11.7	8.1	HTT oil
KL02	13.4	19.2	*8.5*	9.8	11.7	8.1	HTT oil
KL03			*1.7*	5.5	6.6	4.0	
KL04			*6.9*	9.2	10.9	7.9	HTT oil + solid wall
KL05			*4.7*	5.6	6.7	5.3	Ex electric
KL06	11.2	12.2	*8.3*	10.7	12.8	7.2	Ex electric
KL07	6.8	7.5	*5.0*	4.3	5.1	3.5	HTT oil
HD01			*6.5*	6.7	8.0	6.4	
HD02	4.2	4.6	*5.1*	4.5	5.4	4.7	
HD03			*3.2*	3.9	4.6	3.6	
HD04			*9.5*	8.2	9.8	7.2	
HD05			*2.6*	2.4	2.9	2.8	
HD06			*12.4*	10.4	12.5	7.2	
BD01	7.2	8.0	*5.0*	5.6	6.7	4.4	
BD02			*3.6*	6.0	7.2	5.9	
BD03			*13.1*	6.5	7.8	6.5	
BD04			*3.9*	6.2	7.4	5.2	
BD05			*6.2*	4.7	5.6	3.8	HTT oil

According to the model, only 3 subjects would have been in fuel poverty beforehand, but 8 would have been by now had they not had measures installed. ACE Fuel Prophet models the fuel needed to maintain a standard heating regime, so if the household is being very frugal, it might be expected that the modelled figures are higher then the actual. The correlation between the actual and modelled figures is 0.68 which is quite good.

Carbon emissions and their reduction

The degree to which carbon emissions (and thus carbon footprint due to household use) have been reduced has been deduced from the modelled data where the 'before' data were not available. 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 Defra Illustrative Mix of measures (table 1) used for the CERT programme 2008-2011[26]. The resulting savings in carbon emissions (modelled or actual) are shown in Figure 5 added to the household carbon emissions 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 a fuel poverty or housing improvement programme have contributed to a (hypothetical) carbon emissions reduction programme.

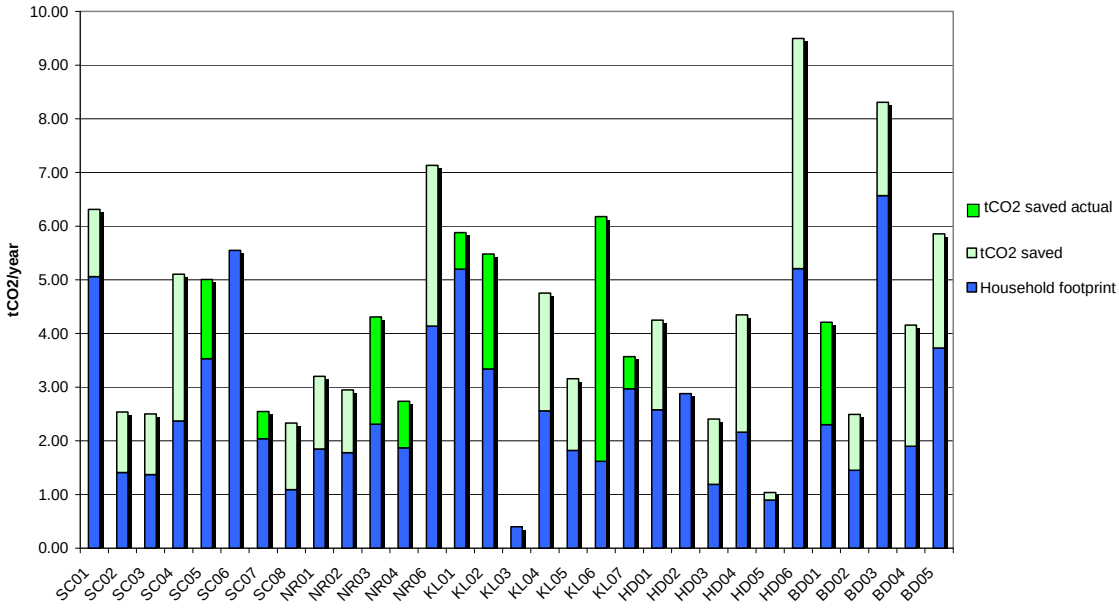

Figure 5: Household carbon footprint before and after measures

Three households are not shown as having a reduction. SC06 is discussed in the case study; overall fuel cost is up, but a small net carbon dioxide emissions reduction has been calculated. 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 the anomalous winter reading already mentioned.

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 only). Taking account of the overall carbon footprint, the reduction is 22% (1.71 on an average 7.83 before measures).

Value of the investment to LAs

This suggests that the investment of the five local authorities in these 31 households has given a carbon emissions reduction of 47.9 tCO_2 each year. It is not known what the cost to the LAs is, but an assessment of the cost to an energy supplier if these measures were installed under a CERT programme can be calculated using the Defra Illustrative Mix and is shown in Table 9.

This shows that the total cost of measures for these 31 households would be in the region of £30,000, an average of £980 per household. The total estimated CO_2 savings under CERT are also shown: these are estimated under the CERT

[26] Defra (2008) Explanatory Memorandum to the Electricity and Gas (Carbon Emissions Reduction) Order 2008. (2008 No 188).

tables to give 1.46 tCO_2 yr^{-1} assuming all were installed in 3-bed semi-detached houses. This compares with the modelled saving of 1.71 tCO_2 yr^{-1}, and the assumptions made in using the CERT tables here give a good degree of confidence in the higher, 1.71 tCO_2 yr^{-1} saving.

Table 9: Measures installed and estimated cost & CO_2 saved

Measure	Number	CERT cost £	Cost of measures £	CERT tCO_2 yr^{-1}	CERT tCO_2 lifetime	Total /yr	Total lifetime
LI	6	354	2124	0.31	12.53	1.86	75.18
LTU*	12	156	1872	0.27	10.75	3.24	129
CW	12	465	5580	0.63	25.37	7.56	304.44
Insl**	1	1882	1882	0.72	21.56	0.72	21.56
CGB	16	257	4112	0.36	4.28	5.76	68.48
CH***	6	2261	13566	4.06	81.22	24.36	487.32
OCB	5	257	1285	0.36	4.28	1.8	21.4
Totals	*58*		*30421*			*45.3*	*1107.38*
average			*981.32*			*1.46*	*35.72*

Abbreviations as per Table 4. *taking the values for a DIY loft insulation for a top-up; ** a grant was paid to the householder equivalent to the max available for a cavity wall home, CERT insulated wallpaper cost taken; *** fuel switching cost taken.

These calculations have been done assuming that the measures were installed in non-Priority Group homes for simplicity. The assumed CO_2 savings we have here are therefore similar to or greater than the calculated savings under CERT for the same set of measures and cost. This suggests that, provided the costs to the LA are not significantly more than under CERT, the value of delivering these types of measures to households at risk of fuel poverty is the same or better than delivering them to supposedly 'fuel-rich' households.

This suggests that if carbon reduction programmes are a priority to the LA, 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.

The question is 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 5 and Table 6, 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 chapter will explore any changes made to their lifestyles in more detail.

Case studies

The object of selecting five case studies from the survey group is to explore their changes in lifestyle and their carbon footprints in more detail. This aims 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 studies are:
A – Mrs F, an 80-year old widow living in a rented three bedroom mid-terrace house in Norwich City
B – Ms C, a lady in the 35-44 age group with three children, the eldest of whom has Down's syndrome 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.
C – Mrs W and her son who is her full time carer. Mrs W is in her eighties and had a stroke which left her with impaired mobility. She also has memory loss. They live in a 3 bedroom semi-detached house in a large Suffolk market town.
D – Mr & Mrs M who are recently retired, living in a 1960s three bedroom house in a small market town in Suffolk
E – Miss Y, aged 25-34, who lives with her daughter aged 4 in a semi-detached house in a rural village in Norfolk, off the gas network.

Case study A

Name	Mrs F	*Location*	Norwich City
Age	80	*Income decile*	a
Household	1	*Ref*	NR03
Act on CO_2 footprint	*Household*		2.37
	Appliances		0.77
	Transport		3.78
	Total Act On CO_2		**6.92**
Food			1.66
Waste			0.013
Water			0.053
Public transport			0.025
Total			**8.67**
Less Air travel in Act on CO_2			0
Total			**8.67**
House	3 bed mid terrace house, pre 1930		
Measures done	Gas central heating, part double glaze, CWI, loft insulation (DIY done by son)		
Heating	gas		

General overview
Mrs F is a widow living in the family home which has been rented for many years. She lives on her own but has frequent visits from family and friends, and makes occasional trips into the city.

Effects of having the measures
Her landlord installed the central heating and cavity wall insulation at her request through the council scheme eighteen months ago, and her son installed the loft

insulation which the landlord checked. It was been much easier to keep warm since then 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 and has been getting out and about more than when the house was colder.

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.

Waste

Mrs F lives in an area which was undergoing a change of waste collection system and now has three wheelie bins to tackle and find space for. The garden waste bin is usually full, but the recycling and household bins rarely exceed a quarter full on collection weeks. Her estimated annual household waste totals 943 kg of which 89% is recycled.

Water

A water meter was recently installed and Mrs F's bills dropped by £18 a month just for switching to the new system and being assessed by the water company. She is generally a low user, even though she uses a watering can to water her pots and plants at least once a day. Her annual use is calculated at 63,752 litres which may be an overestimate.

Food

Mrs F has a modest requirement for food and chooses fresh fish and occasional small cuts of meat rather than processed food.

Travel

Mrs F 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.

Affordable Warmth

Actual AW index now: 5.6
Actual AW index before: 6.9
Modelled AWI before, fuel price adjusted: 5.5
Modelled AWI before, current prices: 6.8
Modelled AWI now: 4.4
Living room temperature during March interview; 21 ˚C (70 ˚F).

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.

Case Study B

Name	Ms C	*Location*	Suffolk Coastal
Age	35+	*Income decile*	c-e (fluctuates)
Household	5	*Ref*	SC01
Act on CO_2 footprint	*Household*		5.06
	Appliances		0.15
	Transport		6.67
	Total Act On CO_2		**11.88**
Food			2.28
Waste			0.027
Water			0.042
Public transport			0.08
Total			**14.31**
Less air travel in Act on CO_2			0
Total			**14.31**
House	3 bed semi pre 1930s		
Measures done	Internal Insulation		
Heating	1) Gas 2)Coal/wood		
Special	Special needs son; infant son; hard to treat home		

General overview

Ms C lives in a traditional wooden construction 1900s house 30 yards from the sea in a rural village. The house is of original type timber frame with weatherboard exterior and a tiled roof. The central heating was installed some years ago, but because of the construction, the house was extremely poorly insulated, and gaps between the clapperboard exterior and the framework meant that draughts found their way into the house through cracks in the internal wall coverings.

The house did not qualify for the standard energy efficiency measures but the council determined that an equivalent amount of grant could be given to enable Ms C and her partner to insulate between the timber frame with Kingspan-type insulating board.

This was particularly important as it enabled the whole house to be warmer, and less reliance on secondary heating to maintain a warm room, especially for her eldest son who has Down's syndrome, and is affected by the cold especially in the night.

The insulation has been completed, and the next stage for them is to complete the internal walling in all rooms.

Effects of having the measures

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. Their income fluctuates as her partner is self-employed and he also travels a good deal, away most weeks in London or abroad. He is visibly better not worrying so much and less stressed. 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.

Food

Most of the shopping is done either at the Co-operative store, or the farm shop. Most milk chosen is organic, and the rest of the fresh produce may or may not be organic depending on value. Fresh meat selected tended to be British and fish from the Atlantic. Fruit and vegetables selected in store tend to have quite large air miles, but the total impact is reduced by that grown in the garden or purchased from the local farm shop.

Waste

The household waste bin is usually half to three-quarters full, and three-quarters of that will be nappies. Recycling is always overflowing, as is garden waste, but an arrangement with the neighbours (many of whom are holiday home owners so not present much of the year) enables her to use additional bins.

Bottles, plastic wrapping and other items are recycled at the recycling bank, and although waste officials have had to restrict the practice, sometimes she is able to pick up things like videos for the children, furniture and even a barbeque that someone else had dumped. Clothes also go to the charity shop, and 2 to 3 buckets of vegetable waste go on the compost heap each week.

Estimated annual waste 2,234 kg, with 90% being recycled.

Water

Ms C tries to economise on water use: for example, bathing all the kids in one tub of bathwater. The garden received just one bucket full in the monitoring period, although it was wet, and the car was not washed. She is thinking about a water meter. Having a family tends to promote higher per household water use, but her estimated use is quite low, so she might save money, at least while the children are still quite young. Estimated annual water use 60,944 litres (this is a much lower than average usage).

Travel

Both Ms C and her partner have cars, and her partner travels a great deal for his job, the diary including a return journey from Heathrow by train after a trip to South America (business travel). However the family also use their bicycles as well as the car for outings, and use the Park & Ride scheme into Ipswich 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 C 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.

Affordable Warmth

Actual figures include wood burner and some coal use; modelled assume only gas heating used. The base building used in the model is solid wall, but the actual building has a much worse U value to start with.

Actual AW index before measures: 9.8
Estimated AW index before, current prices: 10.8
Actual AW index now: 6.7

Modelled AWI before, fuel price adjusted: 6.8
Modelled AWI before, current prices: 8.8
Modelled AWI now: 7.2
Temperature in the kitchen-diner during interview in February: 18 ˚C

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 especially 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 AW Index was based on the mid range of the families' income; it fluctuates considerably due to the nature of Ms C's partner's work.

Note that 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 C 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 in AWI based on actual figures compared with the drop in the modelled figures suggests that Ms C has saved substantially through the application of the insulation boards (which can be seen in the close up picture taken in the small utility room), and that the grant to do this has therefore also had a greater carbon saving than that calculated by the model.

Case study C

Name	Mrs W & AW	*Location*	Suffolk Coastal
Age	75+	*Income decile*	a
Household	2	*Ref*	SC06
Act on CO_2 footprint	*Household*		5.55
	Appliances		0.55
	Transport		4.52
	Total Act On CO_2		**10.62**
Food			1.44
Waste			0.020
Water			0.047
Public transport			0
Total			**12.13**
Less air travel in Act on CO_2			0
Total			**12.13**
House	3 bed semi pre 1930		
Measures done	Gas boiler replacing coal back boiler.		
Heating	Gas and coal open fire		
Special	Disabled after a stroke		

General overview

Mrs W lives in a 1920s-30s semi detached house in a market town with her son Mr AW who gave up his job in internet publishing to become her full-time carer after Mrs W had a stroke which left her with limited mobility. She also has an unreliable memory, unable to recall recent events, but is otherwise alert and communicative. She spends much of her time in her sitting room, which has a nice (single-glazed) window onto her garden, but needs a warm room, and they decided to keep the coal fire which previously had been their main source of heating. The back boiler for the radiators and hot water was replaced with a gas condensing boiler under the council scheme.

The coal fire allows them to have one nice warm room ("toastie") while the rest of the house is cooler (but not so cold as previously). However, there is a floor level draught to allow the chimney to draw and there is a cool downdraught from the window also. Loft and cavity wall insulation were done about ten years ago. They are not sure whether it would be beneficial to have the window double glazed if they could find the money to do so.

Effects of having the measures

The central heating hasn't saved money overall (coal plus gas is more than previous coal alone) but it's made living easier. When one is 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 W needed attention in the night, was a very cold business (before the coal fire was lit) and Mrs W risked catching a chill. However when sitting in one room the coal fire gives a focal point and also a different kind of heat - both warmer and more comforting. "It would take a lot to stop us burning that coal".

They wonder whether it would have been possible to keep the back boiler going and somehow switch between the two – the coal fire heating the radiators when it was on, and the gas heating it at other times.

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.

Waste

A full or three-quarters full black bag is put out once a fortnight for household waste, and includes ash from the fire, which would make up one whole bag a month during October-May. Recycled paper is collected once a fortnight, but little paper reaches the bin as newspapers are used in the fire. The garden waste wheelie bin is usually full each collection, but sometimes the gardening may get a little behind, as on this occasion when only one binful was collected in the month. Mr AW is concerned at the poor facilities for recycling in the area, especially for plastics, and states that the facilities have got worse under the new regime, as disposal arrangements for householders have become too complex and expensive.

Estimated annual household waste 1610 kg of which 7% is recycled.

Water

Mrs W is on the So-lo tariff and metered by the water company (Essex & Suffolk). The six month estimate for this year was twice the actual reading for last year, so they expect a refund. The water footprint has been based on this year's readings. Estimated annual use 68,000 litres, which is low.

Food

Mrs W and AW eat modestly but treat themselves when they can to favourite foods like shortbread fingers. Most of the shopping is done at the local Co-

operative store. They like fresh local vegetables but don't grow them like they used to. Friends and family often bring round meals and dishes for them.

Travel

Because Mrs W needs a wheelchair, all her travel is in the car, which is an elderly estate that can cope with Mrs W 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 did they don't think it could be one of the compact ones as it would probably not be roomy enough for the party and Mr AW, who is tall.

Affordable Warmth

Actual figures have been adjusted for gas + coal use; modelled figures assume coal fire has been replaced by gas alone.

Actual AW index now: 8.5
Actual AW index before: 6.8
Modelled AWI before, fuel price adjusted: 10.4
Modelled AWI before, current prices: 13.0
Modelled AWI now: 7.7
Temperature in the living room during March interview was 20 ˚C – 68 ˚F.

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 W'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.

The disparity between the modelled and actual figures suggests that the thermal comfort given by the fire before was limited to the main room, and not used so much to heat the house using the back boiler; the model may assume more coal was needed to heat the whole house. However, the preference to keep using a coal fire to provide the necessary warmth in the living room, plus the comfort factor in having the open fire leaves the cost of dual fuels exceeding the original cost of coal alone.

Case Study D

Name	Mr & Mrs M	*Location*	Suff Coastal
Age	pensionable	*Income decile*	e
Household	2	*Ref*	SC05
Act on CO_2 footprint	*Household*		3.53
	Appliances		2.12
	Transport		2.64
	Total Act On CO_2		**8.29**
Food			1.60
Waste			0.013
Water			0.054
Public transport			0.036
Total			**9.99**
Less air travel in Act on CO_2			0
Total			**9.99**
House	3 bed semi 1930-95 (1960s)		
Measures done	Cavity wall and Loft Insulation		
Heating	gas		

General overview

Mr & Mrs M live in a 1960s semi detached house in a large village or small market town in a rural area. They are comfortably retired and able to enjoy a little bit of freedom, and to improve their house, with the recent addition of a small conservatory at the back, as well as the insulation package with the support from the council.

Effects of having the measures

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 M finds it gets too warm before the thermostat goes off and Mrs M 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 M likes to have a cool bedroom as she finds it gives her arthritis relief to keep her legs cool when in bed.

Food

The record for this month was quite scant, which may be because Mr & Mrs M were preparing to go on holiday. There was no meat or fish purchased, although they did say they had eaten out for lunch a few times so did not need an evening meal.

They are growing broccoli, broad beans and runner beans in their garden this year, and they also buy between a quarter and a half of their vegetables at the local market each week.

Waste

The household waste bin was about half full when emptied each fortnight, and the recycling bin was full or three quarters full. The garden waste bin was full when emptied, and two-three buckets a week went onto the garden compost heap. Mr M made two trips to the bottle bank and also took the overflow from the garden waste bin to the dump on one week, along with scrap metal and similar items.
Estimated annual household waste 1082 kg of which 81% is recycled.

Water

The water meter was read for a period of three weeks for this exercise, during which the garden pond was refilled, taking approx. 6000l. The calculation of the footprint has excluded that 6000l from the annualising process then added it in again, to give a best estimate of water use. The estimate annual use is very low for a two person household at 77,760 litres.

Travel

Mr & Mrs M enjoy an active lifestyle, with holidays and trips to the nearby towns, by bus when possible.

Affordable Warmth
Actual AW index now: 3.5
Actual AW index before: 4.3
Modelled AWI before, fuel price adjusted: 2.8
Modelled AWI before, current prices: 3.6
Modelled AWI now: 2.7
Temperature in the living room during March interview was 20 ˚C – 68 ˚F.

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

Case study E

Name	Miss Y	*Location*	Broadland
Age	25-34	*Income decile*	e
Household	2	*Ref*	BD05
Act on CO_2 footprint	*Household*		3.73
	Appliances		0.62
	Transport		2.34
	Total Act On CO_2		**6.69**
Food			0.86
Waste			0.006
Water			0.041
Public transport			0
Total			**7.60**
Less Air travel in Act on CO_2			0
Total			**7.60**
House	3 bed semi 1930-95 (1950s)		
Measures done	Oil boiler, but not TRVs, loft insulation top-up		
Special	Child now aged 4 (3 when work done)		

General overview
Miss Y and her 4 year old daughter live at the end of a small village about ten miles from the centre of Norwich. Miss Y works part-time as a teacher. The house is a spacious semi with a good sized garden in which Miss Y grows a range of vegetables. Cavity wall insulation had been done before Miss Y 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. The house is off the gas network.

Effects of having the measures
Although Miss Y 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 Y 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. In addition, the boiler comes on at night, to run the frost thermostat, and the heating comes on as well, even though she has it programmed for a two period on-off morning and evening. She is not sure who she should turn to for help with this as the installer was generally unhelpful when she contacted him about it.

Food

Miss Y and her daughter are vegan and eat no food of animal origin, which although not reflected in the food footprint used, is otherwise documented as being a low footprint lifestyle. Miss Y grows about half her vegetable requirements over the course of the year. Her main food shopping is done online with Tesco and she shops locally for top-ups. She doesn't generally select organic produce unless it is a good buy. Although the food footprint calculator does not accommodate purchase of soya-based produce rather than milk-based produce, she still has a low food footprint.

Waste

Miss Y is very keen to recycle as much as she can. She has a compost heap for food waste which is in turn used on the vegetable patch. The recycling bin is generally half full when it is collected, and general household waste mainly comprises plastic packaging as well as used or broken items that cannot be recycled. She collects tetrapaks and glass bottles to take to the local recycling depot about every 5 weeks, and a bag of clothes is taken to the charity shop at regular intervals.

Estimated annual waste 470 kg of which 67% is recycled.

Water

Miss Y has low water use per person and per household. She only occasionally uses the hose for the garden or car, and regularly uses about three watering cans a day for the garden. Estimated annual use 58,800 litres.

Travel

Miss Y is too far from the main road to give her opportunities to use the hourly/2-hourly express bus service between her two nearest towns, which is the only public transport option available. Her car is a Xsara, which has good fuel consumption figures and suits the needs of her family and friends.

Affordable Warmth

Actual AW index now: 5.8
Modelled AWI before, fuel price adjusted: 4.2
Modelled AWI before, current prices: 5.2
Modelled AWI now, 3.5

Rebound effects

Fuel bills have gone down since the work was done, which means that Miss Y finds it slightly easier to meet the everyday bills which are rising. The heating system does not give a balanced comfort so any notion of 'comfort taking' is inappropriate.

Comparison of Carbon Footprints

Table 10: 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	3 m-th, <1930, gas	3 s-dh. <1930, gas	3 s-dh. <1930, gas	3 s-dh, 1960s, gas	3 s-dh, 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**

The range of carbon footprints split into their various components are shown side by side in Table 10. 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 if 160 litres per person per day in unmetered properties, or in case studies C & D, which are metered, 150 litres per person per day. Indeed if the water diaries and measurements are correct, all of these case studies have a water consumption that is below the target for water consumption conservation. It is most likely that the diaries and average measurements are flawed, but this does not explain the meter readings.

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 $tCO_2\ yr^{-1}$. This is probably the most accurate assessment against the UK average, as the Act On CO_2 ignores the secondary effects covered by food, waste and water, and includes air transport, whereas the UK average is based on the total emissions for all ground based emissions and ignores air transport, divided by the number of households. For both B & C, both of which have vulnerable occupants, the additional emissions from heating their homes can be explained by the need for additional warmth and by specialist transport requirements.

Changes to lifestyles as a result of the measures

One of the main concerns prompting this study was whether saving money on fuel bills would lead to a more carbon intensive lifestyle, using other products. Although the case studies were 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 AW 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 C 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. 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 the Case Studies think about Carbon Footprint as a concept

Two of the case study people were well informed in this area – which both put down to an interest in current affairs and the benefits of Radio 4! All commented about the usefulness of knowing how much their footprint was, but what to do about it was more uncertain. Miss Y 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 F 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.

Indeed it would be very difficult to see what change of lifestyle could be recommended for these households, even though two have relatively high footprints, around the national average. They are not wasteful, as can be seen by the other elements of the footprint. The choice of Mr AW to continue with the coal fire is to provide his mother with the warmth and cosiness she needs. It becomes a moral judgement to suggest an 88 year-old invalid should give up this source of comfort. Ms C's relatively high footprint is for a five-person household including a son with special needs – again including a point source of warmth. The traditional nature of the house makes it harder to heat, but the insulated panels have made a demonstrable difference to their fuel consumption. The family is aware of their carbon footprint, and contain it as far as they can.

What the Case Studies think about Personal Carbon Allowances

The case study participants were asked what they thought of the option to buy or sell carbon credits depending on whether they had some to spare or would need to buy more assuming the trigger point (allowance) was 10 $tCO_2\ yr^{-1}$. It received a wide range of responses, only partly linked to whether their own footprint was above or below 10.

The moral issue seemed of more importance than the possibility of earning money. Mrs F was concerned about what they were going to do with the additional carbon allowance "if I was saving I wouldn't want other people to waste it". A level of altruism was shown: "If mine was going to someone with several children then yes – they could have what I didn't use". Ms C, being in a hard to heat home, was concerned about how they would manage and would try to cut it down, but was also concerned that it might affect the worse off in unfair way.

Mr AW was concerned that it was just another area where the law of unintended consequences would ruin the lives of ordinary people, and would turn out to be unworkable without huge bureaucracy. "PCA sounds very impractical, along the lines of elderly stakeholders/budget holders for care – practical issues are a nonsense." Mr M didn't think he'd buy any more, he'd cut down and go without. "Most likely to cut down heating". Having a relatively low footprint, he was appreciative of the difference between his lifestyle and others - "how to get others to reduce theirs is the big question". Miss Y was more optimistic: "If it worked it would be a good idea – would have to have practicalities right. I think people would focus on energy use more."

These five responses appear to cover the range of responses on the dialogue on personal carbon allowances recently addressed by Defra. However in asking the

question, the interviewer wondered at what level the price of carbon might lead to people selling carbon allowances they couldn't do without in order to afford other necessities, while the same amount was a pittance to much richer people.

Issues to be considered in policies relating to the case studies

- 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.

Issues in measuring and using carbon footprints

Comparing carbon footprints

The aim was to compare this survey sample with the general population to assess whether people who receive measures under an affordable warmth programme have lower carbon footprints than the general public.

Comparison of the carbon footprints of this group with a control group was intended to determine whether this group was significantly different from a group drawn from a wider cross-section of society. The control group was drawn from the database of the Climate Change project being run by Herefordshire Council, a Unitary Authority covering the whole of that county which is a similarly mixed rural/market town/ small city region. Both samples are biased in that both have an element of self-selection, i.e. people chose to take part. 327 people were in the Herefordshire database, but although both surveys use the same engine, the Hereford footprint was produced as a personal one, excluded air travel and included a food footprint. The average food footprint cited in their online report was 2.0 $tCO_2\ yr^{-1}$. Subtracting this from the control average, and rescanning the household one of the project survey to personal ones excluding air transport enabled a comparison to be made, although it is not robust. The calculation of Student's t-test comparing the two groups indicated that the survey sample was not significantly different from the Herefordshire control group.

This means 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.

The comparison with national and local averages has been discussed in the main results chapter. Most of the survey subjects were below local and national averages, which were taken from the EST Green Barometer report[27]. The question is whether these are 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 approach taken by the Green Barometer calculations is based on Defra modelling referenced in their report; when the total emissions in their report are summed, and divided by the total number of households, this gives a total UK emissions per household on 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 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.

[27] EST (2007) Green Barometer Report III, v2.

The REAP methodology developed by SEI[28] takes a slightly different approach but 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. The researchers are producing carbon footprint budgets for every local authority, and comparison with the EST's Green Barometer figures, used here, will be interesting.

This suggests that 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.

Comparisons with other research

The Resources and Energy Analysis Programme (REAP) has developed a number of carbon and ecological footprinting tools. Haq et al have looked in particular at the carbon footprints of the over 50s[29]. Citing Barrett et al, they identify the *per capita* footprint in age groups and suggested that the newly retired have higher carbon footprints. The results for the Fuel Poverty Carbon Footprint survey tend to support this finding, and although the numbers are very small in our survey, there is nothing that goes against the arguments made by Haq et al in the rest of their report.

Work carried out by CSE for Defra on the impact of personal carbon allowances on low income households[30] was based on modelling and not able to include a factor for air transport. They generally found that carbon footprint increases slightly with income until the highest deciles, when there is a rapid increase. However they observed that in the lowest deciles, the variation in carbon footprints is very wide, due in part to the variation in quality of the housing, i.e. its energy performance. This is supported by the trends in our small survey of actual footprints, adjusted for air transport to be consistent with the modelling approach.

A study by Caird and Roy of over 1000 households that had taken part in certain OU courses used Ecological Footprinting rather than carbon footprint to measure sustainability of the household[31]. The ecological footprint (EF) of a city's population is defined as the total area of productive land and sea fishing grounds required to continuously support the city's population using existing technology at their current levels of consumption, without becoming depleted or degraded, and so by extension, the ecological footprint of a household or an individual can also be defined by looking at the acreage required to support their lifestyle. Ecological footprints and carbon footprints are related, but the former takes account of other resource use. Nevertheless, comparing the two is useful because household energy and transport fuel use are the main components of the ecological footprint (about 80%) although the exact percentage varies between households and, as Caird & Roy show, between different characteristics of groups of households. Measurement of the ecological footprint is in ecocalories, 1 ecocalorie being approximately equivalent to needing 100m^2 of land for absorbing carbon dioxide emitted. In this commentary, the findings between characteristics of households

[28] http://www.resource-accounting.org.uk/

[29] Haq et al (2007) Greening the Greys – Climate Change and the over 50s. SEI, York

[30] Roberts S (2008) Carbon rationing: feasible and fair? Energy Efficiency Partnership for Homes workshop 30 April 2008

[31] Caird, S & R Roy (2006) Household Ecological Footprints - Demographics And Sustainability *Journal of Environmental Assessment Policy and Management* Vol. 8, No. 4 (December 2006) pp. 407–429

and their footprints are considered against the findings or our carbon footprint survey.

Their findings showed that households with only adults and children over 16 years had higher EF than those with children under 16, and when this was taken to the per person footprint, adults households had a higher per person footprint. This is a similar finding to that in our survey even with the small numbers of households with children. They also found that households with only adults and older children used twice as much energy in the home and also produced more waste (even than households with children using disposable nappies), which was put down to the greater number of appliances and the greater disposable income in these households. There is insufficient data to say whether this is generally supported in our survey of lower income households, but individual households fall into the pattern. Rural households were also found to have higher EF's than urban ones, which is on the whole born out in our survey.

Interestingly, the size of individual EF was found to vary with the number in the household in almost an identical way to that indicated in our survey, that individual households had a per capita footprint equal to twice that in a 2 person household, with further household members contributing to a lower per capita EF for the household. This is not surprising since the dominance of heating energy for the house is a major factor, but it reinforces the need for promoting household energy saving to individual and small households in order to reduce their carbon or ecological footprint.

The Caird & Roy study did not collect income data but this data was available for about 30% of the respondents. Analysis showed only a weak link between incomes and EF, and they suggested that other demographic data (employment in particular) may be more influential. This was particularly so because of the high EF of households where the head of household was not in employment. Their interpretation was of the need for household energy use, since more people were at home more of the time. This is relevant to our survey but the difference in carbon footprints is not so marked, probably because of the measures installed to make the homes energy efficient.

A study by Basham et al on central heating and housing[32] reviewed the 'before' and 'after' responses of 43 residents to central heating installation. As expected, the residents reported a feeling of a much warmer a drier home, as cited by most of our interviewees, and other issues such as interpersonal relationships, educational attainment and emotional well-being were highlighted as benefits worth emphasising in housing improvement, alongside more specific health benefits. Similar views were expressed by the Fuel Poverty Carbon Footprint participants as shown by the strong responses in Table 6 above to the questions on well-being and concerns about bills generally.

The 2007 Family Spending report [33] contains two tables that provide a reference for the survey group: detailed expenditure on electricity gas and other fuels by decile group and by age of reference person (taken to be head of household for this comparison). Allowing for the increase in fuel prices (and average of 15% for combined fuels was used, it suggests that our survey group spent slightly more on fuel in most deciles compared with the Family Spending Survey average. One might have liked to see the fuel costs rather below this, as the measures installed should have made the homes more energy efficient, but a large percentage of

[32] Basham M, S Shaw & A Barton (2004) Central Heating: Uncovering the impact on social relationships and household management. Torbay Healthy Housing Group, Devon

[33] Wood E (Ed) (2007) Family Spending 2006. ONS

families on low incomes would be in social housing, which are generally among the most energy efficient in the country, keeping the average fuel cost on the low side.

A similar approach was taken to comparing the figures split by age of head of household. Apart from the 30-49 age group, the figures are rather lower than the average for the Family Spending Survey. This is more encouraging; it suggests that energy use in home has been reduced, especially in the case of the 65-74 age group, a critical point at which to prepare them for reducing incomes.

In summary then, although the number in the Fuel Poverty Carbon Footprint survey leads to problems in comparison with other surveys, it supports the main findings on the population as a whole, which means that this group of people who have received measures under fuel poverty programmes do not have significantly different footprints from other groups in society. This is important when considering whether programmes to reduce carbon footprint would have less effect if promoted to people in lower income brackets. The variation at the lowest income level does appear to support the CSE modelling cited, that variation in housing quality has a major influence on the size of the footprint. This suggests that it is imperative to address the energy efficiency of homes of those in the lowest deciles.

Implications of the research

Although this survey was only a small study, it does provide some pointers to a number of issues that have so far been researched mainly through modelling.

The principal issue was whether it was worth local authorities directing their resources to households in fuel poverty if they were targeting carbon emissions reduction through their National Indicators.

The findings of this study are:

- carbon emissions saved through addressing this group appear to be slightly higher than the average that would have been credited for the same measures under CERT. This means that carbon savings have been realised at least as well as expected through energy and climate change programmes.

- there is no evidence that the money saved has been spent on anything other than general day-to–day expenses, under the conditions of rising food, tax, water and petrol prices, to say nothing of the price of fuel itself. During the concluding stages of this report a further increase in costs averaging 20% was announced by a number of energy companies, with a Centrica forecast of increases possibly as much as 70% reported in the press. Consequently the householders can at best stand still with their fuel costs, whilst the carbon emissions savings persist.

However, the average cost of measures appeared to be substantial, even bearing in mind the possibility of drawing in funds from a number of sources, including housing improvement and energy suppliers. Addressing those homes classified as hard to treat i.e. off gas or non-cavity wall or both, where they were treated under one of these programmes, contributed substantially to the warmth experienced by their occupiers. These occupiers were often elderly or with special needs and therefore among the most vulnerable in society.

Many of the people interviewed were very concerned to save resources, and use their income wisely. It is of some concern that despite the new measures, many of the first homes visited had daytime temperatures below the recommended level. Not only this, but those in the case studies were prepared to reduce their heating if there was a limit imposed on the amount of carbon emissions they were allowed under some future policy approach. Social justice was a motivation: the sense of playing their role in society through reducing their emissions (and water and through recycling from the case studies) and wanting fair-play between different sections of the community. Although not a question that was asked formally (unfortunately), many interviewees commented on their reason for participation, and a sense of gratitude towards the council was an oft-cited reason; the council had helped them so they were happy to give something back in return.

However, there was also a suggestion that an increasing number of policies directed towards some sections of society to change their behaviour made it impossible for others to manage, especially the elderly and less well-off. Changes in waste collections was an on-going issue in a number of the authorities at the time of the interviews, and a one-size-fits-all policy (quite literally) was hardly appropriate for an elderly lady with a small back yard who nevertheless produced a small amount of garden or food waste. She was now faced with another charge for its disposal, from a fixed income. Three of the case studies also had a chance to air their feelings on this subject.

Returning to carbon footprinting, it was clear that while some people would have been just as interested in any self-assessment test in a newspaper, others were genuinely interested in the outcome of the interview and potentially taking action. The standard report from the Act On CO_2 calculator appeared to be more geared to the newspaper quiz result, so the version sent to the participants was heavily edited to reflect their individual situations. The current vogue of promoting under-floor insulation was noticeable in all the initial reports (and deleted) despite the expense and great disruption that appears to make the measure applicable in only a very small number of cases. The comments that elicited most interest were information on energy use of different types of televisions, A rated appliances, and tips on eco-driving.

The difficulty experienced in matching the Act On CO_2 calculator to average emissions figures, plus the variation of footprints obtained when using a variety of calculators, even those ostensibly using the same engine (AMEE/dgen), suggests that we have a long way to go to get a standard, valid and reliable measure. It may not be advisable to press on regardless unless this can be sorted out. If we do, we risk losing public confidence in Carbon Footprints as a benchmark, which would undermine efforts to mitigate climate change in the same way that mishandled research reporting such as MMR vaccinations, salmonella in eggs and BSE in cattle undermined public health issues.

Recommendations for further research

However, as stressed throughout this report, the sample was small, and the findings, whilst interesting, cannot be classed as 'significant' with one exception. As far as the limitations on the data compatibility allow, the survey was notable in NOT being significantly different (statistically) from the Herefordshire control group. This is worth considering as the survey group had all received measures to make their homes energy efficient. Does this mean that the control group is similarly biased towards people who are already more energy efficient? It is possible, as both are self-select surveys.

It would therefore be worthwhile doing a larger study to assess carbon footprints and attitudes to reducing them, possibly at the time that measures are installed in order to reduce the bias of self-selection. This might also use the EST's classification of households for marketing purposes, cited in the Green Barometer report. With the wide range of footprints found in this small group it would be worthwhile trying to explore in more detail the types of lifestyles that can show a reduced carbon footprint whilst still enabling families to live modern lifestyles and elderly people to live in warmth and comfort. It is particularly important to study groups of urban and inner-city residents, as the majority of the participants in this survey were of a similar background.

It is also important to research the actual rebound effect of installing measures in households in fuel poverty. There is a problem in the logic of the current statement that comfort-taking runs as high as 30%, as the 'comfort' taken by the people interviewed here runs to achieving a "lovely warm home" which still has a living room temperature below the level of acceptability for being out of fuel poverty. Yet the modelled data on which the comfort-taking is based assumes people are exceeding these minimum temperatures. It may be simply a problem of redefining what is understood by the 'rebound effect'. The actual kWh usage before and after would be a valuable addition to the argument. Only when the direct rebound effects are clearly understood can we really consider the impacts of indirect rebound effects - such as spending money saved on heating bills on high carbon emissions items such as plasma televisions.

Defra's investigation of the potential for Personal Carbon Allowances has resulted in this concept being shelved at least for the time being. This is entirely

compatible with the comments expressed by the case study group. Further work is needed to identify interactions between different types of lifestyle carbon emissions and what is reasonable for different societal groups in order not to disenfranchise large sections of the population. If we can get more ideas of changes that work brought forward into the public eye rather than relying on installing measures that require investment, we may develop some aspirations to a different lifestyle that people find easier to adopt. Information is key in this, so initiatives by organisations like Tesco to carbon label their products[34] will be welcomed.

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http://www.tesco.com/greenerliving/cutting_carbon_footprints/carbon_labelling.page

Conclusions

This project established the carbon footprint for 31 households that qualified for energy efficiency measures under local authority programmes in the East of England using the Government's Act On CO_2 calculator.

The range of footprints discovered was from a very small 1.14 $tCO_2\ yr^{-1}$, to a fairly large 16.64 $tCO_2\ yr^{-1}$, compared with the national average at 10.2 $tCO_2\ yr^{-1}$. The mean footprint for this group was 6.12 and the median was 5.75 $tCO_2\ yr^{-1}$. The majority of the households had footprints around or below the average for their local authority. Compared with a control group from Herefordshire, the mean was lower than the control group but it was not significantly different. The control group was self-selected by response to an on-line project by the unitary authority in Herefordshire.

So from this small sample, no conclusions can be drawn about whether their footprints are significantly lower than the general population, nor whether the benefits of energy efficiency measures have contributed to a low footprint. However, it can be identified that the footprint would have been larger had the measures not been installed, by calculating the impact on fuel bills, and by estimating both the part of the footprint applicable to household energy use (heating, lighting and cooking) - household footprint - and the total CO_2 saved by measures applied to this group.

The average household footprint after measures was 2.68 $tCO_2\ yr^{-1}$, and before was 4.39, giving an average reduction of 1.71 tCO_2 each year, or 39% (of household only). Taking account of the overall carbon footprint, the reduction is 22% (1.71 on an average 7.83 before measures). Due to the rise in energy bills and costs in general, the lower fuel requirement for heating meant that most households were able to afford to heat and eat, with some but not much ease in worry about bills.

This gives a little information to help the argument about direct and indirect rebound effects. Direct rebound effects relate to using fuel to maintain a warmer house than before, because the household can afford to, and indirect effects are those where money is spent on activities in other aspects of the lifestyle that lead to carbon emissions. There was no evidence to show that these householders had increased their emissions of carbon dioxide through additional air travel or appliances such as plasma TVs, and because of difficulties with the survey there was no evidence gathered of the degree of direct rebound effect, i.e. the extent to which the householders heated their homes more as the cost of heating was lower. There is evidence that at least 20% of the survey group maintained a living room temperature below the recommended 21˚C, so that direct rebound effects that may exist were not at the level currently used in policy calculations.

The problem with the calculation of savings is that few of the survey group had actual data from before the measures, so actual fuel costs were supported in the analysis by modelled costs.

- Based on twelve actual records, three households were probably in fuel poverty before the measures were applied; one is still in fuel poverty. Assuming that the measures had not been installed and the previous fuel bills had been increased by an average 15%, the level of price increases in June 2008, an additional household would have been in fuel poverty now and the one still in fuel poverty would have been paying more than a quarter of her income on fuel.
- Based on the current actual fuel use and costs, four out of thirty may be in fuel poverty now. Two of these are in hard to treat homes. One prefers

his home to be kept warmer than standard, so may technically not be in fuel poverty although he is spending more than 10% of his income on fuel.

- Using modelling on all 31 homes to fill in the gaps, three households would have been at risk of fuel poverty before the measures were installed plus a further five would have been borderline. Had the measures not been installed, nine would have been in fuel poverty plus one more borderline, because of the fuel price increases pushing up the cost of home heating – assuming the homes were heated to the standard pattern and temperatures. According to the modelling, none of the households are technically now in fuel poverty.

This difference between modelled fuel poverty and actual data from individuals re-emphasises the difficulties with fuel poverty research. Not only is 'before' and 'after' monitoring intrusive, it is also expensive, potentially displacing funding for measures that could be installed for others. Yet thermal properties of the houses and particular comfort needs of the occupants mean that the models cannot provide all the answers for all the combinations. In addition, the assumption is made that the whole house is heated on the standard pattern (21˚C for the living room 18˚C elsewhere) - an accepted part of the fuel poverty definition that, at least in this study, bears little resemblance to the temperatures people like in their homes in order to feel comfortable. This suggests that research on thermal comfort in the home needs greater understanding – work on comfort in other buildings is relatively well advanced[35].

The amount of carbon savings that can be attributed to these 31 households is 47.9 $tCO_2\ yr^{-1}$. Both the actual savings - as evidenced by changes in fuel bills – and the modelled savings from the measures installed were assessed against the Defra assumptions for the energy suppliers obligation (the CERT programme). This showed that the assumed CO_2 savings for the survey households are similar to or greater than the calculated savings under CERT for the same set of measures and cost. This suggests that, provided the costs to the LA are not significantly more than under CERT, the value of delivering these types of measures to households at risk of fuel poverty is the same or better than delivering them to supposedly 'fuel-rich' households.

This suggests that if carbon reduction programmes are a priority to the LA, 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 also supported by the research on the variability of carbon footprints of households in the lowest income decile. However, this does not hold for programmes to save carbon directed towards the richest in society – the top decile. This means that different messages (and potentially measures) need to be directed towards 10% of our society. This leads to an interesting conundrum for local authorities. In the interests of equality of application of resources, where should the effort in carbon reduction go? The results of this research (supported by the CSE modelling on carbon footprints) suggest that standard measures, and measures for hard to treat homes, will both reduce carbon footprints *and* address fuel poverty in at least 50% (possibly as much as 80%) of the population.

The question is 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 5 and Table 6, is that comfort-

[35] See for example, the Network for Comfort and Energy Use in Buildings www.nceub.org.uk

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 main conclusion from this study is that there is as yet no evidence that people who receive measures under a fuel poverty programme are likely to use any money saved to spend on high-carbon emissions products and services. So the rebound effect, if any, does not seem likely to lead to an increase in carbon footprint. Whether this is the case for all types of households requires further study, but the findings here suggest that a robust study using kWh measurements before and after as well as fuel costs could ease the decision-making of local authority policy-makers when deciding the focus and funds allocation for housing improvement or climate change programmes. One of the facets that also needs further exploration is the value of those programmes that improve so-called hard to treat properties – off the gas network and/or with walls that cannot be filled using cavity wall insulation - as the carbon savings and social benefits for vulnerable people in these homes suggest there may be a double benefit and comparatively greater carbon savings than hitherto calculated.

Appendix 1: Interview plan and questionnaire

Introduction
Purpose of the research
I'd like to note the room temperature while we talk is that ok?

What energy efficiency measures did you have done
When
I'm going to go through the carbon footprint calculator now, then come back to a few more questions at the end

(After calculator)
Have you noticed any difference in your fuel bills since the work was done
(Yes, up, down, down then up after price rises recently, no, no change to direct debits)
How much were your bills before the work was done (estimate is fine)

gas
electricity

I'm going to show you a list of possible things that may have changed since the work was done
Please tell me every one that you think applies

It's been easier to keep warm
The temperature indoors has been quite variable
It's been difficult to keep a comfortable temperature
I've been able to afford things like food and clothing more easily
I've bought some thing(s) I've been saving up for
I've been feeling better in myself
I've treated myself/my family to some thing(s)
I've not been so worried about bills
I've been more worried about bills
There are some problems relating to the work which havent been fixed
I've been getting out and about more
I'm planning to do something I wouldnt have done before

(probe answers)

Finally, I need to ask about your age and income groups
Please would you point out your age range on this sheet (table A1)

and your income range on this sheet, its group in weekly, or monthly, or yearly, whichever you find easiest to think in. (table A2)

How many adults in household
How many infants under 3
How many children under 12
How many children 12-18

employed f/t
employed p/t
retired
student
long term illness or disability
u/e
self-employed

That's it. The temperature while we've been talking has been

Thank you very much for talking to me. One thing before we finish is that I need to find five people who are willing to do a more detailed study. This would involve you keeping a diary of what you do for two weeks (I will supply that diary). Would you be willing to be considered for that?

I'll send you a report on your carbon footprint (and the information about what the detailed study would involve for you to think about).
Any questions you have before I go?

Thank you once again.

Table A1: Age range

Please would you point out your age range on this sheet

16-24
25-34
35-44
45-54
55 - pensionable age
Pensionable age – 74
75 +

Table A2 Income (weekly, monthly, yearly)

Income range – weekly

A	Up to	180
B	181	245
C	246	290
D	291	330
E	331	385
F	386	450
G	451	525
H	525	640
J	641	more

Income range – monthly

A	Up to	780
B	781	1060
C	1060	1245
D	1246	1435
E	1436	1670
F	1671	1940
G	1941	2275
H	2276	2760
J	2761	more

Income range – yearly

A	Up to	9390
B	9391	12720
C	12721	14950
D	14951	17230
E	17231	20000
F	20001	23280
G	23281	27290
H	27291	33120
J	33121	more

Appendix 2: Analysis of the survey group carbon footprints

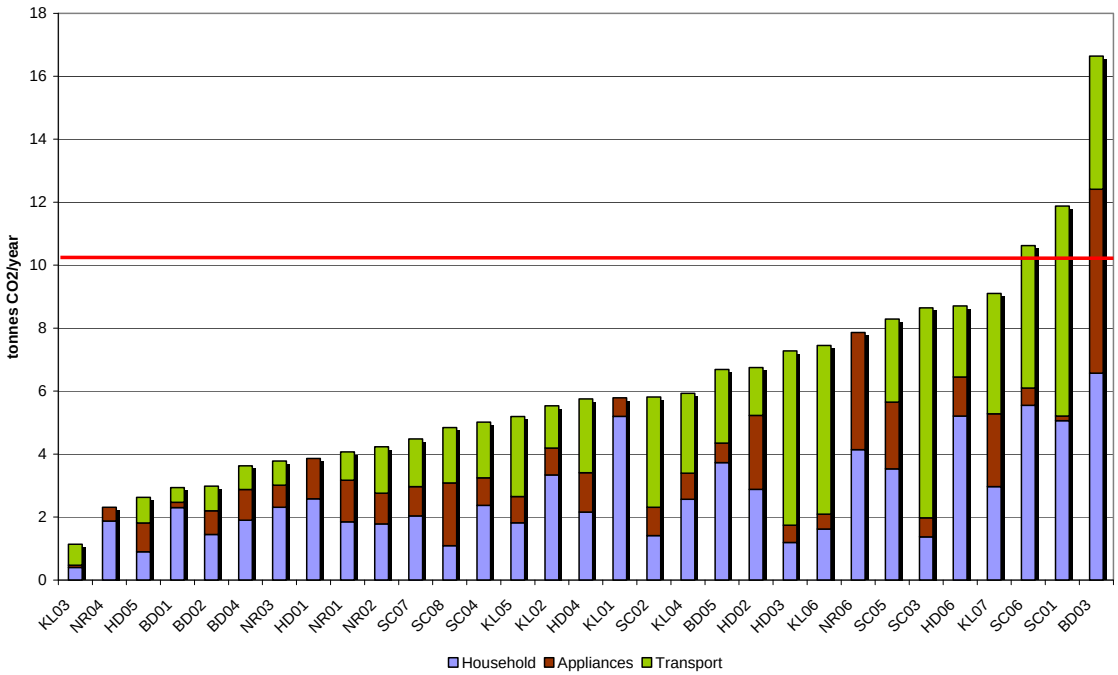

Figure 6: Carbon footprints, low to high

The carbon footprints were prepared using the Act On CO_2 calculator, and are shown in Figure 2 above. Most of these are below the UK average of 10.2 tonnes CO_2 per year.

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 is a single person, retired, living in a small modern terraced house, who believes in low resource use and keeping fit. He is proud of his low emissions car which he spent some time researching to get the best to suit his purposes, but he doesn't use it very much, and apologised to me for driving to nearby countryside to go running, but he found it a bit too far to cycle. He also saves on hot water costs (and water charges) as he swims three times a week, so showers at the local pool. By contrast, BD03 lives in a large house with good public transport access which he uses, as he doesn't drive for health reasons. He likes a warm house, and particularly at night if he is up late or his niece is studying, they will use electric fires for warmth rather than using the central heating. This, plus the ownership of the plasma TV which is often left on stand-by, explains the very high heating and appliance footprint, which is topped off by a high travel footprint as he and his wife fly to Asia twice a year to visit relatives.

This basic carbon footprint was compared at the time of the interviews with the UK and local authority averages, with most subjects being comfortably below both. The footprints, grouped by LA and with the LA averages drawn from the Green Barometer report[36], are shown in Figure 7.

[36] EST (2007) Green Barometer Report III, v2.

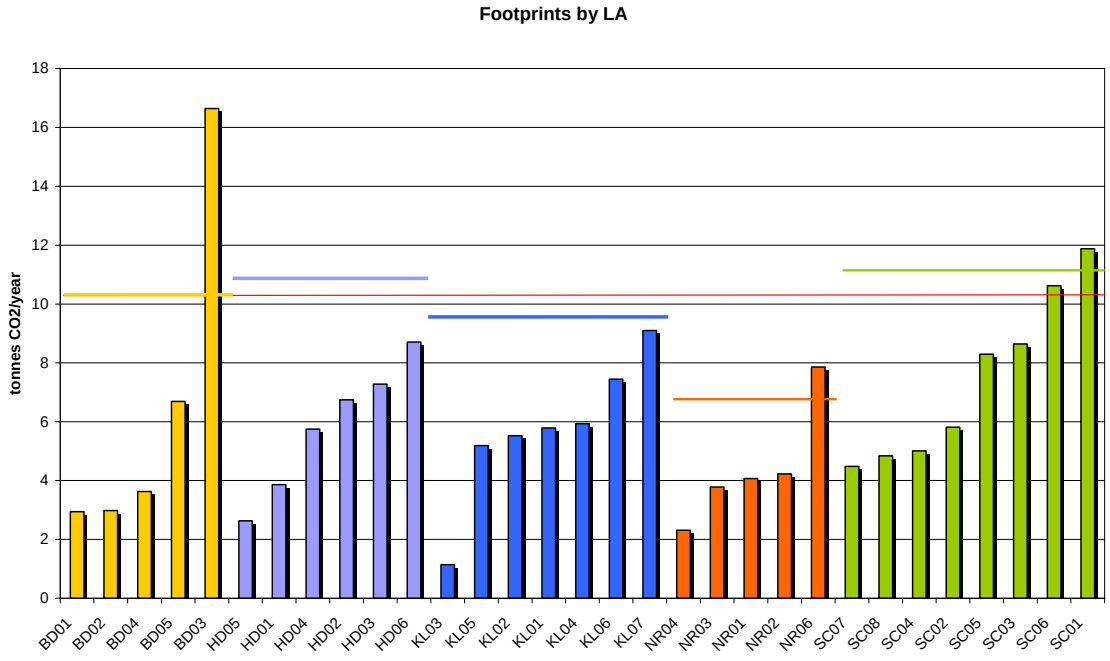

Figure 7: Footprints by local authority, with average lines

This shows the variation in the averages for the areas with Norwich City, at 6.8, very much lower than the others. It could be speculated that the compact nature of the urban area and the availability of public transport might be factors in this. Interestingly, BD01, 03 and 04 are within streets of the Norwich City-Broadland boundary. The figure 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.

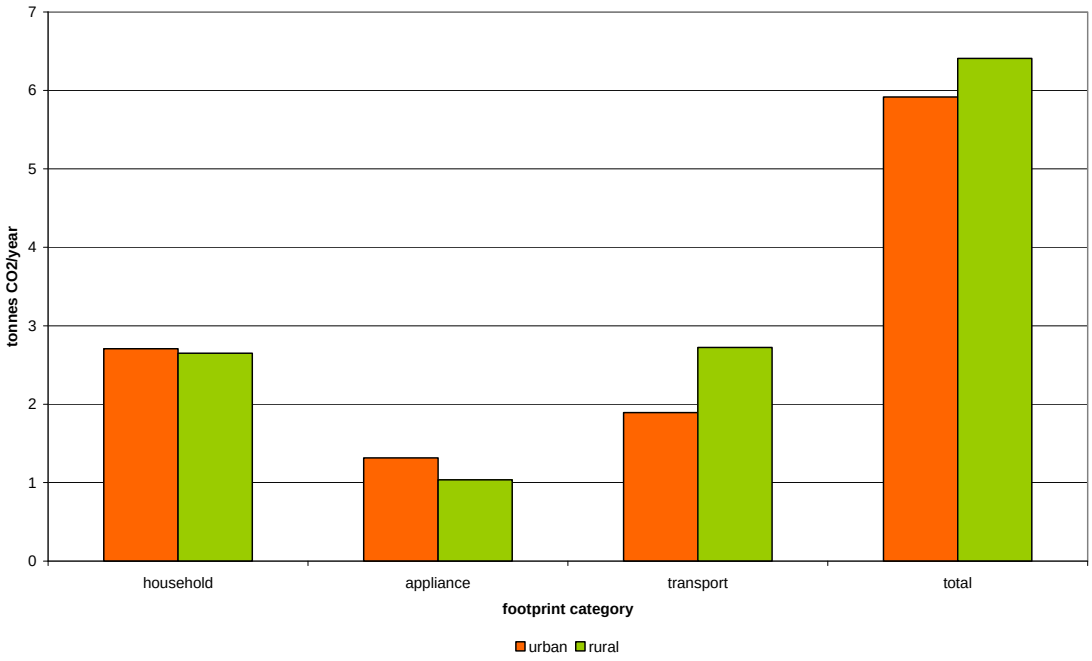

Figure 8: Average footprints, urban vs rural dwellers

These LA areas can be further examined in the light of growing evidence of a distinction between footprints of rural and urban dwellers. The LAs each have provided both urban and rural interviewees, with the exception of Norwich City. Although looking at the individual footprints there is no significant difference between the two (the highest footprint is urban, the lowest is also), the averages

of the two groups show a slight tendency for the results of this survey to support urban-rural distinction, as shown in Figure 8. This shows a large difference between the transport footprints, but not at a statistically significant level.

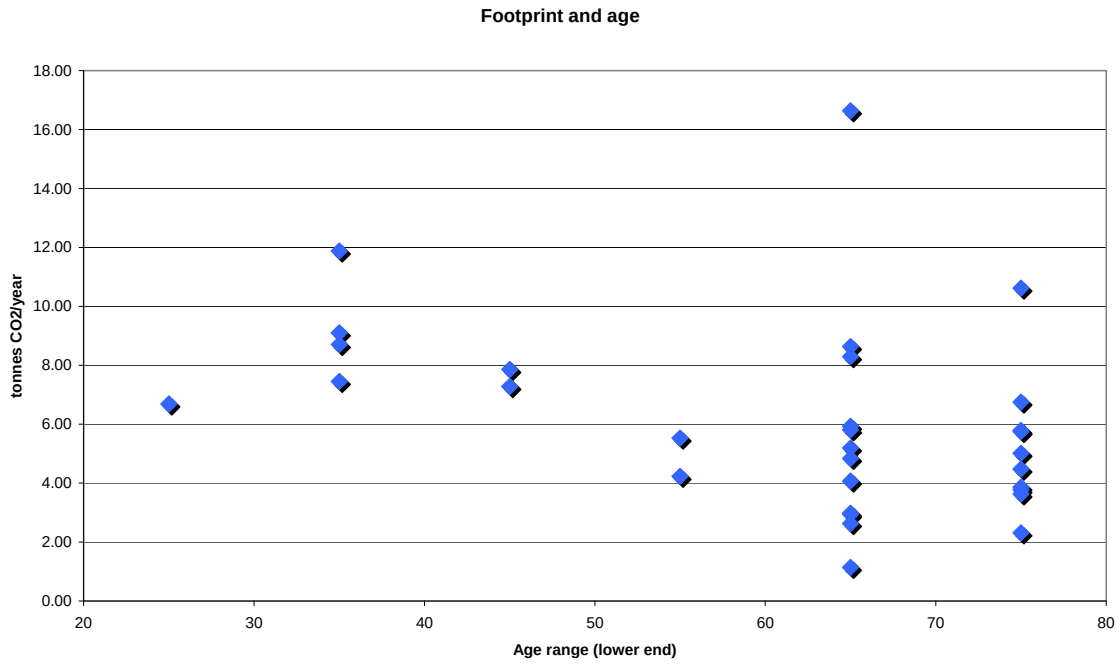

Figure 9: footprints by age range

Figure 9 shows the footprints with age distribution. The medians of those in the working age group are above the medians of the retired groups, but the numbers are too small to make judgements here. It is tempting to suggest that transport becomes a less significant factor after retirement, and this may be linked to income.

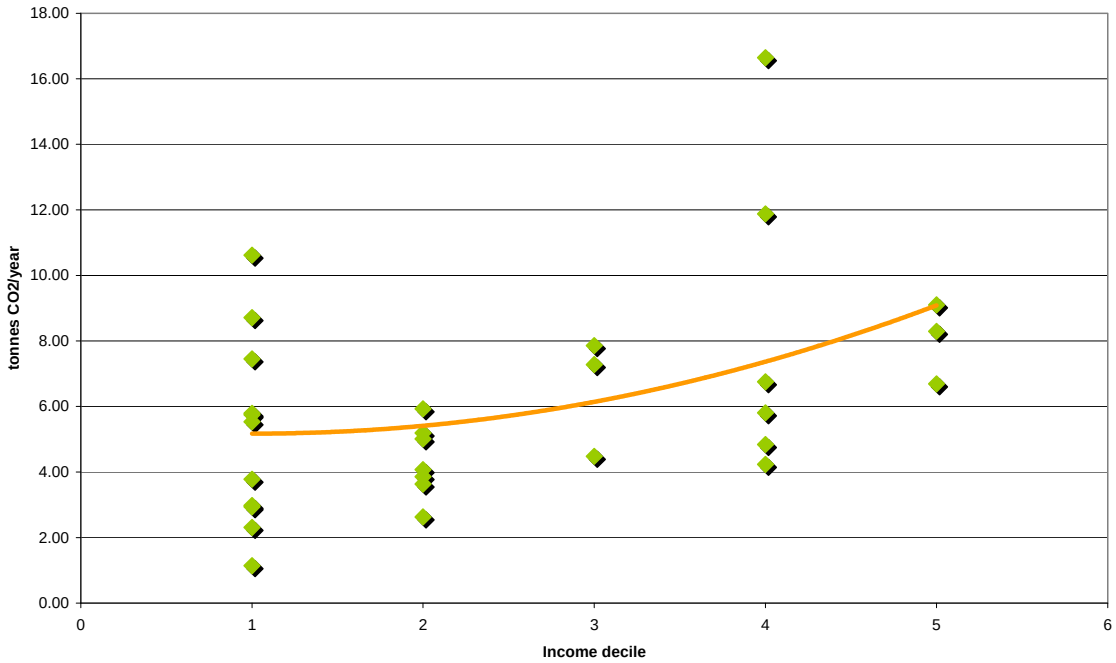

Figure 10: Footprints by income decile with trendline

The trend line (polynomial factor 2) shown in Figure 10 is suggestive of the work done by CSE for Defra on footprints distribution by income[37] which shows a relatively flat line for the lower deciles with a 'hockey stick' curve at the two upper deciles. The range of footprints in the lowest decile in our survey and also supports their view of a wide range of footprints at the lowest decile linked to poor housing.

The footprint by the number in the household shows the likely increase in footprint the more people are in the household (Figure 11) and the footprint per capita emphasises that single person households have a higher per capita footprint (Figure 12), supporting other research on domestic energy use and household size.

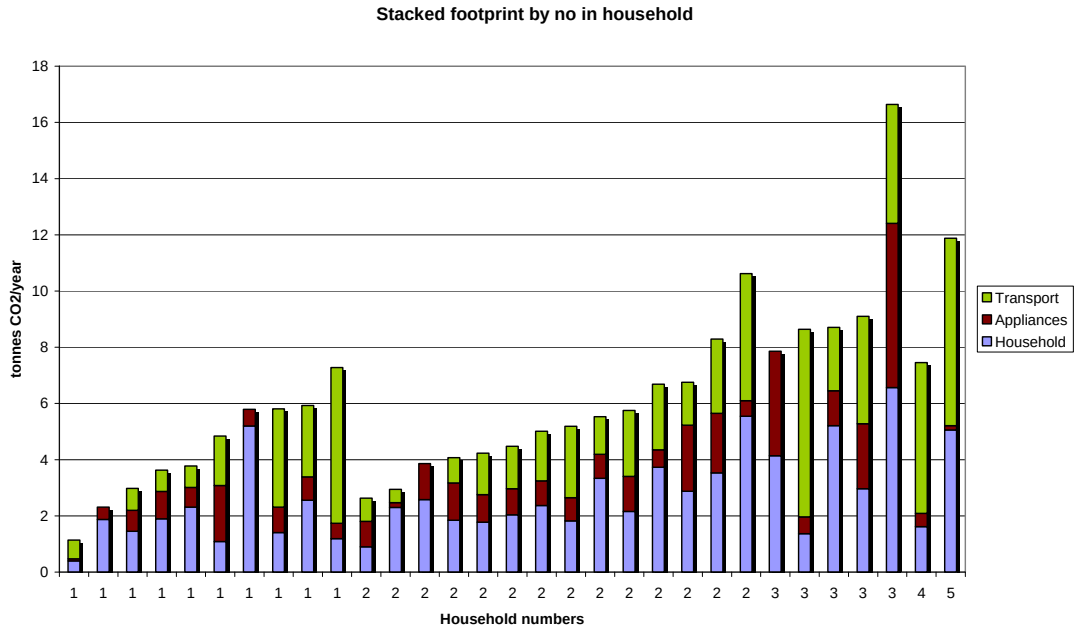

Figure 11: Footprint by number in household

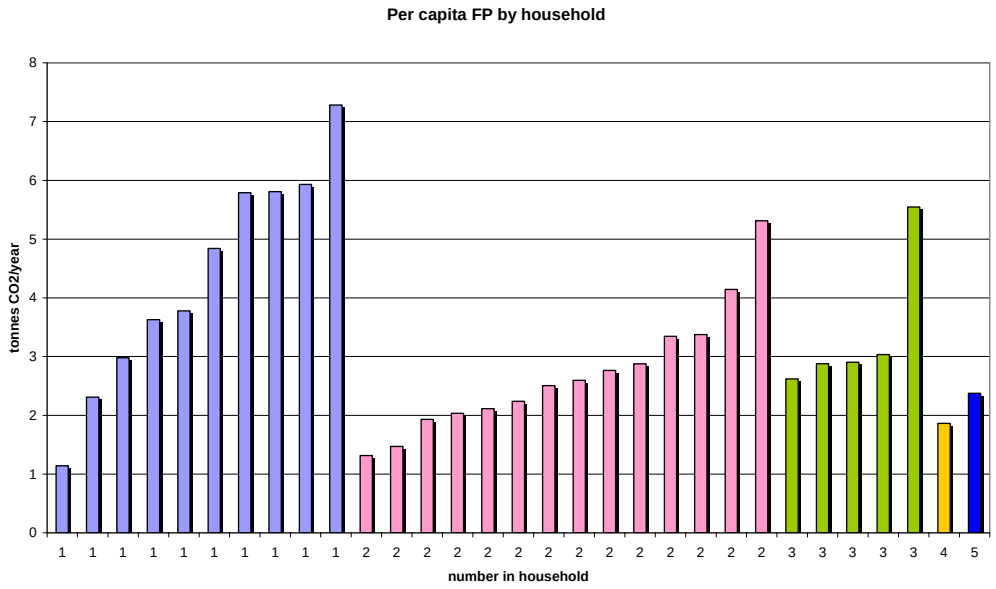

Figure 12: Per capita footprint

[37] Roberts S (2008) Carbon rationing: feasible and fair? Energy Efficiency Partnership for Homes workshop 30 April 2008

The final graph of footprint looks at the footprint by house type. The Energy Performance of the dwelling was not a factor that was measured in this study, but they are grouped according to the basic type, e.g. 2 bedroom end of terrace house, 3 bedroom detached bungalow, etc.

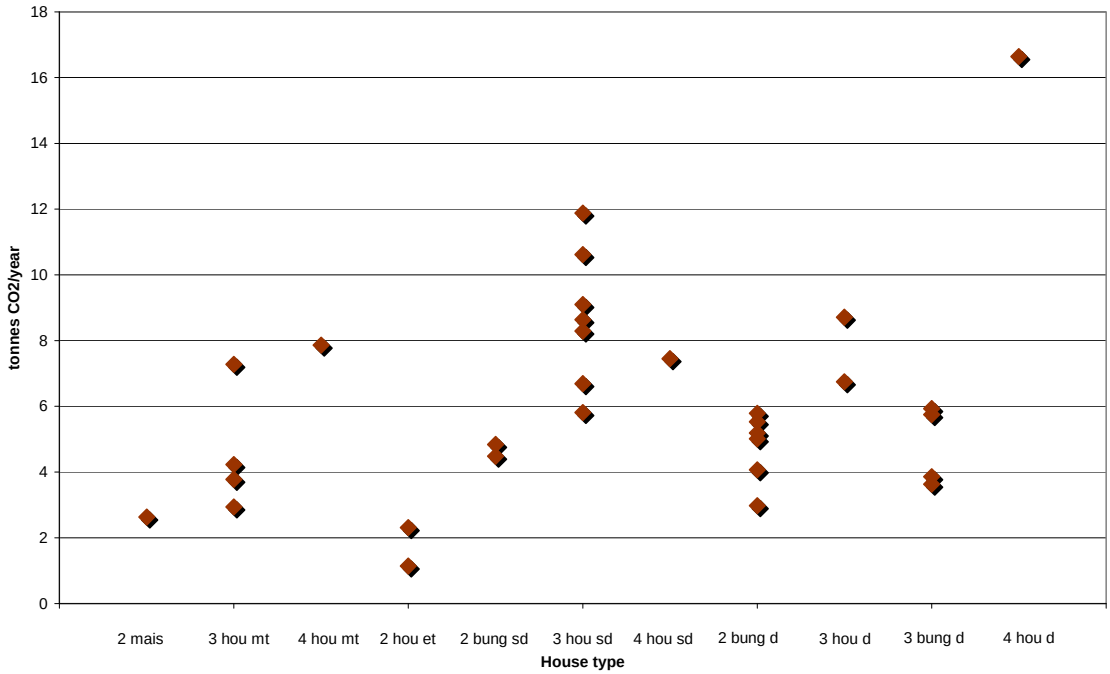

Figure 13: Footprint grouped by house type

There are some general theories that could be drawn from this, 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).

Appendix 3: Modelling Approach

Modelling for the fuel costs and measures done was undertaken using the ACE Fuel Prophet tool (AFP) v2 www.fuelprophet.org.uk .

The first stage was to identify for each house a benchmark fuel cost now, based on the building type and the measures done. AFP is designed to work the other way round, i.e. working from an unimproved building, select energy efficiency and renewable energy measures to identify the required cost saving (or the optimum cost saving for the investment in measures).

So in this case, the best fit for the base building was selected, e.g. 3 bedroom cavity wall semi-detached with basic gas heating, or 2 bedroom solid wall terrace with electric storage or open fire, and find the measures that had been installed in order to get the best fit profile for the survey house after measures, e.g. 3 bedroom cavity wall semi with CWI, loft insulation and gas condensing boiler, or 2 bedroom solid wall terrace with loft insulation and oil central heating. The cost of fuel for the 'improved' building was taken as being the high or very high fuel cost result for the base building less the saving displayed for these measures.

A multiplying factor was used to account for differences in size of the dwellings compared with the base buildings in AFP. This is similar to the treatment of private versus social housing in Defra's Illustrative Mix.

The aim was to find a fuel cost for the improved home that was similar to, or at least not too far away from, the stated fuel costs in the interview. In some cases specific needs for warmth or comments about keeping the house warmer than standard had been made, this was taken into account when selecting the modelled result.

Once this had been achieved for the dwelling, the 'before' cost was estimated on the basis of the unimproved cost, or where partial measures had previously been installed, the base fuel cost less the saving of the partial measures.

Finally, the 'before' cost was adjusted for fuel price rises by reducing the 'before' fuel cost by 15% for gas or electricity and 50% for oil, to represent the price increases since the work was done. The basis for these are stated in the text.

The carbon emissions from heating these homes were calculated using the carbon footprint data, i.e. standard emissions factors for the various fuels within Act On CO_2, which are taken from the BERR energy data, but this did not help to identify the carbon emissions savings due to the measures. The annual and lifetime CO_2 savings due to the measures were taken from the Defra Illustrative Mix.

As the fuel use assumes that a standard heating pattern is used, some variation is to be expected between the modelled results and the actual costs reported. In particular, the majority of those interviewed were at home all day, although many used a modified twice a day heating pattern. During the first phase of interviews (14 in February and March) a thermometer was used in the living room while the interview was in progress, to get a benchmark for the temperature. Only one of the 8 interviewed in Suffolk Coastal reached the standard assumed 21 ˚C, and this one exceeded it, although the heating was not on – the living room faced south and it was a sunny day. Of the 6 in Norwich City, all were in the 20-22 range. It should be noted that the thermometer had not been calibrated so this should be used for information only.

However this suggests that for some areas at least, the fuel costs described may not be bringing the dwelling to the standard pattern, although the modelled data

assumes that it is. Therefore, if anything, the modelled costs should be higher than the actual costs reported.

The table on the following page shows the results of the modelling.

It shows for each house the type and heating fuel (after), the original measures if any, and measures installed. Solid wall houses show one y/s i.e. yes –solid wall insulation, and three n/s – no solid wall insulation. Ewa is electric warm air heating, the rest of the electric heating was storage. The other less usual headings are GB-gas boiler, OF-open fire, SF- solid fuel (boiler), LTU – loft top-up, OB-oil boiler. Costs before and after where reported are for electricity and heating fuel (gas or oil plus supplementary where appropriate). Costs after in bold are actual payments, otherwise are based on direct debit payments.

Carbon savings were based on AFP cost savings. SC06, HD02 were known to be spending more (see text), KL03 was using so little that a reliable figure could not be estimated.

AFP b and a are the modelled before and after cost for a standard size building of the type named, the next column estimates how much larger or smaller the dwelling might be compared with the AFP base building (1 is the same size). This then multiplies the standard AFP figures into the next two columns AFPb2 and AFPa2, which were used to indicate fuel use and carbon savings. The final column AFPb2£ adjusts the AFPb2 figure to account for fuel price rises between the two sets of figures, so AFPb2£ should reflect what people were paying before measures installation, whereas AFBb2 reflects what they might have been paying in June 2008 had the measures not been installed. Note that AFP figures are for total household energy use, and should be compared with the total of the actual electricity and fuel costs. There has been no adjustment in the actual electricity costs for appliance use.

There are clearly some results where actual costs do not match the modelled ones well, but for the most part these can be explained from comments about the lifestyle of the household concerned, and they tend to be outliers in the carbon footprint as well.

Table 11: Modelled data for fuel costs and carbon savings

		Measures before								Measures installed								Cost B4		Cost after		C saving calculations				AFP before, after, size and price adjusted					
Code	House	Fuel		LI	CW	GB	CH	ES	OF	SF	LI	LTU	CW	Insl	CGB	CH	OF	OB	£e	£f	£e	£f	cost saving	Gas	Oil	Switch	tCO/yr saved	AFPb	AFPa	sizing	AFPb 2	AFPa 2	AFPb 2£
SC01	3-hou-sd	gas	1	y			y			y				y/s			y				200	800	*144*	*1250*			*1.25*	1020	900	1.2	1224	1080	979
SC02	3-hou-sd	gas	1	y			y						y								**300**	**415**	*130*	*1128*			*1.13*	730	600	1.0	730	600	584
SC03	3-hou-sd	gas	1	y									y								250	300	*130*	*1128*			*1.13*	730	600	1.0	730	600	584
SC04	2-bung-d	gas	1	y								y	y								300	280	*315*	*2734*			*2.73*	790	580	1.5	1185	870	948
SC05	3-hou-sd	gas	1	y		y	y					y	y		y				**400**	**300**	400	450	*170*	*1476*			*1.48*	**710**	540	1.0	710	540	568
SC06	3-hou-sd	gas	1	y	y				y	y					y		y		**175**	**460**	**190**	**610**						**1110**	660	1.1	1221	726	977
SC07	2-bung-sd	gas	1	y	y			y				y			y				**1200**		**300**	**400**	*210*			*504*	*0.50*	640	430	1.0	640	430	512
SC08	2-bung-sd	gas	1	y	y										y						400	250	*143*	*1241*			*1.24*	560	430	1.1	616	473	493
NR01	2-bung-d	gas	1	y				y					y		y						**226**	**338**	*564*			*1354*	*1.35*	1050	580	1.2	1260	696	1008
NR02	3-hou-mt	gas	1	y				y				y		n/s	y						**300**	**200**	*486*			*1166*	*1.17*	1040	500	0.9	936	450	749
NR03	3-hou-mt	gas	1						y		y		y		y	y			**250**	**400**	**250**	**276**	*230*	*1996*			*2.00*	**640**	410	1.0	640	410	512
NR04	2-hou-et	gas	1	y	y	y									y				**220**	**460**	220	340	*100*	*868*			*0.87*	**530**	430	1.0	530	430	424
NR06	4-hou-mt	gas	1				y				y			n/s	y						**800**	**700**	*345*	*2995*			*2.99*	730	500	1.5	1095	750	876
KL01	2-bung-d	oil	2	y	y				y	y							y	y	**200**	**1500**	**200**	**1000**	*340*			*680*	*0.68*	**1100**	760	1.0	1100	760	880
KL02	2-bung-d	oil	2	y			y			y		y						y	**300**	**900**	**300**	**500**	*340*		*2140*		*2.14*	**1100**	760	1.0	1100	760	880
KL03	2-hou-et	gas	1	y					y			y			y	y					**60**	**100**						690	420	0.9	621	378	497
KL04	3-bung-d	oil	2	y			y							n/s		y		y			**200**	**600**	*348*		*2191*		*2.19*	1050	760	1.2	1260	912	1008
KL05	2-bung-d	gas	1	y		y						y	y			y					200	340	*154*	*1337*			*1.34*	700	560	1.1	770	616	616
KL06	4-hou-sd	gas	1	y	y			y							y	y			**1000**		**480**	**300**	*525*	*4557*			*4.56*	800	450	1.5	1200	675	960
KL07	3-hou-sd	oil	2	y	y			ewa										y	**1200**		**480**	**440**	*300*			*600*	*0.60*	790	540	1.2	948	648	758
HD01	3-bung-d	gas	1			y	y				y		y								250	500	*192*	*1667*			*1.67*	770	610	1.2	924	732	739
HD02	3-hou-d	gas	1	y	y							y							**320**	**320**	**408**	**400**						**720**	620	1.2	864	744	691
HD03	3-hou-mt	gas	1				y				y		y								**178**	**266**	*140*	*1215*			*1.22*	640	500	1.0	640	500	512
HD04	3-bung-d	gas	1			y	y				y		y								**288**	**600**	*252*	*2187*			*2.19*	770	560	1.2	924	672	739
HD05	2-mais-u	gas	1			y	y				y										**150**	**150**	*16*	*139*			*0.14*	420	400	0.8	336	320	269
HD06	3-hou-d	gas	1	y		y						y	y		y		y				**360**	**800**	*494*	*4288*			*4.29*	900	520	1.3	1170	676	936
BD01	3-hou-mt	gas	1	y		y	y					y	y		y				**200**	**450**	**200**	**270**	*220*	*1910*			*1.91*	**630**	410	1.0	630	410	504
BD02	2-bung-d	gas	1	y	y										y						**171**	**171**	*120*	*1042*			*1.04*	560	460	1.2	672	552	538
BD03	4-hou-d	gas	1	y	y										y	y					1100	1000	*200*	*1736*			*1.74*	620	520	2.0	1240	1040	992
BD04	3-bung-d	gas	1	y	y	y	y					y			y						250	200	*260*	*2257*			*2.26*	660	460	1.3	858	598	686
BD05	3-hou-sd	oil	2	y	y							y					y				150	**1000**	*338*		*2128*		*2.13*	800	540	1.3	1040	702	832