



# A study of fuel poverty and low-carbon synergies in social housing

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## **Executive Summary**

Fuel poverty, the circumstance where a household spends more than 10% of its income on energy bills, is predicted as being in the region of 5.5 million in the UK. If domestic energy tariffs increase with predictions, it is reasonable to expect that the number of fuel poor households will continue to rise. It is therefore more important than ever to understand the energy behaviour and general concerns of those currently in fuel poverty, so that appropriate measures and policies can reflect the diversity of occupants within the category of fuel poor. Indeed, as the number of fuel poor households continues to grow, it is likely that the practices within households in this category will become more diverse. This diversity is important as it will affect not only the choice of measures for reducing energy consumption but also the likely post-measure “rebound effect”, where a perceived energy saving might not be achieved in full if the household changes their energy behaviour directly as a result of having lower energy bills. This paper describes some of the findings of a pilot socio-technical study involving qualitative interviews with social housing tenants, combined with basic energy modelling of the individual dwellings (using the Tarbase model) to estimate the carbon emissions of that house. The results suggest that categorising such a large number of dwellings and families into one large “fuel poor” group risks ignoring the range of responses to fuel poverty by different tenants. In addition, the diversity in construction type of social housing in the UK makes it difficult to gauge the total cost for refurbishing such a large number of buildings. The conflicts and synergies between the low-carbon and fuel poverty agendas are discussed. While energy-saving refurbishments, with their high capital costs, might be proposed as alternatives to fuel subsidies and payments, this will affect different families, in different dwellings, in different ways.

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## **1. Introduction**

The current trends provided by the latest released data<sup>1</sup> suggest that the available solutions to fuel poverty do not match the scale of the problem. While the main hurdle, as with refurbishing existing homes more generally across the stock, is the capital cost of building improvements, there is also the question of whether we understand what fuel poverty actually means for householders, and how it impacts on their daily lives. In this report we investigate whether we can usefully combine an estimation of the energy performance of a building with an understanding of the practices of the occupants. With current estimates of UK fuel poor households at 5.5 million (approximately 21% of the entire housing stock), it is perhaps misleading to ascribe a certain type of behaviour to such a wide and diverse demographic. In particular, questions about the nature of low-carbon living, and the possible connections between the fuel poverty and low-carbon building agendas become important.

The feasibility study described in this report combined a simple domestic building energy model<sup>2</sup> with in-depth interviews of the occupants. The scale of the project was such that only a very small sample could be covered with the available resources, though three different parts of the country were included within the sample. The aim of the study was to highlight the synergies between the low-carbon building refurbishment and fuel poverty agendas mentioned above, while investigating whether a multi-disciplinary approach of this nature (i.e. accounting for the occupant and the building) could be more than just the sum of its parts – particularly, if there is a connection between energy consumption and energy practice in fuel poor households that discipline-specific studies might miss.

This report comes at a time when funding schemes for reducing both fuel poverty and carbon emissions in UK dwellings are being significantly changed. After 2012, it is likely that the privately-funded Green Deal and Energy Company Obligation (ECO) will be the main sources of funding for making changes to fuel poor homes. However, there are flaws in this type of approach and these will be overviewed for the Green Deal in particular.

With such a small sample of case-studies, there is clearly the need to draw on additional research and statistics to supplement the conclusions and policy recommendations, and these are referenced throughout the study.

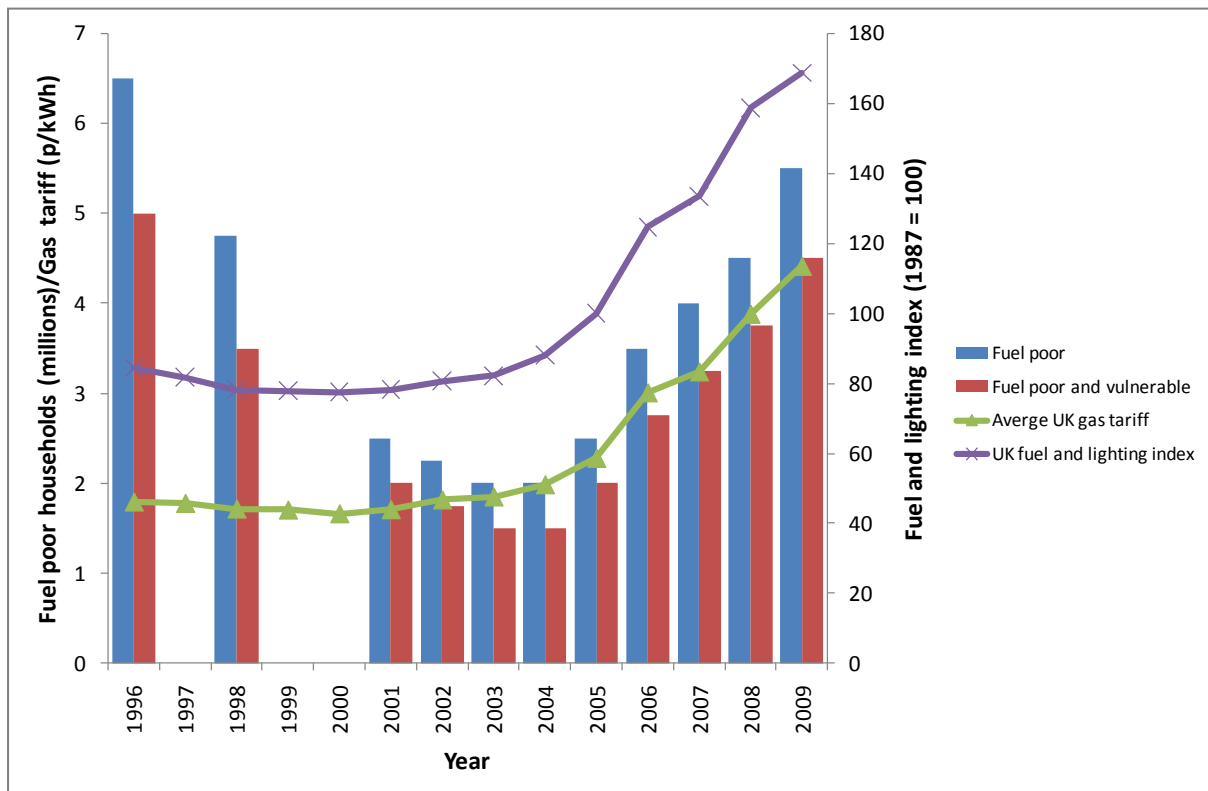
## **2. Fuel poverty in the UK – an overview**

Fuel poverty is defined as existing in households where 10% (or more) of the income is spent on energy bills. The definition of fuel poverty, and the way statistics have been collated, has changed over time<sup>3</sup>. However, Figure 1 shows recent trends in fuel poverty, as suggested by the UK Government’s own figures<sup>4</sup>. Approximately £3bn per annum is spent on winter fuel allowances, helping such households to heat their homes – but such payments do not solve or reduce the fundamental problem of poor buildings with poor performance; rather the subsidy is used as a short-term measure, though one that can be essential in the absence of any other intervention.

Also shown in Figure 1 is the sensitivity of fuel poverty to average UK gas tariffs and, related to this, UK “fuel and lighting” index (essentially the proportion of the retail price index (RPI) that can be apportioned to fuel use<sup>5</sup>). It appears that, particularly since

2003, the increase in fuel poverty in the UK has been driven by the rapid rise in the cost of the main heating fuel. Prior to this, during a time of relatively constant retail gas prices, subsidies and payments to fuel poor households appear to have had a significant effect. The data also suggests that the success of recent energy efficiency programmes has been limited, in that the trend between gas price and fuel poverty remains strong year-on-year from 2003 to the present. To break this cycle, in the absence of more restrictions on the price being paid by the consumer for a kWh of gas, it could be argued that energy efficiency improvements to the housing stock need to be several orders of magnitude greater than currently seen.

A further note of caution is demonstrated by Figure 1, where a very high proportion of fuel poor households are classified as being “vulnerable”; that is, the dwelling has children, elderly or sick/disabled occupants present. In 2009, nearly 82% of fuel poor households could also be categorised as vulnerable. This suggests that the effect of fuel poverty on the occupant could be even more serious (e.g. the effect of an under-heated property on elderly occupants), but also the options available to that household to rise out of fuel poverty might be limited by the status of the occupants.



**Figure 1 – Fuel poverty households in the UK and effect of fuel price**

Much existing qualitative research on the experience of living in fuel poverty in the UK was conducted between 2000 and 2005, when the numbers of households experiencing fuel poverty were somewhat lower than present. As such, this work represents an era in which the fuel poor consisted mainly of households on very low incomes. Such older studies still hold relevance to how we understand the needs of the fuel poor today, however, given that most people living in fuel poverty fall into the lowest 30% of earners<sup>3</sup>. In 2005, Harrington et al<sup>6</sup> found that people respond to fuel poverty in four ways:

1. The majority of people in fuel poverty keep warm and compromise their living standards in other ways;
2. Some people in fuel poverty are forced to compromise on fuel through extreme poverty;
3. A minority of people living in fuel poverty economise on fuel to be able to afford other activities;
4. A further minority include those who cannot stay warm despite spending considerable amounts on fuel because of the inefficiency of their home.

More recent studies tend to back up these findings, with Andersen and White<sup>7</sup> adding the finding that people with low incomes tend to find energy spending less flexible than spending on food. However, these authors also note that most people living on low incomes (in a survey of 700 households) report frugality in their energy use, to varying degrees.

The experience of those living in fuel poverty has to be tied in to the larger economic and social conditions of present times. Wilkinson and Pickett's<sup>8</sup> work on equality in societies is particularly informative. One of the reasons that the fuel poor are categorised as such in the UK is the relatively unequal nature of our society. A less equal distribution of wealth is more likely to result in the poor struggling to make ends meet. Less equal societies are also less likely to invest money into the social housing stock, given that social equality within a nation is a function of how much people are willing to invest in those less well off than themselves. Equally, Lodziak<sup>9</sup> points out that the cost of basic essentials, such as energy, food and shelter, has risen in the past 30 years, faster than have incomes.

### **3. Low-carbon refurbishments to combat fuel poverty**

The *need* for instigating large-scale carbon-saving refurbishments in the UK housing stock is now well-established<sup>10</sup>. Less clear is *how* to instigate this change. Previous grant and subsidy schemes, such as the Carbon Emissions Reduction Target (CERT) scheme (due to finish in 2012), do not provide a pathway to deep-cut carbon savings; the CERT scheme was launched with a long term target of reducing CO<sub>2</sub> emissions by 4.2 million tonnes per year<sup>11</sup>, only 3-4% of current total domestic CO<sub>2</sub> emissions (based on 26 million houses with average CO<sub>2</sub> emissions of 5 tonnes per house). While early-adopter markets might be identified, where a small number of households at higher income levels may be willing to pay for energy-saving refurbishments, purely market-driven solutions are unlikely to achieve stock-wide carbon savings (e.g. even with CERT scheme assistance, solid wall insulation measures are still likely to require a financial input of several thousand pounds from householders<sup>11,12</sup>). The Green Deal, announced by the UK Government, aims to deal with this problem by encouraging larger organisations, such as energy companies, to provide the upfront cost of the technologies, as discussed in section 6.

Appropriate refurbishment measures to reduce dwelling energy consumption, and the options open for installing and financing those measures, will change depending on several factors including dwelling type, occupant income and dwelling ownership (i.e. privately rented, privately owned or social housing). Therefore, policy decisions for implementing energy-saving measures in higher income, privately owned dwellings will not be relevant for many fuel poor households.

The one sector in the housing stock that has demonstrated an ability to make changes to existing dwellings is that of social housing. Housing associations and local authorities are often the most active in refurbishing homes<sup>13,14</sup>, partly due to the existing infrastructure that they provide, which allows technologies and measures to be installed in the first place. Approximately 383,000<sup>15</sup> socially-housed households were fuel poor in 2008 – a large enough number that, should a method be found for low-carbon retrofitting these homes, the implications on the entire housing stock (and the embryonic “green” refurbishment market) would be significant.

Therefore, fuel-poor social housing is used in this study as a potential opportunity for both successfully installing energy-saving measures and reframing the fuel poverty problem. This is justified as i) user-acceptance for these dwellings is likely to be higher than average as the measures will have a direct effect on the fuel poverty status of the occupant and ii) the existence of a housing association/local authority body will provide an infrastructure that does not currently exist in the private market. If the mass-retrofitting of the UK domestic stock requires an initial financial stimulus, it therefore seems sensible to focus this on fuel poor social housing.

#### **4. Research methods**

The research under this project had two main elements: a detailed assessment of the energy use of the building, based on an existing model designed by the research team, and an in-depth qualitative interview with members of the household about their energy use. Seven households were identified as case studies for this research, located in Edinburgh, Leeds, London and Kent. All seven households were based in social housing, and they were sampled for diversity, representing a variety of housing types and conditions. Households were mainly contacted through the researchers’ links with housing associations, who then put the team in touch with specific households with which they have regular contact. The households in Kent were contacted directly, as one of the research team had worked with them previously.

While this small number of households is not representative of the stock, it did allow for an in-depth study of the dwellings, allowing the building modelling to incorporate very specific aspects of energy use and for household practices to be discussed in detail in the interview stage of the work.

While procedures for assessing dwelling energy consumption do exist, such as the Standard Assessment Procedure (SAP)<sup>16</sup>, they are often configured with the intention of mass-replication (for millions of homes) and also standardisation of behaviour and building variables (to allow comparisons between dwellings). There are two potential problems that this can cause, one relating to energy and the other to behaviour. Firstly, even a very simple energy assessment tool requires input that adequately describes the building. So, for example, taking a single, average UK climate to assess all UK buildings, as is the case for SAP, is questionable.

More complex is how one should represent the occupant. While SAP-type tools directly link appliance usage and occupancy to floor area, this makes it quite difficult to assign energy consumption or behaviour to a specific house that might be subject to a very particular set of criteria, such as a fuel poor household. The Tarbase Domestic Model<sup>2</sup>

used in this study allows information such as exact floor areas of different zones, number of adults/children, specific appliances in use with the house and a range of climates to be used in the assessment. This makes the model slightly more versatile, and therefore more appropriate to a study that is attempting to understand energy behaviour as well as overall building efficiency. However, Tarbase is still a steady-state building model and is certainly not a substitute for data – but the configuration of the model is sufficient for highlighting certain aspects of energy use that can be linked to the interview results. The required building input was obtained from each individual household during a site visit, carried out as a typical energy audit procedure.

The interview stage of the work was combined with the above site visit to minimise disruption to the occupant. At each household an in-depth interview lasting about an hour was conducted with a self-selected adult occupant. Sometimes other members of the household and research team also became involved with the interview, by joining in the conversation between the principle interviewer and occupant. The interviews included questions on energy practices, fuel poverty and environmental issues. Occupants were asked to explain how they use energy as well as to reflect on the experience of living in fuel poverty. They were also asked to explain how they see themselves in relation to the environmental and climate change agendas. Interviews were recorded and transcribed, and analysed according to qualitative analysis principles using appropriate software<sup>17</sup>. The analysis focused on determining the nature of occupants' energy practices, to what extent these were responses to fuel poverty, and their understandings of environmental issues relating to energy use.

## **5. Study of fuel poor households**

### **5.1 Building case-studies**

Table 1 provides an overview of the seven dwellings used, all of which were owned by various social housing organisations. This table does not include the detailed input used for the energy modelling (such as list of electrical appliances and thermal performance of building elements) but is a useful overview for comparing why one dwelling may have an estimated energy consumption that differs from another.

With every case-study being a socially-housed household in a high-risk fuel poverty demographic, there were some commonalities across the seven homes. However, due to the variation in house type, occupant number, location and income, there were clear variations in how the occupants used energy and the possible solutions that might exist to improve the energy efficiency of each dwelling. Defining the input variables of the energy study is therefore vital to understanding why, for example, recommendations for improvements in one dwelling might not apply to another – or, alternatively, the effects of the same improvements will be different between dwellings.

**Table 1 – Building details of seven case studies**

Building no.	Floor area (m <sup>2</sup> )	Occupants*	Location	Housing type	Glazing	Main heating fuel
1	41	2	Edinburgh	Filled cavity, mid floor, flat	Double	Gas, boiler eff. 80%
2	33	1	Edinburgh	Filled cavity, ground floor, flat	Double	Gas, boiler eff. 80%
3	86	2.4	Leeds	unfilled cavity, terraced housing	Double	Gas, boiler eff. 65%
4	90	2.2	Leeds	unfilled cavity, terraced housing	Double	Gas, boiler eff. 65%
5	67	1.5	London	Filled cavity, terraced housing	Double	Gas, boiler eff. 90%
6	67	2.3	London	Filled cavity, terraced housing	Double	Gas, boiler eff. 90%
7	59	1.2	London	Filled cavity, terraced housing	Double/single	Gas, boiler eff. 90%

\* Refers to adults and children, e.g. 2.4 = 2 adults, 4 children

## 5.2 Energy assessment results

The technical assumptions and calculation engine used for the Tarbase Domestic Model is detailed elsewhere<sup>18</sup>. The model allows the user to estimate the baseline energy consumption (or carbon emissions, fuel bills etc) and then choose a number of refurbishment options to estimate the potential savings that might be possible for that specific dwelling.

### 5.2.1 Baseline dwellings

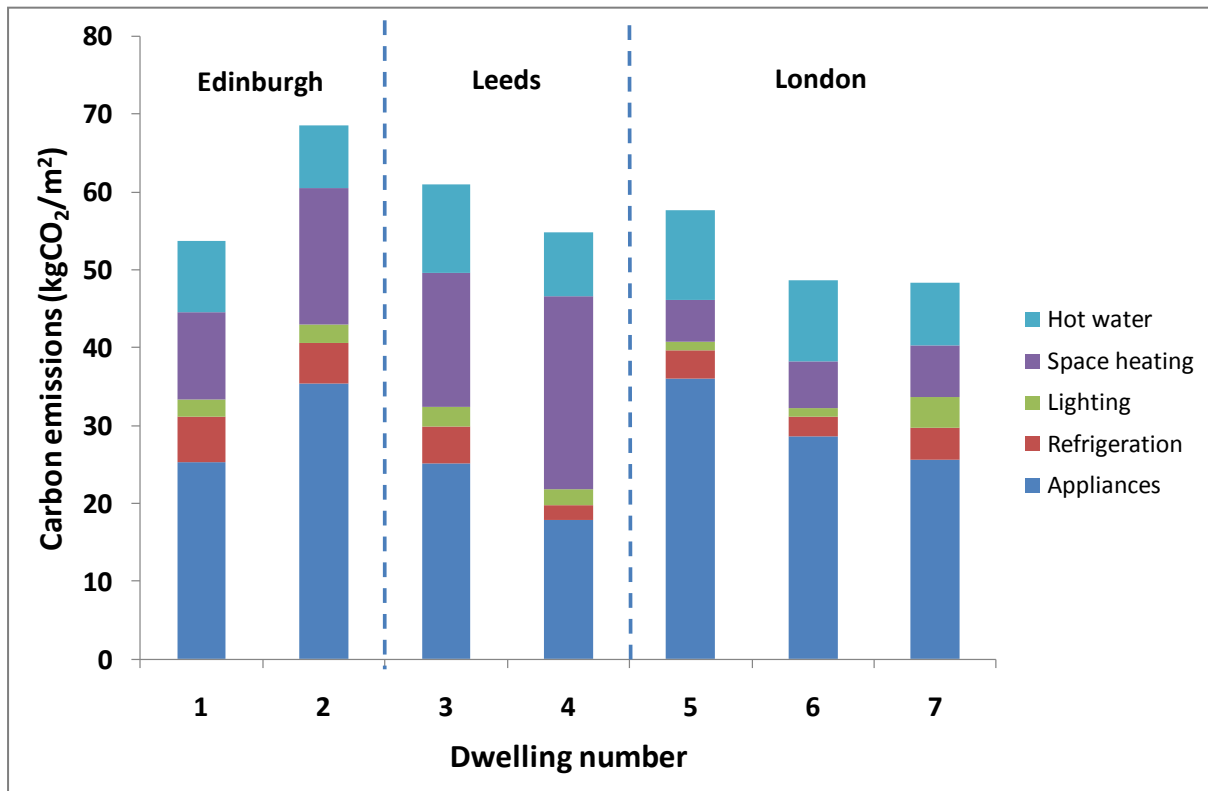
The results for the seven homes in this study are given in Figure 2 in terms of total annual carbon emissions per unit floor area.

There are several things to note when interpreting these results. Firstly the carbon emissions are normalised by floor area, so that they are in a similar form as might be given in, for example, an energy performance certificate. While this allows a comparison between all homes, a larger home will tend to have a lower kgCO<sub>2</sub>/m<sup>2</sup> than a smaller, similar home – although the larger home will clearly have higher total carbon emissions.

Accepting the above point, it might still be expected, with the use of local climates in the Tarbase model, that the Edinburgh households would have higher space heating than the other dwellings. However, due to the relatively high standard of building fabric in these homes, they perform slightly better than might otherwise be the case. There is still an issue, in dwelling 2, of high electrical consumption due to a large number of uncommon electrical cooking appliances used by the single occupant in this dwelling, such as portable electric hobs (again, an uncommon internal activity that would not necessarily be picked up by other building models). This, combined with the fact that the dwelling is the smaller of all studied, produces the highest carbon emissions per unit



floor area. Conversely, it can be seen that this household still has very low energy bills (which are not normalised by floor area – see section 5.2.3).



**Figure 2 – Modelled annual carbon emissions for seven case-study dwellings**

Investigating other dwellings, the homes in Leeds (buildings 3 and 4) have noticeably high space heating per unit floor area, for dwellings that should be significantly lower than the UK average (if governed by Decent Homes Standards, for example). As these dwellings are also the largest studied, the total energy bills (discussed later) are quite high as a result.

The climate in London, and the existence of cavity wall insulation, results in quite low space heating for homes 5, 6 and 7. It should be noted, however, that steady-state models have a tendency to under-predict space heating – partly due to the difficulty in specifying dynamic processes in a building (such as thermal mass), but also the fact that “random” behavioural decisions relating to space heating (e.g. leaving windows open during the winter to improve internal air quality, not switching the boiler off when comfort temperature is exceeded etc) cannot be modelled adequately. Nevertheless, the comparison between dwellings and the effect of refurbishments (section 5.2.2) is still valid.

The variation in the “appliance” category is particularly interesting. This reflects the discussions in section 5.3, such as the use of electricity as entertainment for homes with children present. This is important as, quite rightly, the first proposed changes to a household in fuel poverty will usually be centred on insulation. However, if that home has a very high electrical consumption (and this might be a direct result of the socio-demographic of that home), what are the options for the social housing provider to reduce the fuel poverty status of that household? Are we left with just simple energy bill

subsidies as a solution, which must be paid every year? Or should much larger capital cost improvements be introduced that are directly concerned with electricity use, such as onsite generation? It is suggested that much more empirical work is needed in this area – are fuel poverty homes also high electrical consumption homes due to home entertainment being seen as a relatively cheap family activity?

### **5.2.2 Modelled carbon-saving refurbishments**

Having established the modelled baseline of each dwelling from the site visits, a series of refurbishment options were modelled for each specific building. These refurbishment options, listed in Table 2, are grouped into two categories of “cost effective” and “long-term payback”. The former includes appliance, lighting, draughtproofing and cavity-wall insulation measures (NB – Roof insulation was either already present or not applicable in all seven case-studies). Measures that will have relatively long paybacks (i.e. the time taken for the energy-savings to pay for the capital cost of the refurbishment) include replacement boilers, high performance glazing and solar thermal panels. Such technologies are unlikely to produce financial returns for several decades, though this will depend on the state of the technology in the baseline dwelling.

A large number of assumptions have to be made when modelling such technologies, and these are informed by work from the Tarbase project. These assumptions include:

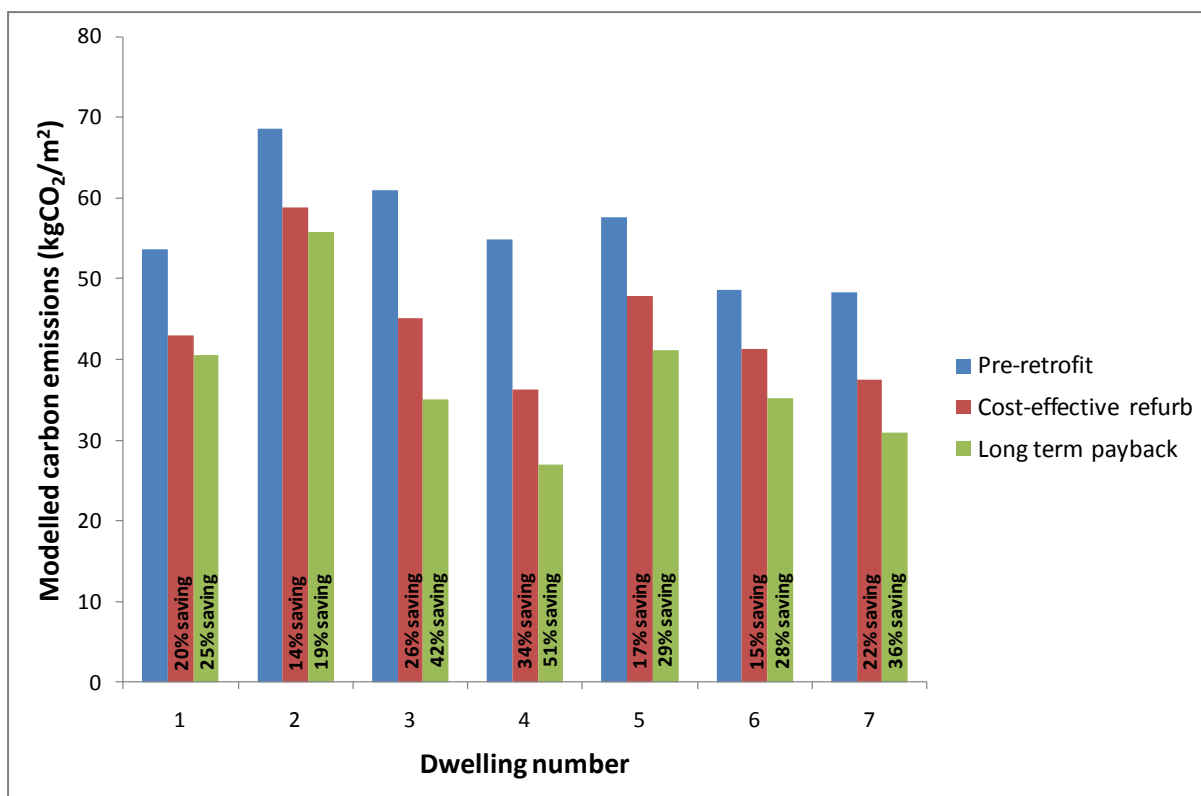
- The improvement in appliances covers a wide selection of technologies including washing machines, ovens, dishwashers and consumer electronics. These were modelled as part of the Tarbase project but are not all market-ready technologies; they are used as an indication of the potential energy savings that might be possible in the area of domestic appliances
- Air-tightness is only reduced to 0.5ac/h from draughtproofing due to concerns about internal air quality (particularly as mechanical ventilation solutions are not being considered suitable for this type of refurbishment)
- Roof insulation could be improved in some dwellings but the improvement is likely to be incremental, e.g. increasing existing roof insulation from 150mm to 200mm is not likely to achieve dramatic improvements in energy efficiency
- For dwellings 1 and 2, it is unlikely that a new boiler would be advised in reality, as the efficiency improvement would not justify the £2,500-£3,000 capital and installation costs of a new condensing boiler
- All buildings currently have double-glazing, but a high performance glazing is suggested as a possible improvement, though not necessarily cost-effective
- Solar thermal panels are sized based on the system meeting 50% of the domestic hot water demand. While larger systems will produce more hot water, this will not necessarily meet the hot water demand outside the summer period, and so will not produce a significant improvement on the displacement of mains hot water.
- Building Regulation Part L1B<sup>19</sup> suggest a target U-value of 0.55W/m<sup>2</sup>K for a cavity wall that has been filled during a refurbishment. This has been used where relevant
- Carbon intensities of 0.52kgCO<sub>2</sub>/kWh and 0.19kgCO<sub>2</sub>/kWh are used for electricity and gas respectively

**Table 2 – Summary of refurbishment options for the seven case-studies**

Building no.	Cost-effective				Long term payback/speculative		
	Appliance improvement	Lighting improvement	Draughtproofing	Wall insulation	New boiler	Glazing	Solar thermal panel
1	As recommended by Tarbase	Increased use of CFL (mostly already used)	Improve from 0.78ac/h to 0.5ac/h	Cavity insulation present already	Improve efficiency from 80% to 91%	Install high performance double-glazing (U-value of 1.6W/m <sup>2</sup> K)	N/A
2		All lighting CFL already	Improve from 0.83ac/h to 0.5ac/h				
3		Increased use of CFL (mostly already used)	Improve from 0.74ac/h to 0.5ac/h	Cavity insulation to improve U-value from 1.6W/m <sup>2</sup> K to 0.55W/m <sup>2</sup> K	Improve efficiency from 65% to 91%		3.4m <sup>2</sup> of panels to meet 50% of hot water requirement
4		All lighting CFL already	Improve from 0.74ac/h to 0.5ac/h				2.6m <sup>2</sup> of panels to meet 50% of hot water requirement
5		Increased use of CFL (mostly already used)	Improve from 0.67ac/h to 0.5ac/h	Cavity insulation present already	New boiler already present		3.7m <sup>2</sup> of panels to meet 50% of hot water requirement
6			Improve from 0.67ac/h to 0.5ac/h				3.3m <sup>2</sup> of panels to meet 50% of hot water requirement
7			Improve from 0.78ac/h to 0.5ac/h				2.2m <sup>2</sup> of panels to meet 50% of hot water requirement

Figure 3 shows the modelled savings from the two refurbishment options for each of the seven dwellings (normalised by floor area). There is a range of savings achieved; for the “cost-effective” option the households are modelled to see savings of between 14% and 34%, whereas the “long term payback” options increase this to between 19% and 51%. Unsurprisingly, larger savings are possible for the worst homes – dwellings 3 and 4 do not have cavity-wall insulation present and so the potential for savings are considerable. The other five dwellings have reasonably good baselines in terms of insulation (compared to the rest of the UK), though significant savings are still possible.

These savings could be pushed further with additional micro-generation, particularly solar-photovoltaic panels. While this can be modelled by Tarbase, it is deemed impractical to have both solar thermal and solar photovoltaic systems present for these particular dwellings. The capital cost for installation is also likely to be considerable, though the economic arguments for doing so would be more favourable with current feed-in tariff schemes. Such technologies would also lead the investigation into wider discussions about how to decarbonise the electricity supply for domestic buildings, incorporating onsite, near site and off-site renewable technology – this is beyond the scope of the study.



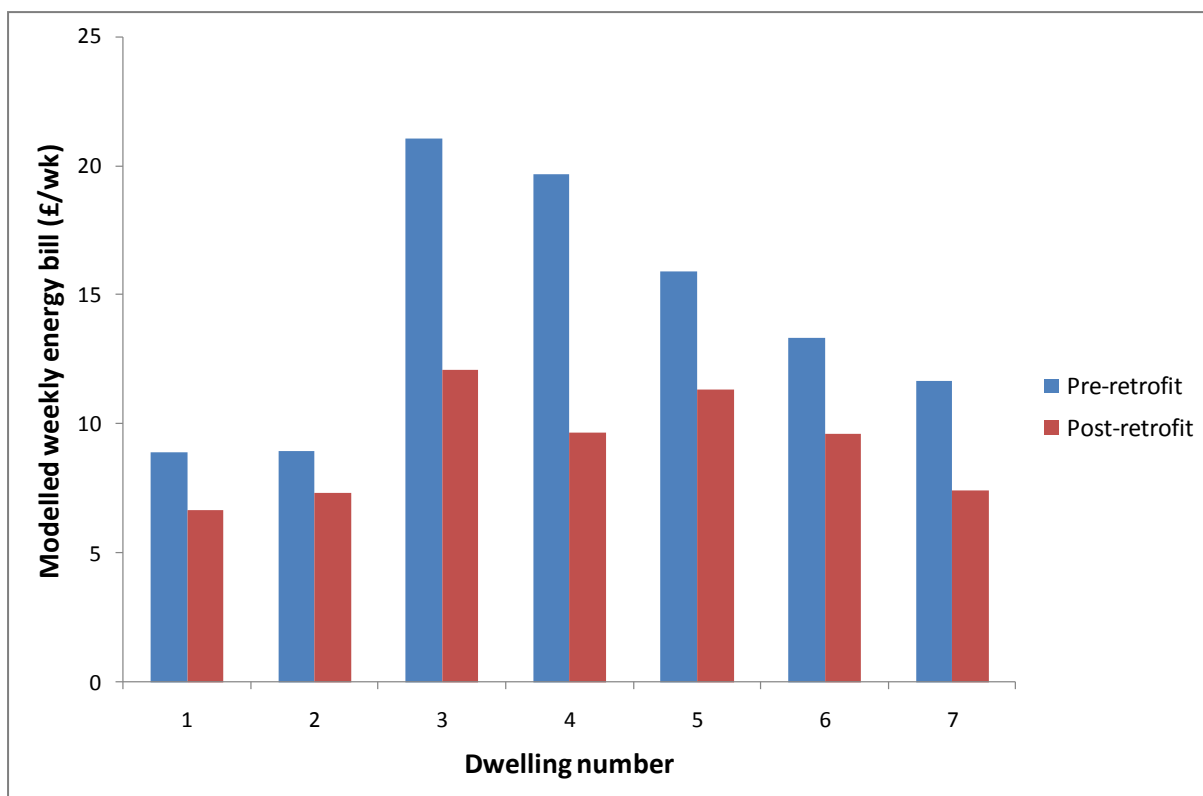
**Figure 3 – Modelled effect of refurbishment options for seven dwellings**

### 5.2.3 Effect on energy bills

The impact of the described measures on energy bills is of a similar scale, as shown in Figure 4 (Note: these results are not normalised by floor area so house-by-house comparison is different to Figure 2 and 3). The post-retrofit category includes the long-term payback measures. These are modelled energy bills (for all electricity and gas use), and are not directly comparable to the estimates of maximum fuel use provided by the occupants themselves (as discussed in section 5.3).

The proposed refurbishments are found to produce savings of between £2 and £10/week. Using this metric of weekly expenditure allows a direct comparison with average energy expenditure in the UK, as shown in Figure 5 from the Housing Energy Fact File<sup>20</sup>.

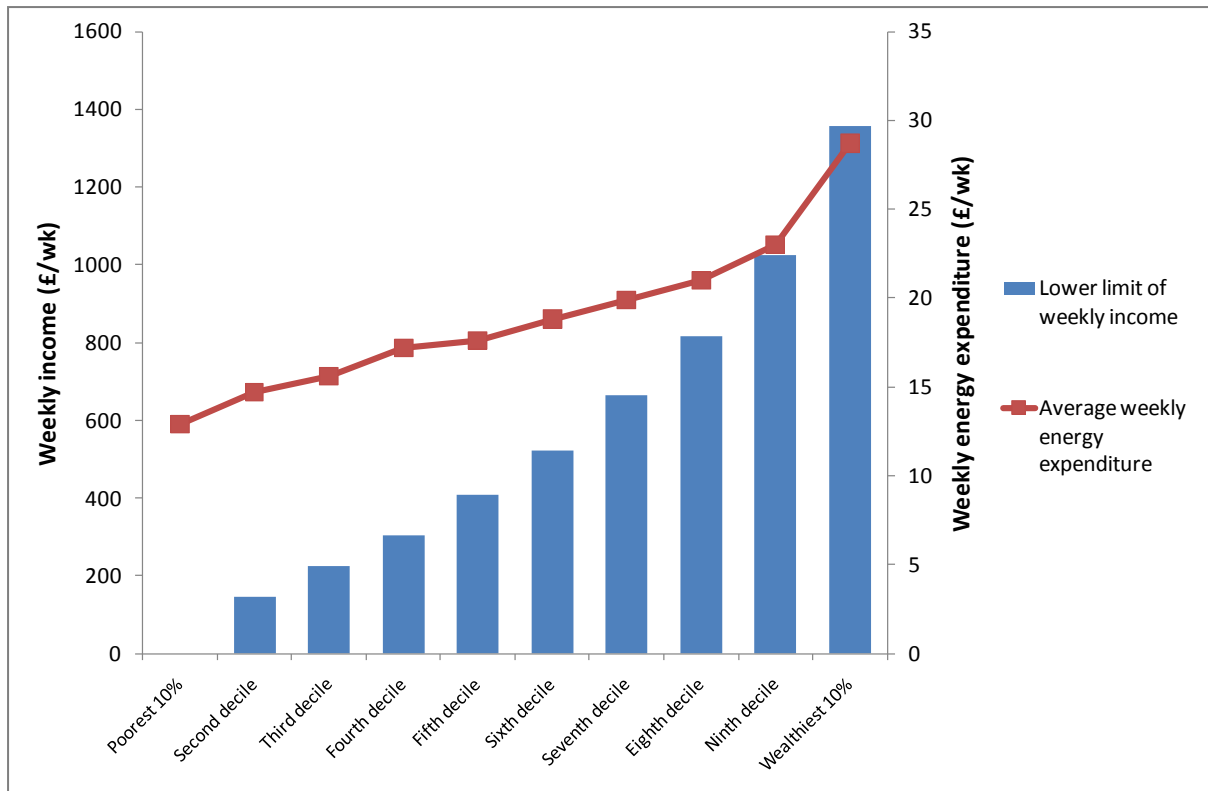
The data in Figure 5 splits UK households into income deciles, with the lower income limit of each decile shown. The average weekly energy expenditure clearly rises with income, though this data does not show the variation of expenditure within each decile; average expenditure of each decile is given, but this does not account for extreme groups within each decile. However, while this graph is not sufficient for exploring fuel poor categories in detail, it does provide ballpark estimates for what constitutes typical energy expenditure for different income brackets.



**Figure 4 – Modelled weekly energy expenditure for the seven dwellings**

A comparison of Figures 4 and 5 shows that households 3 and 4 might be spending the same amount on energy (in the region of £20/week) as is typical for the ninth income decile – despite the household clearly being in a much lower income decile (see section 5.3). This describes the problem of a poor quality (in terms of energy efficiency) home being occupied by a low-income household.

Not evident from Figure 5, though described in the original data source, is the fact that the wealthiest 10% decile, despite much larger total energy expenditure, only spends in the region of 2.7% (on average) of their household income on energy. The poorest decile spends an average of 8.4% of household income on energy. However, this should not be confused with the “10%” threshold describing fuel poverty – within each decile a wide range of expenditure: income ratios are likely, which are effectively hidden by the average ratio used for each decile group.



**Figure 5 – Average UK weekly energy expenditure income deciles**

### 5.3 Results of occupant interviews

To accompany the previous energy analysis, the results of seven qualitative interviews will now be described. The following section will:

- Describe the occupants of the seven households that were interviewed
- Characterise occupant reactions to fuel poverty in relation to their use of energy within the household
- Report on the interviewees understanding of ‘environmentalism’ and their own place within the environmental and low-carbon agenda.

It was found that interviewee responses to fuel poverty to a great extent echoed the earlier study by Harrington et al<sup>6</sup>. All four responses they identify were observed, although there was a marked difference between households in the responses that they took. Most noticeably, those households with very low incomes were more likely to respond by compromising on fuel, or by not staying warm. It was also noticed that while people on very low incomes might say they could keep warm, their houses were either noticeably cold, or they had specifically put the heating on for the site visit.

#### 5.3.1 Description of the household occupants

Given that the housing types in this study were sampled for diversity, in terms of size, location and condition, the occupants also showed some diversity as is represented in Table 3. Here we can see that the households vary both in composition, age and to some extent ethnic diversity. Household income comes from various sources, including work, benefits and pensions, and varies considerably, although most of the participants (with the possible exception of households 4 and 6) are likely to be in the bottom quintile of earnings<sup>21</sup>.

While reported incomes were relatively low, it was not clear which households actually met government definitions as living in fuel poverty. Notably, despite the first household having a combined income of just £800 a month, their relatively low reported fuel bills (which are no doubt partly due to the reasonable condition of the building in which they live) mean that they do not qualify as living in fuel poverty. It is important to note here that fuel bills and incomes in section 5.3 are both based on estimates made by occupants during the qualitative interview. These may be under- or over-reported, and the fuel bills in particular do not account for seasonal variation. They do however give us an indication of the household finances of the occupants concerned.

In the subsequent discussion, pseudonyms are used instead of real names for all interviewees.

**Table 3 - Table describing the households interviewed**

<b>Household no.</b>	<b>Pseudonym</b>	<b>Composition of household</b>	<b>Age of main respondent</b>	<b>Highest educational qualification</b>	<b>Occupation of main respondent</b>	<b>Main source of income</b>	<b>Reported income per month</b>	<b>Reported maximum fuel bills per month</b>
<b>1</b>	Mildred	Retired couple	60-69	Secondary school	Retired	Pension	£800	£48
<b>2</b>	Mohammed	Single man	50-59	GCSE or equivalent	Incapacity benefit	Benefits	£360	£50
<b>3</b>	Sally	Two single mothers with 4 children	40-49	GCSE or equivalent	Cleaning Supervisor	Salary	£850	£200
<b>4</b>	Barbara	Couple with one child and fostered babies	50-59	Degree	Foster carer	Salary	£1,800	£270
<b>5</b>	Sarah	Single mother with 5 children	30-39	NVQ2	Volunteer and Mother	Benefits	£1,110	£88
<b>6</b>	Kate	Couple with 3 children	20-29	GCSE or equivalent	Mother	Salary	£1,600	£48
<b>7</b>	Jane	Single mother with 2 children	40-49	GNVQ	Mother	Benefits	£1,280	£160



### **5.3.2 Frugality**

One of the most noticeable characteristics of the households visited was their frugality. While the respondents reported a variety of monthly income levels and energy costs, all took some measures to reduce their energy use by being frugal with these resources. Usually such frugal measures were more common among the less well off, as the quote from Mohammed below exemplifies.

“I will put the central heating on for half an hour, an hour, put it off and keep it off until it goes cooler, then I put it on again.” Mohammed (Edinburgh)

Given that our respondents are often in the bottom quintile of earnings, such frugality in energy use is very much connected to a broader approach to budgeting. Elsewhere this has been characterised as the ‘milky bar economy’: where families are more likely to buy a Milky Bar as a treat for their children as these are 20 pence cheaper than other brands such as Mars Bar<sup>22</sup>. The level of budgeting implied here (where 20 pence counts) is seen in the close monitoring of energy use, especially in cold weather or during difficult financial times, that is unlikely to be apparent in wealthier homes. Respondents keep a close eye on their gas and electricity meters, as Sally explains:

“I constantly check to see if it is going into emergency. I probably check it every couple of days. You know, just to see what I’ve used on it.” Sally (Leeds)

Note that by ‘going into emergency’ Sally is explaining that she is using the facility to go into debt on a prepayment meter. Such micro-management of energy use is unusual, given the inconspicuous nature of the consumption of energy use, as discussed by Shove<sup>23</sup>.

As well as affecting the use of energy directly, frugality with energy use spreads more widely into the respondents’ life practices. For instance, people find ways of moderating their family’s need to keep warm, by enforcing limits to heating levels, by wearing jumpers, or by going to bed early to watch TV as a family. Barbara, for instance, has a maximum limit on the thermostat:

“I will only let them put it up to 22. They’re not allowed to put it higher than 22 without getting a telling off from me.” Barbara (Leeds)

While this level of heating (22°C) may seem slightly high, she lives in a draughty house with chronic heating problems, and needs to keep the babies she fosters warm. There is also the issue that thermostats are not necessarily reliable indicators of true whole-house temperatures.

It is evident that living in fuel poverty can have a huge impact on respondents’ quality of life, and their freedom to choose where to be and what to do from day to day. Here the lowest income interviewee, Mohammed (he earns £360 per month, and spends a reported £50 on fuel bills), explains.

“If it’s cold I have to spend my time more in the house. Like the last four weeks... I stayed in. I was using more! And if the weather’s nice I just go for a

walk. Maybe go and sit in St James Centre, to save some of the heating.”  
Mohammed (Edinburgh)

Mohammed was interviewed after a very cold winter, during which he has to stay in the house in order to keep warm. In warmer weather he goes to the local shopping centre rather than staying in to save on the heating bills. Note that these are direct reactions to the cost of energy and to living in financially restricted circumstances. As such, most of the respondents interviewed here are engaging in energy saving out of real necessity rather than through any environmental motivation. This issue is discussed further in section 5.3.5.

### **5.3.3 Bottom lines and cultural practices**

There are other influences on energy use for people living in fuel poverty. Apart, perhaps, for those living in the most extreme conditions, respondents talked about their energy use as important in maintaining living standards for their families, whether this was through keeping up essential standards, or using energy for entertainment.

Many families had a bottom line in terms of the need to use energy, which related to the need to keep warm, cool or entertained. For instance, Jane is the mother of two children with skin conditions, and lives in a damp house. For her the bottom line is to be able to keep her children’s clothing and bedding etc. clean. As such, she has to use the washing machine regularly, and in the winter to use her tumble drier.

“Especially with the tumble dryer, like I said the tumble dryer eats so much, but I have to use it.” Jane (London)

Other bottom lines are often focused around children in the family, with two interviewees wanting to keep the babies in the house warm (Sally and Barbara) and others emphasising the need for their children to be entertained.

The status of energy as a tool for entertainment was particularly interesting. The households we visited that had children also had extensive resources for entertainment (Sky plus, playstations, Xboxes etc.). While this was not explicitly stated by respondents, we can imagine that such resources provide the main form of entertainment for their children. As such, they are used heavily on a daily basis. As Sally explains:

“The telly’s on practically from when ... Matthew gets up, usually about half past 7, and then it will be on ‘til whoever is last to go to bed... so maybe midnight?” Sally (Leeds)

It was noticeable that in the households with children, entertainment was not compromised on. Sally, for instance, did recognise that her electricity use was determined to a great extent by her children’s use of entertainment devices, something that was outside of her control as her work took her out of the house for 7 days a week:

“It’s a bit harder with them, like the Playstation ... it does my head in. You know, they are on it and there’s not a lot I can do about that... I do 7 days so to be honest most of the time I’m not here. And if I says to them you can only go on the Playstation 3 hours a day I’m wasting me breath.” Sally (Leeds)

There also is an implication that Sally understands the need of her children to use these devices: she would be wasting her breath because there is not much else for them to do around the house.

The idea that energy is connected to entertaining is also seen in the hosting practices of the families we visited. Indeed during several interviews it became apparent that in advance of our visit the heating had been turned up, or the lighting increased. As Mildred's husband in Edinburgh put it: "you're lucky we've got the lights on for you because normally we don't have the lights on". It seems that certain social standards that people hold are not to be compromised on, and this translates into expensive, but perceived as essential, use of energy.

### ***5.3.4 Fabric of the house and energy consumption***

Consumption of energy in the households we interviewed was highly influenced by the fabric of the house concerned. In some of the households we visited, residents were locked in to unsustainable energy practices because of the construction of the house, or the condition of the appliances within it. Others were able to live much more efficiently because of recent improvements to the house. The consequences of this are important: these households have limited choices with regards to the expense and environmental impact of their lifestyles.



***Figure 6 - Boiler in household 3 (Sally)***

To take the example of household 3 in Leeds, or Sally's home, this house had a rather unusual construction, with a wall made out of PVC to the front, which provided very limited insulation. In addition, the boiler in the house was up to 40 years old, unreliable and highly inefficient (see Figure 6). Given these structural constraints on her family, it is difficult to see how Sally can escape from fuel poverty, or live a low-carbon lifestyle in the structural circumstances in which she finds herself. This overarching picture is backed up by the modelling work in section 5.2.3 – a home that, due to poor

construction and boiler, produces energy expenditure which is within the higher percentiles of the UK, yet has a low-income family occupying it.

These structural circumstances had an important impact on occupant's experiences of fuel poverty. The fact that heating bills are driven both by climate (another external factor beyond these families' control) and the quality of building they rent means that our respondents noted a lack of control in relation to their use of energy. This can be particularly disempowering, given the micro-management of energy noted above. Indeed, given that the tenant is trying to control energy use through their frugality, the lack of control associated with the quality of the building in particular is particularly frustrating.

This lack of control is recognised by those of the tenants that suffer most extensively from the condition of their households. So Jane, for instance, who is a disabled single mum with two children with skin conditions, is frustrated by the damp problem in her home, but has little faith in there being any resolution to this. As she says:

“[Housing Association] are a bit lazy. Because I've been waiting five years for damp to be done ... People come and um and ah and make notes and go away and never come back again.” Jane (London)

Given Jane's financial situation, she has no option to act for herself on this issue (for instance to pay for and arrange damp treatment). Interestingly, despite the fact that all our interviewees were tenants, some of the wealthier interviewees did make considerable changes to their houses themselves, and had considered fitting energy efficiency improvements.

Generally speaking, however, it is important to note that people living in fuel poverty have only limited capacity to act, recalling some of our own work on sustainable living elsewhere<sup>24</sup>. Understanding that capacity is important as it gives us an idea as to what measures might be most appropriate to address the dual problems of fuel poverty and the environmental impacts of energy emissions. To be precise, the frugality that we noticed at the beginning of this section can only go so far towards alleviating both of these problems, because of the structural drivers of practice noted in this section.

### ***5.3.5 Understandings of 'environmentalism'***

It was considered important to investigate how and if our respondents understood their own actions in relation to either environmentalism or the more specific 'low-carbon agenda'. To this end we asked each respondent the question “can you describe to me a person that lives in an environmentally friendly way?”. Reactions to this question varied considerably – some respondents had no clear idea of what that would mean, others gave rather telling responses. Witness, for instance, Sally from Leeds, and her daughter who was listening in to the interview.

“Sally: You mean like the solar panels, and, you know, that type of thing?...  
Sally's daughter: Yeah, do we know anyone like that, mum?”

It is clear here that 'environmentalism' is not something that 'we' do or that anyone 'we' know does. Indeed none of my respondents claimed that they lived in an

environmentally-friendly way, despite the likelihood that people that live without many resources are likely to have less impact on the environment than the rich (see also energy expenditure data from Figure 5). Also intriguing is the example of solar panels as a sign of environmentalism: while this is a very visible sign that someone takes environmental living seriously, it is also a technology that is to a great extent out of reach for people living in fuel poverty. In a sense then, the respondents we interviewed had a vision of environmentalism and low-carbon living which is wholly inappropriate for the specific conditions in which they live. None of the respondents spontaneously connected their energy frugality to a sense that they were making a contribution to environmentalism.

Interestingly, however, the frugality that people practice, seems to have an impact on their understanding of what environmental means. When pressed to explain what they understood by environmental living, two of our respondents responded as follows:

“I do think it is important to recognize that they are not infinite resources and that they do need to be carefully controlled and managed.” Barbara, Leeds

“I don’t feel we are wasting anything, because you used to see the adverts with the heat going out of the roof and everything, but we don’t have that problem” Mildred, Edinburgh

Here both Barbara and Mildred define environmentalism in terms of conserving resources, a practice they are accustomed to in their everyday lives. This connects very strongly with the frugality that we noted above in reaction to both fuel poverty, and to generally constrained circumstances.

### **The Green Deal and Energy Company Obligation**

Having identified that the cost of energy efficiency refurbishments was prohibitive, particularly when faced with ambitious energy targets, the UK Government proposed the Green Deal in 2010, to be implemented in 2012. A homeowner (though the scheme might also apply to non-domestic buildings) would approach a registered private company to, effectively, loan them the capital cost of a range of accredited measures, subject to specific criteria.

The energy bill savings accrued from the installation of these measures would then be used to pay off the loan over an agreed period of time (currently suggested as being up to 25 years). It is also proposed that the homeowner would receive a proportion of the energy savings as an incentive for signing up to the scheme. Crucially, if the homeowner was to move, the loan repayments would remain with the property not the occupant, and therefore transfer to the new occupant. This issue, in particular, requires new legislation that is currently being discussed.

The measures must reach a “cost-effective” definition relating to their potential payback – this is often referred to as the “Golden Rule”, ensuring that measures save enough money that the provider of the loan can recoup their investment within the designated time period. However, when addressing vulnerable homes, there may be socially responsible reasons where refurbishments are necessary even if they do not meet the Golden Rule. The Energy Company Obligation (ECO) is being discussed as an additional funding source with this in mind. The ECO will be focussed on vulnerable and low-income households and will be funded by energy companies. Information on the detail of this scheme, and integration with the Green Deal, is not yet available. There also remains a list of concerns relating to the implementation of such mechanisms, and the reliance on private-sector funding. Some of these concerns are included in section 6.

## 6. Discussion of policy implications

The policy areas of fuel poverty and carbon-saving refurbishments has been casually linked in the past, but sometimes without an appropriate understanding that a “household” is a sum of both house and occupants. While funding streams can be appropriate for reducing both the carbon emissions of the domestic stock and fuel poverty, such policies can only be effective if they are sensitive to the interaction of a fuel poor family with their home.

Currently, and for the near future, the main mechanism being proposed for dealing with these issues appears to be the Green Deal (see text box, above), possibly combined with the Energy Company Obligation (ECO) for fuel poor homes. This programme would encourage private companies (such as national energy companies) to provide the capital for various low-carbon refurbishments, with this investment paid by the homeowner (or, perhaps, social housing provider) through savings in energy bills, with interest payments likely on the initial investment. The size of interest payments are yet to be decided but this may be the first stumbling block; a survey by the Great British Refurb Campaign<sup>25</sup> showed only 7% of respondents being “likely” or “fairly likely” to use the Green Deal if interest rates were as much as 6% (with many companies currently suggesting that higher interest rates would be required). Assuming the occupant would still find the deal attractive, they would receive a certain percentage of the projected savings, but the majority of the saving would go to the organisation purchasing the technology to pay for the initial loan. Investments in the region of £12billion are being suggested for social housing, with this sector reported by a National Housing Federation (NHF)/Camco study as being worth 11% of the green deal retrofit market<sup>26</sup>. This significant market share would suggest that focusing on social housing could open up the retrofit market in the UK, by effectively making social housing providers “early adopters” of technologies that then drives maturation in other markets (as defined by Rogers model of technology adoption<sup>27</sup>).

The NHF/Camco report also suggests carbon savings in the region of 21% might be *possible* in the social housing sector – still somewhat short of Government targets for carbon savings but more significant than any savings generated by CERT-type schemes. However, this estimate is then qualified by suggesting that a figure of just 4% is currently more likely. Additionally, to ensure effectiveness, the report calls for such schemes to work with additional policy drivers such as feed-in tariffs and the renewable heat incentive.

However, there remain several concerns with the Green Deal. On a technical basis, attempting to quantify the effect of technologies on energy bills, such that the technology provider and occupant can agree a payback deal, would be difficult based on the currently available tools. SAP, for example, would not be a reliable approach for predicting future bills of a retrofitted house, and structuring a regular repayment arrangement around. Furthermore, if the occupant of a home, pre-retrofit, has been underheating their property (not uncommon in fuel poor households), then they are likely to “takeback” some of the post-retrofit savings to improve their thermal comfort<sup>28</sup> – namely, heating their homes to a higher temperature. How could this be accommodated in the above repayment scheme?

Also, whether this is an optimum approach for most measures is questionable. For a relatively low capital cost technology (roof insulation, cavity wall insulation, draughtproofing and low energy lighting), effectively borrowing the money to pay for such measures, and paying interest on this upfront cost, would seem ill-advised for cost-effective, short payback technologies. The Green Deal would effectively result in the occupant/social housing provider paying more for that technology than if they had paid the upfront cost themselves – a situation that might be unnecessary for a relatively low-cost measure. For larger capital cost measures, the payback period (time taken for the technology to pay for itself) can be several decades. This can include solid wall insulation, new boilers, double-glazing, and onsite generation – while the recipient of the technology would benefit from this situation, the economic incentive for an organisation to invest in such measures would therefore appear to be weak. Furthermore, with a suggested limit of £6,500 per house for Green Deal investment, most of these technologies would be immediately ineligible. It is worth noting that estimated costs for deep-cut carbon savings refurbishments (i.e. in the region of 50% savings and above) vary between £7,000 and £32,000 per home<sup>15</sup>. It is therefore important to question just how far a maximum limit of £6,500 per home will actually go in improving a fuel poor home. This is particularly true for social housing, which are more likely to already have some of the cheaper measures installed.

Returning to the 4-21% carbon-saving range suggested by NHF/Camco above, an additional problem is evident that relates to fuel poverty, but not necessarily to carbon targets. The future savings to building carbon emissions and energy bills are strongly influenced by the carbon intensity and “cost intensity” of the energy being used. Focussing just on space heating, the carbon intensity of gas (the main heating fuel in the UK) has been relatively constant for several years. This would suggest that, crudely, carbon emission savings (from reduced gas usage) will be “future-proofed” in that the fuel being used has the same intensity in the future as it does now (this ignores fuel switching that might occur from, for example, a change to heat pump technology). However, Figure 1 demonstrates that “cost intensity” of energy, namely retail gas prices, are increasing considerably year-on-year and this has a huge impact on fuel poverty numbers. So, in summary, even if the Green Deal produced 21% savings in carbon emissions, this initial 21% reduction in fuel bills could gradually evaporate over time if retail gas prices are allowed to rise for social housing tenants. Though details are still emerging about this scheme, several weaknesses are clear that might make large scale changes to fuel poverty difficult to achieve in reality.

Moving away from the proposed Green Deal, there is the Warm Front scheme that has been running for several years though, at time of writing, is being re-structured due to a change in available funding. The scheme involved making energy improvements, mainly for low income households, such as loft and cavity wall insulation, replacing the heating system etc. A report by Gilbertson et al suggested multiple positive effects for households where this kind of measure is introduced<sup>29</sup>. While few reported lower heating bills, most householders reported improved and more controllable warmth, improved physical health and comfort, improved family relations, a use of more space in the home during winter, and various other positive side effects. This suggests that households benefit from improvements to the home by improving their living conditions, bringing them out of certain elements of the experience of fuel poverty. In many ways this can be seen as a positive ‘rebound effect’: with families clawing back

some of the quality of life standards that many of us take for granted, once their houses are more able to cope with the weather. Given the approach of these families to budgeting which we have seen elsewhere<sup>22</sup>, it is unlikely that such a rebound will spiral to result in substantially increased carbon emissions. Despite this relative success, the Warm Front scheme will end in 2012.

Given that we have also investigated how fuel poverty impacts on the day-to-day lives of the fuel poor, it is interesting here to reflect on how this relates to the 'low-carbon living' agenda, or more broadly, the governments' sustainable consumption policy. To date, UK government work on sustainable consumption has tended to focus on individual solutions to this rather systemic problem, emphasising the responsibilities of individuals to address climate change<sup>24</sup>. This work also tends to fail to differentiate between types of UK resident, thereby offering similar advice to different types of people, about how they can live a low-carbon lifestyle. Our work on the fuel poor would argue for a much more nuanced view of 'the public'. This section of community in particular, for instance, is less able to take any personal action on climate change which involves investments (e.g. insulating, changing a boiler, buying new appliances). On the other hand, they are likely to heed messages about saving energy more effectively, since frugality is already a deep part of their daily practice. This suggests that the fuel poor are likely to be a good target for investment from government in the form of improving the homes that they inhabit, and thereby allowing for even more low-carbon lifestyles – subject, of course, to an understanding of the rebound effect. Additionally, some aspects of the fuel poor's lifestyles that rely on fuel are strongly rooted in cultural practices, and the importance of these should not be underestimated. Understanding the fuel poor's lifestyles in detail should allow for meaningful investment by government, which both reduces carbon footprints, and decreases energy bills for those on the lowest wages.

## **7. Conclusions**

The combination of the described study with previous research has produced the following conclusions, relating to fuel poverty and carbon-saving synergies in the UK domestic stock.

### **1. A household is a sum of the house and the occupant**

This statement is true for all domestic buildings, but is particularly true if focussing on a specific section of society, such as the fuel poor or low-income families more generally

### **2. Behavioural responses in fuel poor homes seem to be specific to that particularly sector**

While this can be subtle, and more empirical data is needed in this area, choices made by those in fuel poor homes can have clear effects on their energy consumption but also might influence the choice of measures suitable for that home.

### **3. "Electricity as entertainment" in low-income homes, particularly those with children, can have a significant impact on the household's fuel poverty status**

If a family is unable to opt for more expensive forms of leisure (e.g. holidays, going out), the use of home entertainment is a viable and affordable choice.



However, this can have a direct effect on the fuel poverty status of that family through higher than average electricity consumption – with electricity being ~2.5 times more expensive than gas, it is important not to discount this effect. The choices for then bringing that family out of fuel poverty are more difficult – insulation measures will not have a high impact on electrical usage for a gas-heated home.

**4. The fuel poor do not recognise themselves as living ‘low-carbon lifestyles’ but it seems likely that they do**

The frugal responses that our sample display, suggest that their fuel poverty results in a rather low carbon impact. Helping those in fuel poverty to recognise this, and rewarding this through policy, could be a positive way of encouraging continued action.

**5. Energy inefficiency is not the main driver of fuel poverty in the UK**

The small changes in the efficiency of the UK stock over the last decade have had minimal impact on fuel poverty numbers. That is because this is driven by, in particular, gas prices. However, we are attempting to measure very small changes to the overall efficiency of the stock – if large-scale changes are made to fuel poor homes then it may be possible to reduce the sensitivity of such households to rising fuel prices, though without eliminating this problem.

**6. The proposed Green Deal is not suitably structured for achieving large-scale reductions in fuel poverty and domestic carbon emissions**

As discussed, the Green Deal is subject to several limitations and weaknesses that make it difficult to see how it can have a large impact on fuel poverty numbers in the UK. If large-scale measures are needed to have a genuine, and long lasting, effect, then £6,500 per home is not likely to be sufficient for fuel poor social housing tenants to rise out of fuel poverty. It is currently unclear whether the ECO will be sufficient to compensate for any of the weaknesses of the Green Deal when applied to fuel poor homes.

**7. Large-scale changes to buildings are necessary if a substantial impact to both fuel poverty and domestic carbon emissions is made – but this requires a greater understanding of the sector**

It is clear that, if more expensive and complex measures are to be installed in fuel poor homes, a greater understanding of the occupant is needed. Existing energy behaviour, energy frugality (as governed by income) and the response of the occupant to any potential energy-saving improvement will not be universal across the stock.

**8. Fuel poor behaviour may become more common, and even be seen as the “norm” as domestic energy prices rise**

Quite dramatic rises in fuel poverty have been seen in recent years, and projected reductions in heating subsidies will not improve this situation. We are now at a stage where fuel poverty, at 21% of the entire domestic stock, is not “unusual” and actually comprises a large socio-demographic grouping in the UK. Projecting gas and electricity price rises onto this suggests that this percentage will only rise further such that the choices made and behaviour recorded in

current fuel poor homes might be replicated in even greater numbers of homes in the future. This makes it even more important that we understand the nature of energy use in such households.

**9. Fuel poor social housing is a sensible, and fair, sector to concentrate investments in low-carbon refurbishments**

If carbon-saving targets are to be met, then a vast investment is required for improving the condition of the UK domestic stock – several orders of magnitude greater than current schemes can provide. Any initial public investment should be focussed on a sector that has the ability to instigate change, as this will ensure a greater rate of technology installation, with expected secondary effects on other sectors such as the private market (as those technologies become cheaper and more reliable). Social housing organisations would seem like a suitable starting point in this respect, and their involvement would allow a greater understanding of post-retrofit effects of the installed refurbishments. Additionally, the funding should help vulnerable occupants, who are not able to make such changes themselves, such as the fuel poor. Inaction will have serious implications for a rapidly rising section of the UK.

# Appendix I – Examples of Tarbase model input/output

**Input Page** Project title: Building 1

= required input  
= drop-down inputs

### Dimensions

Width (North and South walls) (m)	13.4	m
Length (West and East walls) (m)	3.7	m
Floor to ceiling height (m)	2.3	m
Number of storeys	1	
Total internal floor area (m <sup>2</sup> )	46	m <sup>2</sup>
Heated space (m <sup>3</sup> )	106	m <sup>3</sup>
Perimeter of ground floor (m)	34	m

### CO2 Intensities:

	Current	Refurb	
Grid	0.517	0.517	kgCO2/kWh
Space heating	0.245	0.245	kgCO2/kWh
DHW	0.245	0.245	kgCO2/kWh

### Energy tariffs:

	Current	Refurb	
Grid	0.1146	0.1146	£/kWh
Space heating	0.08	0.08	£/kWh
DHW	0.08	0.08	£/kWh

### Room specification

Room	Floor area (m <sup>2</sup> )	Comfort temperature (°C)	Lighting type			
			1	% of total	2	% of total
Hallway	3.5	21.5	GLS	100	GLS	0
Living room	13.2	21.5	GLS	100	GLS	0
nr/s	0.0	21.5	GLS	100	GLS	0
Kitchen	8.5	18	GLS	100	GLS	0
Bedrooms	16.6	18	GLS	100	GLS	0
Bathroom	4.4	26.5	GLS	100	GLS	0

### Boiler

Combi/regular	Combi
Type	Gas non-condensing
Average efficiency	79.9 %
SEDBUK rating	D
% lagging on pipes	0 %
Cylinder volume	0 litres

NB for electric heating choose gas non-condensing at 100% efficiency with grid CO2 intensity for heating

### Cooking

		kgCO2/kWh		p/kWh	
Oven Fuel	Fuel type	Current	Refurb	Current	Refurb
Hob fuel	Gas	0.25	0.25	0.08	0.08

NB if not electric choose gas

### Construction

	U-value (W/m <sup>2</sup> K)	Effective U-value (W/m <sup>2</sup> K)	Area (m <sup>2</sup> )	Glazing			Doors/other opening		External surface? (mark with 'x')					
				Material	U-value (W/m <sup>2</sup> K)	Frames	External shading	Area (m <sup>2</sup> )	U-value (W/m <sup>2</sup> K)	Area (m <sup>2</sup> )	External	Adjoins to corridor/stairs	Adiabatic	
N	0.69	0.69	30.7	Double	2.75	PVC	1	5.3				x		
S	0.69	0.69	30.7	Double	2.75	PVC	1	3.4	3.0	5.22		x		
E	0.69	0.69	8.4	Double	2.75	PVC	1	0.0				x		
W	0.69	0.69	8.2	Double	2.75	PVC	1	2.0				x		
TOTAL WALLS	0.77	0.55	28.1					11.3	3.0	5.2				
Roof	0.79	0.79	48.0	Single	1.4	Wood	1	0.0				x		
Floor	0.35	0.35	46.0									x		

### Household details

Adult Males	1
Adult Females	1
Children School age	0
Infiltration rate	0.77
boiler operation weekday	10 hrs
boiler operation weekend	11.25 hrs
Occupied weeks per year	49 hrs

### Location

Birmingham	
x Cardiff	
Edinburgh	
London	
Newcastle	
Manchester	

### Calculates infiltration rate via SAP

No. of chimneys	0	m <sup>3</sup> /hr
No. of open flues	0	
No. of intermittent fans/vents	0	
No. of fuelless gas fires	0	
Airchange due to above	0.00	ac/h
Number of storeys	1	
Structural infiltration	Masonry 0.35	
Suspended floor	No	
Effect of floor	0	
Draught lobby? Y/N	Y	
% windows/doors draughtstripped	100	
Window infiltration	0.05	
OR override value	0.77	ac/h

Figure A – Input page of Tarbase Domestic Model

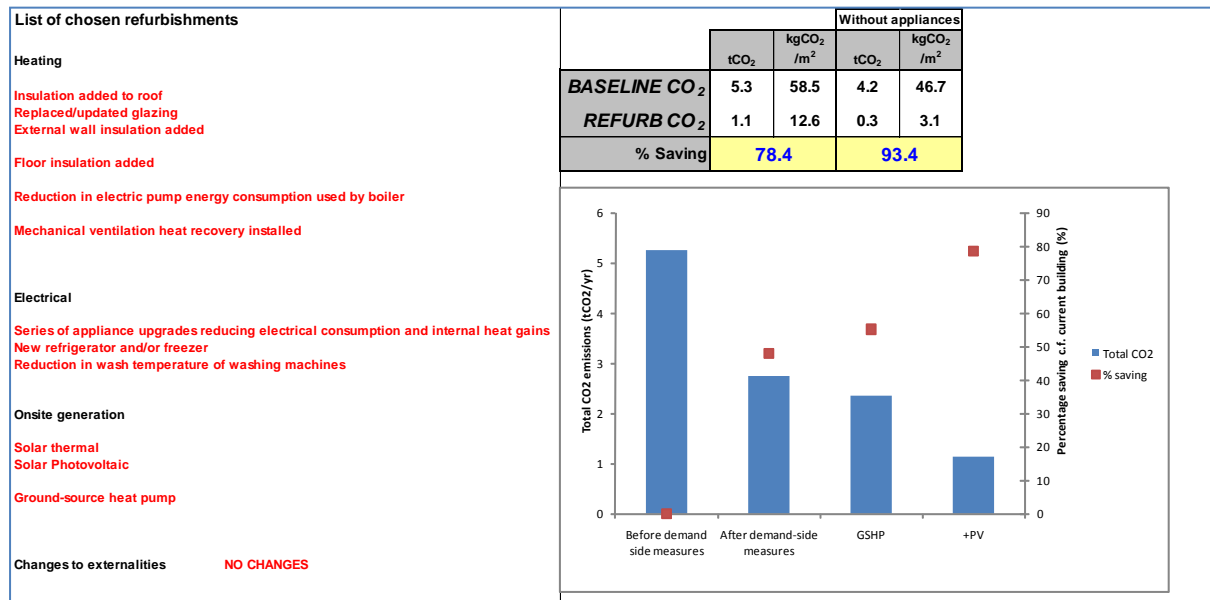


Figure B – Output page of Tarbase Domestic Model

## Appendix II - Detailed results from modelling of carbon emissions (kgCO<sub>2</sub>/m<sup>2</sup>) for selected refurbishments

Building no.	1	2	3	4	5	6	7
<b>Baseline</b>							
Appliances	20.7	28.9	25.2	17.9	36.1	28.5	25.6
Refrigeration	4.7	4.2	4.8	1.9	3.6	2.6	4.1
Lighting	1.8	1.9	2.5	2.0	1.1	1.1	4.0
Space heating	11.2	17.6	17.2	24.9	5.2	5.9	6.7
Hot water	9.1	8.0	11.3	8.1	11.6	10.4	7.9
<b>TOTAL</b>	<b>47.5</b>	<b>60.6</b>	<b>60.9</b>	<b>54.8</b>	<b>57.6</b>	<b>48.6</b>	<b>48.3</b>
<b>Cost-effective</b>							
Appliances	14.4	23.8	18.2	10.7	27.8	22.6	18.5
Refrigeration	3.0	2.6	3.0	1.2	2.3	1.6	2.6
Lighting	1.5	1.9	1.7	2.0	1.1	1.1	1.5
Space heating	10.5	16.0	11.0	14.3	5.0	5.5	6.9
Hot water	9.1	8.0	11.3	8.1	11.6	10.4	7.9
<b>TOTAL</b>	<b>38.6</b>	<b>52.3</b>	<b>45.1</b>	<b>36.3</b>	<b>47.8</b>	<b>41.2</b>	<b>37.5</b>
% saving	18.8	13.7	25.9	33.8	17.0	15.2	22.4
<b>Long term payback</b>							
Appliances	14.4	23.7	18.1	10.6	27.7	22.5	18.4
Refrigeration	3.0	2.6	3.0	1.2	2.3	1.6	2.6
Lighting	1.5	1.9	1.7	2.0	1.1	1.1	1.5
Space heating	8.1	13.1	6.6	9.1	4.2	4.7	4.5
Hot water	9.1	8.0	5.6	4.1	5.8	5.2	4.0
<b>TOTAL</b>	<b>36.1</b>	<b>49.3</b>	<b>35.1</b>	<b>27.0</b>	<b>41.1</b>	<b>35.1</b>	<b>30.9</b>
% saving	24.0	18.6	42.4	50.8	28.6	27.7	35.9

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