Causes and Implications of Socio-Economic Differentiation in Residential Energy Efficiency Retrofitting

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In many ways, energy efficiency can be seen as Europe's biggest energy resource

European Commission, 2011

Abstract

Analysis of fuel expenditure statistics indicates that for the majority of householders, more fuel efficient homes can explain approximately 15% of fuel demand changes between 2002 and 2008. The analysis suggests that other factors, such as rising fuel costs and warmer winters, account for vast majority of the demand changes during this period. But in upper quartile income households, any demand reduction brought about by energy efficiency was undetectable against the changes caused by price and temperature variations.

This thesis provides evidence of disproportionately low insulation retro-fitting rates in upper quartile income homes and suggests two predominant causes. Firstly, approximately 95% of upper quartile income householders were ineligible for retro-fit assistance from the state agencies and secondly, the relative value of energy efficiency is less in the most affluent households, because the proportion of income spent on fuel tends to decline as incomes rise.

Fuel expenditure statistics indicate that the household fuel demand reductions delivered by greater household energy efficiency between 2002 and 2008 would have been approximately 30% greater if the most affluent households had retro-fitted basic energy efficiency measures at similar rates to their lower income neighbours.

Household surveys in two affluent districts support one of the principal findings from the study of fuel expenditure statistics, that energy efficiency tends to be less valuable to affluent households, which tends to make the fuel rich, collectively, more apathetic towards energy efficiency. However when motivational barriers are removed, the fuel rich tend to accept energy efficiency retro-fits in disproportionately large numbers.

The thesis concludes that effective household emission reduction programmes need policies which also stimulate greater energy efficiency by increasing the value of energy efficiency, particularly in affluent homes.

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Acronyms

BIS – Department of Business Innovation and Skills

CERT – Carbon Emission Reduction Target

DCLG - Department For Communities & Local Government

DECC – Department of Energy & Climate Change

DEFRA – Department For Environment Food & Rural Affairs

ECO – Energy Company Obligation

EEC - Energy Efficiency Commitment Supplier Obligation (1 and 2)

EESoP - Efficiency Standards of Performance

EFS - Expenditure and Food Survey

EHS - English Housing Survey

EHCS - English House Condition Survey

EST – Energy Saving Trust

LCF - Living Costs And Food Survey

LSOA – Lower Level Super Output Area

MSOA – Middle Level Super Output Area

UKDS – United Kingdom Data Services

ONS – Office For National Statistics

RSL – Registered Social Landlord

SAP - Standard Assessment Procedure

USEIA- United States Energy Information Agency

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1 INTRODUCTION

1.1 Background

Policies and regulations to reduce environmental degradation and deter pollution have traditionally tended to drive change by 'making the polluter pay'. The Environmental Protection Act 1990 and The Climate Change Levy Regulations, 2001, are examples of this approach. However when dealing with household fuel consumption, the strategies developed by Department of Energy and Climate Change to reduce residential carbon dioxide emissions (DECC, 2009a, 2011a) do not appear to consider how fuel demand is distributed across society, or how to 'make the polluter pay'.

Other than an instinct that relatively wealthy householders in larger properties would probably consume more fuel than less affluent householders in smaller homes, it was not clear at the outset of this research how household emissions were distributed. Nor was it evident which households were responding to HM Government's calls and initiatives to encourage householders to retro-fit additional insulation and install more efficient heating systems.

The literature has been able to answer to some of the more basic queries, for example, "what type of properties tend to consume most power and emit most carbon dioxide?" or "do high income households typically consume disproportionate amounts of fuel?" However the literature was unable to provide detailed answers to questions, such as "do householders who have not made their homes more energy efficient tend to share particular characteristics? If so, why?" From these more detailed questions, the central theme of this study developed, "has energy efficiency retro-fitting in UK homes become socially differentiated and if so, what are the implications for energy efficiency policies?"

1.2 **Policy Context**

Under The Kyoto Protocol (UN, 1997), the European Union has pledged to reduce greenhouse gas emissions to 92% of 1990 levels by Commitment Period 2018-2022. In 2008, the EU specified that Member States reduce carbon dioxide emissions to less than 80% of 1990 levels by 2020, with a commitment to reduce emissions to less than 70%, if other major carbon dioxide emitters agree to additional reductions. In 2011, the EU added a further objective, to reduce fuel consumption in 2020 by 20% on 2007 levels (European Commission, 2011).

The Inter-Governmental Panel on Climate Change (2007) concluded that direct and indirect consumption of fossil fuels and land use changes have been the principal causes of rising concentrations of atmospheric carbon dioxide over the last 250 years. By either reducing the overall fuel demand and/or switching to less carbon intensive fuels, more efficient energy consumption can help to check the rise in atmospheric carbon dioxide and so help to minimize the impact of rising global temperatures.

To meet the EU obligations and prepare the UK for a shift away from an economy dependent upon fossil fuels, the 2008 Climate Change Act commits HM Government to reduce greenhouse gas emissions by 34% by 2020 and 80% by 2050, taking 1990 emissions as the base case. In 2011, the government accepted an additional target proposed by the Committee on Climate Change, to reduce emissions by 50% by 2025.

These targets, developed to control man-made climate change, have become a major energy efficiency driver but limiting the global impact of climate change by reducing greenhouse gas emissions is only one of a series of benefits available to an economy and a society less dependent upon fossil fuels and which uses energy more efficiently. In the last ten years North Sea fuel production peaked and the UK is no longer self-sufficient in either gas or oil. By 2020, DECC (2011a) anticipates that over half of the national fuel demand will be met by imports. This increasing dependence upon imported fuel comes during a period when many researchers, for example Aleklett et al (2010) and Sorrell et al

(2009a) anticipate that the global economy is likely to experience 'peak oil', the point where global demand for fuel and hydrocarbon products outstrips the supply. An economy that is less dependent upon imported fossil fuels would be more resilient when faced with increasing fuel supply interruptions (DECC, 2011a).

Using energy more efficiently would also reduce the cost of renewing the power generation and distribution infrastructure. HM Government estimates that by 2020 total investment in electricity and gas infrastructure, excluding renewable power, will be of the order of £200 billion (Harvey, 2011). Additionally by the same year the EU Renewable Energy Directive requires that the UK is able to meet 15% of the national fuel demand from renewable sources. The operating costs of renewable power generation may be lower than conventional power stations, but developing renewable energy infrastructure is more expensive (Power, 2011). So, by lowering the overall demand, the cost of developing that national renewable energy capacity would be diminished.

Energy efficiency improvements could also create jobs. The 'green' economy offers employment opportunities in high technology sectors, such as 'smart' electricity grids, or in more labour intensive occupations, including retro-fitting insulation in UK homes. DECC (2010a) estimates that the household energy management strategy 'Warm Homes Greener Homes' could, alone, create up to 65,000 additional jobs.

A more energy efficient housing stock would also help to reduce fuel poverty and cushion the impact of fuel price rises in vulnerable households. An energy inefficient home is one of the three primary causes of fuel poverty (DECC, 2011b, Boardman, 2010, see Appendix 1) and under the Warm Homes and Energy Conservation Act (2000), the Government is obliged to ensure that 'as far as is reasonably practicable', people do not live in fuel poverty by 2016 in England and 2018 in Wales.

1.3 The Low Carbon Residential Challenge

The low carbon strategy for the UK economy was set out in The UK Low Carbon Transition Plan (DECC, 2009a). The Plan sub-divides the economy into five sectors: the power sector;

homes and communities; workplaces and jobs; transport; and, agriculture, land and waste. The aim is to allow each sector to develop to meet the needs of a growing population, whilst simultaneously reducing the energy demand of each group by making the various actors much more energy efficient. In the residential sector this means that energy efficiency and micro-generation measures must be retro-fitted in the entire housing stock.

In percentage terms, the residential sector element of the proposals is particularly ambitious. Residential carbon dioxide emissions are to be reduced by 29% on 1990 levels by 2020 and by 2050, the emissions from UK homes must be 'almost zero' (DECC, 2009a) or 'close to zero' (DECC, 2011a).

That is not to say that homes must be zero energy at that point, rather the energy services which householders need must be catered for by reducing residential fuel consumption by about 80% and the unabated demand met using building-integrated renewables and low carbon intensity primary fuels (Boardman, 2012).

New homes after 2016 are to produce no net carbon dioxide, which is a technological challenge for the construction industry, as the number of households in the UK rises from 26 million in 2008 to an estimated 29.5 million by 2023 (DCLG, 2010a). But arguably the more significant barrier is the thermal renovation of the existing housing stock. The Committee on Climate Change (2008) estimates that 99% of existing homes with still be used in 2020 and, unless demolition rates (DCLG, 2010b) alter drastically, by 2050, 95% of existing homes will remain in use and they will make up about 75% of the housing stock.

In other words 19 out of every 20 UK homes standing in 2012 must be retro-fitted so that residential carbon dioxide emissions are net zero and every twentieth house, demolished and replaced by a 'zero carbon' home. The scale of this ambition is summed up by the Department of Business Innovation and Skills (Low Carbon Construction Innovation & Growth Team, 2010).

"There are approximately 25 million existing homes to be retro-fitted by the end of 2050. There are approximately 21 million minutes between now and the end of 2050."

The Innovation & Growth Team suggest that an overall investment of around £200 billion, equivalent to approximately £7,500 per dwelling at 2010 prices, would reduce residential carbon dioxide emissions by 60%. However making homes net zero carbon requires fuel demand to be reduced by about 80%, rather than 60% (Committee on Climate Change, 2008, Boardman et al, 2007) and several researchers, for example the Energy Savings Trust (2008) and Enseling and Hinz (2006) have highlighted that the costs per tonne of carbon emissions abated increase significantly as the emission reduction target becomes higher (Appendix 2).

Based upon the findings of Killip (2011) and the Energy Saving Trust (2009) and assuming that approximately 20% of emissions are abated by decarbonizing the grid, suggests that thermally retro-fitting the housing stock so that homes produce net zero carbon may cost between £20,000 and £40,000 per property, at 2012 prices. This is equivalent to between £500 billion and £1 trillion, or all HM Government receipts for one to two years. It is difficult to conceive that an investment in private housing on this scale would be centrally funded. Therefore it appears likely that home owners must be persuaded to carry out the work.

1.4 Thesis Structure

This thesis attempts to quantify fuel demand changes attributable to greater energy efficiency in the home, and identify the characteristics of active and inactive retro-fitters to inform a review of recent and current energy efficiency polices. Chapters 2 to 5 include discussions on UK residential energy demand, retro-fitting policies, retro-fitting trends and barriers to retro-fitting. The research questions are framed in Chapter 6. The research questions were addressed by analysis of primary and secondary data. The research methods and the study findings are described in Chapters 7 to 12 . The implications of the research are discussed in Chapter 13 and the project is reviewed in Chapter 14.

2 RESIDENTIAL ENERGY DEMAND

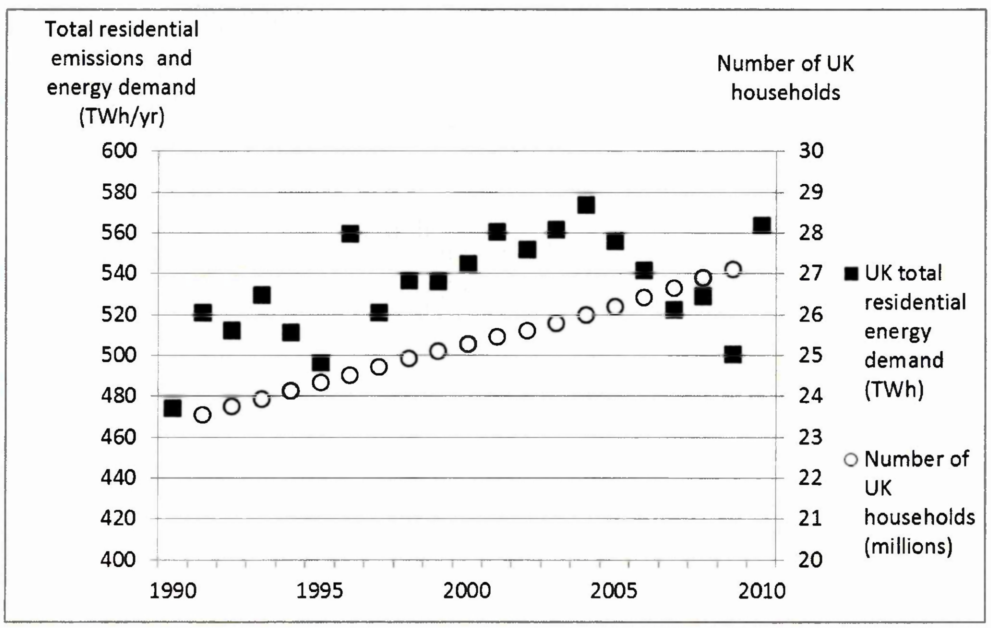
2.1 Introduction

This chapter provides background information on some of the inter-connected factors which influence household fuel demand, including the relative cost of fuel and the energy efficiency of the housing stock. The literature reviewed indicates that the housing stock has become more energy efficient, but where greater energy efficiency has reduced the cost of energy services, some of the savings on fuel expenditure have been used to purchase additional fuel. Indeed the greatest changes in residential fuel demand appear to be the result of variations in the price of fuel and average winter temperatures, rather than greater energy efficiency.

2.2 General Residential Energy Demand Trends

The UK's annual residential energy demand, illustrated Figure 2-1, grew progressively from 429 TWh/yr in 1970 to 574TWh/yr in 2004 (DECC, 2011c).

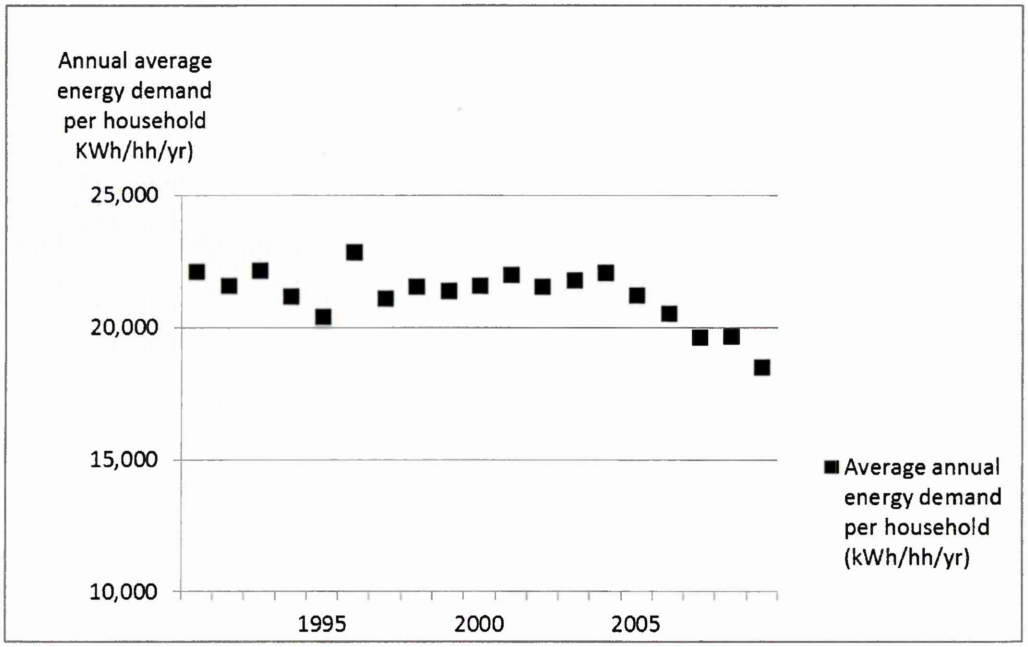
Figure 2-1 *Total UK residential fuel demand and the number of households*



Between 2004 and 2009, total household demand declined by just over 13%, before rising sharply in 2010, as a result of prolonged period of cold weather in December that year (DECC, 2012a).

Although total residential demand was rising between 1990 and 2004, the average fuel consumption per household remained relatively stable (Figure 2-2), indicating that the demand increase over this period was largely a function of the increasing number of households (Figure 2-1). The causes of declining demand after 2004 are considered further in the subsequent sections.

Figure 2-2 *Average energy demand per household*

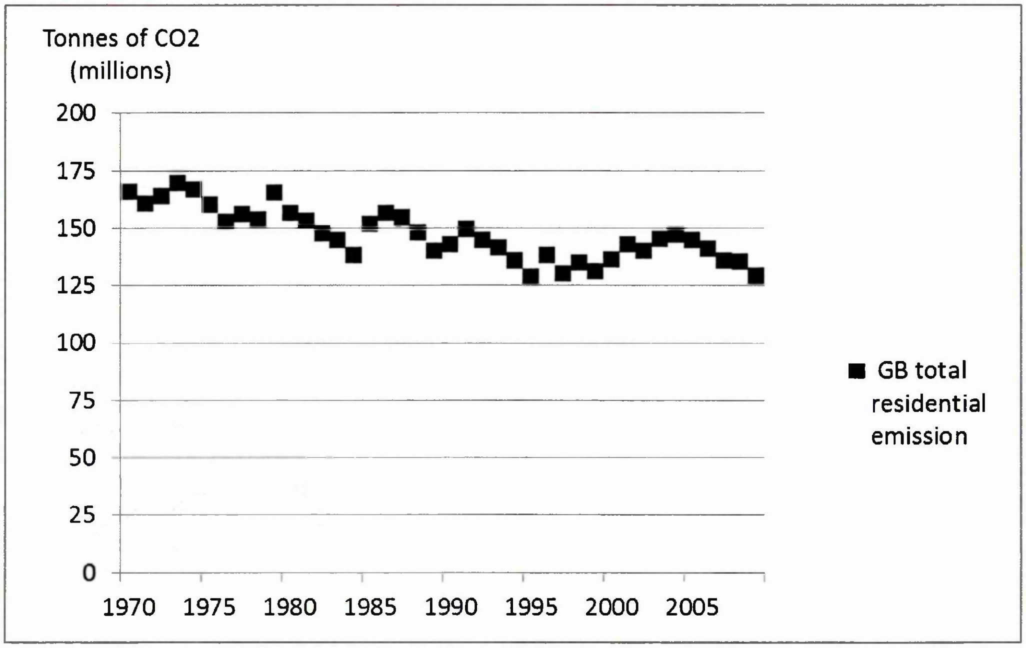


Source for Figures 2.1 and 2.2: Fuel consumption data, Table 1.1.1, Digest of UK Energy Statistics, 2011c, converted in TWh (1Toe = 11630kWh). Housing data from DCLG (2010a) Live Table 401, downloaded 4 Nov 2011.

2.3 Residential Carbon Dioxide Emissions

In contrast to fuel demand, which rose between 1970 and 2005, direct residential carbon dioxide emissions, emitted as a result of primary fuel combustion in the home, or in the case of electricity, at the power station, have been declining throughout the last forty years - see Figure 2-3.

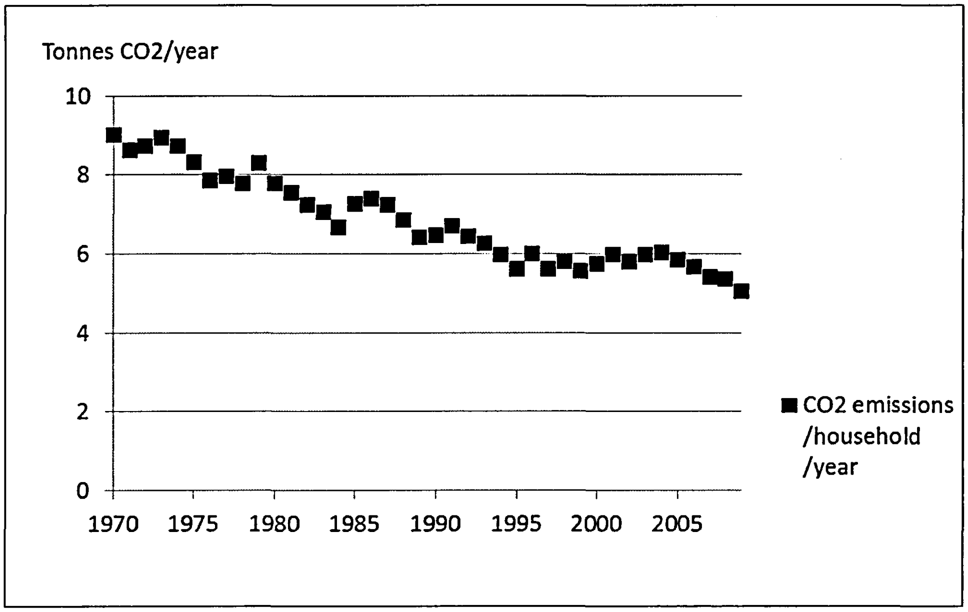
Figure 2-3 *Total annual direct carbon dioxide from British housing*



Source: Palmer & Cooper, 2011

The annual growth in the number of homes from 1970 onwards has been just under 1% (Appendix 3). Therefore a national fall in residential emissions must also be marked by a larger proportional reduction in emissions per household and, as illustrated in Figure 2-4, emissions of carbon dioxide per household have fallen by just over 40% since 1970.

Figure 2-4 *Direct carbon dioxide emissions per household*[1]



Source: Palmer, 2011

Dresner & Ekins (2006) studied fuel consumption data and noted that residential electricity consumption rose by 13% between 1990 and 2000, but that the rise in demand was accompanied by a fall of 24% in the carbon dioxide produced generating this electricity, as the proportion of electricity generated by gas, a less carbon intensive fuel than coal, increased. Therefore the relatively stable average fuel demand per household throughout the 1990's, which is illustrated in Figure 2-2, was accompanied by a decline in average household carbon dioxide emissions as a result of the decarbonisation of grid electricity (Figure 2-4).

However from 2004 onwards, declining household emissions were matched by an almost identical fall in energy delivered to UK homes (DECC, 2010b). Therefore, although the downward trend in carbon dioxide emissions, illustrated in Figure 2-3 and Figure 2-4,

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[1] Carbon dioxide emissions calculated using DEFRA 2009 emission factors (gas = 0.185, solid fuel = 0.296, oil = 0.245 kg CO_2/kWh. Electricity conversion factors are from the Market Transformation programme, reproduced by Palmer J (2011) in GB Housing Energy Fact File, 2011.

appears to have been reasonably constant over the last 40 years, the fuel statistics indicate that the downward pressure on emissions came from upstream decarbonisation throughout the 1990s, but after about 2004, falling emissions were the result of reductions in fuel demand.

2.4 Energy Efficiency of the Housing Stock

Commentators, campaigners and politicians, for example The Minister of State for Energy and Climate Change, Greg Barker[2] (2011) have contributed to an impression that the UK's housing stock is particularly energy inefficient. EU data on household energy efficiency however suggests that this is not the case. In fact the energy efficiency of UK homes was about the EU average in 2006 (Boonekamp, 2009) and homes in the UK tended to be more energy efficient than properties in countries with similar climates, for example Ireland or Belgium (Appendix 4).

As illustrated in Figure 2-5, the energy efficiency of the average UK home has consistently risen over the past 40 years. Figure 2-5, illustrates the average SAP rating per property, where SAP is the Government's Standard Assessment Procedure for rating the energy efficiency of dwellings. The SAP rating is expressed on a scale of 1 to 100, the higher the number, the lower the running costs per unit area.

So the energy efficiency of the housing stock per m^2 has been increasing, but the average fuel demand per household has remained largely static since at least 1990 (Figure 2-2), suggesting that the fall in expenditure which could have been delivered by greater energy efficiency has been used to buy more fuel, and/or the size of homes and the number of appliances per property, increased.

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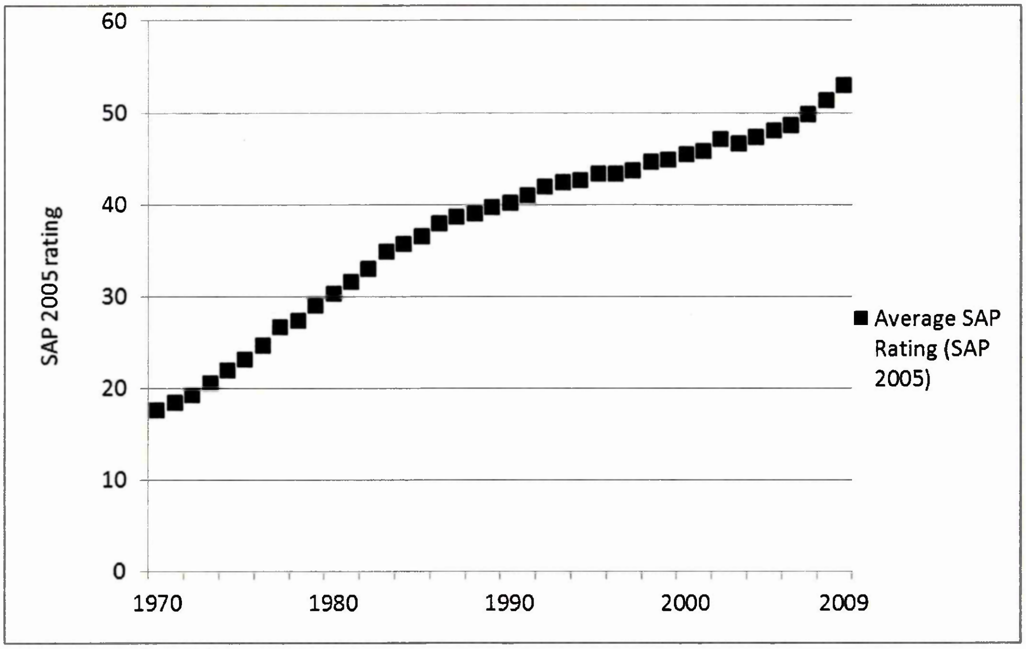
[2] Greg Barker MP advised that "the fact is that homes in the UK are amongst the most expensive to heat in Europe yet we don't have the most expensive gas and energy prices"

Figure 2-5 *Change in SAP 2005 rating of UK housing*



Source: DECC, (2011b)

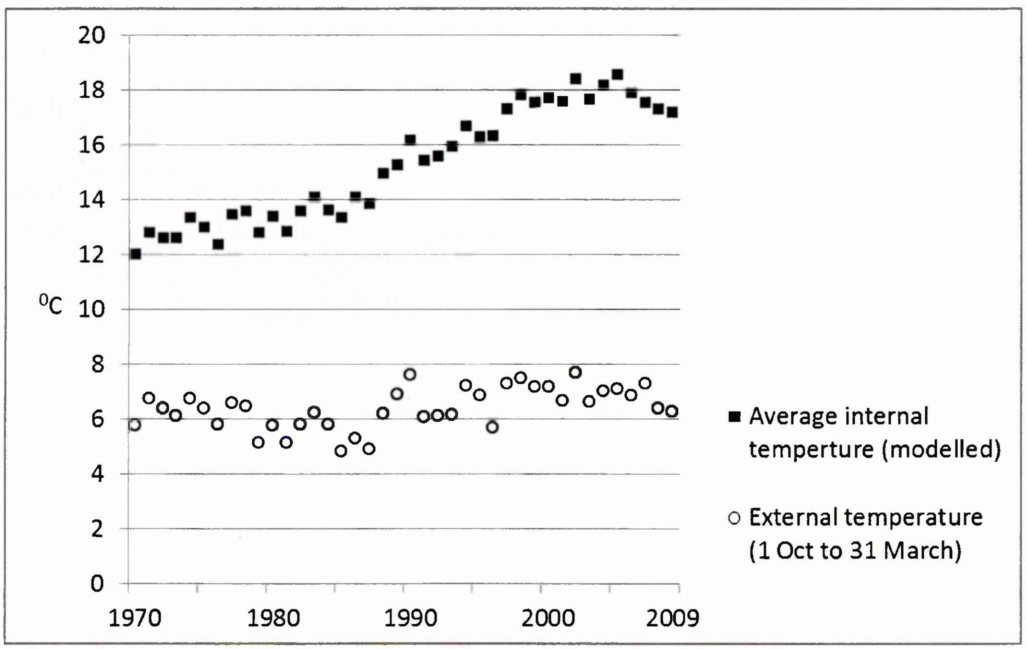
Summerfield et al (2010a) suggest that fuel price rises and changes in ambient temperatures can explain 99% of the variation in fuel demand since 1998. If this is the case, energy efficiency improvements in the housing stock will have not reduced fuel demand, although arguably energy efficiency improvements could have off-set increases in fuel demand per household, which would otherwise have come through. But Summerfield also noted that fuel price rises may trigger greater energy efficiency, which in turn reduces fuel demand. In other words, rising fuel prices may have acted, to a degree, as a fuel efficiency proxy, the effects of which would not become apparent in the demand statistics until fuel prices fell.

Work by DECC (2011d) on the other hand, suggests that recent improvements in the energy efficiency of the housing stock have contributed to quantifiable reductions in the demand for fuel. DECC (2011d) studied the fuel bills of approximately 925,000 homes and found that in nearly 16,000 households, where the only energy efficiency enhancement was cavity wall insulation, household gas consumption fell by an average of 16% in comparison to the control. Average gas consumption fell by 10% in 11,000 homes where the only energy efficiency improvement was a loft insulation top-up.

2.5 Internal Temperatures

Over the last twenty years, modeling by The Building Research Establishment suggests that average temperatures in UK homes have risen by about $4^{0}C$ (DECC, 2011c), whereas average British winter temperatures have risen by about one degree (DECC, 2011c). As indicated in Figure 2-6, average internal temperatures steadily increased to about $18^{0}C$ by 2000. Since 2005, the rising trend has been reversed and average internal temperatures declined by about $1^{0}C$ in four years.

Figure 2-6 *Representative average household and external temperatures*



Source DECC, 2011c, Energy Consumption UK, Table 3.16

Milne & Boardman (2000) found that 20^0C was the *"most likely comfort temperature in an energy efficient house"* and that householders will continue to invest in warmth, providing that it is affordable, until the internal temperature is around this point. Therefore one potential interpretation of the declining internal temperatures since 2005 is that warmth became less affordable and as discussed in the next section, between 2005 and 2009, fuel prices rose after more than a decade of steady real term falls.

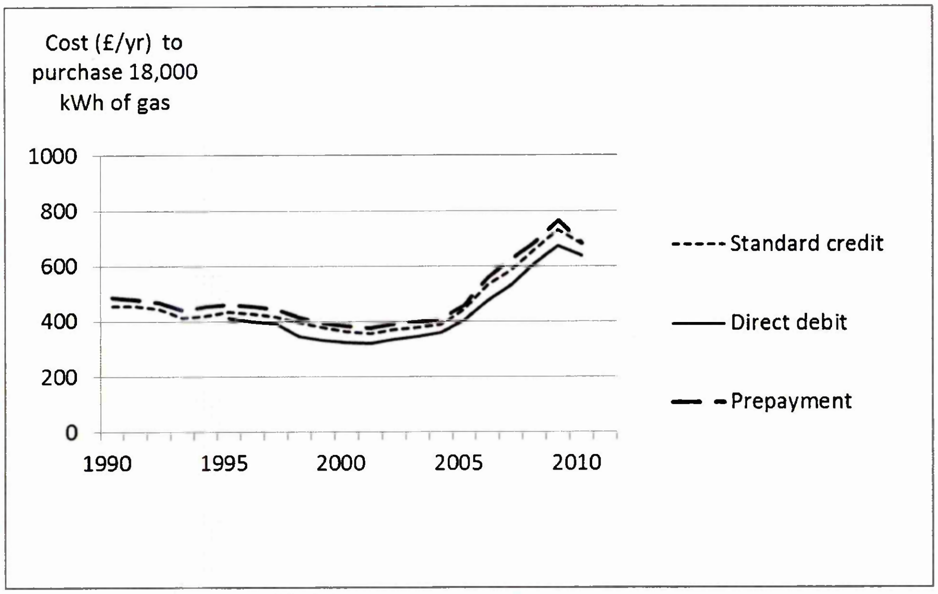
As illustrated in Figure 2-5, the thermal efficiency of the housing stock has risen steadily for at least the previous 40 years. However average internal temperatures, illustrated in Figure 2-6, also rose over the same period, suggesting that some of the energy savings made by improving the thermal efficiency of people's homes, were 'taken back' to increase the internal temperature. This rise in internal temperatures, coupled to increasing demand for domestic appliances (Utley and Shorrock, 2008) offer several reasons why the average fuel demand per household remained relatively stable between 1990 and 2004 (Figure 2-2), whilst UK homes became ever more energy efficient (Figure 2-5), at least when considering the power demand per m^2.

2.6 **Fuel Price**

Based upon regression analysis of fuel prices, external temperatures and fuel demand, Summerfield (2010a) concluded that the short term elasticity of fuel demand and fuel price was 0.2, that is 100% rise in fuel prices would reduce demand in the short term by 20%, (see also Hunt et al, 2003). Bernstein and Griffin (2005) reported that in the longer term, residential gas consumption elasticity was -0.3, as compared to -0.2 in the short term, as consumers made longer term adjustments to their appliances and properties.

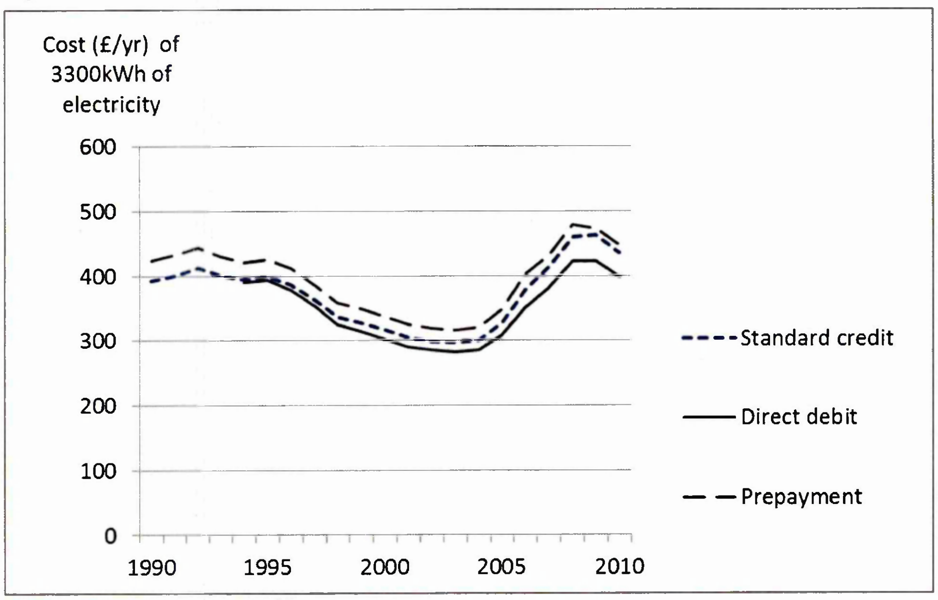
Therefore an understanding of how fuel price has varied is key to understanding how changes to the energy efficiency of the housing stock have affected residential demand. Average domestic gas and electricity fuel bills, (DECC, 2011e), inflated using the annual Consumer Price Index to the equivalent cash price in 2010, are illustrated in Figure 2-7 and Figure 2-8.

Figure 2-7 *Domestic gas charges, at 2010 prices*



Source: DECC, 2011e QEP, Table 2.3.1

Figure 2-8 *Domestic electricity charges, at 2010 prices*[3]



Source: DECC, 2011e QEP, Table 2.2.1

[3] Fuel prices have been adjusted using the CPI, in line with ONS procedures (ONS, 2011). Annual CPI was taken referenced from http://www.rateinflation.com/consumer-price-index/uk-historical-cpi.php?form=ukcpi, who in turn reference ONS.

As illustrated, domestic fuel prices for gas and electricity fell in real terms by approximately 20% and 25% respectively between 1990 and 2005. However because living standards were rising faster than prices, the actual fall in the price of fuel, as a proportion of the national earnings, was more dramatic. At 2006 prices, a MWh of household fuel, based upon a tonne of oil equivalent, was consumed for every £1340 of household disposable income earned in 1970 (DECC, 2011c). By 2010, a MWH of household fuel was consumed for every £648 of disposable income earned.

Palmer (2011) noted that energy costs fell as a proportion of total household spending, from more than 6% in 1970 to 4% in 2008 and that from 2001 to 2004, a period of low energy prices, fuel represented, on average, less than 3% of household spending. The trend of falling gas prices was reversed in 2003 and between 2005 and 2009 gas prices rose, in real terms, by approximately 80% and electricity prices increased by nearly 50% over the same period. This coincided with the 13% fall in fuel demand illustrated in Figure 2-2.

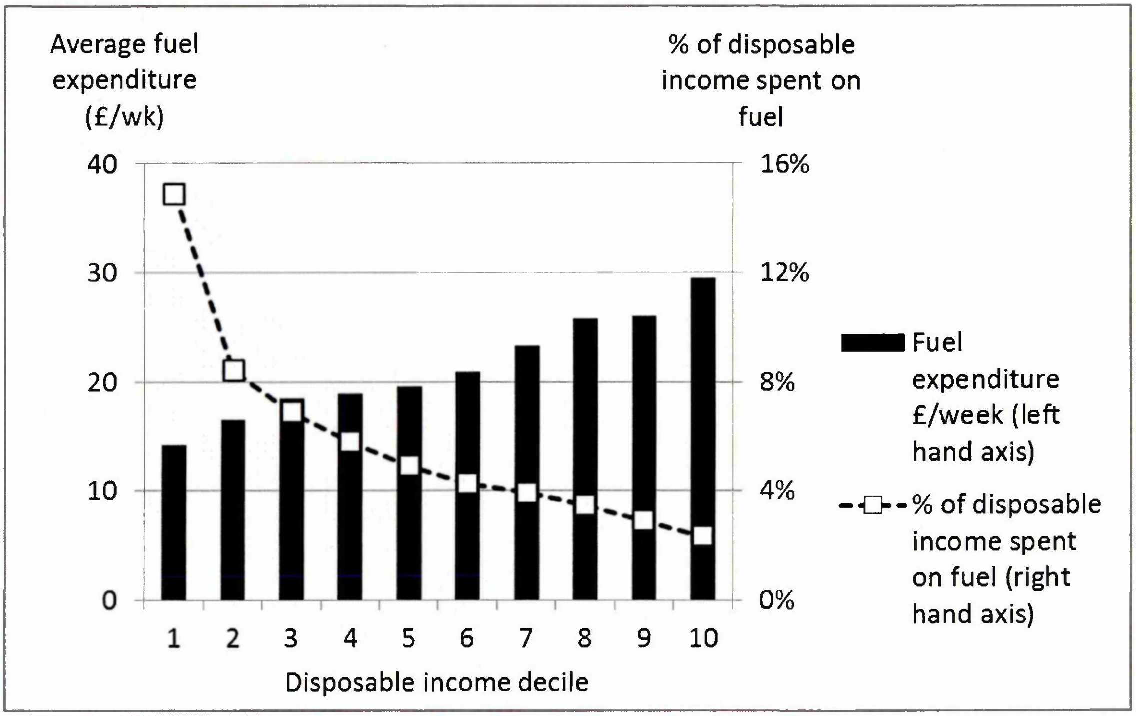
Therefore considering the trends in energy consumption, fuel price, energy efficiency and internal temperature, it appears that between 1990 and 2003, UK households purchased additional energy services, maintaining their homes at higher temperatures and servicing more appliances, but the amount of fuel purchased per household remained relatively static. Effectively, advances in the energy efficiency of the housing stock and domestic appliances were being taken back to purchase additional warmth and power more household equipment.

After 2003, energy demand per household began to decline. This period has also been marked by rising fuel prices after decades of real term declines. Falling average internal temperatures over this period suggest that least a proportion of the demand reduction after 2003 was the result of fuel price inflation, which made warmth less affordable.

2.7 **Energy Demand and Income**

The general relationship between household income and residential fuel bills is illustrated in Figure 2-9. The graph was prepared from data in the Living Cost and Fuel Survey, 2009 (ONS, 2011), but reflects the form of graphs for 2004 and 2006 reported by Utley and Shorrock (2008), Druckman and Jackson (2008). The figure shows average household fuel expenditure by income decile in 2009, where a decile describes 10% of a population and Income Decile 10 earn the most and Income Decile 1, the least.

Figure 2-9 *Average household fuel expenditure by income decile, 2009*



Source ONS, 2011 Living Cost and & Food Survey, 2009

The figure indicates that, in 2009, the highest earning decile collectively spent over twice as much on fuel as the lowest earning decile. Utley and Shorrock (2008) noted that in 2004 the spending ratio between the highest and lowest earning deciles, was 2.3 and Druckman reported the same ratio from a study of expenditure in 2006.

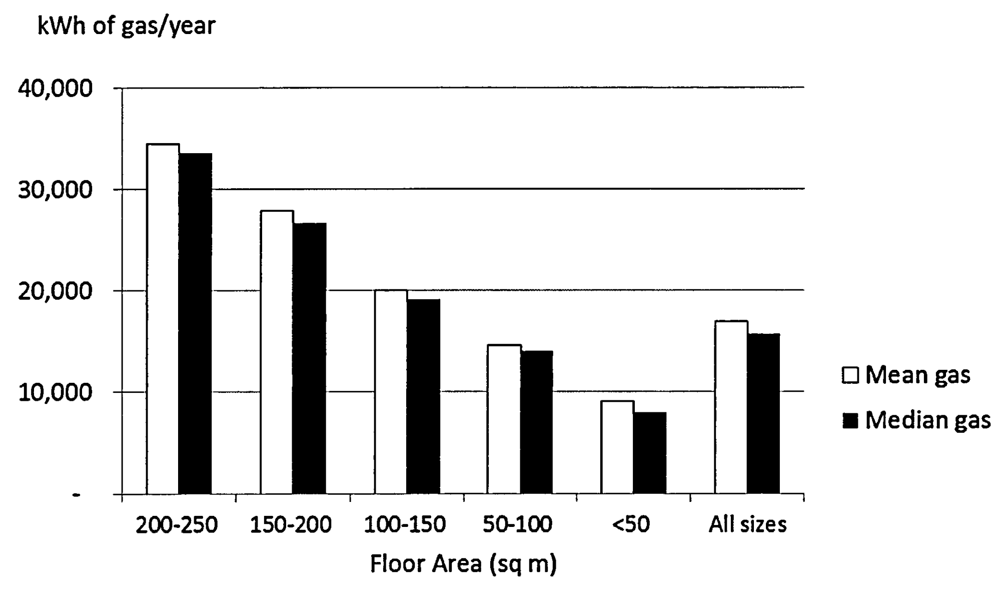
Figure 2 9 also indicates that although the highest income households collectively consume disproportionate quantities of fuel, fuel bills, as a proportion of income, tend to decline as incomes rise. Druckman & Jackson (2008), Roberts et al (2007) and Dresner & Ekins (2006) also highlighted this relationship. Figure 2.9 suggests a robust correlation between average household income per income decile and residential fuel expenditure. However when fuel expenditure is considered at the level of individual household, the link between income and fuel demand becomes less clear and the literature on the issue becomes contradictory, with different researchers reaching different conclusions.

Dresner & Ekins (2006) concluded that "*household energy use and expenditures depend largely on factors other than income*", a position supported by Roberts et al (2007). Whereas Weber and Matthews (2008), Druckman & Jackson (2008) and Cheng and Steemers (2011), reported a close correlation between income, total expenditure and fuel demand. Weber concluded that "*expenditure and income have been found to be the strongest predictors of household energy requirements*". Understanding the link between income and household fuel demand is important to energy efficiency policy and the issue is considered in greater detail in Section 6.5 and Appendix 5.

The links between income and fuel demand may also be direct and indirect. For example higher income households can generally afford to purchase more energy services (this point is supported by evidence from this research in Section 10.3), but income also influences fuel demand indirectly by for example, influencing the size of an individual's home.

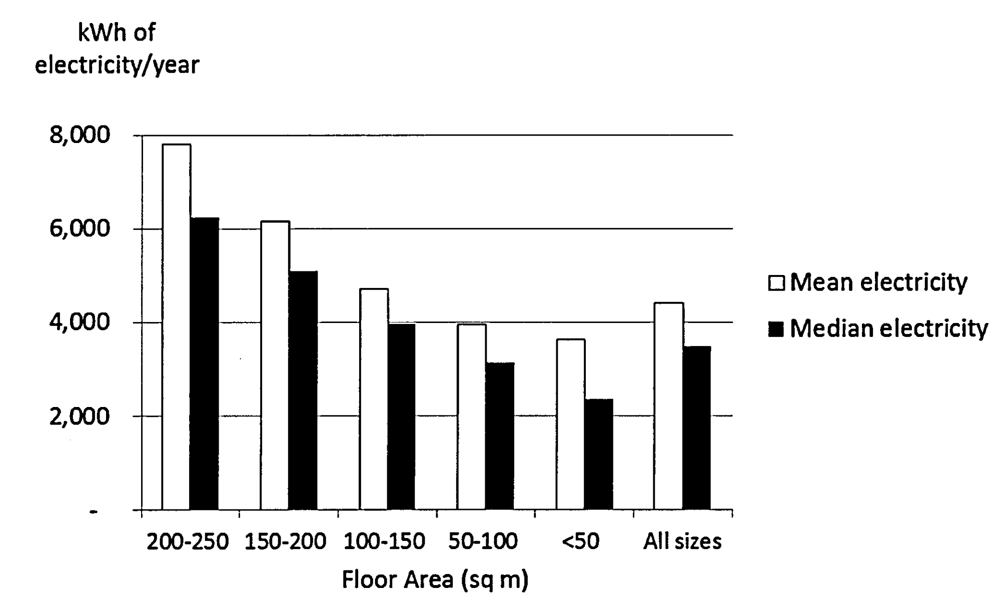
Boardman et al (2007) reported that between 1996 and 2001, in a study of single people in the private sector, the 'highest' earners bought or rented properties that were on average 17m^2 larger than the homes of the 'lowest' earners. On average, householders living in properties over 200m^2 use over twice as much gas and nearly four times as much electricity, as those whose homes occupy less than 50m^2 (DECC, 2011c). Figure 2-10 and Figure 2-11 illustrate the distribution of average gas and electricity demand by the dwelling floor area and a clear positive correlation is evident between the two.

Figure 2-10 *Mean and median gas demand by dwelling size, England, 2008*



Source DECC, Energy Consumption UK, 2011c, Table 3.25.

Figure 2-11 *Mean and median electricity demand by dwelling size, England, 2008*



Source DECC, Energy Consumption UK, 2011c, Table 3.25.

Such a correlation is, of course, not unexpected. However the key point is that income influences fuel demand directly and indirectly, by affecting the proportion of disposable income available to spend on fuel and indirectly, by influencing co-varying factors such as the property size.

2.8 Energy Demand and Tenure

There are nearly five times more private homes than socially owned properties (Table 2-1) and when operated to standard conditions (Box **2-1**), emissions from private homes account for nearly 90% of the residential total, but they make up 82% of the stock (DCLG, 2009a).

Table 2-1 *Proportion of residential carbon dioxide emissions by tenure, England, 2007*

	Average household CO_2 emission (T/year)	Proportion of British Housing Stock	% of total emissions (2007)
owner occupied	7.3	70%	77%
private rented	6.1	12%	11%
local authority	4.4	9%	6%
RSL	4.0	9%	5%
all private	7.1	82%	89%
all social	4.2	18%	11%

Source: DCLG, 2009a EHCS, Table SS7.1

Table 2-2 *Average floor area* (m^2) *by tenure, 2007*

	Private			Social			All
	Owner Occupied	Rented	All Private	Local Authority	RSL	All Social	
Area (m^2)	101	77	98	65	64	64	92

Source: DCLG, 2010c, Table SS2.0

The emission statistics quoted in Table 2-1 and Table 2-4 are derived from the English House Condition Survey (EHCS), published annually by the Office for National Statistics (ONS). The statistics are based upon calculations of how much energy would be required to heat and power each home surveyed to achieve a standard condition, in this case 21^{0}C in the living room and 18^{0}C for the remainder of the home for a prescribed period.

However as discussed in Chapter 10, few householders warm their homes to standard conditions and in general, when comparing actual fuel spending to standardised fuel bills, the less a household earns, the greater the proportional underspend, in comparison to standardised fuel expenditure. Therefore the data in Table 2-1 and Table 2-4 should be considered as indicative only.

Box 2-1 *Standardised fuel demand*

Table 2-3 *Occurrence of social and private housing, England 2007*

	pre 1944		post 1944		Total
	N	% of stock	N	% of stock	
Private homes	7818	91%	10480	77%	18298
Social homes	812	9%	3078	23%	3890
Total	8630	100%	13558	100%	22188
	N	% of tenure	N	% of tenure	
Private homes	7818	43%	10480	57%	100%
Social homes	812	21%	3078	79%	100%

Source: DCLG (2009b) Table 1.1

Social sector housing tends to be smaller (Table 2-2), more modern (Table 2-3) and is less likely to be detached, than private housing and all three factors have a bearing on the comparative fuel demands of private and social sector housing. Before the 1930's, homes were predominantly constructed with solid walls and single glazed windows (Roberts, 2008a). In the 1930's cavity walls became the standard form of construction. Initially cavity walls tended to be un-insulated, but the 1976 Building Regulations made cavity wall insulation mandatory in new homes (Boardman, 2010).

The older, solid walled homes now make up approximately 30% of the housing stock (DCLG, 2010c) and they are predominantly in private ownership. As indicated in Table 2-4 these older homes use disproportionate amounts of energy because many suffer higher heat loss through the building fabric and as a result of poorly controlled ventilation. When operated to standard conditions, housing constructed before 1944 make up 38% of the housing stock, but account for nearly half of the residential carbon dioxide emissions.

Table 2-4 *Proportion of residential carbon dioxide emissions by dwelling age, England, 2007*

Dwelling age	Average household CO_2 emission (T/yr)	Proportion of English housing stock	Proportion of English residential CO_2 emissions
pre-1919	9.0	19%	29%
1919-44	7.2	19%	20%
1945-64	6.2	22%	19%
1965-80	5.7	24%	19%
1981-90	5.1	7%	6%
post 1990	4.5	9%	7%
Average	6.6		

Source: DCLG, 2010c, EHCS report, Table SS7.1

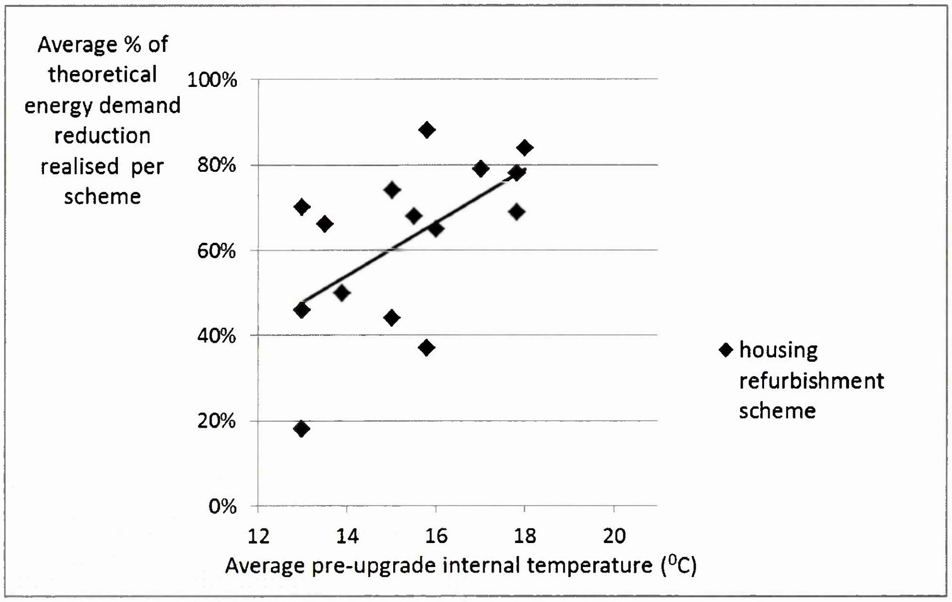
The form of social homes also contributes to their lower fuel demands. Detached homes tend to have greater external surface areas for heat transfer and less than 0.5% of social housing is detached (DCLG, 2010c), in contrast to 20% of private sector homes.

2.9 Energy Efficiency and Rebound

Households tend to purchase additional warmth until the internal temperature of their home can be maintained at around 20^0C (Milne & Boardman, 2000). At lower internal temperatures, some of the expenditure savings derived from a more energy efficient home are used to purchase more energy (Milne & Boardman, 2000, Sorrel, 2009b and

Sanders & Phillipson, 2006). This characteristic of energy efficiency programmes is referred to as 'direct' rebound'.

Figure 2-12 *Proportion of theoretical energy demand reductions realized by residential energy efficiency upgrade programmes*



Source: Milne& Boardman, 2000

Milne's original data, illustrated in Figure 2-12, suggests that in 2011/12, average rebounds of about 25% should be anticipated in the UK, with 40% to 50% rebounds in the coldest homes. Sanders & Phillipson (2006) reviewed the findings from studies of 13 residential energy efficiency up-grade programmes and found that, on average, approximately 50% of the anticipated fuel demand reductions were not realized after an energy efficiency upgrade programme. However Sanders concluded that approximately two thirds of the rebound, which Sanders referred to as a 'reduction factor' was due to issues such as workmanship, inadequate thermo-dynamic models, seasonal influences on relatively short term monitoring programmes and the variety of behaviors exhibited by residents. Sanders concluded that typically one third of the reduction factor, which is equivalent to 15% of the predicted demand reduction, was the result of 'direct rebound'.

Milne was unable to study the potential linkage between income and internal temperature and instead referred to a 1978 report by Hunt & Gidman which reported that household income was a significant factor in determining household temperatures. Analysis by the author, discussed in Section 10.3.3, indicates that low income households tend to purchase less energy services than more affluent households, supporting the work of Hunt & Gidman.

Raising the temperatures of the coldest homes and making warmth more affordable were specific objectives of some of the energy efficiency policies discussed in greater detail in Chapter 3. Therefore post-intervention increases in internal temperatures should be welcomed. However the rebound issue highlights the potentially contradictory objectives of policies which use energy efficiency improvements to reduce household fuel demand whilst also making warmth more affordable.

In addition to 'direct rebound' Herring (1998) quoting from economic theory developed by Brookes (1979), Khazzoom (1980) and Saunders (1992), highlighted the potential for energy efficiencies to lead to 'indirect rebound' where increased energy efficiency at the micro-economic scale leads to increased fuel demand at macro-economic levels, as reduced resource costs drive down the price of goods, raising demand and providing capital which can be re-invested in other activities.

This thesis does not consider whether residential energy efficiency contributed to greater demands for goods and services in other sectors of the economy. However as noted by The Green Fiscal Commission (2009), indirect rebound effects mean that *"improving energy efficiency alone won't be enough to meet our carbon targets"* and the need to take account of indirect rebound and develop holistic energy efficiency strategies is referred to again in Chapter 13, when the implications of the research findings for energy policies are considered in the light of the study findings.

2.10 **Implications**

Affluent households collectively purchase more energy and higher levels of energy services than households in lower income groups. However as a proportion of their income, the highest income households collectively spend less on fuel than those on lower incomes. In which case it is reasonable to anticipate that this group are the least likely to respond to price signals by buying less fuel as fuel prices rise, or making their homes more energy efficient, or both. Nevertheless, as discussed in the next chapter, retro-fit assistance has been predominantly targeted towards low income households, with market forces largely left to drive energy efficiency in affluent households, which collectively use most fuel, but who appear least likely to respond to fuel price signals. Additionally private homes tend to be older, larger and less energy efficient than the social housing stock, but retro-fit policies have also tended to focus upon social sector housing.

3 RESIDENTIAL ENERGY EFFICIENCY POLICIES

3.1 Introduction

In October 2012, the Government launched The Green Deal, a 'pay-as-you-save' initiative to boost retro-fitting in residential and commercial buildings by removing the up-front costs faced by renovators, and encourage renovators to tackle more challenging projects in hard-to-treat homes. However The Green Deal will divert funds from programmes which were previously centrally coordinated. Consequently The Green Deal appears to rely upon voluntary action at the household level more than earlier retro-fit policies.

In view of this change, one of the lines of research of this thesis has been to characterise householders who have been particularly active, or relatively inactive, voluntary retro-fitters during previous energy efficiency programmes. In preparation for disaggregating the nation's households into two groups, one eligible for retro-fit assistance and the other, ineligible, this chapter provides background information on recent UK residential energy efficiency programmes, including:

- Warm Front, a centrally funded grant aid scheme which subsidizes certain energy efficiency improvements in households living in private sector homes who are considered potentially vulnerable to fuel poverty;
- The Supplier Obligations, a series of mandates which require energy supply companies to reduce residential fuel demand, or more recently, residential carbon dioxide emissions;
- Decent Homes, a programme to improve the standard of rented housing, focusing largely upon the social sector;
- Energy efficiency product standards, such as the Part L of the Building Regulations;

- Other initiatives, such as: Energy Performance Certificates, the boiler scrappage scheme, and, advice lines and campaigns, such as the Energy Saving Trust, Act on CO_2 initiative.

One policy area not included in these discussions is residential micro-generation. In April 2010, HM Government initiated a system of Generation Tariffs and Feed in Tariffs (FITS) to encourage residential micro generation. Prior to 2008 there were less than 2000 homes with photovoltaic (PV) panels. Between April 2010 and June 2012, PV panels were fitted to 275,000 homes (Palmer and Cooper, 2012).

In time, if householders install sufficient capacity, on site micro-generation and renewable heat systems will meaningfully influence the fuel demand statistics. However, the period covered by this research precedes the Feed in Tariffs and so the influence of micro-generation on residential energy demand is not considered in this thesis. However, there is evidence that the take-up of PV panels has been socially differentiated, for example in the Home Energy Efficiency Database (HEED3) collated by the Energy Saving Trust and so this point is picked up again in Section 14.6 when further lines of research are considered.

3.2 **Warm Front**

Warm Front was launched in 2000 to lift vulnerable households out of fuel poverty (Appendix 1). Warm Front did not include a demand reduction objective. Rather the ambition was to bring the homes of a target group of householders up to a 'satisfactory' SAP Rating of 65, which was more than ten SAP points above the national average in 2009 (DECC, 2011b).

From the perspective of this study, Warm Front is important because it focused energy efficiency grants towards a sub-set of the population; householders living in privately owned homes who were potentially in fuel poverty and 'vulnerable', because they were elderly, disabled or with children.

The benefits system was use to define and identify the 'potentially vulnerable' and the list of benefits, referred to as 'Passport Benefits' which conveyed eligibility for a Warm Front grant, are listed in Appendix 6. Eligible households were awarded up to £1500 (direct.gov.uk, 2012), with up to £3500 in specific cases, to install insulation and/or replace their heating systems. Those in receipt of the Passport Benefits are known as the 'Priority Group' and in 2004, there were 2.8 million Warm Front Priority Group households (Sefton, 2004), which was equivalent to 14% of UK households. Between 2000 and 2006/7, energy efficiency improvements were installed in 1.6 million English homes under the scheme (Powells, 2009).

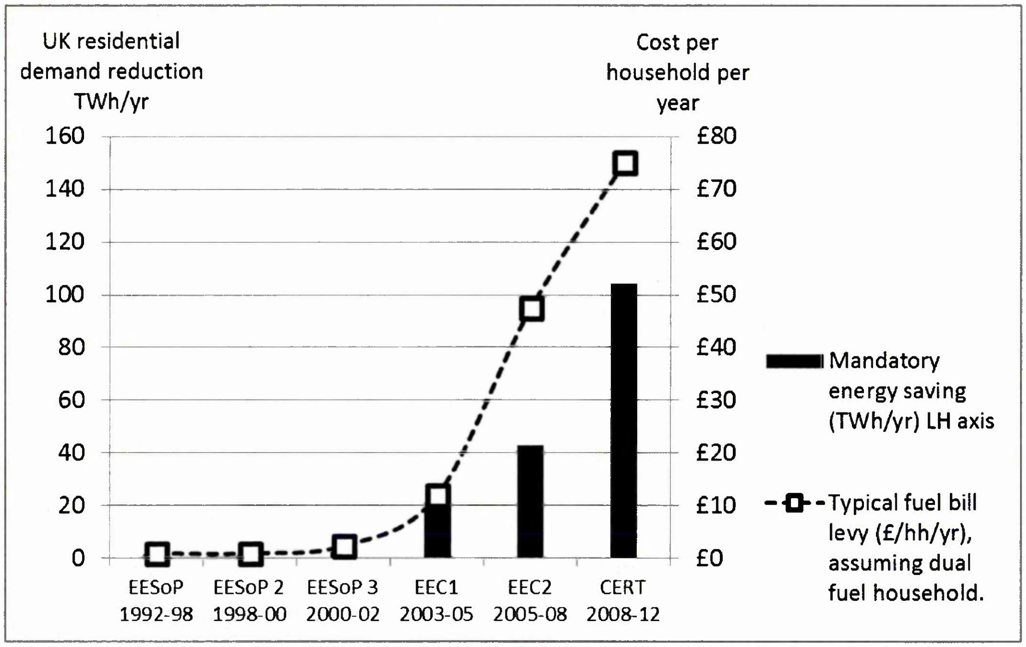
3.3 The Supplier Obligation

Energy companies above a certain size are mandated to deliver theoretical energy demand reductions, or carbon dioxide emission reductions, in UK homes within specified periods. The obligations are funded by a levy on all residential gas and electricity bills. Since 1994 there has been succession of progressively larger Supplier Obligation programmes, including:

- Energy Efficiency Standards of Performance (EESoP to EESoP3, which ran for up to four years each between 1994 and 2002;
- Energy Efficiency Commitments, EEC1 (2003 to 2005) and EEC2 (2005 to 2008);
- Carbon Emissions Reduction Target (CERT), 2008 to 2012; and,
- the Energy Company Obligation (ECO), launched in 2012.

The energy saving ambition for each phase of the Supplier Obligation, and the cost per household is illustrated in Figure 3-1. The figure is an extension of a graph published by Rosenow (2011). As indicated, HM Government's energy saving ambitions increased sharply after 2002 and the annual demand reductions under CERT are more than forty times those required under EESoP3.

Figure 3-1 *Supplier Obligation energy efficiency targets and the cost to UK households*



Sources: OfGEM (2003), Sustainable Development Commission (2007), Committee on Climate Change (2011a)

Notes: The Supplier Obligation for CERT is specified in tonnes of carbon per year. The conversion to TWh is based upon OfGEM's opinion (2008a) that the CERT target is equivalent to doubling the EEC2 target and takes into account a 20% target uplift in 2008. The cost per household for EESoP3 is based upon £1.20 per fuel and assumes that the levy is charged for two fuels per household.

The Energy Efficiency Commitments and CERT were residential energy efficiency programmes. However both programmes, unlike the preceding EESOP Supplier Obligations, were also designed to assist the Government to achieve two fuel poverty objectives: a) *'to attempt to eradicate fuel poverty by 2016'* and b) an ambition *'to eliminate fuel poverty in vulnerable households by 2010'* (DEFRA, 2004).

To achieve these social targets, the Energy Efficiency Commitment required that 50% of the notional demand reductions must be achieved by improving energy efficiency in Priority Group homes. The Energy Efficiency Commitment Priority Group was based upon the Warm Front Priority Group, but a beneficiary no longer had to be vulnerable, making 28% English households eligible for prioritized assistance (DEFRA, 2006a).

Table 3-1 provides a summary of the objectives and demand reductions attributed to the Energy Efficiency Commitment and CERT. Table 3-1 indicates that considering EEC1 and EEC2 together, 46% of the EEC energy efficiencies were achieved in the homes of Priority Group householders, who as noted previously made up 28% of all households.

Table 3-1 *Supplier Obligation objectives and achievements*

Criteria	EEC1 2002-05	EEC2 2005-08	CERT 2008-12
Emission reduction target	n/a	n/a	293 MT CO_2
Energy demand reduction target	62TWh	130TWh	Approx twice EEC2 (OfGEM, 2008b)
Energy demand reduction claimed	86.8TWh	151TWh	n/a
% of target to be achieved in Priority Group households	50%	50%	40%
% achieved in Priority Group households	48.5% (equivalent to 68% of target)	44% (equivalent to 63% of target)	43% at June 2011
% of households in Priority Group	28%[3]	28%	42%

Sources: OfGEM (2005, 2008b), DEFRA (2006a), DECC (2011f).

1) EEC2 figures exclude 36TWh carried over from EEC1
2) CERT emission reduction targets are based upon savings across the lifetime of the measures.
3) In a separate paper, DEFRA (2006b) report that the Priority Group is 35% of households. The lower DEFRA (2006a) estimate quoted is the same as the author's own estimate discussed in Chapter 7.

Under CERT, the Priority Group was enlarged by including all households where an occupant was 70 or over and under CERT approximately 42% of households were eligible for prioritized retro-fit assistance. Additionally under CERT the Priority Group target was reduced from 50% to 40%, largely neutralizing the social context of the obligation because the target was approximately equal to the proportion of Priority Group households in the population.

Suppliers have been free to choose how to meet their obligations and a key feature of the obligation is that suppliers were not required to spend a fixed amount or demonstrate that the Supplier Obligation levy had been spent (OfGEM, 2005). Consequently the policy promoted the most cost effective energy efficiency measures, which as illustrated in Appendix 7 include cavity wall insulation and loft insulation and both these measures have been widely adopted by energy suppliers (Appendix 8) to meet their Supplier Obligation.

3.4 **Decent Homes**

Since 2000, social landlords have been required to ensure that they provide their tenants with Decent Homes, which includes programmable efficient heating systems, cavity wall insulation where appropriate and 50mm-200mm of loft insulation, depending upon the effectiveness of the heating system. The Public Accounts Committee (2010) noted that by April 2009, 1,140,000 new central heating systems had been fitted under the Decent Homes programme, which had also delivered new windows in over 1,000,000 council homes and 882,000 council homes had received insulation improvements.

In 2002, the programme was also extended to include vulnerable householders in private sector housing, but DCLG estimate (National Audit Office, 2010) that between 2001 and 2011, only £1.2 billion was spent on making private sector homes 'Decent', in comparison to the £37 billion spent in the social sector. Additionally because the private sector money was not ring fenced, DCLG are unsure of the precise level of investment in these households. Therefore the best estimate appears to suggest that spending in social sector housing outweighed spending in private sector homes by about £30 to £1, when the social stock is only about one and a half times larger than the privately rented stock (Table 2-1).

The focus upon social sector housing is reflected in the relative changes in the SAP Rating of social housing and private homes, indicated in Table 3-2. In 1996, the energy efficiency of the social and private housing stock was comparable, but by 2005, the average SAP rating in a social sector home was eight SAP point greater than the private sector average.

Table 3-2 *SAP level in houses by tenure, England, 1996-2005*

	1996	*2005*	*Change 1996 to 2005*
Private housing	40	45	5 (13%)
Social housing	41	53	12 (29%)

Source Boardman et al, 2007a

3.5 **Product Regulations**

The efficiencies of gas and oil fired boilers have improved from about 65% to over 90% in the last 30 years (Everett, 2007, referenced by Roberts, 2008a). Part L of the 2000 Building Regulations requires that all domestic gas boilers installed after 1 April 2005, must be energy efficient condensing models. The same requirements for oil fired boilers came in two years later. Boiler replacement can be expected to have a meaningful impact upon residential fuel demand, if social policies and/or financial pressures have meant that energy efficient products have been taken up at different rates by different social groups. And as discussed in Chapter 4, there is evidence which indicates that the installation of energy efficiency boilers has been disproportionately high in social housing.

3.6 **Non-Priority Group Initiatives**

By the end of the Energy Efficiency Commitment Supplier Obligation approximately 80% of the £3.2 billion spent during the initiative had been invested in Priority Group homes (DEFRA, 2006a). As indicated previously, less than a third of households were in the Supplier Obligation Priority Group, so average Supplier Obligation spending per household was at least ten times greater per household in Priority Group homes than in non-priority households. Then on top of the Supplier Obligation revenues, all Warm Front finance was spent in Warm Front Priority Group homes who were effectively a sub-set of the Supplier Obligation Priority Group.

By comparison the Non-Priority Group, which represents approximately two thirds of households, had relatively little financial or logistical assistance to retro-fit. Supplier Obligation funds have been used to discount proprietary products such DIY loft insulation and professionally installed cavity wall insulation and these discounts have been universally available.

A small number of local authorities have also been more pro-active, offering all householders discounted or free, basic insulation measures. An example of such a scheme is the Warm Zones which were funded from Supplier Obligation and local authority coffers. However such schemes tended to be local, or regional, and housing statistics (DCLG, 2011) indicate that the proportion of local authorities in a Warm Zone was approximately 6%, so in the national context, such schemes can have had only a limited impact.

Some local authorities have been supplied with Supplier Obligation funds to distribute as 'cash back' offers to rebate part of the costs of home insulation. For example Cheshire East Council ran annual schemes for several years offering £200 cash back for loft insulation. Such offers were typically short term with limited budgets. Additionally all householders have also been able to apply for a one off subsidy of £400 in 2011, if they replaced their inefficient boiler with an efficient condensing model. 120,000 awards were made in England before the scheme was closed (Energy Saving Trust 2012).

The key point is that the vast majority of financial and logistical assistance to encourage retro-fitting has been targeted towards households in social housing or householders who were eligible for certain income related benefits and credits. For the majority of householders, there has been limited financial or logistical assistance to either pay for insulation retro-fitting or to identify suitable measures, leaving Non-Priority householders with financial and logistical barriers fitting which were not faced by Priority Group householders.

3.7 The Green Deal

The Green Deal was launched in October 2012, but some of the components of the scheme have still to be put in place. Under the scheme fuel consumers will be able to make their homes more energy efficient without paying for the improvements up-front.

Rather the work will be financed and the debt repaid from savings made on household bills. Green Deal finance is attached to the property, rather than the owner, and when a property is sold the liability for any outstanding debt is transferred, along with the benefits of a more energy efficient home, to the new owner.

To qualify for Green Deal finance, the fuel expenditure savings from retro-fitting, based upon average household fuel expenditure must be equal to, or greater than, the repayments necessary to pay off the loan. This is the Green Deal 'Golden Rule', albeit adjusted slightly from the original concept during a 2011 consultation process (Richards, 2012). Additionally the energy improvement measures must be 'approved' and fitted by an accredited installer, following an inspection by an accredited adviser.

Where approved measures do not meet the Golden Rule, the organization funding and coordinating the work, known as a Green Deal Provider, may request an Energy Company Obligation (ECO) subsidy from an Energy Supplier, with the full emission reduction credits awarded to the Energy Supplier, to count to their ECO targets, discussed below.

3.8 The Energy Company Obligation

In October 2012 the CERT Supplier Obligation was replaced by the Energy Company Obligation, generally referred to as ECO. DECC (2011g) advised that the revenue generated by ECO will support the Green Deal in 'hard-to-treat homes' and assist low income and vulnerable householders to make their homes more energy efficient and reduce their carbon dioxide emissions.

Energy companies must gain a number of ECO points, which they can collect under three schemes: Affordable Warmth, which aims to help low income and vulnerable households to more easily heat their homes by reducing their notional heating by £3.6 billion, over the lifetime of the measures (DECC 2011g).

A Carbon Saving Obligation, to reduce carbon dioxide emissions by 0.52 Mt CO_2/year in hard-to-treat homes, such as solid wall properties and those with hard-to-treat cavity walls and a Carbon Saving Communities (CSC) Obligation. Under the CSC, at least 20% of carbon savings delivered by ECO must be in low income communities in the bottom 15% of the Index of Multiple Deprivation and 15% of the CSC must be delivered in rural settlements (Richards, 2012).

3.9 Minimum Standards

Whilst current government initiatives, for example The Green Deal, focus upon incentivizing householders, mandatory change is proposed for the private rented sector. DECC (2012a) advised that under the Energy Act 2011, from April 2016, domestic landlords must consent to a tenant's energy efficiency improvement proposals, where financial support is available, such as the Green Deal and/or ECO funding. Then from April 2018, all private rented properties should be brought up to a minimum energy efficiency standard rating, likely to be set at EPC rating "E" providing that there is no upfront financial cost to the landlord.

3.10 Implications

Social objectives have demanded that retro-fit funding and logistical assistance has been disproportionately focused upon low income households and social sector tenants, who collectively use least fuel. This does not necessarily mean that the policies have been ineffective from an emissions perspective. By financing relatively low cost measures, which are particularly cost effective, and by delivering them at scale, the Decent Homes and the Supplier Obligations, may have delivered significant emissions reductions per £ invested in energy efficiency enhancement.

Nevertheless, the retro-fit policies did not appear to have a clear strategy for driving change in households who were considered able-to-pay, other than to rely upon market forces to encourage retro-fitting. But the households considered able-to-pay appear collectively to have been the least likely to respond to price signals, because as incomes rise, the proportion of income spent on fuel tends to decline.

The Green Deal marks a shift away from this approach and subsequently retro-fit finance, qualified technical support and quality assured installers should become much more widely available to householders wishing to improve the energy efficiency of their homes. But at the same time it appears likely that the outcome of emission reduction policies will rely increasingly upon voluntary retro-fitting by individual householders as a proportion of the Supplier Obligation revenues are diverted from centrally coordinated retro-fit programmes and into support for The Green Deal.

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4 RETRO-FITTING TRENDS

4.1 Introduction

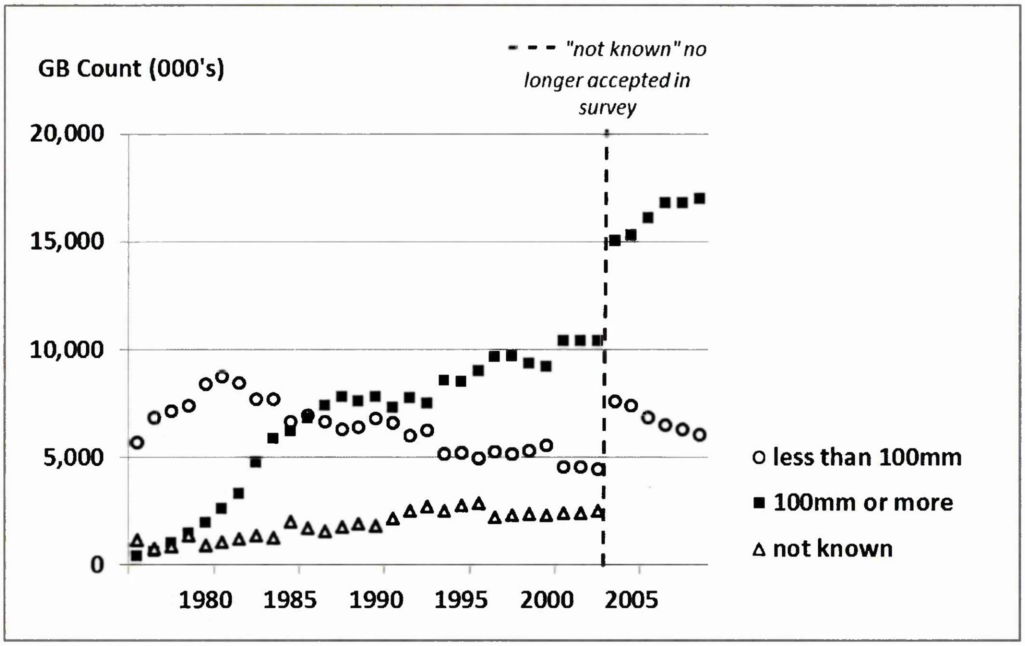
This chapter discusses the recent retro-fit trends in loft insulation, high efficiency central heating boilers and cavity wall insulation - the cost effective technologies which account for the majority of recent improvements in the energy efficiency in the housing stock (OfGEM 2005, 2008b).

The review of the literature discussed in this chapter indicates that the number of homes retro-fitting insulation per year, or installing a more energy efficient boiler, has increased since 2000. However the literature provides little indication on the characteristics of the homes and households who have been carrying out the work, other than indicating that retro-fitting has been disproportionately common in social housing.

4.2 Loft Insulation Trends

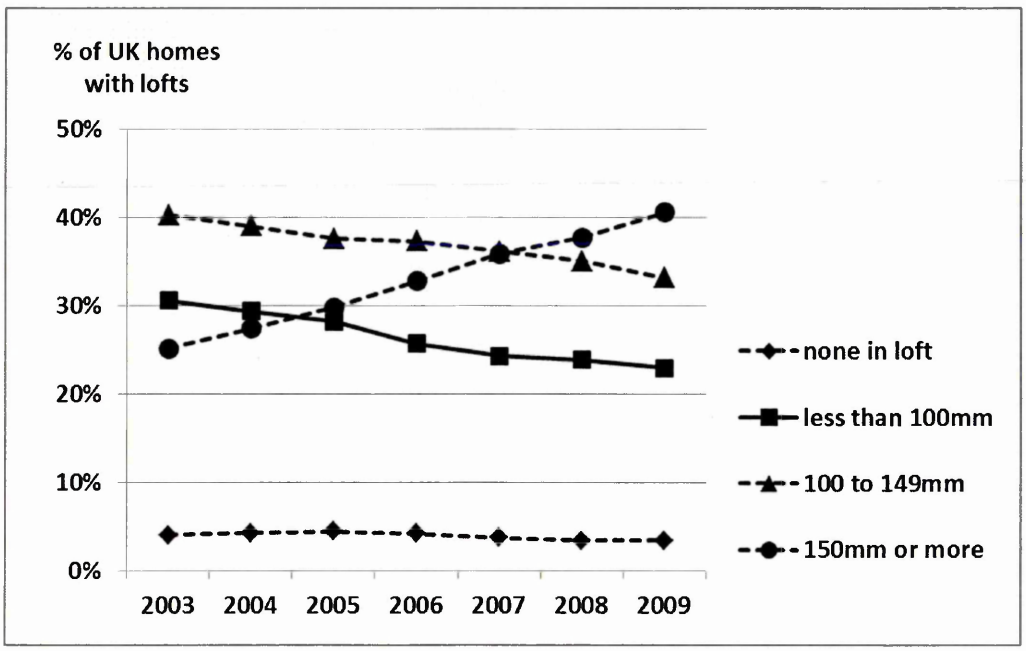
UK statistics describing the number of homes with loft insulation does not generally separate retro-fit from new build, but subtracting the number of new homes from the insulation statistics provides a measure of the loft insulation retrofitting activity. DECC (2011c) statistics describing the number of UK homes with over 100mm of loft insulation since 1970 are illustrated in Figure 4-1. Subtracting the data from the number of new homes (DCLG 2010a), indicates that loft insulation was retro-fitted, to over 100mm, in about 175,000 homes per year between 1975 and 2003. This may well be an under estimate, because, as indicted in Figure 4-1, until 2003, the database included several million homes where the presence and thickness of the loft insulation was 'not known'.

Figure 4-1 *Ownership of loft insulation in Great Britain 1976 to 2011*



Source: DECC (2011c) Energy Consumption UK, Table 3.15a

Figure 4-2 *Loft insulation depth in UK homes*



Source: DECC (2011c) Energy Consumption UK, Table 3.15a

After 2003, the data is sub-divided by insulation thickness and as shown in Figure 4-2, the proportion of homes with less than 150mm of insulation has fallen since 2003, as loft insulation has been 'topped-up' and new, better insulated homes have been built.

Between 2003 and 2009, the number of homes with under 150mm of loft insulation fell by approximately 15%, or 3.1 million. Discounting new build homes from this figure suggests that loft insulation was installed in, or added to, about 440,000 homes per year from 2003 onwards. This estimate may be cross-checked against retro-fitting estimates published by OfGEM (2005, 2008b) which indicate that the energy supply companies claim to have financed or subsidized (all loft insulation is subsidized from Supplier Obligation revenues – see Section 3.6) approximately 2.5 million loft insulations between 2003 and 2008 (Appendix 8), equivalent to 420,000 installations per year.

DCLG (2010c) has published some cross sectional data on the characteristics of the households with different thicknesses of loft insulation and statistics on loft insulation depth by tenure, the house size and household income group, factors closely associated with variations in fuel consumption (Gough et al, 2011), has been extracted and are listed in Appendix 9. Possible trends suggested by the cross-sectional data in Appendix 9 are discussed in much greater detail in Section 7.5, but data on un-insulated lofts and tenure has been picked out and reproduced in Table 4-1 because the data highlights that in 2007, homes with less than 100mm of insulation in the loft were disproportionally privately owned and inadequate loft insulation was particularly prevalent private rented properties.

Table 4-1 *Tenure of homes with lofts and less than 100mm of loft insulation, England, 2007*

Tenure	*Homes with lofts*		*<100mm loft insulation*	
	N	*%*	*N*	*%*
owner occupied	14833	75%	4184	75%
private rented	2167	11%	939	17%
local authority	1451	7%	255	5%
Registered social landlord (RSL)	1457	7%	188	3%
Total dwellings	19908	100%	5565	100%

Source DCLG (2010c) EHCS Report Table SS6.4

However other than the contrast by tenure, in 2007 the distribution of lofts with less than 100mm of insulation was reasonably evenly spread by socio-economic group, although householders over 60 years old were slightly more likely than younger householders to live in a home with over 100mm of loft insulation.

When considering household income, a greater disparity is evident between income groups when greater thicknesses of insulation are considered. As indicated in Table 4-2, the likelihood that a home has been fitted with over 200mm of loft insulation tended to decline with increasing income. The data has been divided into quintiles, where each quintile includes 20% of English households and Income Quintile 1 includes the 20% of households earning the least.

Table 4-2 *Proportion of English households with a loft and over 200mm of insulation, 2007*

Income Quintile	% of households with a loft and over 200mm of insulation
1 (lowest)	24%
2	24%
32	19%
4	20%
5	18%

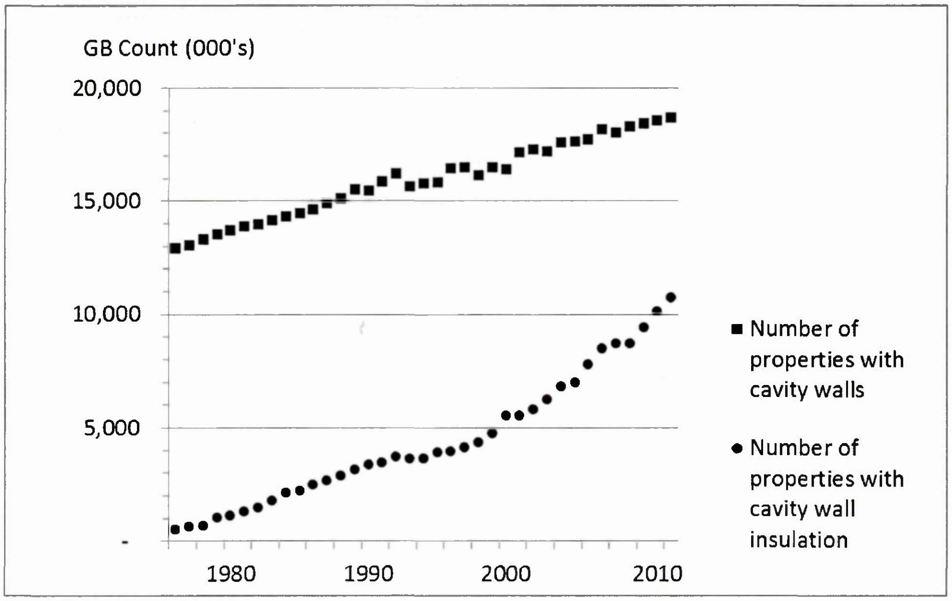
Source DCLG (2010c) EHCS Report Table SS6.4

These relationships may not be surprising, after all the policies discussed in Chapter 3 were designed to promote energy efficiency in low income households. However the key point is that by 2007 the data suggests that the rate of voluntary retro-fitting, in the homes of householders judged able-to-pay, appears not to have been keeping pace with loft insulation retro-fitting organized and financed by the state agencies in Priority Group households .

4.3 Cavity Wall Insulation

DECC (2011c) report that between 1977 and 1998 cavity wall insulation was fitted in 3.7 million homes. As illustrated in Figure 4-3, this is 700,000 more installations than the number of homes constructed over this period, suggesting a retro-fitting rate of about 65,000 homes per year, until 2000. After 2000, retro-fitting rates increased and the difference between the number homes with cavity walls and the number of homes with cavity wall insulation suggests that there have been on average, approximately 320,000 homes retro-fitted with cavity wall insulation annually since 2002.

Figure 4-3 *Number of British homes with cavity walls and cavity wall insulation*



Source: DECC (2011c) Energy Consumption UK, Table 3.15b

The cross-sectional data published by DCLG (2010c) and reproduced in Appendix 9 indicates that by 2007, in homes constructed with cavity walls, cavity wall insulation was much more likely in social sector homes than privately rented or owner occupied properties. The likelihood that a cavity wall remained un-insulated was approximately 50% greater if a householder was renting privately, rather than from a social sector landlord.

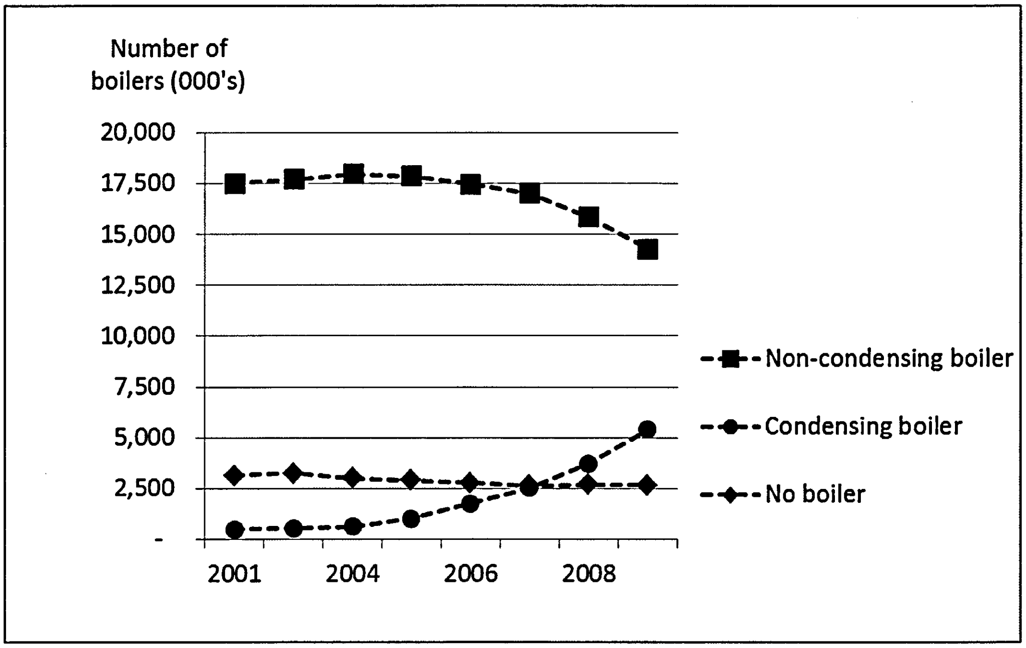
Households where at least one occupant was over 60 years old were approximately 30% more likely to be living in a home where the cavity walls had been insulated than in homes where all residents were less than 60 years old. Cavity wall insulation also tended to become less common as household incomes increased. In other words, by 2007 the distribution of filled cavity walls is generally consistent with the distribution of insulated lofts and the cross-sectional picture suggests that by this point, cavity wall insulation was disproportionately common in Priority Group households.

4.4 Condensing Boiler Ownership

Palmer & Cooper (2011) reported that three-fifths of the residential energy efficiency improvements since 1970 are the result of more efficient heating systems, and two-fifths come from better insulation. Consequently any social differentiation in boiler replacement is also relevant to an assessment of the fuel demand reductions which may be attributable to energy efficiency improvements in the homes of different social groups.

Figure 4-4 shows the take-up of energy efficient condensing boilers in England since 2001. Between 2002 and 2009 nearly five million condensing boilers were installed in English homes (DECC, 2011c) and the corresponding fall of four million non-condensing boilers between 2004 and 2009 suggests that approximately 80% of the condensing boilers were replacements for less efficient heating systems.

Figure 4-4 *Boiler types in England, 2001-2009*



Source: DECC, 2011c, Energy Consumption UK

The social cross sectional data, reproduced in Appendix 9, indicates that in 2007, the proportion of homes with condensing boilers was relatively constant by floor area, household type and household income. However the data also indicates that by that point, the proportion of social housing with a condensing boiler was several percentage points greater than in private homes. Additionally, as indicated in Table 4-3 which is based upon data from DECC (2011c) and DCLG (2010c), there is evidence that after 2007, the gap in condensing boiler ownership between social and private sector homes, widened. By 2009 approximately 33% of social sector homes and 26% of privately owned homes had been fitted with an energy efficient condensing model.

Table 4-3 *Condensing boilers ownership, 2007 to 2009*

	English dwellings with a boiler					
	2007		2009		Change 2007 to 09	
	N	%	N	%	N	%
Owner occupied	1800	13%	3,537	26%	1,737	13%
Private rented	249	12%	810	29%	561	17%
Local authority	271	16%	518	34%	247	18%
Registered social landlord	215	14%	527	33%	312	19%

Source: Energy Consumption UK, DECC, 2011c and DCLG (2010c) EHCS Report Tables SS6.1 and SS6.3

4.5 Implications

The statistics indicate that retro-fitting rates accelerated after 2000 when policies were introduced to make warmth more affordable, reduce the residential sector energy demand and raise the quality of social sector housing. The cross sectional data suggests that by 2007, these social policies were having detectable effects on retro-fitting, as factors such as a householder's age, their income and the tenure of their home have become associated with the occurrence of basic insulation and more energy efficient boilers.

The literature offers little commentary on social differentiation in retro-fitting and the commentary available, for example Boardman (2012), tends to take the view that retro-fitting is likely to have been biased towards better-off occupants and owners who can afford the investment. This may well be the case when considering the residential installation of micro-renewables after the introduction of the 'Feed in Tariff' (FIT) in 2010 (see Section 3.1). However with regards to energy efficiency, rather than micro-generation, the cross sectional data discussed in this chapter suggests prioritization has 'left behind' a group of relatively affluent householders who received little, if any, direct assistance from state agencies to over-come some of the barriers to insulation retro-fitting which are discussed in the next chapter.

5 RETRO-FIT BARRIERS

"Where the reduction in energy bills over time more than off-sets the initial outlay, we would expect rational consumers to exploit this. But much of the available potential has continued to remain unexploited."

Committee on Climate Change, 2008

5.1 Introduction

The Energy Saving Trust (2011a) divided the principal retro-fit barriers into three categories: the affordability of the measures, awareness of what can be achieved and how to achieve it; and motivational issues linked to scale of the task and benefits which accrue. Following this structure, this chapter is divided up under these headings with a fourth section which considers the retro-fit barriers created by government policies.

The review concludes that the literature frequently appears to be simplistic and potentially susceptible to bias because the research tends to have been based upon the views householders who have not carried out retro-fit work. Additionally the review found that researchers tended not to explore a householder's understanding of a barrier sufficiently to be sure that the same answer from different householders meant that both shared the same opinion.

5.2 Affordability

As part of an environmental attitudes survey, DEFRA asked 2,009 English adults if they had installed cavity wall insulation (Thornton, 2009). From the responses, the surveyors identified a sub-group of 309 householders who had not insulated their cavity walls, although their homes were potentially suitable. The group represented about 30% of householders with cavity walls and excluded householders who were unaware of cavity wall insulation.

The sub-group was asked why they had not installed cavity wall insulation. The largest response was categorized as *"I cannot afford it"* (27%) and this group was twice as large as the next most common answer, *"I never thought about it"* (14%). The disaggregated data suggests that the proportion of households who report that they cannot afford cavity wall insulation increases with declining household income, although a meaningful number of relatively high earning households, with incomes exceeding £40,000, also reported that they could not afford to install the insulation.

Therefore this study could support the view expressed by Boardman (2012), that retrofitting is likely to have been biased towards affluent householders who can afford the investment. DEFRA (2008) also found that pro-environmental attitudes are frequently associated with above average income households. But Thornton's data also indicates that households earning over £40,000 per year were over-represented in a sub-group of 309 householders whose homes had un-insulated cavity walls, suggesting that although they were less likely to report that the cost of the measures was the most significant barrier, affluent householders were less likely to have retro-fitted cavity wall insulation.

Thornton did not ask how much respondents were able to pay, or prepared to pay, nor is it clear whether respondents understood how much cavity wall insulation would cost, or the potential financial benefits that it would deliver. In which case, for a proportion of householders, when they report the issue is one of 'affordability', the barrier could have been one of awareness, or motivation.

Peacock et al (2009) questioned 1,004 UK homeowners about their willingness to invest to make their homes more energy efficient. Interviewees were asked to consider purchasing a set of measures that would: reduce their current fuel bills by 60%, but which cost a one off fee of £10,000, (Option A); save 40% of their current fuel bills, for a fee of £5000, (Option B); or, reduce their current fuel bills by 20% for a fee of £1000 (Option C).

Approximately 5% of respondents reported that they were 'very interested' in Option A, 8% were 'very interested' in Option B and 17% in Option C. In 2009, the average fuel bill for a household purchasing gas and electricity on standard credit was approximately £1170 (Figure 2-7). Therefore less than one household in five was 'very interested' in Option C which would, using a simplistic approach to assessing payback, return the investment in less than five years, generate a profit thereafter, provide a more comfortable home and potentially increase the value of the property. When asked *"which factors would make them think twice about carrying out home* [energy efficiency] *improvements",* Peacock found that cost was quoted as the most important barrier for 80% of the group 'interested' in the retro-fit options and 90% of the 'disinterested' group, but it is unclear whether the issue is the up-front costs or the pay-back period.

5.3 **Awareness**

The Energy Saving Trust (2011) reported that one third of households they surveyed were unaware of the benefits of cavity wall insulation and/or how to get the work done. The figure fell to one fifth of householders, when the Energy Saving Trust enquired about loft insulation. However Thornton (2009) indicates that the proportion of the population who are unaware of how to fit basic insulation is relatively low. Two percent of householders who had not insulated their lofts reported that they were unaware of how to do the work and 6% of those who had not insulated their cavity walls said they were unaware of how to go about getting the work done.

Pelanur (2012) carried out 198 'semi-structured' interviews of random members of the public on the street in Cardiff and Manchester. He noted that a lack of information was reported by 17% of respondents as a barrier to the take-up of insulation, however cost was raised as an issue by four times as many householders.

5.4 **Motivation**

5.4.1 Household characteristics

The relevant point for this report is whether particular social groups display disproportionate levels of disinterest in the benefits of residential energy efficiency and if so, why? DEFRA (2008a) surveyed over 2000 householders nationally, and based upon weighted returns, reported that approximately 35% of the population state that they will not voluntarily insulate their homes.

DEFRA's findings resonate with observations from the Kirklees Warm Zone (2011, pers comm) where approximately 20% of householders did not accept cavity wall insulation or loft insulation, even when the measures were to be installed free of charge. This point was picked up by DECC (2011g) when they noted that the Supplier Obligations drove the market for free or cheap insulation, rather than tapping into a true demand from householders who wish to make their homes more energy efficient.

Those who report that home insulation is 'highly acceptable' were classified by DEFRA as Positive Greens or Waste Watchers. These groups make up 18% and 12% of the population respectively. 30% of Positive Greens are degree educated and the group includes a disproportionate number of socio-economic AB class households. They are most likely to be owner occupiers, and they are most likely to live in a pre-1930s house. Waste Watchers tend to be older than average and on low incomes.

DEFRA's work suggests that motivation is a potential social differentiator, with affluent, better educated households expressing a greater willingness to insulate their homes. In which case, greater motivation in affluent households, coupled to the ability to pay (Section 5.2), may have resulted in a retro-fitting bias towards more affluent households, as suggested by Boardman (2012). However DEFRA did not compare the survey of attitudes and intentions with actual retro-fitting activity and as discussed later, retro-fitting data suggests that affluence is linked to disproportionately low levels of voluntary retro-fitting, unless the up-front barriers to retro-fit are removed.

5.4.2 Pay-back

If householders are to see a financial return on their investment in energy efficiency, in addition to an increase in their levels of comfort, the value of their property value must increase correspondingly, and/or their fuel bills must fall sufficiently to enable them to recoup their investment before they move on. Therefore the residence and pay-back periods become important considerations. However neither factor was discussed together in the literature reviewed.

Until the housing market takes full account of the energy efficiency of a property, retro-fit is likely to be less attractive to householders who expect to move before their investment has been repaid. The Green Deal (Section 3.6) may address this issue from a financial rather than logistical perspective, providing purchasers appropriately value the prospect of lower energy bills and enhanced comfort.

At the rates quoted in Appendix 2, the simplistic pay back periods for the low cost retro-fit options are several years and as indicated in Table 5-1, would appear unlikely to have unduly influenced the majority of home owners during the recent energy efficiency programmes discussed in Chapter 3, because the majority of householders stay in a property for at least 10 years. Nevertheless, payback periods could be a particular issue, even for basic insulation measures, in smaller starter homes or where residents are elderly and unsure how long they will remain in their home.

Table 5-1 *Length of residence in current home, England, 2008-09*

Length of residence (years)	15.8	11.0	<1	1-2	2-3	3-4	5-9	10-19	20-29	30+
% of owner occupiers	Mean	Median	3.7	4.2	7.4	10.2	19.8	21.5	16.0	17.2

Source DCLG (2010d)

Mallaband (2012) conducted interviews with 20 householders to study the barriers to retro-fit. Nine households reported that their particular life stage, for example just starting a family, old age or an impending house move, prevented them from carrying out home improvement work.

5.5 **Policy**

5.5.1 Grants and assistance

As indicated previously, the inaccessibility of the grants and prioritized assistance for the majority of householders has the potential to act as a *de facto* barrier to households who are considered 'able-to-pay'. Additionally existing policies may also prevent action if ineligible householders delay retro-fitting because they assume that a time will come when they become eligible for state assistance. This could have been a factor in the CERT programme, where one of the qualifying criteria was a householder's age. However no studies of this phenomenon as a potential barrier were evident in the literature considered.

5.5.2 Tenure

Private sector rented homes have been shown in previous chapters to be less energy efficient than either social housing or owner occupied homes and social housing has not only the highest levels of energy efficiency, but also the most rapidly improving energy efficiency (Boardman et al, 2007a). The Committee on Climate Change (2008) highlighted the poor alignment of retro-fit incentives in the private rented sector where the landlord generally pays for retro-fitted energy efficiency measures, but the tenant sees the benefit of the work. Impending regulations, (Section 3.9), are to be developed to address this issue.

5.5.3 Planning and conservation

There are nearly half a million homes in conservation areas in England (Godefrey Cook, 2009) which is equivalent to 2% of the stock. The type of renovation and energy efficiency up-grade work which can be carried out on these properties is restricted. In terms of low cost retro-fit, planning and conservation issues are unlikely to have been a significant barrier or socio-economic differentiator at this stage because the work does not alter the external appearance of the building.

However Friedman and Cooke (2012) suggest that planning may become significant to the mass take-up of external measures such as solid wall insulation, or micro-renewables, not only in conservation areas and but potentially also in 'traditional buildings' which require 'special consideration' under Part L of the Building Regulations (English Heritage, 2010) and significantly represent approximately 40% of the housing stock.

5.6 **Chapter Summary**

The literature suggests that cost is primarily reported as the major barrier to retro-fit, even for low cost energy efficiency measures with short pay-back periods, in relatively high income households. The research also suggests that at least a third of householders are apathetic towards retro-fit, with between one in five (Kirklees Borough Council, 2011) rejecting basic insulation measures, even when they are to be installed free of charge and one in three households advising that they will not improve the energy efficiency of their home (DEFRA, 2008a).

The literature on retro-fit barriers relies heavily on social surveys which aim to identify householder's opinions and attitudes to retro-fit, with little, if any, cross referencing with retro-fit statistics. Consequently it is possible to draw conclusions on socially differentiated attitudes to retro-fit, but not socially differentiated retro-fitting rates, because the studies provide little, if any, evidence on how householder's attitudes to retro-fit are reflected by their actions.

Boardman (2012) suggested that retrofitting is likely to have been biased towards affluent householders who can afford to carry out the work and DEFRA (2008a) found that affluent householders appear more receptive to retrofitting. However Thornton (2009) found that households where the total income was over £40,000 per year, were disproportionately likely to be living in a property with un-insulated cavity walls. Additionally the state intervention programmes are likely to have countered the acceptability of retro-fit and it's relatively low cost fit in affluent households, because the policies effectively removed the financial, motivational and awareness barriers to retro-fit for a disproportionately high number of low income households. Market forces are also likely to have exacerbated the effects of targeting retro-fit assistance towards low income households because fuel efficiency is comparatively less valuable to higher income householders. Therefore although social attitude surveys suggest that retrofitting may have been biased towards affluent households, this thesis suggests the opposite is more likely to be the case based upon insulation statistics and a review of energy efficiency policy and household economics

6 RESEARCH QUESTIONS & RESEARCH TASKS

6.1 Context

The UK is committed to an ambitious strategy to reduce greenhouse emissions and the national energy demand whilst simultaneously increasing economic output and catering for a rising population. The transformation is to be achieved by reducing both the carbon intensity of the power sector and by using energy more efficiently. In the housing sector, the goal is to reduce total fuel demand by approximately one third in ten years, as the number of households rises by approximately 10%.

The low carbon housing ambition, set out in the Transition Plan (DECC 2009a, 2011a) was preceded by social programmes, such as Warm Front and Decent Homes, which were developed to 'eliminate' fuel poverty and to raise the standard of the rental stock. Since 2003, when the Energy Efficiency Commitment Supplier Obligation introduced the concept of a Priority Group (Section 3.3), the energy efficiency emission reduction and social improvement agendas have been viewed as inter-related. Consequently the policies developed to tackle both issues have tended to assume that objectives could be achieved by simultaneously improving the energy efficiency of the housing stock, or in some cases specific segments of the stock.

As a result of this duality, the post 2003 strategies tend not to have focused on where most emission reductions are likely to be made. For example there is no evidence that the policy initiatives have taken into account that the largest household emissions are generally linked to older properties, larger properties, and homes where the householder receives a comparatively high income. Infact the opposite appears to be the case. Approximately 80% of the Energy Efficiency Commitment Supplier Obligation revenue has been invested in Priority Group households (DEFRA, 2006a). However this disproportional investment delivered less than 50% of the schemes notional energy demand reductions (OfGEM 2005, 2008b).

Post 2003 energy efficiency policies also appear to have taken no account of the fact that although the wealthiest households collectively use the most fuel, they tend to spend a lower proportion of their income on fuel and therefore they may be less motivated to use energy more efficiently. Consequently, unless other factors such as the relative affordability of retro-fit, or attractiveness of a more comfortable home, are more influential, the synergistic influences of selective assistance and market forces may have acted as a barrier to insulation retro-fitting in the most affluent homes, the very households which have, on average, disproportionately high energy demands.

6.2 **Research Questions**

The cross sectional data discussed in Chapter 4 suggests that the social agendas within the energy efficiency programmes have had a significant influence on which households have fitted basic insulation measures, such as cavity wall insulation. If Non-Priority homes have not kept pace with the Priority Group, social trends in retro-fitting will have developed and the households which collectively emit most are likely to have retro-fitted basic insulation measures the least. This hypothesis leads to the first two questions:

1. *What are the predominant characteristics of the homes and households in the Priority and Non-Priority Groups?*
2. *Has the level of retro-fitting by Priority Group and Non-Priority householders differed? And if so, how are these differences expressed in the retro-fitting statistics?*

Of particular interest from a policy perspective is how Non-Priority householders have responded to calls to make their homes more energy efficient, because they own the majority of the stock and they are responsible for the majority of the emissions. Their voluntary response may also indicate how The Green Deal may develop, because the policy relies upon voluntary retro-fitting by individual householders. And this leads to the third and fourth questions:

3. *Within Non-Priority households, has voluntary retro-fitting been differentiated by the characteristics of the householder and their home and if so, how?*

4. *If retro-fitting has been socially differentiated, what impact if any, has the differentiation had upon changes in residential fuel demand?*

Researching these questions indicated that voluntary retro-fitting remained comparatively equal by income group until household incomes exceeded the 75%ile level and then declined sharply, particularly in the case of cavity wall insulation. So the answers to Questions 1 to 4 lead to the development of a fifth question:

5. *What are the motivating factors for, and barriers to, voluntary retro-fitting in affluent households?*

6.3 Contribution to the Literature

Thermal renovation by retro-fitting additional insulation and more efficient heating systems is fundamental to the transformation of the residential sector. If current targets are to be achieved approximately 99% of private homes will have to be thermally renovated and fitted out with micro generation equipment, so that they are 'zero net carbon' by 2050. Under current policies, the successful transformation depends upon householders voluntarily making their homes more energy efficient. However, very little is known about the characteristics of voluntary retro-fitters. Of equal interest from a policy perspective are the householders who have not begun to make the transition to a low emission home.

Currently it is difficult to isolate retro-fit statistics from data describing the housing stock as a whole, before attempting to understand the characteristics of voluntary retro-fitters. So this study will build upon the existing information by disaggregating retro-fitting work carried out by state agencies from private projects and then characterise the householders who have, or have not, voluntarily fitted basic insulation measures over a specific period.

Additionally, in a break with the literature which has largely focused upon issues of social justice and energy efficiency, this study has considered retro-fitting in households who collectively use the most fuel and who appear to offer the greatest opportunity for emission reductions over the next ten years.

Finally the study will provide additional evidence to inform two existing debates: to what extent has residential energy efficiency reduced fuel demand? And how significant is the association between household income and residential fuel demand? The literature on both issues, discussed in Sections 2.4 and 2.7 is ambivalent and, with regards to the link between income and household fuel demand, Palmer & Cooper (2011) noted that there is *"a limited understanding how income and poverty affect energy use in homes. Better survey data would help to unpack the links between income and energy use, and this field is ripe for more research."*

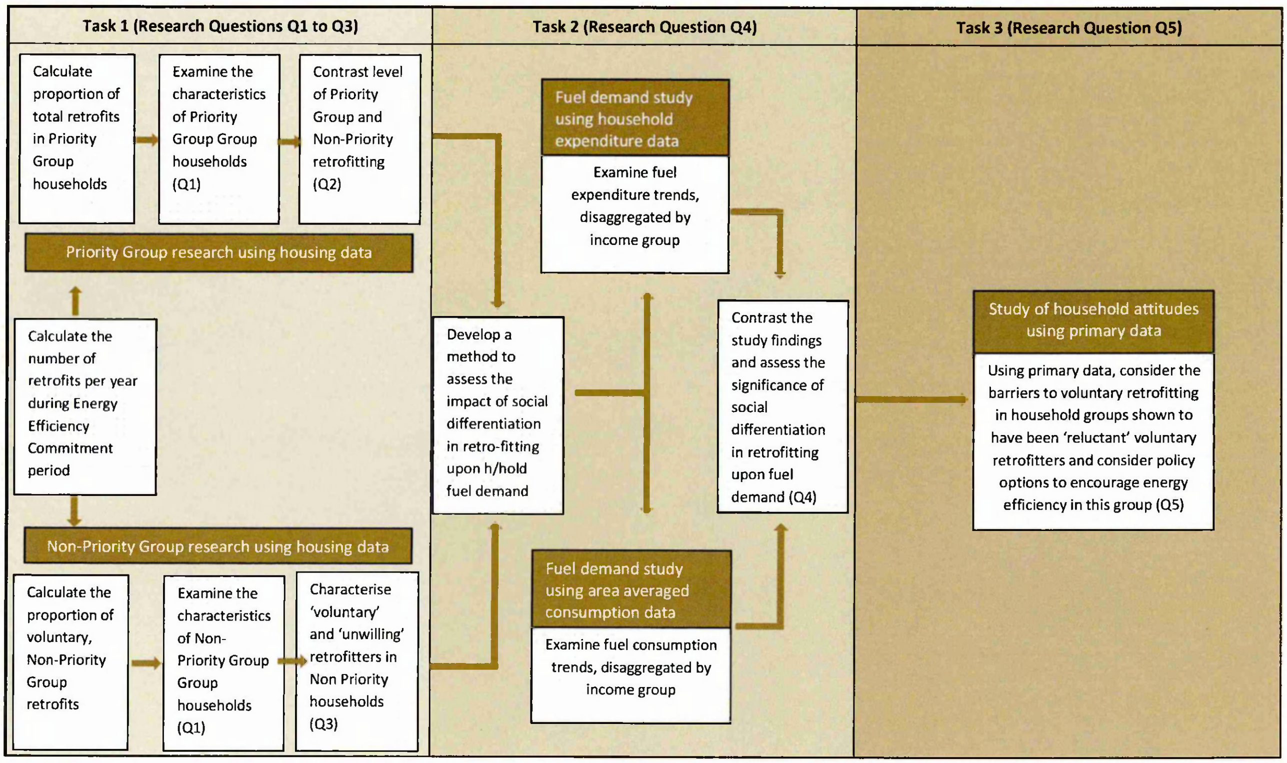
6.4 The Research Tasks

Based upon the research questions, the study was divided into three Tasks, which each included several study elements. The connections between the various studies, the Tasks and the Research Questions are summarised in Figure 6-1.

During Task 1, householders who had voluntarily retrofitted basic insulation measures during a specific period were identified and the level of voluntary retro-fitting contrasted with the amount of work carried out by state agencies in Priority Group homes. In Task 2 the fuel demand in these groups was tracked to determine whether social variations in retro-fitting had meaningfully impacted residential fuel demand. Building upon the findings of Tasks 1 and 2, the attitudes in affluent homes to retro-fit and a retro-fit policy options were considered in Task 3.

Tasks 1 and 2 were carried out using secondary data from the Office for National Statistics, and DECC. Task 3 on the other hand used primary data from two household surveys. The research methods for each task are described in Chapters 7, 9 and 11 and the research findings from each task are discussed in Chapters 8, 10 and 12. The remaining sections of this chapter are a preamble to the methods chapters, justifying the selection of income as an Independent Variable and discussing potential weaknesses in the income data.

Figure 6-1 *The Research Tasks*



6.5 Income as an Independent Variable

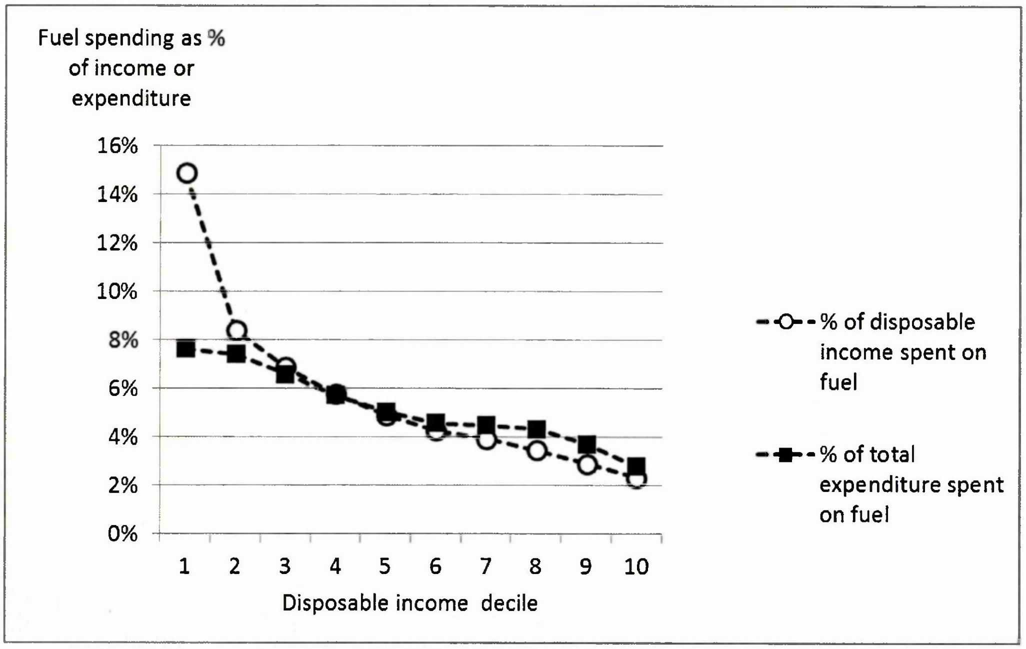
UK literature is contradictory about the strength of the correlation between income and household fuel demand (Section 2.7). Research by this author, discussed in Appendix 5, indicates that income and household fuel demand are more closely correlated than indicated by many of the studies in the literature and later in this thesis income is also shown to be an important predictor of retro-fitting activity. Additionally the cost of fuel is a key political consideration.

Therefore income appears to be a key factor in an assessment of energy efficiency and fuel demand. However, as discussed in the remaining sections of this chapter, income is defined in several different ways and there is some evidence to suggest that the income data is not wholly reliable, particularly around the extremes of the distribution.

6.5.1 Expenditure or Income

Although income appears more frequently in social surveys and is more readily used in policy solutions, several researchers, for example Utley and Shorrock (2008), have chosen to study the relationship between household energy consumption and expenditure, rather than income. Weber and Matthews (2008) reported that in the US the regression of household carbon footprints, which includes emissions from all household activity, is more robust when correlated to household expenditure (R^2 = 0.7), rather than income (R^2 = 0.5).

Figure 6-2 *Household fuel spending as a proportion of disposable income or total household expenditure, 2009*



Source: ONS, 2011, Living Cost and Food Survey 2009

Figure 6-2 illustrates the proportion of disposable income and total expenditure reportedly spent on fuel. The graph was constructed using data from the Office For National Statistics (ONS, 2011) Living Costs and Food Survey, 2009. As illustrated, expenditure on fuel as a proportion of income and total expenditure tends to be broadly similar for Income Deciles 2 to 10. However Income Decile 1 households reported aggregate spending was approximately twice aggregate income.

Gough et al (2011), in a study of total household carbon emissions, reflects upon the issue and suggests that the imbalance between income and expenditure may be attributable to deficiencies in the earnings statistics, especially among the self-employed. However a cross check by the author using the ONS Expenditure and Food Survey 2007 (ONS, 2009), the forerunner to the Living Costs and Food Survey, revealed that in the 20% of households earning the least, 79% of recorded income came from social security; 11% from pensions and investments; wages and salaries account for 5% and only 2% of recorded earnings were from self-employment.

An alternative explanation, which was not discussed in the literature considered, is that a proportion of households categorized as Income Decile 1 have been mis-classified as a result of earnings which were not identified by the ONS surveyors. In which case, as concluded by Weber and Matthews (2008) from their US study, expenditure is likely to be a more reliable Independent Variable than income.

However expenditure is less easily applied as a policy tool; is less widely discussed in the literature; is less relevant from a policy impact perspective and, in a longitudinal assessment, the discrepancy is not particularly significant, because as illustrated in Appendix 10, the discrepancy between income and expenditure reported by Income Decile 1 households remains relatively constant between 2003 and 2008, varying by about 10% over this period. Therefore, in view of policy benefits, the research discussed in this thesis has focused upon income as a social differentiator, rather than expenditure.

6.5.2 Which Income To Measure

The literature refers to various income definitions, including: income, gross income, net income, disposable income, basic income, full income, AHC (After Housing Costs) income, BHC (Before Housing Costs) income and Equivalent Income and Boardman (2010) described the definition of household income as an 'open debate'. DEFRA (2008b) suggests two income definitions and for England these are:

- *Basic Income:* which includes all household income, net of income tax and national insurance, but excludes income related directly to housing, for example council tax benefit. This is also referred to as AHC income;
- *Full Income:* the Basic Income plus all housing related benefits. This is also described as BHC income. Full income also appears to be analogous to Disposable Income, as recorded in ONS expenditure surveys and applied in several references discussed in this chapter.

Full Income is the headline figure which is used in official statistics and is the income statistic which has been applied wherever possible in this research. However it is beneficial to acknowledge an alternative metric, Equivalent Income, because it features widely in the literature.

Palmer et al (2008) noted that a single person and a couple with the same income and the same fuel use, spend approximately the same proportion of their income on fuel, but once their nearly identical fuel bills have been paid, the couple has to share the remaining money, giving them less disposable income per head, after meeting their fuel costs. To account for this, many of the papers in the literature, for example Dresner & Ekins (2006), Roberts et al (2007), Gough et al (2011) and Thumin et al (2011), convert income into Equivalent Income by applying standard income reduction factors for each additional adult and child in the household.

However energy demand per head falls as the headcount per household rises (Boardman, 2010, Appendix 11) and the income equivalising method does not account for this. Equivalisation also makes the research findings difficult to understand and prone to misinterpretation. Palmer concluded that using Equivalised Income is "*simply wrong and can lead to completely erroneous conclusions*". The difficulties of working with Equivalent Income were also acknowledged by Sefton and Chesshire (2005). Therefore although there are good arguments for equivalising income data when considering fuel poverty and social issues, providing the adjustment is carried out thoughtfully this study has used Full Income wherever possible because it appears to be more relevant in environmental analysis.

7 TASK 1 METHODS- PRIORITIZATION AND RETRO-FIT

7.1 Introduction

The task aim was to answer the first three Research Questions by contrasting the socio-economic characteristics of voluntary and Priority Group retro-fitters. The study required retro-fit statistics to be identified, assembled, disaggregated by socio-economic group and Priority Group status and analysed. This chapter describes the data sources, data preparation and validity testing. The research findings are discussed in Chapter 8.

To achieve the study aim, three objectives were set. The first was to sub-divide a representative sample of the population into two groups by their eligibility or ineligibility for prioritized assistance. The second objective was to compare retro-fitting rates in Priority Group and Non-Priority homes and the third objective was to identify the predominant socio-economic characteristics of householders who have been active, or inactive, voluntary retro-fitters. Analysis was carried out using SPSS V17 and V18 and Microsoft Excel.

7.2 Source of Priority Group and Retro-fit Data

Secondary data analysis offered the best approach to this task because of logistical concerns about collecting sensitive household statistics from an externally valid sample. Several local authorities were consulted and the literature describing related research projects reviewed. During method development databases were assembled using the Census 2001, DECC gas consumption statistics and Energy Saving Trust retrofitting records. Following a scoping exercise, these alternative approaches were set to one side in favour of a method based the ONS English House Condition Survey (EHCS). The EHCS was preferred because the alternatives were based upon area averaged data, rather than household specific information, making the results of any analysis less precise and more difficult to interpret.

The EHCS is household specific, comprehensive, accredited by The UK Statistics Authority as 'National Statistics' (ONS, 2012), a quality standard for HM Government statistics and has been widely used in the literature (Cheng and Steemers (2011), Palmer and Cooper (2011), Hulme and Summers (2009), Utley and Shorrock (2008), allowing the research to readily build upon existing knowledge.

The EHCS is a serial cross sectional survey which records the characteristics of English households and their homes. ONS carry out the survey continuously, interviewing approximately 8500 households annually and returning shortly afterwards to survey their homes. The results are reported annually on a two year rolling basis, so the 2007 EHCS is based upon 24 months of data, collected between April 2006 and the end of March 2008.

Six years of annual EHCS data, from April 2002, to March 2008, in five data files, named 2003 to 2007, were available at the start of this study. The six year period covered by the five surveys exactly matches the duration of the Energy Efficiency Commitment Supplier Obligation (Section 3.3) and restricting the analysis to this period, when more recent surveys subsequently became available, avoided potential internal validity issues as a result of changes to prioritization policies when one Supplier Obligation gave way to another in 2008.

However because only five files were used to describe changes over a Supplier Obligation which lasted six years, when discussing data describing retro-fitting over the entire period, rather than annual averaged data, the results are based upon the five year annual average, adjusted to cover the sixth year of the Supplier Obligation.

7.3 Database Weights and Measurement Uncertainty

The EHCS is a multi-stage clustered sample. Householders are selected at random but certain tenures, particularly social tenants, are over-sampled to maintain statistical power when studying rarer sub-groups. DCLG (various years) also note that the data has a non-response bias. To compensate for the clustering and bias, ONS publish household and dwelling grossing factors, referred to as weights, to make the survey nationally representative. Two weighting systems are available, household weights and dwelling weights. In this study the data was weighted by the number of households rather than the number of dwellings to control for the influence of second homes, which were considered more likely to have lower fuel bills and less likely to have been retro-fitted.

In common with all surveys, the EHCS is affected by sampling and measurement uncertainty (DCLG, various years). To calculate analytical confidence intervals, DCLG consider that it is valid to treat the data as a Simple Random Sample, rather than a cluster sample, providing that the analysis is based upon the entire database or a 'large' sub sample.

7.4 Missing and Adjusted Data

ONS cross-check survey data with other databases, most notably the Census, and then adjust the data for perceived inaccuracies. For example in the 2005 database (DCLG, 2007), the income data was adjusted in just over one quarter of the cases. Details of the adjustment procedure are presented in EHCS Technical Report 2007, Chapter 9, which is reproduced Appendix 12.

The EHCS lists Cases where household interviews or property surveys were completed. However the database weights are based upon Cases where both an interview and a property survey were carried out and in many of the data files, the number of households interviewed is slightly higher than the number of properties which were subsequently surveyed. Prior to weighting the data, these incomplete records were identified and removed from the assessment. This was a large task because data from the five surveys is collectively stored in over 350 separate files and each file may list data on hundreds of variables for approximately 17,000 households. Once the weights had been applied, the adjusted files were checked to ensure that they remained valid by checking the total number of households with the control totals published in the User Guides.

7.5 **Dependent Variables**

The EHCS identifies the number of homes with certain characteristics, for example cavity walls or condensing boilers, but until 2007 did not question householders about retro-fitting. Tracking changes in the numbers of homes with certain measures was considered and then rejected as the databases do not distinguish between measures which were retrofitted and measures which were installed as standard in approximately 1 million new English homes constructed during the six year Energy Efficiency Commitment (DCLG, 2010a).

To control for new built, the decline in the number of homes without certain forms of insulation were used as retrofit proxy variables. Care was taken to consider the variables' internal validity and the steps taken to control for the demolition or extension of homes are discussed in Section 7.7.

As indicated in Appendix 8, the most widely retro-fitted energy efficiency measures during the Energy Efficiency Commitment period were cavity wall insulation, loft insulation and condensing boilers. But data on the boiler type only became available in the 2007 EHCS and so ownership of an energy efficient boiler was not studied in any detail and the two Dependent Variables carried forwards for detailed consideration were:

- Homes with unfilled cavity walls; and,
- Homes where a loft had less than 125mm of insulation (rockwool or equivalent).

7.6 **Definitions**

7.6.1 Un-insulated loft

The Building Regulations 2006 require 270mm of mineral wool, or equivalent, loft insulation and the Energy Saving Trust (2012) recommend that insulation is retro-fitted to this level. However setting the loft insulation retro-fit threshold in this study too close to The Building Regulations level would have risked mis-classifying households where loft insulation has been retro-fitted, but to less than the Building Regulations specification.

For example Decent Homes accreditation requires a minimum thickness of 50mm in homes with gas central heating and 200mm in electrically heated homes and by specifying that a home had not been retro-fitted until it had, say, over 200mm, risked excluding homes where loft insulation was added, but to less than 200mm of loft insulation. Conversely, setting the thickness too low could have included too many households where insulation has been retro-fitted to a potentially inadequate standard.

When estimating the proportion of households without loft insulation, DECC (2012a, 2011h and 2010c) selected 125mm of loft insulation as the assessment criteria and the DECC threshold was adopted to define an un-insulated loft in this study.

7.6.2 Priority Group

The Energy Efficiency Commitment and Warm Front had related, but different definitions of the Priority Group. In this study, both groups have been combined because both were eligible for cavity wall and loft insulation, professionally installed at no charge to the householder. Additionally all social sector tenants have been considered as Priority Group householders because they benefited from free insulation. The derivation of a variable which captures the Priority Group cases is described in Section 7.8.

7.7 Monitoring the Validity of the Dependent Variables

The retro-fit proxy variable was unable to distinguish between un-insulated homes that had been demolished rather than retrofitted with insulation, as both effectively reduced the number of un-insulated properties in the database. Some 15,000 to 20,000 properties are demolished annually (DCLG, 2010b) and local authority properties represent approximately 80% of the demolished stock (DCLG, 2009b). If all the demolished stock was un-insulated, some 12,000 to 16,000 of the Priority Group retro-fits per year inferred from the database, could have been the result of demolition, rather than retro-fitting.

The EHCS also indicates that during the Energy Efficiency Supplier Obligation period approximately one third of homes were suitable for cavity wall insulation and just over half had a loft with less than 125mm of insulation. Applying the frequency of un-insulated stock to the demolition data, and assuming the demolition was focused upon Priority Group housing, suggests that the annual Priority Group retro-fit statistics discussed in Chapter 8 are likely to over-estimate the annual Priority Group cavity wall retro-fitting rate by about 5,000 homes per year and the loft insulation rate by about 10,000 homes per year, equivalent to 3% and 5% respectively. These potential over-estimates were factored into the analysis.

The internal validity of the derived Dependent Variables was tested by comparing the retro-fitting rates predicted using the derived variables, with other references. The derived variables indicate that over the six year Energy Efficiency Commitment approximately 430,000 householders per year topped up their loft insulation to over 125mm and 290,000 homes retro-fitted insulation into their cavity walls (see Table 8-2, Chapter 8).

In comparison OfGEM (2005, 2008b) estimated 420,000 loft top ups per year and DECC housing data (2011c) indicates 440,000 top-ups to over 150mm of insulation, annually (Figure 4-2). The close correlation between the three different loft retro-fit statistics suggests that the loft retro-fit proxy variable is likely to be a good approximation of the annual average loft insulation retro-fitting rate.

The derived cavity wall statistic is not as closely correlated with the reference data, but this may well be a reflection on the quality of the reference statistic. A direct measure of the number of Priority Group and Non -Priority homes installing cavity wall insulation was not evident in the literature, but DECC (2011c) housing statistics suggest about 320,000 cavity wall installations annually (Figure 4-3), which exceeds the estimate derived from the EHCS in this study by about 10%. However the DECC housing statistics fluctuate considerably around the mean, suggesting that the EHCS derived estimate may be the more reliable.

With regards to the external validity of the database, the ONS cross checked the database against 2001 Census data and weighted the data accordingly. The survey is a random sample and within the uncertainty limits calculated and reported with the results, the survey is considered to be representative of all English households.

7.8 Independent Variables

Whether a householder chose to retro-fit insulation is likely to be connected to a range of factors, including: how long they expect to stay in their home; their attitude to energy efficiency, their lifestyle; and the availability of assistance and advice. Additionally the impact of energy efficiency enhancements on fuel demand will also depend upon a variety of variables, including the size of the property, the preferred internal temperature and the relative cost of fuel.

Exploratory analysis using Chi Square and Cramers V tested the strength of association and changes in the strength of association, between homes with insulated cavity walls and 15 screening variables, which variously described the characteristics of the householder and their property. The screening short-list was drawn up from a review of the literature and consideration of whether the variable could readily be applied when developing, or reviewing policy.

The results of the association tests are summarized in Appendix 13, and, based upon both the strength of association and the change in association over the Energy Efficiency Commitment period, the relationship between five Independent Variables and the Dependent Variables listed in Section 7.5, were taken forward for more detailed study. The short-listed Independent Variables were:

- Priority Group eligibility;
- the age of the householder;
- their full household income;
- the floor area of their home; and,
- the standardised fuel expenditure (Box **2-1**).

Four of the Independent Variables correspond to variables in the EHCS, however the EHCS does not include a variable which unambiguously categorizes households by their eligibility for the Priority Group, which is conferred by receipt of certain Passport Benefits (Appendix 6). On the other hand the EHCS does include benefits data which indicates which Cases received a Warm Front or Supplier Obligation Passport Benefit, other than Council Tax Benefit.

A Priority Group variable was derived from this incomplete list and then compared to DEFRA's estimate of the proportion of households who were eligible for Priority Group retro-fit assistance (DEFRA, 2006a). When applied to the weighted database, the derived variable accounted for between 24.5% (2005) and 26.1% (2003) of the households in England. However this estimate was nearly 3 percentage points less than the proportion of Priority Group households estimated by DEFRA.

Fortunately, the EHCS also includes a variable derived by DECC and ONS, named *hhvulx*. *hhvulx* identifies '*vulnerable households in receipt of means tested benefits*" but the EHCS User Guide does not identify the benefits in question. DECC (pers comm, 2012) confirmed that *hhvulx* is solely based upon Passport Benefits, including eligibility for Council Tax Benefit, but not all the Passport Benefits. Therefore by combining *hhvulx* with the variable derived from EHCS benefit statistics, a Priority Group variable was developed which accounted for 28% of English households, conforming to the DEFRA (2006a) estimate of the size of the Priority Group.

The derived variable was supplemented by adding all social tenants to acknowledge the retro-fit assistance provided by the Decent Homes programme. As indicated Table 7-1, once combined, the complete Priority Group variable accounted for approximately one third of all households in England.

Table 7-1 *Derived number of Priority Group households*

	Statistic	2003	2004	2005	2006	2007
Priority Group (inc social tenants)	N ('000s)	6911	7053	7034	7062	6985
	%	33.4%	33.7%	33.3%	33.3%	32.7%
Non-Priority Households	N ('000s)	13813	13879	14101	14159	14395

Source ONS various years, English House Condition Surveys

7.9 Summary

To minimize external validity issues when assessing the impact of polices at a national level, quality approved survey data, collected from large nationwide surveys, was used in Task 1 to answer Research Questions 1 to 3. This approach was also compatible with other research into residential fuel consumption which used the same data, allowing the study to more readily build upon existing studies of residential fuel demand and household energy efficiency.

However the use of secondary data had a number of drawbacks, principally the need to use proxy Dependent Variables to describe annual retro-fitting activity and the complexity of the data files, which had to be very carefully rendered into a common format. Nevertheless careful testing and cross checking of the derived variables and the composite data files suggested that the rendered data remained true to the original survey. The results of the data analysis are set out in the next chapter.

8 TASK 1 FINDINGS –PRIORITIZATION AND RETRO-FIT

8.1 Context and Summary of Findings

The hypothesis outlined in Chapter 6 is that prioritized retro-fit assistance policies, added to the relatively low cost of fuel in affluent households, will have caused an imbalance in residential insulation retro-fitting rates, with lower income households insulating their homes more frequently than their higher income counterparts.

The research findings discussed in this chapter generally support this thesis. Retro-fitting appears to have been less common in Non-Priority Group households, particularly in socio economic groups with high aggregate fuel demands, such as households with upper quartile incomes and those living in large properties. But, in the minority of cases where a high income householder was eligible for state assistance, affluent householders have been particularly active in seeking out, or accepting, free insulation.

8.2 Priority Group and Non-Priority Households

In 2007, Priority Group households were predominantly low income - two thirds had Quintile 1 and 2 incomes (Table 8-1). They tended to live in more modern homes which were more energy efficient than the average property. Non-Priority households, on the other hand, were more likely to live in larger, detached homes and a higher proportion of Non-Priority homes were rated as EPC (Energy Performance Certificate) rated F or G, indicating that a higher proportion of Non-Priority households lived in homes that are particularly inefficient at retaining warmth.

Table 8-1 *Characteristics of Priority Group and Non-Priority Group Homes and Households, 2007*

		Priority Group H/holds		Non-Priority H/holds		Implication
		N ('000s)	% of total	N ('000s)	% of total	
HRP occupation	f/t work	1457	21%	9664	67%	Priority Group are disproportionately retired, unemployed or economically inactive. Incomes tend to be lower than in Non-Priority households.
	p/t work	668	10%	1055	7%	
	retired	2856	41%	3264	23%	
	unemployed	420	6%	72	1%	
	f/t education	72	1%	187	1%	
	other inactive	1512	22%	154	1%	
Household income quintile	1	2638	38%	1641	11%	
	2	2195	31%	2079	14%	
	3	1203	17%	3073	21%	
	4	666	10%	3610	25%	
	5 (high)	283	4%	3992	28%	
Tenure	Owner occupier	2540	36%	12682	88%	Over half of Priority Group households live in social housing. Their homes tend to be more recent, smaller and more energy efficient than Non-Priority Group homes.
	Private rented	759	11%	1714	12%	
	Social	3686	53%	0	0%	
Building age	pre 1919	1135	16%	3368	23%	
	1919-44	1173	17%	2558	18%	
	1945-64	1821	26%	2393	17%	
	1965-80	1654	24%	3016	21%	
	1981-90	533	8%	1284	9%	
	post 1990	668	10%	1777	12%	
EPC rating	B	26	0%	4	0%	
	C	905	13%	726	5%	
	D	2741	39%	4329	30%	
	E	2347	34%	6256	43%	
	F	722	10%	2525	18%	
	G	243	3%	557	4%	
Property floor area (m^2)	less than 50	1276	18%	909	6%	
	50 to 69	2186	31%	2818	20%	
	70 to 89	2199	31%	4023	28%	
	90 to 109	723	10%	2446	17%	
	Over 110	601	9%	4199	29%	
Property type	end terrace	765	11%	1221	8%	Few Priority Group households live in detached properties. As a result of a tendency to live in flats or terraced homes, which tend to be smaller and more energy efficient, Priority Group households collectively have lower standardised fuel demands.
	mid terrace	1493	21%	2479	17%	
	semi	1681	24%	4253	30%	
	detached	404	6%	3506	24%	
	bungalow	803	11%	1222	8%	
	flat	1840	26%	1714	12%	
Std fuel expenditure quintile	1	2037	29%	2240	16%	
	2	1630	23%	2646	18%	
	3	1304	19%	2973	21%	
	4	1122	16%	3152	22%	
	5 (high)	892	13%	3384	24%	
Total		6985	33%	14395	67%	
Mean SAP 05		52.7 (95%CL 52.7)		48.9 (95%CL 48.9)		

Source: English House Condition Survey and English Housing Survey 2007

As a result of the form and/or size of their homes, Non-Priority households tended to have larger standardised fuel expenditures. However as discussed in Box **2-1**, Chapter 2, the standardised data tells only part of the story because low income households tend to maintain their homes at lower temperatures (Hunt & Gidman, referred to by Milne & Boardman, 2000 and Section 10.3.3) and the contrast between the fuel expenditures in Priority Group and Non-Priority households is likely to be greater than indicated by the standardized data in Table 8-1.

8.3 **Retro-fitting During The Energy Efficiency Commitment**

The relative frequencies of homes with un-insulated cavities or lofts in each full year of the Energy Efficiency Commitment, disaggregated by Priority Group status and each of the four other Independent Variables; income, age, property size and standardised fuel expenditure, are illustrated in a series of graphs in Appendix 14. The best fit trend lines in the graphs were the source of the retro-fit statistics in Table 8-2 and Table 8-4.

Considering first retrofitting rates for the residential sector as a whole are listed in Table 8-2. Sub-dividing householders by their income indicates that retro-fitting in Income Quintile 5 households has been disproportionately low. This high income group accounts for 20% of un-insulated cavity wall stock, but only 2% of the cavity wall retro-fits during the Energy Efficiency Commitment period.

However the EHCS indicates that retro-fitting did not simply diminish with increasing income. Average incomes for those aged 35 to 54 were higher than in the 55 to 64 age category, but, absolutely and proportionately, retro-fit rates were higher in the younger group. A more complicated relationship between income and retro-fitting is evident, which is discussed further in Section 8.4.

Table 8-2 *Annual average retro-fitting of basic insulation, April 2002 to March 2008*

Variable		Cavity wall insulation retro-fits		Lofts topped up to over 125mm	
		Annual average ('000s)	% of annual total	Annual average ('000s)	% of annual total
Full Household Income Quintile	Q1	77	27%	86	20%
	Q2	73	25%	97	22%
	Q3	53	18%	88	20%
	Q4	82	28%	91	21%
	Q5	5	2%	70	16%
	Total	290	100%	432	100%
HRP[2] Age	16 to 34	75	26%	127	29%
	35 to 44	48	17%	96	22%
	45 to 54	30	10%	60	14%
	55 to 64	25	9%	47	11%
	65 +	111	39%	101	24%
	Total	289	100%	431	100%
Floor Area (m^2)	<50	68	23%	98	23%
	50 to 64	166	58%	251	58%
	65 to 89	115	40%	167	39%
	90 to 109	11	4%	13	3%
	110 +	-71	-25%	-98	-23%
	Total	289	100%	431	100%
Standard Fuel Expenditure Quintile	Q1	16	5%	75	17%
	Q2	43	15%	107	25%
	Q3	93	32%	96	22%
	Q4	96	33%	78	18%
	Q5	41	14%	75	17%
	Total	289	100%	431	100%

Source: English House Condition Survey (2003 to 2007)

1.Housing stock numbers are averages of un-insulated stock, 2003 to 2007 inclusive.

2. HRP – household representative person

Income Quintile 5 householders were more willing to fit loft insulation than cavity wall insulation. However further analysis of the EHCS indicates that this group of householders occupied 23% of the 'hard to treat' solid wall housing stock in 2007, but they represented 20% of the population. Therefore loft insulation may have been the only low cost retro-fit option for a slightly higher proportion of this income group.

However the slight preference for solid walled homes is insufficient to account for the order of magnitude difference in cavity wall and loft insulation retro-fitting within this group. Rather the contrast appears to indicate a rejection of cavity wall insulation by many of the most affluent householders, who were nevertheless willing to top-up the insulation in their loft.

The reason for the rejection is unclear, but may be connected to the negative publicity linking retro-fitted cavity wall insulation to internal damp problems. In which case, additional research into moisture transfer across the cavity and a programme of awareness raising may be effective at countering low cavity wall insulation rates for a proportion of high income householders.

Where householders are sub-divided by age, those over 65 years old were more willing to fill their cavity walls than top-up their loft insulation. This is the reverse of the retro-fitting trend in Income Quintile 5 households and the relative unattractiveness of loft insulation in pensioner households may have been a reflection of access and logistical barriers faced by older householders when considering this form of retro-fit.

Those under 34 years old and over 65 have been disproportionately active retro-fitters and the rise in retro-fitting in those over the retirement age supports the notion of a 'hassle factor' and that making time to carry out the work, or commission a contractor, was a barrier for some working age householders. This trend is discussed further in the next section, where it becomes clear that retro-fit assistance appeared to overcome this barrier for many working age householders.

The 20% of households with the lowest standardised fuel expenditure, retro-fitted cavity wall insulation in low numbers, although they did install loft insulation in disproportionately high numbers. Further analysis of the EHCS indicates that 50% of this group of householders live in flats. This is three times the average per fuel expenditure quintile and an elevated proportion of high rise properties would provide one reason why cavity wall insulation, which tends to be installed from the outside, was fitted in disproportionately low numbers by this group, in comparison to loft insulation. Other potential issues could include the higher proportion of private rented properties in the stock of flats, or how loft insulation is accredited in multi-occupancy buildings in the database.

In properties over 65m^2, retro-fitting rates generally declined with increasing floor area and in the largest homes, those over 110m^2, the number of homes with un-insulated cavity walls and/or lofts grew by approximately 70,000 and 100,000 households per year respectively throughout the six year Supplier Obligation.

As described in Section 7.5, new homes have been controlled for in this study and the rise in number of un-insulated stock in the 'over 110m^2' category must was initially considered to indicate a flaw in the method. However a review highlighted that stock transfers between the size classifications would explain the growth in the number of un-insulated homes in a category, providing the total number of homes without measures continues to fall. The approach to control for this effect is set out in Box 8-1 and once home extensions have been taken into account, the statistics indicate that retro-fitting in the over 110m^2 housing stock was very low or negligible.

Overall, when considering the housing stock as a whole, the analysis of the EHCS indicates that retro-fitting has been disproportionately low in the following groups:

- Income Quintile 5 householders;
- Those living in properties over 90m^2;
- Households with the largest or smallest standardised fuel expenditure; and,
- Homes where the principal householder is between 45 and 65 years old.

To enable the transfer of un-insulated stock between the size categories to be approximated and controlled for, other housing statistics were considered to estimate the number of new homes in the over $110m^2$ category. Some 1.04 million new homes were built in England during the Energy Efficiency Commitment (DCLG, 2010a) and based upon the relative frequency of large homes in the 2005 housing stock at the mid-point of the Supplier Obligation period it is estimated that approximately 200,000 of these new homes would have been over $110m^2$.

The EHCS indicates that over the six years of the Energy Efficiency Commitment, the number of homes over $110m^2$ increased by approximately 1.4 million. Discounting the new homes suggests that approximately 1.2 million homes were extended and re-classified as over $110m^2$ during the six year Supplier Obligation.

The EHCS (Appendix 14) indicates that in the over $110m^2$ category, the number of homes with un-insulated cavity walls and un-insulated lofts increased by approximately 510,000 and 710,000 respectively during the Energy Efficiency Commitment period. If the 1.2 million extensions estimate is reasonable, the EHCS indicates that approximately 40% (480,000) of the extended and re-classified properties had un-insulated cavities and 60% (720,000) had less than 125mm of loft insulation.

This estimate correlates closely with the proportion of un-insulated homes in the housing stock. Analysis of the 2005 EHCS from the central period of the Energy Efficiency Commitment indicates that 42% of English homes had un-insulated cavities and 58% had less than 125mm of loft insulation. Therefore the increase in un-insulated homes in the 'over $110m^2$ group closely matches the expected rate, if retro-fitting rates in this size category were low or negligible.

Box 8-1 *Estimating the effects of home extensions on the retro-fit statistics*

8.4 Voluntary and Prioritized Retro-fitting

The thesis, outlined in Chapter 6, is that the social policies within the energy efficiency initiatives will have exacerbated the effect of the market to make retro-fit less attractive to high income householders. To consider this point, the retro-fitting data discussed previously has been disaggregated by eligibility for prioritised retro-fit assistance. The analytical results are listed in Table 8-3.

Considering first those properties where an un-insulated cavity wall was filled, Table 8-3 indicates that, on average, the number of Priority Group and Non-Priority households retro-fitted their cavity wall with insulation in almost identical numbers, 141,000 and 147,000 per year, respectively. However Non-Priority homes were twice as numerous as Priority Group households and so a household which was eligible for prioritized assistance was, on average, twice as likely as a Non-Priority home to retro-fit cavity wall insulation.

Approximately 58% of loft insulation top-ups were in Non-Priority households, which is closer to the relative frequency of this group in the population (67%, Table 7-1) and which indicates a general preference towards insulating the loft rather than filling the cavity walls, when the work is left up to the householder.

Table 8-3 *Average number of retro-fits per year, April 2002 to March 2008*

Variable		Number of installations per year ('000s)					
		Cavity wall insulation installations			Loft insulation topped up>125mm		
		Total (see Table 8-2)	Priority Group homes	Non-Priority Group	Total (see Table 8-2)	Priority Group homes	Non-Priority Group
Income Quintile	Q1	77	71	6	86	64	22
	Q2	72	24	49	97	46	50
	Q3	53	12	40	88	29	58
	Q4	82	24	57	91	22	69
	Q5	5	10	-6	70	19	50
	Total	289	141	147	431	181	250
HRP Age	16 to 34	75	46	29	126	68	58
	35 to 44	48	18	30	96	44	52
	45 to 54	30	16	13	60	20	40
	55 to 64	25	16	9	47	24	23
	65 +	111	45	66	101	25	77
	Total	289	141	147	431	181	250
Floor Area (m^2)	<50	68	21	46	98	38	60
	50 to 64	166	89	77	251	93	158
	65 to 89	115	32	83	167	60	108
	90 to 109	11	4	7	13	4	9
	110 +	-71	-5	-67	-98	-13	-85
	Total	289	141	147	431	181	250
Standard Fuel Expenditure Quintile	Q1	15	4	12	75	26	49
	Q2	43	20	23	106	31	75
	Q3	93	38	55	96	31	65
	Q4	95	49	46	78	49	29
	Q5	41	30	11	75	44	32
	Total	289	141	147	431	181	250

Source: English House Condition Survey and English Housing Survey (2003 to 2007)

Table 8-4 *Proportional retro-fitting during six year Energy Efficiency Commitment, April 2002 to March 2008*

Variable		Number of retro-fits per 100 un-insulated homes in that group			
		Cavity wall insulation		Loft insulation top up	
		Priority (100=100%)	Not Priority (100=100%)	Priority (100=100%)	Not Priority (100=100%)
Income Quintile	Q1	47	7	38	17
	Q2	19	41	32	28
	Q3	18	22	34	22
	Q4	67	26	43	22
	Q5	66	<	78	14
HRP Age	16 to 34	67	22	84	29
	35 to 44	24	17	47	19
	45 to 54	29	7	28	14
	55 to 64	29	6	35	10
	65 +	34	40	16	31
Floor Area (m^2)	<50	23	50	58	52
	50 to 64	66	32	60	53
	65 to 89	26	26	34	23
	90 to 109	8	<	1	<
	110 +	<	<	<	<
Standard Fuel Expenditure Quintile	Q1	4	10	34	36
	Q2	24	17	30	34
	Q3	50	31	30	24
	Q4	71	24	49	10
	Q5	59	6	48	10

Source: English House Condition Survey, (2003 to 2007)
< indicates groups where the number of un-insulated properties increased over the Energy Efficiency Commitment

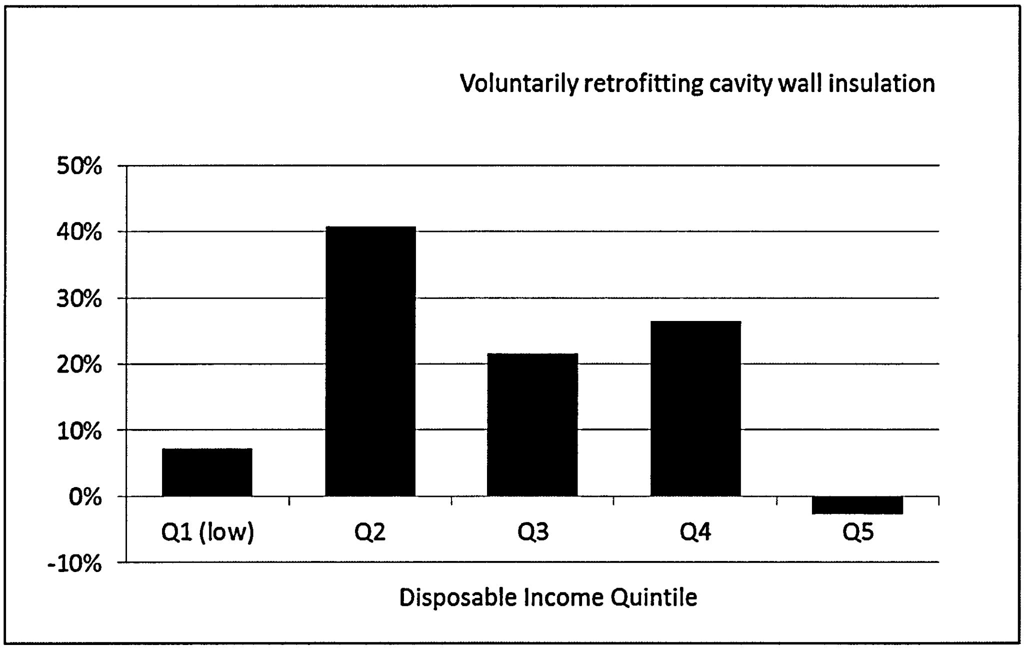
Table 8-4 expresses the absolute retro-fitting rates listed in Table 8-3 in proportional terms, making the influence of prioritization upon the retro-fitting trends easier to identify. The data has been adjusted to take into account the estimated 5000 to 10000 Priority Group demolitions per year (Section 7.7), the transfer of un-insulated stock into the 'over 110m^2' group (Box **2-1**) and the six year duration of the Energy Efficiency Commitment (Section 7.2). When adjusting the floor area statistics, the increased number of un-insulated properties in the 'over 110m^2' group, were apportioned equally amongst the four sub-110m^2 categories.

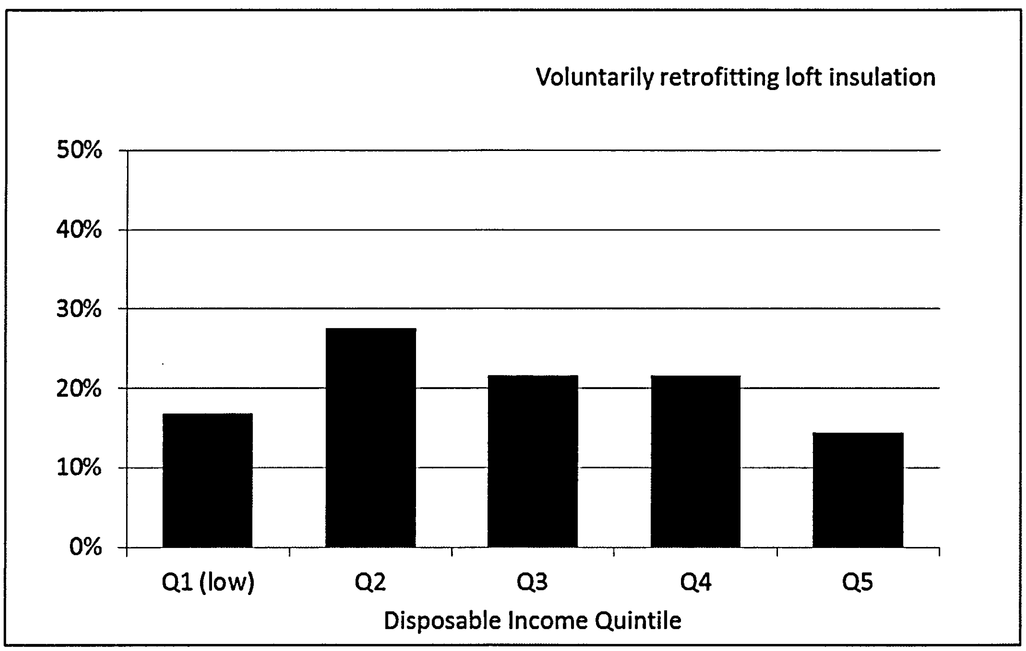
Table 8-4 indicates that Income Quintiles 1, 4 and 5 have been disproportionately reliant upon, or motivated by, retro-fit assistance provided by the state agencies. Over the six years of the Energy Efficiency Commitment, over two thirds of Income Quintile 4 and 5 householders who qualified for assistance, took up the offer of free, or heavily subsidised, professionally installed, cavity wall insulation. The take up was greatest in Income Quintile 5 Priority Group households, where four fifths of eligible households had accepted free loft insulation at the end of the Energy Efficiency Commitment period.

However, the relatively high take-up rates of prioritized assistance by Income Quintile 4 and 5 households must be set against the fact that, together, these households represented only 3% of the un-insulated cavity wall stock and 4% of the homes with un-insulated lofts. By comparison, voluntary retro-fitting in Income Quintile 5 households was low. In fact voluntary retro-fitting of cavity wall insulation in this group was undetectable against the background variation in the data.

Income Quintile 4 householders on the other hand retro-fitted voluntarily in proportions not dissimilar to households in lower income groups and, overall, once state assisted and voluntary retro-fitting statistics have been combined, Income Quintile 4 households were the most active retro-fitters during the Energy Efficiency Commitment period (Table 8-2).

Figure 8-1 *Retro-fitting in potentially suitable, Non-Priority homes, April 2002 to March 2008*





Source: English House Condition Survey 2003 to 2007

The income disaggregated, Non-Priority retro-fit statistics listed in Table 8-4 and illustrated in Figure 8-1 show several general trends in voluntary retro-fitting during the Energy Efficiency Commitment period. Firstly households on middle incomes, in this case defined as Income Quintile 2,3 and 4 homes, were disproportionately willing to retro-fit without assistance from state agents – approximately one third of households in this group filled their un-insulated cavity walls and a quarter topped up the loft insulation.

Voluntary retro-fitting was less popular in Income Quintile 1 homes, but Non-Priority homes are in the minority in this income group (Table 8-1), and they collectively use the least fuel. Potentially more significant are the low voluntary retro-fitting rates in Income Quintile 5 households because Non-Priority households represent 95% of this income group and they also collectively purchase disproportionately high amounts of energy (Figure 2-9).

A second feature of the graphs is the rejection of voluntary cavity wall insulation by Non-Priority Income Quintile 5 households, when approximately 15% of these households topped up their loft insulation over this period. Working with vintiled (5%ile) data indicates that the income level where voluntary cavity wall filling drops sharply occurs at approximately the 75%ile income mark.

The fuel expenditure statistics in Table 8-4 suggest a similar picture to the income data. The 40% of households with the highest standardised fuel expenditures were disproportionately willing to seek out or accept retro-fit assistance, but they also tended to be less willing to voluntarily retro-fit than households with lower fuel demands, when they were ineligible for prioritised assistance.

Voluntary retro-fitting of cavity wall insulation and loft insulation was six times and three times more common respectively, where a householder was over 65 than between 55 and 64. However in homes eligible for prioritized assistance, this age related retro-fitting differential was largely absent from the cavity wall filling statistics and when considering loft insulation rates, the relationship had been reversed, see Table 8-4. These statistics suggest that the motivational barriers experienced by working age householders can be substantially overcome with the offer of free or heavily subsidized installation, although as noted in Section 5.4, a significant minority are likely to continue to refuse freely installed insulation.

The data in Table 8-4 disaggregated by floor area, indicates that voluntary retro-fitting has been largely limited to homes less than $90m^2$ and householders in sub-$65m^2$ have been the most willing to either accept assistance and/or voluntarily insulate their homes.

Table 8-5 overleaf ranks socio economic criteria by the proportion of this group which voluntarily filled their cavity wall or installed additional loft insulation. The ranked data reinforces the earlier observations: households living in small homes, and/or households with limited incomes, but not the lowest quintile and/or retired households have been the most active, voluntary retro-fitters. Average income earners and those with average fuel demands have voluntarily retro-fitted more than most, but householders in the largest properties, and/or those receiving Quintile 5 incomes and/or the largest standardised fuel expenditures, have retro-fitted the least, unless they were supported by the state agents.

Table 8-5 *Voluntary retro-fitting ranked by household characteristic, April 2002 to March 2008*

Rank	Variable	Group	Number of retro-fits per 100 un–insulated Non-Priority homes	
			Cavity wall filled (100=100%)	Loft topped >125mm (100=100%)
Most active voluntary retro-fitters	Floor area	<50 m^2	50	52
	Income quintile	Q2 (£/yr)	41	28
	HRP age	65 yrs +	40	31
	Floor area	50 to 64m^2	32	53
	Std fuel expenditure quintile	Q3 (kWh/yr)	31	24
Moderate retro - fitters	Income quintile	Q4 (£/yr)	26	22
	Floor area	65 to 89m^2	26	23
	Std fuel expenditure quintile	Q4 (kWh/yr)	24	10
	HRP age	16 to 34 yrs	22	29
	Income quintile	Q3 (£/yr)	22	22
	HRP age	35 to 44 yrs	17	19
	Std fuel expenditure quintile	Q2 (kWh/yr)	17	34
Least active voluntary retro-fitters	Std fuel expenditure quintile	Q1 (kWh/yr)	10	36
	HRP age	45 to 54 yrs	7	14
	Income quintile	Q1 (£/yr)	7	17
	Std fuel expenditure quintile	Q5 (kWh/yr)	6	10
	HRP age	55 to 64 yrs	6	10
	Income quintile	Q5 (£/yr)	<	14
	Floor Area	90 to 109m^2	<	<
	Floor Area	110m^2 +	<	<

Source English House Condition Survey, 2003 to 2007 inclusive. Properties without lofts or cavity walls have been excluded.

8.5 After The Energy Efficiency Commitment

Trends under CERT, the Supplier Obligation which superseded the Energy Efficiency Commitment in 2008, were not the focus of this thesis, but they are relevant to conditions in 2012 when the Green Deal and ECO were introduced. Therefore, with a view towards considering the implications of this research for The Green Deal, insulation and housing statistics from 2008 and 2009, the first two years of the CERT Supplier Obligation have been considered and the early trends which developed under CERT are discussed in Appendix 15.

The research indicates that retro-fitting in Income Quintile 5 homes, which was very low during the Energy Efficiency Commitment period, did not pick in the first two years of CERT. If the trends evident by 2010 continued, the number of Income Quintile 5 households living in homes with un-insulated cavity walls is likely to be similar in 2012 to the number of such households at the beginning of the Energy Efficiency Commitment, nearly 11 years earlier. Also as a result of enlarging un-insulated homes (Section 8.3), the number of homes over 110m^2 with un-insulated cavity walls is almost certainly higher in 2012 than in 2002, when the first major supplier obligation was introduced.

8.6 Review of the Task 1 Findings

The analysis of EHCS supports the thesis discussed in Chapter 6, that market forces and social prioritization policies have caused disproportionately low insulation retro-fitting rates in the most affluent households. The results suggest that simply having the financial resources to retro-fit is insufficient to counter the combined effects of social policies and the relatively low cost of fuel in affluent homes.

This analysis also suggests that there may be a disconnection between the attitudes of affluent householders, reported in social surveys (Section 5.4) and their actions. In which case, social surveys into energy efficiency may benefit from cross referencing with quantitative fuel demand data and retro-fit statistics.

More detailed analysis of the retro-fit statistics indicates that high income households are much more closely associated with un-insulated cavity walls than un-insulated lofts, indicating that the relatively the low cost of energy in higher income households allowed householders wanting to be more energy efficient to be more discriminating in their choice of insulation. Consequently better research into the potential risks of cavity wall retro-fitting and better dissemination of the findings may boost cavity wall retro-fitting rates in high income households.

Those over 65 years old have been much more willing than working age householders, particularly those between 45 and 64 years old, to voluntarily fit additional insulation into their homes. However this differential largely disappeared in cases where state agencies financed and organised the work, indicating that for many working age householders, motivation is a particularly important retro-fit barrier.

Overall the analysis of the EHCS indicates that retro-fitting has been disproportionately low in households with upper quartile incomes, those living in properties over $90m^2$; households with the largest or smallest standardised fuel expenditure; and in homes where the principal householder is of working age, but in their mid-40's or older. These social groups also exhibited disproportionately low voluntary retro-fitting rates.

Low retro-fitting rates in high income households has the potential to have meaningful effects on the level of emissions abated by the energy efficiency programmes because income is positively correlated to household fuel demand (Druckman and Jackson, 2008, The Carbon Trust, 2006) and the significance of this linkage is the research subject of Task 2.

9 TASK 2 METHODS - RETRO-FIT AND RESIDENTIAL FUEL DEMAND

9.1 Introduction

The task aim has been to assess whether the socially differentiated retro-fitting rates discussed in Chapter 8, meaningfully influenced household fuel demand or the outcomes of energy efficiency policies designed to reduce demand whilst making warmth more affordable.

As discussed in Chapter 2, household fuel consumption is influenced by a wide range of factors and to understand the effect of any one factor, the influence of all the other factors must be controlled for. This chapter: describes the sources of the fuel expenditure and fuel consumption statistics; discusses how the data was prepared for analysis and, how the validity of the study was tested. The study findings are discussed in Chapter 10.

9.2 Data Sources

Two sources of fuel expenditure data have been contrasted. The first was the EHCS, discussed in the previous chapter. The comparative data was taken from the ONS Expenditure and Food Survey (EFS, 2003 to 2007), which is widely referenced in studies of fuel demand (Gough et al, 2011, Thumin et al, 2011, Summerfield et al, 2010a, Druckman and Jackson, 2008, Utley and Shorrock, 2008, Roberts et al, 2007).

The EFS records the annual spending habits of around 6000 randomly selected English households. Data is collected during household interviews and from expenditure diaries. Each survey runs continuously throughout the year. Area based gas consumption statistics, issued annually by DECC (2011i) have also been analysed to provide contrasting evidence and to test the internal validity of the expenditure analysis.

9.3 Research Method

As mentioned in Box **2-1**, the EHCS fuel expenditure data is based upon a model of the surveyed property and the database lists the expenditure required for a household to purchase 'standard conditions' – in this case 21^{0}C in the living room, 18^{0}C throughout the remainder of the house, and sufficient power to meet needs of the average household.

The EFS on the other hand, lists actual household spending on fuel immediately prior to the survey. Therefore the EFS fuel expenditure data takes into account all of the factors which influence household fuel demand, including the fuel price, but the EHCS data is independent of the cost of fuel.

Contrasting indexed fuel expenditure data in the EHCS from year to year allows the notional effect of energy efficiency improvements on fuel expenditure to be estimated. This notional figure can be adjusted by the ratio of EHCS fuel expenditure to EFS expenditure in each socio-economic group to account for increasing under-spending on fuel, which increases as incomes decline (Section 10.3.3).

Then, when the effect of one factor has been calculated and controlled for, in this instance energy efficiency, the expenditure balance in the EFS data represents the fuel demand changes caused by all the other factors. By progressively identifying and stripping away the effects of other quantifiable factors, for example changes in external temperature, the balance in the EFS data tends towards the fuel bill savings which are the result of relative fuel price changes. The method is described in greater detail in the course of this chapter as the various steps in the assessment procedure are discussed and the calculations are set out sequentially in Appendix 16.

The EFS does not provide sufficiently detailed income statistics to allow the Cases to be disaggregated by their Priority Group status. Rather the research results have been disaggregated by disposable income, which as noted in Sections 2.7 and 8.2, is correlated to fuel demand and eligibility for Priority Group assistance. The study has been limited to the period covered by the Energy Efficiency Commitment Supplier Obligation. In common with Task 1, when discussing total changes over the six year supplier obligation rather than annual averages, the data has been adjusted to account for the six year programme when data from only five data bases was used (Section 7.2).

9.4 Weights, Uncertainty and Missing Data

The EFS is a multi-stage clustered sample (ONS, various years). To compensate for the clustering and bias, UKDS publish household and dwelling grossing factors and, in common with the study of the EHCS, household weights were applied. The survey has been treated as a Simple Random Sample when calculating the confidence limits on the mean. The EFS is based upon complete responses. Any missing data is imputed by ONS with reference to the 2001 Census.

9.5 Fuel Expenditure Factors

To determine the relative influence of various factors upon fuel demand, fuel expenditure in 2003 was adjusted to 2007 conditions to permit a direct comparison between fuel expenditure in either year. Factors which are particularly associated with fuel demand inflation or deflation were identified from the literature and are listed below:

- changes to the charging structure. The Sustainable Development Commission (2007) reported that environmental charges in fuel bills rose from £12.00/year in 2003 to on average £47.50[4]/year in 2007 (Figure 3-1, Section 9.9);
- floor area. DECC data (2011c) indicates that floor area is closely correlated with fuel demand and there has been an increase in the number of large un-insulated properties (Box 8-1).

- energy prices and external temperatures. Summerfield et al (2010a) reported that 99% of demand changes since 1998 can be explained by variations in fuel price and temperature alone (Section 2.4).
- household composition. Boardman (2010) quoting Fawcett, Lane and Boardman (2000) (Appendix 11) explained how household composition influences fuel demand. However analysis of the EHCS from 2003 and 2007, indicates the size of the average household group remained stable at 2.4 residents per home and so this variable was screened from the assessment.

The next four sub-sections describe how the various inflationary and deflationary factors for the parameters listed above, were calculated. All calculations were based upon expenditure adjusted to remove VAT at 5%.

9.6 Fuel Price Inflation

The composite fuel price inflator listed in Table 9-1 was based upon gas, electricity and heating oil inflation (DECC, 2011d) and the proportion of the residential demand which is met by that particular fuel (DECC, 2010a).

Table 9-1 *Fuel price inflation, 2003 to 2007*

	Coal	Gas	Electricity	Renewable	Oil
Average residential market share 2003-2007	1%	68%	23%	1%	7%
Retail price inflation	-	75%	54%		67%
Composite fuel price inflation			+70%		

Source DECC: QEP, Tables 2.1.1 (2011e) and Digest of UK Energy Statistics, Table 1.1.5 (2010a)

9.7 Floor Area Inflation

Regression analysis of the EHCS by the author indicated that fuel demand increased by 4% for every 10% increase in floor area. Average household floor areas per income quintile increased over the Energy Efficiency Commitment period, but analysis of the EHCS revealed that increases in the average floor area varied by income group. The income specific, floor area fuel demand inflators are listed in Table 9-2.

Table 9-2 *Income specific, floor area fuel demand inflators, 2003 to 2007*

Income Quintile	Mean floor area 2003	Mean floor area 2007	Change 2003 to 2007		Fuel demand change due to floor area inflation
	m^2	m^2	m^2	%	%
1(low)	67.5	73.4	5.9	9%	+3%
2	74.7	78.9	4.2	6%	+2%
3	81.7	86.6	4.8	6%	+2%
4	90.3	97.2	6.9	8%	+3%
5	110.9	125.5	14.7	13%	+5%
95% confidence on the mean	All within +/- $0.05m^2$	All within +/- $0.07m^2$			

Source: ONS English House Condition Surveys 2003 and 2007

9.8 Adjusting for External Temperature

The influence of ambient temperature variations upon fuel expenditure was estimated using the Hitchen's Formula (Day, 2006) and monthly temperatures records (DECC, 2010b) to determine the degree day ratio between the first and last EHCS surveys during the Energy Efficiency Commitment period. The degree day calculations are reproduced in Appendix 17.

9.9 Adjusting for Tax Changes

During the second Energy Efficiency Commitment period (2005 to 2008), fuel bills attracted an average (median) annual charge of approximately £47.50 (Sustainable Development Commission, 2007) to finance the Renewables Obligation, the Energy Efficiency Commitment and the EU Emission Trading Scheme. In 2003 the levy was £12.00 (Sustainable Development Commission, 2007). A £35.50 supplement was added to the 2003 fuel bills, once spending in 2003 had been inflated to 2007 conditions, to permit a more direct comparison with the 2007 expenditure records.

9.10 **Validity and Compound Uncertainty**

The EFS, like the EHCS discussed in the previous chapter, is graded as 'National Statistics' by the UK Statistics Authority (ONS, 2012). The EFS has been weighted against the 2001 Census data and, within the uncertainty limits calculated, the survey is considered to be representative of English households.

However a review of the EFS, discussed in Appendix 5, identified Case specific fuel expenditure validity issues. The ONS (2010, pers comm) acknowledged the issues and confirmed that they can be resolved by using averaged data. But averaged data increases the uncertainty that a test result is a precise measure of the true mean. Computing the compound uncertainty of the averages would be possible, but the analysis would be complicated and probably unnecessarily detailed for an assessment based upon proxy data and a series of adjustment factors which are themselves averages or simplifications. Therefore, rather than merely report the compound statistical uncertainty, gas demand statistics were referenced to provide an alternative line of evidence on the links between fuel demand changes, income and insulation retro-fitting.

The research method does not control for the influence of new homes upon the fuel expenditure statistics. Therefore the estimated fuel demand reductions which are attributed to energy efficiency enhancements are a reflection of changes to the entire housing stock, rather than retro-fitted properties. However, providing that the new homes are reasonably evenly distributed by income group, the new build statistics will not meaningfully influence this assessment.

9.11 **Using Expenditure as a Proxy for Fuel Demand**

This study investigates changes in fuel expenditure. However the regulations set residential emission reduction targets, rather than energy expenditure objectives. Therefore knowledge of how retro-fit has influenced fuel expenditure is in many ways less useful than understanding the links between retro-fit and emissions. Direct extrapolation from residential fuel expenditure to household energy demand or domestic emissions is difficult because of variations in the household fuel mix and the variety of residential fuel tariffs. However some general conversions are nevertheless possible.

As indicated in Figure 2-7 and Figure 2-8, households paying by direct debit bought, on average, 13% more electricity and 14% more gas per £ spent on fuel, than households pre-purchasing fuel. Pre-payment is predominantly associated with lower income households - analysis of the 2007 EFS by the author indicates that 28% of Income Quintile 1 household pre-paid for gas in comparison to 3% of Income Quintile 5 households.

Table 9-3 *Index of fuel purchased per expenditure unit by income group*

Income Quintile	1	2	3	4	5
Gas	1.00	1.01	1.02	1.02	1.03
Electricity	1.00	1.01	1.01	1.02	1.03

Source Expenditure and Food Survey, 2003

However fuel expenditure adjustment factors listed in Table 9-3, which were based upon the relative frequency of payment methods per income quintile, indicate that the effect of tariff variations, based upon income related differences in payment method, are relatively trivial, but are nevertheless taken into account when the result are considered in Chapter 10.

9.12 **Comparative Fuel Demand Statistics**

The association between household income and the proportional changes in residential gas demand, the principal heating fuel, has been studied using area based, weather corrected, gas consumption data. Data are available (DECC, 2011f) at Middle Order Super

Output Area (MSOA) level, where an MSOA is a geographical unit typically occupied by 2000 to 3000 homes. The statistics only date back to 2005 consequently this study element was limited to the period covered by the second Energy Efficiency Commitment (EEC2), which ran from April 2005 to March 2008. Nevertheless the fuel demand statistics for EEC2 provide clear evidence with which to test the energy expenditure analyses.

Average residential gas consumption in 2005 for 6633 MSOA in the nine English Government Office Regions was matched to corresponding gas demand statistics for 2008. The absolute and proportional gas demand changes in each MSOA were calculated. Where the proportional demand change was more than two standard deviations from the regional mean, the data was investigated as a potential outlier.

In 33 MSOA, where outlying data coincided with Cases with less than a few hundred gas customers, or where there was a large change in the number of meters over the intervening period, the data was excluded from the study. The 33 excluded MSOA are listed in Appendix 18, with the reason for their exclusion from the assessment.

9.13 **Summary**

A method has been developed to calculate the proportion of residential fuel demand changes attributable to more efficient use of energy in English homes, in contrast to the demand changes caused by other influences, such as the relative price of fuel and the external temperature.

The method allows the data to be disaggregated by income group and so by applying the retro-fitting rates in different income group calculated during Task 1, the Task 2 method enables the impact of socially differentiated retro-fitting during the Energy Efficiency Commitment to the estimated and then compared to other lines of evidence, such as area based gas consumption statistics. The research findings are discussed in Chapter 10.

10TASK 2 FINDINGS – RETRO-FIT AND RESIDENTIAL FUEL DEMAND

10.1 Context

To make sense of the demand changes brought about by energy efficiency improvements, the effects of other factors which influence household fuel demand, such as fuel price and ambient temperatures, must be understood and controlled for. Annual average temperatures were higher in the last few years of Energy Efficiency Commitment period (DECC, 2010b) and between 2002 and 2008 the average price of gas and electricity bought on standard credit increased by approximately 95% and 50% respectively (DECC, 2011d). In fact during the six year Energy Efficiency Commitment period, average household fuel bills increased approximately five times faster than median incomes (ONS, 2012).

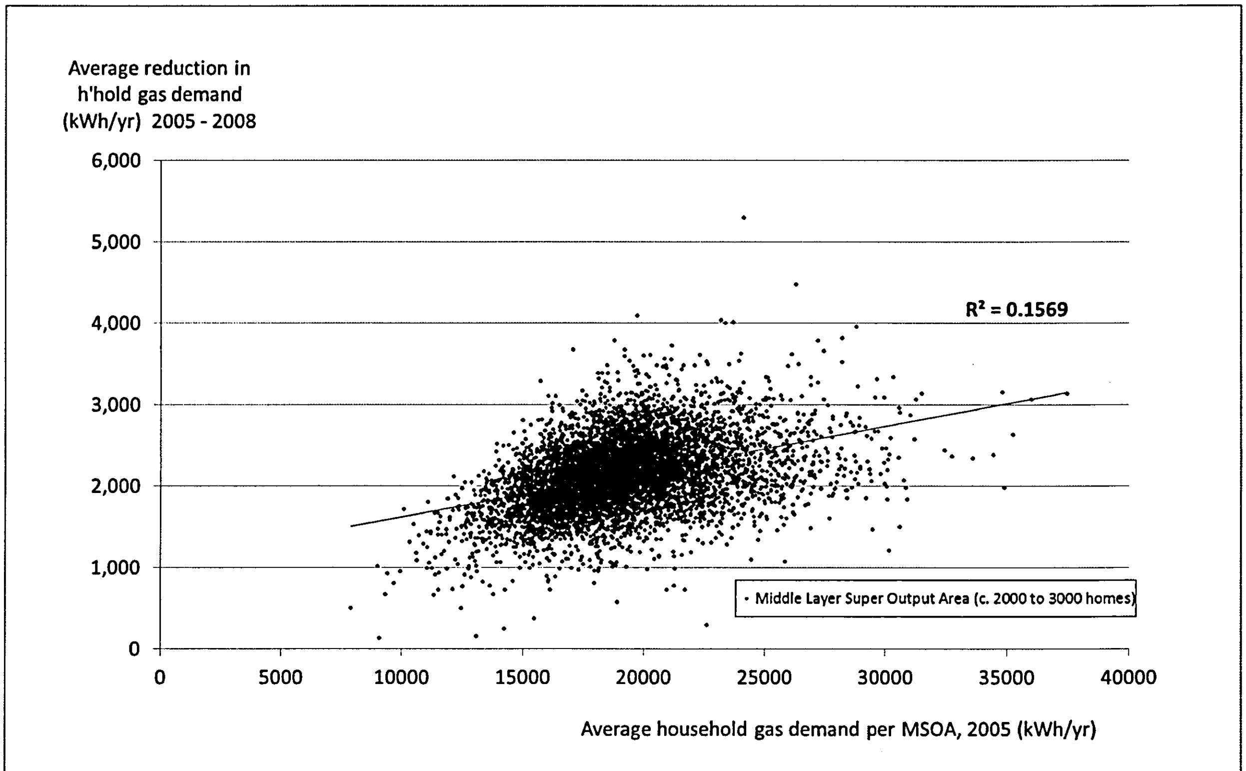
Regression analysis by Summerfield et al (2010), mentioned previously in Section 2.4, indicated that 99% of fuel demand changes in the UK after 1998 can be explained by changes in fuel price and external temperature alone. In which case, fuel prices rises and temperature variations could effectively account for all the reductions in household fuel demand during the Energy Efficiency Commitment and the potential demand reductions brought about by any energy efficiency gains would effectively have been 'lost' because they were taken back to purchase additional energy services. However DECC (2011d) identified meaningful reductions in fuel demand after retro-fitting basic insulation measures (Section 2.4).

The Task 2 findings discussed in this chapter support the findings of both DECC and the observations of Summerfield et al. The analysis suggests that the primary causes of recent changes in household demand were rising fuel prices and warmer winters. However the results indicate that more efficient energy consumption contributed to a demand reduction in most income groups, except in the homes of the 25% of households with the highest incomes, where retrofitting has been disproportionately low (Chapter 8) and where the effects of greater fuel efficiency were undetectable in the expenditure statistics.

10.2 Gas Consumption and Declining Demand

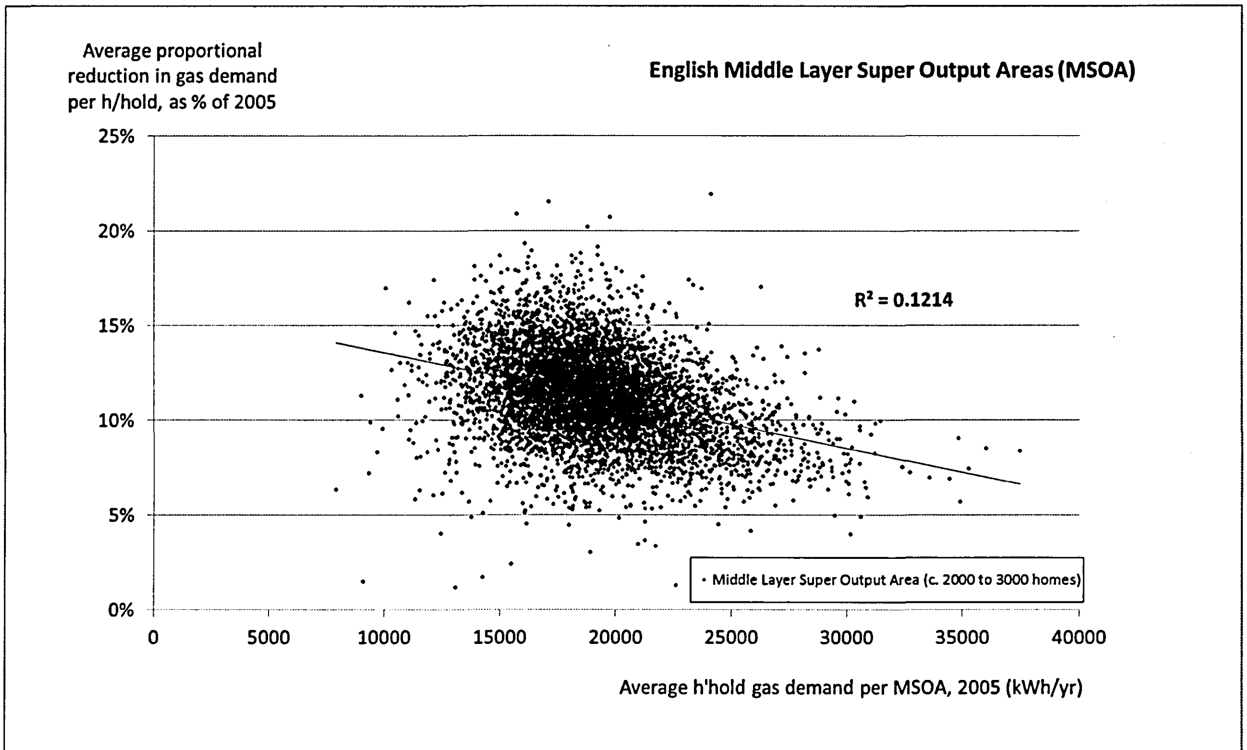
The average household gas demand per MSOA in 2008 was 16968kWh per year (95%CL 17040, 16894), which is 2127kWh per year (95%CL: 2021, 2233) less than in 2005. The decline in average gas demand per MSOA between 2005 and 2008 is positively correlated with the average gas demand per household in 2005 ($r = 0.4$, $p <.001$). In other words, the higher the household gas consumption in 2005, the greater the absolute reduction in demand tended to be over the following three years. This relationship is illustrated in Figure 10-1, where each point on the scatter graph represents the average gas demand per MSOA in 2005, plotted against the fall in demand between 2005 and 2008.

Figure 10-1 *Reduction in average household gas demand between 2005 and 2008 vs average household gas demand in 2005*



Source: DECC 2011i, sub-regional gas consumption statistics, www.decc.gov.uk

Figure 10-2 *Proportional reduction in average residential gas demand between 2005 and 2008 vs average demand in 2005*



Source: DECC (2011i), sub-regional gas consumption statistics, www.decc.gov.uk

A negative correlation emerges when the demand changes are considered in proportional terms. As illustrated in Figure 10-2, the average gas demand per MSOA in 2005 is inversely correlated to the proportional reduction in demand per MSOA between 2005 and 2008 ($r = -0.35$, $p<.001$). More detailed analysis indicates that this distribution is also evident at the regional and county levels and to illustrate this point, plots showing average household gas demand and proportional demand changes in each of the nine English regions are presented in Appendix 19. The regional correlation coefficients from the Appendix 19 graphs are summarized in Table 10-1.

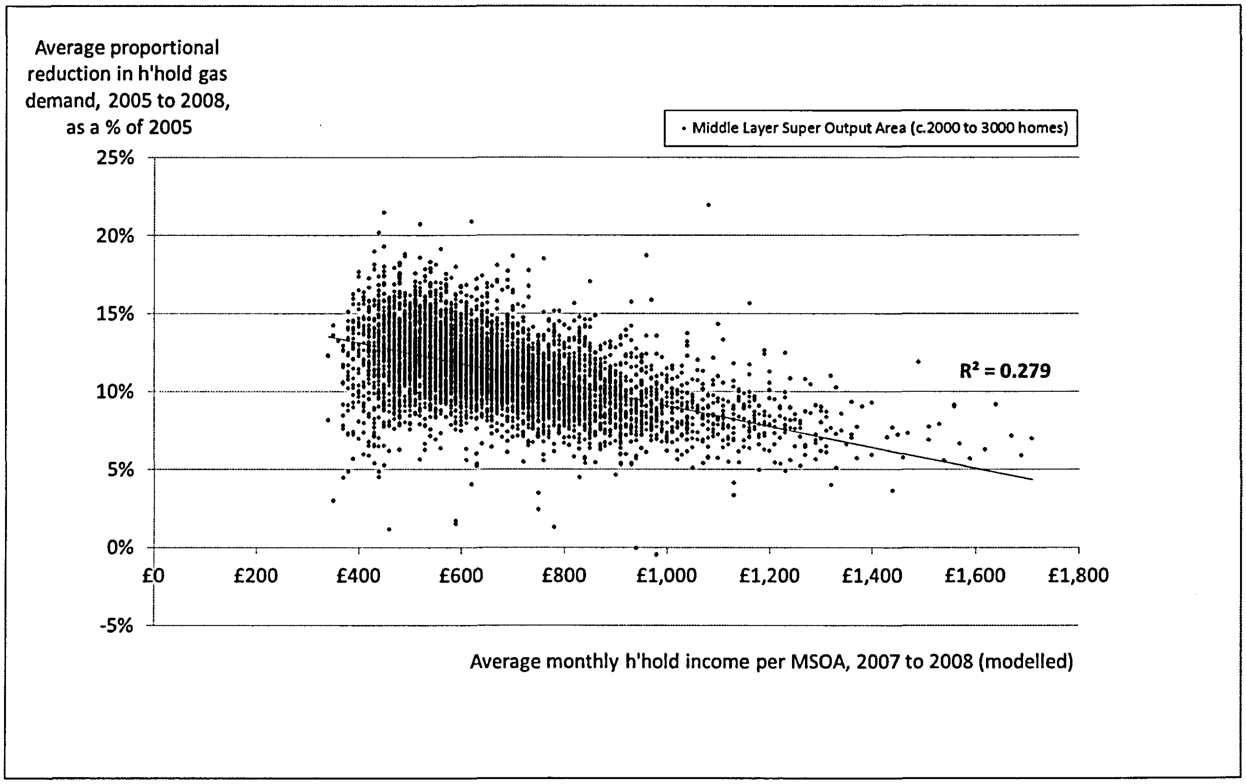
Table 10-1 *Regional correlation coefficients for gas demand in 2005 and proportional reduction in gas demand between 2005 and 2008*

Region	r	R^2	p
East Midlands	-0.31	0.10	<.001
East of England	-0.48	0.23	<.001
London	-0.43	0.18	<.001
North East	-0.17	0.03	<.001
North West	-0.47	0.22	<.001
South East	-0.47	0.22	<.001
South West	-0.29	0.09	<.001
West Midlands	-0.34	0.11	<.001
Yorkshire	-0.26	0.07	<.001

Source: Fuel consumption data from DECC (2011i), sub-regional gas consumption statistics

Although the moderate to strong negative correlations listed in Table 10-1 indicate that gas demand in 2005 was a reasonably good predictor of the proportional reduction in demand over the subsequent three years, Figure 10-3 indicates that the average incomes in 2007 are a better predictor of the areas where gas demand declined most, proportionately, between 2005 and 2008.

Figure 10-3 *Proportional reduction in average residential gas demand between 2005 and 2008 vs average household income*



Sources: Fuel consumption data from DECC, 2011i. Income data from HM Government, 2011b. Income estimates for April 2007 to March 2008.

The correlation between proportional changes in household gas demand and average incomes in 2007 was strong (r = -0.53, p<.001) because in general, more affluent households reduced the level of energy services purchased, least. And as indicated in Table 10-2, in more affluent areas, the decrease in the size of the reduction was not only limited to proportional changes in fuel demand. In the 28% of MSOA where average household incomes were over £750 per week, i.e. upper quartile income homes where insulation retro-fitting had been disproportionately low, both absolute and proportional declines in gas demand became less as average incomes per MSOA, rose.

Table 10-2 *Average reductions in household gas demand by income group, 2005 to 2008*

Mean weekly h/hold income per MSOA	<£500	£500 to £740	£750 to £990	£1000 to £1240	>£1250
Reduction as % of 2005 fuel demand (95% CL)	12.5% (12.3, 12.7)	11.8% (11.8, 11.9)	9.8% (9.7, 9.9)	8.6% (8.4, 8.8)	7.5% (7.2, 7.9)
Reduction in kWh/yr (95% CL)	2174 (2141, 2206)	2186 (2173, 2199)	2017 (1994, 2040)	1869 (1814, 1924)	1731 (1617, 1845)

Sources: Fuel consumption data from DECC (2011i). Income estimates for 2007 from HM Government (2011).

The inverse correlation between income and fuel demand could be the result of the comparatively low retro-fitting rates in upper quartile income households (Chapter 8). However the fall in internal temperatures after 2005 (Section 2.5) suggests that rising fuel costs were a contributor to changes in household demand after 2005 and the relatively high cost of fuel in low income homes (Figure 2-9) could also explain the relationships illustrated in Figure 10-2 and Figure 10-3.

Therefore household income appears to have influenced household fuel demand directly because low income households were more likely to respond to price pressures by reducing demand and indirectly, as energy efficiency is more valuable in low income households and also because low income households were prioritized for retro-fit assistance.

The overlapping influences of income on fuel demand and energy efficiency improvements appears to be reflected in the correlations between the regional proportion of fuel poor households, insulation retro-fitting rates and the changes in gas demand. The correlations listed in Table 10-3 indicate that the proportional reductions in regionally averaged household demand for gas were strongly correlated to reductions in the proportion of un-insulated properties in each region.

Table 10-3 *Correlations between regional changes in average household gas demand, 2005 to 2008, proportion of homes retro-fitted, 2005 to 2008 and % of households in fuel poverty, 2008,*

	Changes in regional average		
	Annual h/h gas demand (kWh)	% homes with <125mm LI	% homes with un-insulated CW
Household gas demand	1		
Proportional changes in homes with <125mm LI	r =0.71, p<.05	1	
Proportional changes in homes with un-insulated CW	r =0.60, p<.05	r=0.55, p=.06	1
% of fuel poor households in 2008	r =--0.61, p<.05	r =--0.50, p=.09	r =--0.50, p=.09

Sources: Fuel consumption data from DECC (2011i). Insulation statistics from EHCS, 2003 and 2007. Fuel poverty statistics from DECC website, 2012c.

In other word, proportional gas demand fell most in the regions which, proportionally, retro-fitted most. These regions also tended to be those where the proportion of households in fuel poverty was highest, suggesting that households in these regions may have been most responsive to fuel price rises and, if fuel poverty policies were targeted appropriately, where prioritized assistance would have been most widely available.

10.3 Fuel Expenditure and Declining Gas Demand

10.3.1 Introduction

In the following two sub-sections, evidence from the EHCS and EFS is used to indicate that both fuel price rises and more energy efficient buildings have contributed to the reductions in household fuel demand recorded during the Energy Efficiency Commitment.

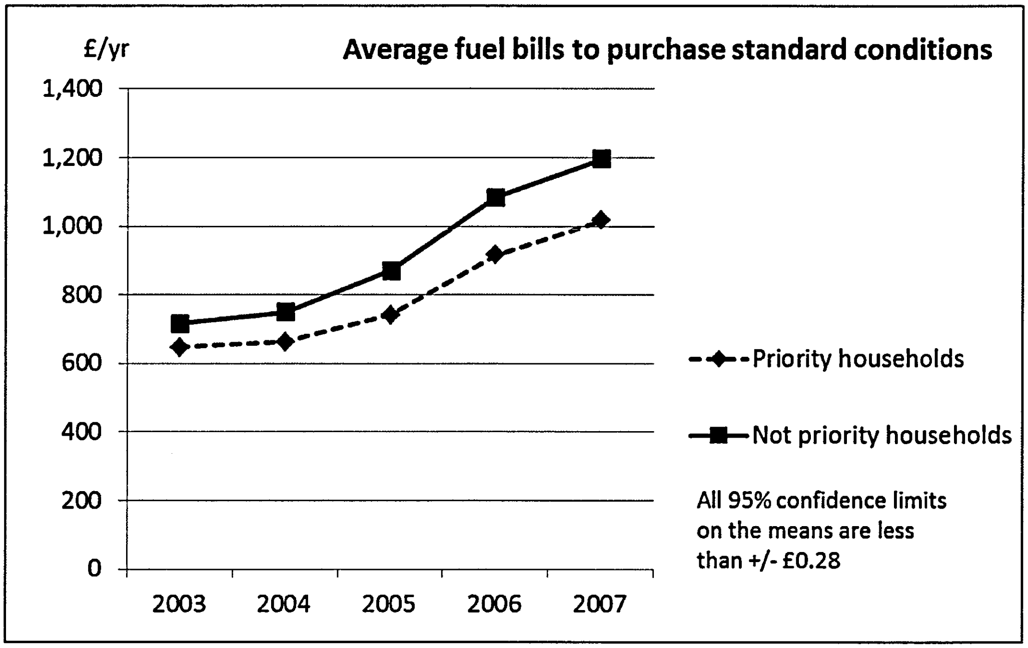
Where practicable, factors which affect expenditure without necessarily changing demand, for example changes to the Renewables Obligation levied on residential bills, have been controlled for (Section 9.5). However there are regional differences as a result of inter-company tariff variations and historic regional preferences towards private companies derived from the local energy boards (Read, 2012). No attempt has been made to correct for all the alternative fuel tariff variations and in this chapter the term 'fuel demand' is an approximation, based upon fuel expenditure, adjusted to remove VAT at 5%.

10.3.2 Energy efficiency and declining fuel demand

Figure 10-4 charts the changes in average fuel expenditure to purchase standard conditions. Standardised fuel bills in Non-Priority and Priority Group households increased by 67% and 57% respectively between 2002/03 and 2007/08. If the Task 1 research findings, discussed in Chapter 8, are accepted, Priority Group householders were approximately twice as likely as Non-Priority householders to have retro-fitted insulation in their homes during this period.

Therefore the widening gap between average standardised expenditure in both groups suggests that energy efficiency enhancements should have delivered a proportion of the fuel demand reductions evident in the gas consumption data, providing that fuel bill savings were not used to purchase more fuel. However during this period the rebound potential was limited by fuel price inflation, which would have rendered notional efficiency derived expenditure savings all but 'invisible' to the householders concerned. Therefore the diverging energy efficiencies and standardised fuel demands in Priority Group and Non-Priority homes, evident in Figure 10-4, are likely to have been reflected in lower, proportional increases in actual fuel bills in Priority Group households.

Figure 10-4 *Average residential fuel bills under standard operating conditions, 2003-2007*



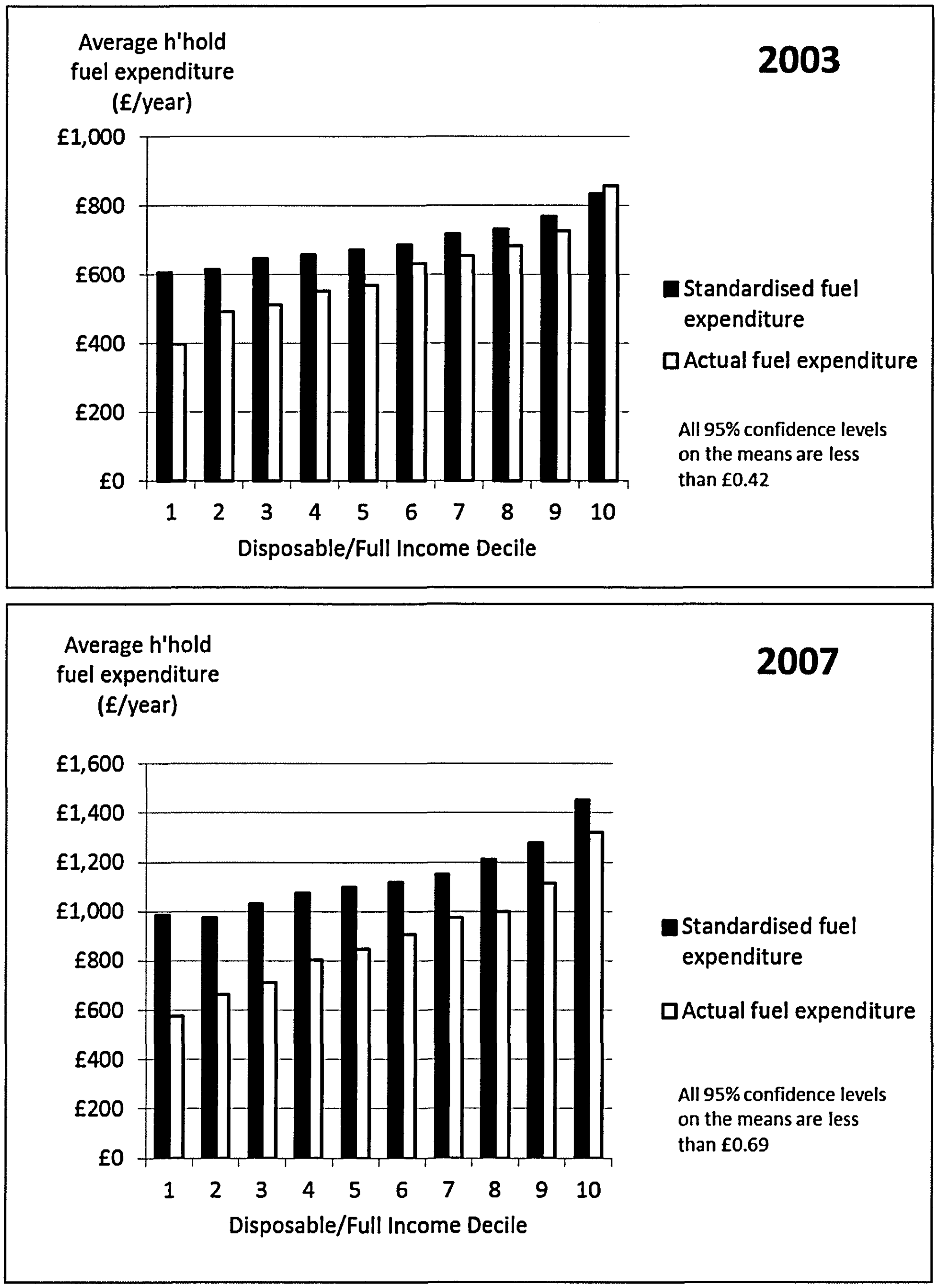
Source English House Condition Survey 2003 to 2007

10.3.3 Rising fuel prices and declining fuel demand

If the finding of Milne and Boardman (2000) is accepted (see Section 2.9), that householders will continue to invest in warmth, providing that it is affordable, until the internal temperature is around 20^{0}C, the modeled 1^{0}C reduction in average internal temperatures between 2003 and 2009 (DECC, 2011c), discussed in Section 2.5, could be a symptom of rising fuel prices.

Additionally changes to the ratio between standardised fuel expenditure and actual fuel bills provides further evidence that rising fuel prices contributed to a fall in residential fuel demand. As mentioned previously, standardised fuel expenditure represents the amount needed to be spent on fuel to maintain each home surveyed at 21^{0}C in the living room and 18^{0}C throughout the rest of the house for a specified period. When households purchase more, or less, energy services, there is a change in the ratio of standardised fuel expenditure, recorded in the EHCS, to actual expenditure, listed in the EFS. The ratios of standardised to actual fuel spending for each income decile in 2003 and 2007 are illustrated in Figure 10-5.

Figure 10-5 *Standardised fuel expenditure vs actual fuel expenditure, 2003 to 2007*



Sources: Standardised fuel expenditure from the English House Condition Surveys (EHCS), 2003 and 2007. Actual fuel expenditure statistics from the Expenditure and Food Surveys (EFS), 2003 and 2007.

Figure 10-5 indicates that in 2003, only Income Decile 10 householders typically purchased sufficient fuel to heat and power their homes to standard conditions and that under-spending on fuel tended to increase as average incomes decreased. By 2007 all income groups, when considered in deciles, had reduced the level of energy services purchased, because the disparity between actual fuel spending and standardised expenditure had increased in all income groups. Households were spending more on fuel (Figure 2-7), but were buying less. This coincided with a period of declining internal temperatures (Figure 2-6) and the expenditure records suggest that this loss of comfort was experienced in all income deciles, but that the 30% of households earning the least reduced the level of energy services purchased, the most. The loss of comfort indicated by these statistics suggests a proportion of the falling demand for fuel was an involuntary response to rising fuel prices.

10.4 **Energy Efficiency and Fuel Demand Reduction**

10.4.1 Introduction

Although average household fuel expenditure was greater in 2007, the standardised to actual fuel expenditure ratio, discussed in Section 10.3.3, indicates that the level of energy services purchased in 2007 was less than 2003. However changes in external temperatures and improvements in the energy efficiency of the housing stock meant that less energy would have been required in 2007 to purchase the 2003 level of service.

Therefore temperature changes, price rises and energy efficiency improvements were all acting to reduce fuel demand, and in this section, expenditure records are used to estimate the relative contribution of each deflationary factor. The results and the calculations are set out more fully in Appendix 16.

10.4.2 Real term changes in fuel expenditure

The results of comparative analysis of fuel bills in 2007 and 2003 are listed in Table 10-4 and they indicate that if the size of homes, fuel prices and ambient temperatures had remained unchanged between 2003 and 2007, annual fuel bills in 2007, in Income Quintile

1 households would have been on average, approximately £165 + VAT higher. Income Quintile 5 households would have spent on average, £240 + VAT more on fuel.

Table 10-4 *Average fuel expenditure (£/yr), 2003 and 2007*

Year	Adjustment	Units	Household Income Quintile				
			1	2	3	4	5
2007	exc VAT @5%	£/yr	615	735	815	950	1125
2003	exc VAT @5%		425	510	560	635	755
2007	Based upon 2003 expenditure (exc VAT) adjusted to 2007 conditions		775	915	995	1140	1365
Real terms reduction in spending between 2003 and 2007			160	185	180	190	235

Source Expenditure and Food Surveys (EFS), 2003 and 2007.
Uncertainty: For confidence intervals on the expenditure averages see Figure 10-5.
Notes: Inflationary factors accounted for include fuel price changes, floor area variations and HM Government environmental charges – see Section 9.9 and Appendix 16. Numbers have been rounded.

The 'missing' 2007 expenditure is a function of a combination of factors, including more efficient buildings, warmer weather in 2007 and the depressed demand for fuel in response to fuel price rises.

10.4.3 Fuel expenditure and external temperature

Using Hitchins' Formula (Day, 2006) to calculate the different number of degree days in the two 24 month periods covered by the 2003 and 2007 EHCS and EFS respectively (Appendix 17), indicates that the last two years of the Energy Efficiency Commitment were warmer than the first two and that approximately 6% less fuel would have been required to purchase the same level of energy services in the period covered by the 2007 EHCS. The consequent real terms expenditure savings, and the proportion of the overall expenditure reductions due to warmer weather in 2007 are listed in Table 10-5, which indicates that approximately one third of the fuel demand reductions in 2007, when contrasted to 2003, were the result of changes in external temperature.

Table 10-5 *Fuel expenditure savings due to warmer weather in 2007 than 2003*

Item	Household Income Quintile					Mean
	1	2	3	4	5	
Fuel expenditure 'savings' in 2007 due to warmer weather (£/year)	45	50	55	65	80	60
% of 2007 reduction in fuel spending (see Table 10-4)	27%	27%	30%	33%	35%	30%

Source Expenditure and Food Surveys (EFS), and DECC (2010b).
Uncertainty: statistical analysis (Day, 2006) indicates that averages based upon degree day calculations using monthly average temperature, accurately predict the result of degree hour based calculations to +/- 4% on 95% of occasions.
Numbers have been rounded.

10.4.4 Fuel expenditure and energy efficiency

Contrasting the relative changes in standardised expenditure in 2003 and 2007 provides an estimate of the expenditure savings which may be attributed to changes to the housing stock. Once adjusted for increases in floor area and differences in under-spending on fuel in different income groups, the comparative standardised fuel bills are a measure of the average expenditure reductions per household attributable to energy efficiency improvements. The results, summarized in Table 10-6, indicate that in the majority of households, approximately 10% to 20% of the reduced fuel demand in 2007, relative to 2003, was the result of energy efficiency improvements to the housing stock.

Table 10-6 *Estimate of fuel expenditure savings due to more energy efficient housing stock*

Item	Household Income Quintile					Mean
	1	2	3	4	5	
Fuel expenditure 'savings' in 2007 due to energy efficiency only (£/year)	30	30	20	30	-5	20
% of real term 2007 reduction in fuel spending (see Table 10-4)	20%	16%	12%	15%	-2%	12%

Source: English House Condition Surveys (EHCS), 2003 and 2007.
Numbers have been rounded.

However there was a marked contrast between Income Quintile 5 households and the 80% of households receiving Quintile 1 to 4 incomes. In Quintile 5 households, any demand reductions brought about by energy efficiency improvements were undetectable, once the increase in average floor area had been accounted for.

10.4.5 Fuel expenditure and fuel price

For all income groups at least half of the real term expenditure savings in 2007 appear to be associated with factors other than external temperature or more energy efficient homes – see Table 10-7. Taking into account the linkage between fuel price and demand (Summerfield et al, 2010) it is reasonable to suggest that the majority of the 'other' demand reductions were the result of the 70% rise in average household fuel bills between 2003 and 2007.

Table 10-7 *Estimates of the real term reductions in fuel expenditure, 2003 to 2007*

	Factor	Household Income Quintile					
		1	2	3	4	5	Average
Real term reduction in fuel expenditure, (£/year)	Energy efficiency improvements	35	30	25	30	-5	20
	Warmer weather in 2007	45	50	55	65	80	45
	Other factors, inc fuel price	85	105	105	100	160	110
	Total	165	185	185	195	240	185
		Household Income Quintile					
		1	2	3	4	5	Average
Real term reduction in fuel expenditure (% of 2003)	Energy efficiency improvements	20%	16%	12%	15%	-2%	12%
	Warmer weather in 2007	27%	28%	31%	34%	33%	31%
	Other factors, inc fuel price	52%	56%	56%	51%	69%	57%
	Total	100%	100%	100%	100%	100%	100%

The results of the fuel expenditure assessment listed in Table 10-7 suggest that if Income Quintile 5 households had made the same energy efficiency driven demand reductions as Income Quintile 4 households, their fuel demand would have fallen by approximately 15% more over the Energy Efficiency Commitment period and nationally, demand reductions delivered by energy efficiency would have been approximately 30% higher.

10.5 Cross Referencing Consumption and Expenditure Data

The results of the study of fuel expenditure may be cross referenced with the findings published by DECC (2011d) and the Transco area based gas demand statistics. The study of retro-fitting, discussed in Chapter 8, indicates that between 2003 and 2007 inclusive, cavity wall insulation was installed in approximately 10% of the housing stock, with a similar proportion topping up the loft insulation. Based upon the average delivered energy reductions per measure (DECC, 2011e) and taking into account the fact that retro-fitting was concentrated in the 80% of households receiving Quintile 1 to 4 incomes, the energy efficiency improvements recorded in the EHCS can be expected to have lowered real term demand for gas by approximately 2% over the six years of the Energy Efficiency Commitment.

By comparison, the gas consumption statistics illustrated Figure 10-1 suggest that weather corrected gas demand fell by about 11% between 2005 and 2008. Based upon the estimates listed in Table 10-7, that some 10% to 15% of demand reductions were delivered by energy efficiency improvements, more efficient energy use could account for a fall in household gas demand of approximately 1.5% to 2%.

The comparison is imperfect because the periods covered by the expenditure and fuel consumption data were not identical. Nevertheless the compatibility of the results of the gas consumption and fuel expenditure analyses, coupled with the high degree of statistical confidence in the expenditure averages, provides a measure of confidence in the research method and the study findings.

10.6 Review of Task 2 Findings

The link between average fuel demand and average incomes had been established previously in the literature (Section 2.7), although the link between both factors at a household level is contested (Appendix 5). The findings of Task 1 built upon the literature by providing evidence that changes in energy efficiency are also linked to income, as a result of national polices and market forces. And the Task 2 results have extended the

Task 1 findings by highlighting the consequences of low insulation retro-fitting rates in the most affluent households.

Although rising fuel prices have resulted in households in all income groups cutting back on the amount of fuel purchased, the most affluent 25 % of householders have collectively made little, if any, reductions in their household fuel demand as a result of improving the energy efficiency of their homes. Therefore, counter-intuitively, when considering the proportion of demand changes attributable to rising fuel costs only, it appears that rising fuel prices have made the greatest impact in the most affluent households. However this is because this group have been most reluctant to invest in energy efficiency measures for their homes and they have been largely ineligible for state assistance to retro-fit.

The research indicates that the demand reductions delivered by the energy efficiency improvements during the Energy Efficiency Commitment period could have been approximately a third greater if the most affluent households, those with upper quartile incomes, had engaged in the energy efficiency and retro-fit programmes to the same degree as their less affluent neighbours.

The analysis also suggests that the combined impacts on household fuel demand of rising fuel prices after 2005 and warmer weather in 2006/08, were an order of magnitude greater than the demand reductions brought about by energy efficiency improvements in the housing stock during the Energy Efficiency Supplier Obligation. This statistic tends to suggest that the contribution from greater energy efficiency was relatively minor. However when comparing the relative impacts of these factors upon household fuel demand, several points should be considered.

Firstly energy efficiency measures tend to improve comfort. Price driven demand reductions are delivered at the expense of comfort, unless they stimulate energy efficiency. Also the increasing discrepancy between the fuel bills and standardised expenditure in lower income households indicates that the discomfort caused by rising fuel prices was unequally apportioned. Therefore price driven demand reductions created equity issues.

Secondly, direct demand reductions in response to market and climatic variations are elastic and could be reversed by cooler winters or real term reductions in fuel costs, as was case two years later in 2010 (Figure 2-2 and DECC, 2012a). Energy efficiency on the other hand effectively sequestrates a proportion of the demand and this leads to the third point. Demand reductions delivered by energy efficiency improvements are incremental, and providing that change is one directional, relatively small, annual energy efficiency improvements can deliver meaningful demand reductions.

In addition to using disproportionate quantities of fuel, additional analysis of the EHCS indicates that high income householders own a disproportionate amount of the 'hard-to-treat' and un-insulated 'easy-to-treat' stock. Therefore their engagement with The Green Deal, or subsequent energy efficiency polices, is a pre-requisite if the Transition Plan targets are to be achieved and this points lead to the third research task, a more in depth analysis of the barriers to retro-fitting in affluent households, which is discussed in the next two chapters. Additionally the research also highlights the power and importance of the market as a potential policy tool to directly and indirectly control fuel demand and this point is considered further in Chapters 13 and 14.

11TASK 3 METHODS –HOUSEHOLD SURVEY

11.1 Introduction

Tasks 1 and 2 indicated that during the Energy Efficiency Supplier Obligation period, Income Quintile 5 households, the 20% of households with the highest incomes, collectively voluntarily retro-fitted insulation in their homes in disproportionately low numbers and that energy efficiency improvements in the homes of this group did not meaningfully reduce their fuel demand.

One implication of these findings is that relatively affluent home owners, who collectively use most fuel and emit most carbon dioxide (Utley & Shorrock, 2008, Druckman & Jackson, 2008, Gough et al, 2011), were relatively disengaged from the retro-fit programme during the Energy Efficiency Commitment period and that this trend continued until at least 2010 (Appendix 15).

The aim of Task 3 was to study this phenomenon in greater detail as affluent householders are particularly important to the ambitions of The Transition Plan. The research method was based upon household surveys carried out in randomly selected homes in two affluent districts. The remainder of this chapter discusses how the districts were selected, how the household survey was developed and the analysis of the data. The study results are discussed in Chapter 12.

11.2 Selecting the Study Areas

Based upon the Census 2001, a short-list of potential Middle Order Super Output Areas (MSOA) was considered. The study areas needed to be: affluent with a high proportion of owner occupation; accessible and safe for the researcher; similar, but with contrasting levels of retro-fit assistance. Following a review of MSOA in northern England, two were selected, Macclesfield 006 in the Cheshire town of Wilmslow, and Kirklees 051, in and around the West Yorkshire town of Kirkburton, just south of Huddersfield. Background data for each MSOA is summarized in Table 11-1.

Table 11-1 *Background Information For Kirklees 051 and Macclesfield 006*

Item and Census Code		Macc 006	Kirk 051	England
Age Group (UV04)	under 25	26%	40%	31%
	25 to 34	11%	9%	14%
	35 to 44	15%	13%	15%
	45 to 54	15%	15%	13%
	55 to 64	12%	10%	11%
	65 +	22%	12%	16%
House Type (UV56)	Detached	46%	41%	23%
	Semi-detached	16%	29%	32%
	Terraced (inc end-terrace)	18%	27%	26%
	Flat, or apartment	19%	4%	19%
Social Grade (UV50)	AB: High/intermediate manager/professional	47%	33%	22%
	C1: Supervisory, junior manager, professional	33%	31%	30%
	C2: Skilled manual workers	4%	12%	15%
	D: Semi-skilled, unskilled manual	5%	12%	17%
	E: Benefits, unemployed, low grade workers	11%	13%	16%
Average household weekly income, 2007, modelled		£850 (95% CL £990, £710)	£650 (95% CL £750, £550)	£521 (95% CL £512, £530)

Source: Census 2001 for Kirklees 051 and Macclesfield 006. MSOA income data is from HM Government (2011b)

Both districts have disproportionately high percentages of householders in the A or B professional classes and above average proportions of detached homes. Each characteristic made both areas potentially suitable, but they were specifically targeted for other reasons.

Macclesfield 006 was chosen because the area is particularly affluent and the proportional reduction in gas demand during the Energy Efficiency Commitment was very low (DECC, 2011f). Average household income in Macclesfield 006 is at the 85th percentile (HM Government, 2011b) but the area is at the 4th percentile in terms of the proportional gas demand reduction between 2005 and 2008 9 (DECC, 2011f). The modest fall in gas demand was regarded as a potential indicator of low insulation retro-fitting rates.

Kirklees 051 by contrast was in the Kirklees Warm Zone, one of 11 in the UK (Section 3.6). Warm Zones were council managed programmes aimed at reducing fuel poverty and household fuel demand by retro-fitting basic insulation measures. Kirklees Borough Council operated a particularly pro-active Warm Zone, offering free loft and cavity wall insulation to all households in the borough in potentially suitable properties, whereas other participating councils tended to ask for a nominal charge from householders judged able-to-pay.

Therefore the retro-fit assistance afforded to all residents in Kirklees mirrors, to a large degree, the assistance offered to Priority Group households nationally, but in Kirklees, the measures were freely offered to all, irrespective of their income. In Macclesfield 006 on the other hand, although the council periodically made strictly limited cash back schemes available to residents who had retro-fitted insulation into their home, residents were largely left to retro-fit voluntarily.

Of all the Kirklees districts, Kirklees 051 was selected for the research because average incomes are amongst the highest in the borough, average house prices are the highest in the borough (Kirklees Borough Council, 2012) and the take-up of free insulation during the lifetime of the Warm Zone was higher in Kirkburton than most other council wards. During the initial property audit by the Council, the proportion of potentially suitable homes in the Kirkburton Ward, with cavity wall and/or loft insulation was 23%, the third lowest of the 23 wards in the borough. Subsequently Council contractors visited all homes in the ward on up to three occasions with the offer of free insulation. After the retro-fit programme, the proportion of potentially suitable homes with cavity wall and sufficient loft insulation in the district had risen by 65 percentage point to 88%, the third highest increase in Kirklees (Kirklees Borough Council, pers comm, Appendix 20).

11.3 Selecting The Research Method

The research methods considered included focus groups, structured interviews and postal surveys. External validity issues, particularly concerns over self-selection, lead to the rejection of focus groups or postal surveys in favour of a Simple Random Sample and structured interviews. This approach had the advantage of adopting the research methods employed by ONS, making comparisons with national statistics, such as the EHCS, more valid.

11.4 Developing the Questionnaire

Previous studies, for example Thornton (2009) and Energy Saving Trust (2011) (Chapter 5), identified interviewees who had not retro-fitted their homes with basic insulation and then asked them to identify what had prevented them from carrying out the work. This study on the other hand, has included home owners who had retro-fitted their homes to determine what barriers they overcame and what motivated them to do the work. The intention has been to provide a more holistic picture of the barriers to, and motivations for, retro-fit.

The questionnaires, reproduced in Appendix 21, were designed to identify motivating factors and retro-fit barriers. The survey was also used as an opportunity to test householder's opinions on The Green Deal and a potentially complimentary strategy developed by the Environmental Change Institute (Boardman et al, 2007) which would require progressively higher minimum energy efficiency standards for existing homes. The questionnaires for both districts were similar, but not identical. Both surveys were piloted twice and refined before the full surveys were carried out in April and May 2011.

11.5 Ethical Considerations

Following an ethical review and minor changes to the proposed questionnaire, ethical approval for the study was awarded by the Departmental Ethics Committee. Ethical measures included:

- Four week's pre-notification to the police and community officers of the survey;
- One week's pre-notification by post to all selected households informing them of the survey and telling them how to withhold consent;
- No names or addresses of interviewees were collected during the survey;
- All questions included 'do not know' and 'prefer not to answer' options;
- Signed consent was requested from all interviewees, who were also given details describing how to subsequently withdraw consent; and
- Surveying was carried out between 10am and 5pm.

11.6 Generating the Sample

In the 2001 Census there were 2926 households in Macclesfield 006 and 2358 in Kirklees 051. Statistical power increases with sample size and the intention was to make each sample as large as practicable. Five hundred randomly selected households in each district were notified of the survey. Homes were visited on a weekday and where there was no response, a second call was made over a weekend to reduce a non-response bias towards non-working householders. Only householders who own their property and therefore had the ability to decide whether to retro-fit, were interviewed. Full responses were obtained from 53 home owners in Macclesfield 006 and 65 in Kirklees 051.

11.7 **Non Response Bias**

During the pilot trial, householders in properties with remotely controlled access, such as flats with communal lobbies or homes with automatic gates, were found to be unwilling to participate or were not at home. To maximize the survey returns from a fixed number of pre-selected addresses, householders in flats and gated properties were subsequently excluded from the survey.

The effect of excluding the larger gated homes from the survey is difficult to gauge precisely, but is probably minimal – the number of gated homes in Kirklees 051 and Macclesfield 006 was estimated during the survey to be less than 1% and about 5% respectively.

However the impact of excluding all flat owners was probably more significant. As set out in Table 11-1, nearly one fifth of Macclesfield 006 households live in flats and excluding these householders is likely to have contributed to a bias against those under 35 years old. Only one interviewee less than 35 years old, effectively re-setting the sample frame to the 'over 35's only'.

11.8 **Data Weights**

The survey returns have been listed with Census data in Table 11-2 and contrasting the survey with the Census indicates that the views of householders under 55 years old, full-time or part-time workers and householders in semi-detached homes in Kirklees 051 and terraced houses in Macclesfield 006, were under-represented in the sample.

Variables common to the Census and the survey included the house type, the age of the Household Representative Person (HRP) and the HRP's economic activity. Non- response weights based upon HRP age and their economic activity were calculated according to the method described by Crockett (2011) and results of the calculations are listed in Appendix 22.

Table 11-2 *Comparison Of Survey And Census Data*

Variable	Census		Kirklees 051		Macclesfield 006	
	K/lees	Macc	Survey	Census	Survey	Census
House Type	Count households		% hholds (ex flats)		% hholds (ex flats)	
Detached	954	1359	59%	42%	72%	58%
Semi-detached	672	482	12%	30%	17%	20%
Terraced (including end-terrace)	631	517	29%	28%	9%	22%
Flat, maisonette or apartment	97	568	0%	n/a	2%	n/a
Total	2354	2926	100%	100%	100%	100%
HRP Economic Activity	Count people		% households where HRP is...			
Employee: part-time	665	668	8%	20%	4%	18%
Employee: full-time	2087	2130	46%	61%	49%	59%
Unemployed	82	82	2%	2%	2%	2%
Economically inactive: retired	576	737	45%	17%	45%	20%
Total p/t, f/t, unemployed and retired	3410	3617	100%	100%	100%	100%
Age Group	Count people		% households where HRP is...			
35-44	877	934	15%	26%	15%	23%
45-54	1010	937	19%	30%	13%	24%
55-64	646	758	31%	19%	25%	19%
>65	831	1352	34%	25%	47%	34%
Total 35->65	3364	3981		100%		100%

As discussed in the appendix, weighting by HRP age or economic activity produced broadly similar adjustments to a third variable, property type. The analysis indicates that weighting by either HRP age or HRP economic activity reduces, but does not remove the non-response bias. Nor is one weighting system clearly better than the other. However several of the relatively large economic activity weights were based upon small samples and so to minimize the effects of disproportionate influence being attached to the opinions of a small number of respondents, age was selected as the principle weighting variable. Additionally when analysing the data, the effects of the weighting system were monitored by analysing weighted and un-weighted responses.

11.9 Missing Data

For the most part, interviewees provided answers to all the survey questions. However:

- 26 (22%) of households did not know their approximate fuel bill; and,
- 11 householders in Macclesfield 006 and 10 householders in Kirklees 051, equivalent to 21% and 15% respectively, did not provide information on their income.

Analysis of missing income cases indicates that 16 (76%) were over 65 years old and 20 (95%) were over 55 years old. When data has been disaggregated by income, the non-responses were analysed separately and their opinions closely match those returns where the HRP was over 65 years old. Both groups were treated as sub-groups in their own right and no attempt was made to infer the missing information.

11.10 Internal Validity Of The Survey

Three threats to the internal validity of the survey are highlighted in this section and then consider further when the research findings are discussed in Chapter 12.

11.10.1 Factual Answers

When the ONS carried out the EFS they asked residents for detailed information on their income and expenditure and requested corroborating information, for example fuel bills and expenditure diaries. In this survey no corroborating information was requested, although some residents voluntarily checked their fuel bills. Therefore the factual elements of the survey frequently represent the interviewee's understanding of the facts rather than necessarily the facts themselves.

11.10.2 Intentions and Actions

The interviewees were asked for their opinions on several issues for example *"under these circumstances, how likely is it do you think that you would take out a Green Deal Loan?"* The purpose of the question was to gauge intent, but as indicated in Section 5.4, corroborating data is required before the results can be relied upon to describe the correlation between intent and action. The survey approach could however be used in an options appraisal, to assess for example, whether one proposal would be more likely to achieve a greater reduction in emissions than another.

11.10.3 Understanding the interviewee's perspective

The survey established why a householder had or had not carried out a task, but upon reflection did not establish the interviewee's perspective (see also Section 5.2). For example, when an interviewee explained that they had not retro-fitted because of the cost, the interviewee's understanding of the costs and cost benefits was not tested.

11.11 External Validity

Three of the survey questions were common to questions used by DEFRA (2008a) and Thornton (2009). The objective was to provide a measure of potential bias in the samples by contrasting the survey findings with literature data. This approach allows the results to be contrasted to national statistics, however the limited sample size and the geographical restrictions placed upon the survey design suggests that corroborating evidence is required before the data from this survey could reasonably be extended across wider areas or groups. Nevertheless the survey does provide a point of comparison for other studies, including Tasks 1 and 2 of this thesis. The survey results are discussed in the following chapter.

12TASK 3 FINDINGS – HOUSEHOLD SURVEY

12.1 Context and Summary

Tasks 1 and 2 indicated that home-owners with upper quartile incomes insulated their homes in disproportionately low numbers during the Energy Efficiency Commitment Supplier Obligation period. In this chapter the survey results from Macclesfield 006 and Kirklees 051 are discussed and the analysis suggests that apathy has been a particularly significant retro-fit barrier in affluent districts. The results indicate that as the emission reduction agenda re-focusses towards retro-fitting hard-to-treat homes (Section 1.3), a combination of complimentary policies, probably including measures which increase the value of energy efficiency, are likely to be required to drive voluntary retro-fitting in affluent households.

12.2 Addressing Bias

Both samples had an age bias, which was alleviated by applying weights to the data (Appendix 22). The weighting sensitivity analysis indicated that in all but two instances the occurrence of any variable was changed by less than a few percentage points by weighting. The study conclusions remain unchanged whether weighted and unweighted data was tested (Appendix 23).

12.3 Testing the Sample Validity

Although the survey was based upon a random sample, interviewees chose whether to participate, exposing the survey to a degree of self-selection, which in turn could have created a pro-energy efficiency or pro-environmental bias in the sample. Two lines of evidence were considered to test for such a bias: interviewee's answers to three questions which had previously been included in a national survey of environmental attitudes

(DEFRA, 2008a) and the proportion of surveyed homes with insulation. The results of the validity assessment are discussed in Appendix 24.

The validity review indicates that the survey respondents from both districts held stronger pro-environmental attitudes than the national average. This bias affects the external validity of the results, but may nevertheless be an accurate reflection of households in either district. However, above average levels of retro-fit insulation in contrast to relatively low levels of discretionary spending on other home improvements, such as new kitchens or bathrooms, suggests that the samples had a 'pro-environmental' or 'pro-energy efficiency' bias, which has been borne in mind when drawing conclusions from the study.

12.4 Over-Coming Retro-fit Barriers

Owners of homes with insulated or un-insulated cavity walls in Macclesfield 006, where retro-fitting for the majority of householders was voluntary, were asked what barriers they overcame to fill their cavity walls, or what barriers had prevented them from retro-fitting cavity wall insulation. The results, listed in Table 12-1 and Table 12-2, are not statistically significant because the sample was too small, but nevertheless the results suggest a relationship between the barriers reported and whether the interviewee had carried out the work, which could inform future studies.

Table 12-1 *Barriers to cavity wall insulation, Macclesfield 006*

Item		Barrier to retro-fit?		Total
		No barrier	A barrier identified	
Cavity insulated by owner	Count	13	9	22
	% of total	64% (95%CL 43%, 83%)	36% (95%CL 20%, 48%)	100%
H'hold in home with un-insulated cavity	Count	0	10	10
	% of total	0%	100%	100%

Cross tabulation is not statistically significant. One cell (25%) has an expected chi square count of less than 5.
Weighted by age

Approximately one third of home owners reported overcoming at least one barrier, including time constraints or insufficient knowledge. However two thirds felt that they had not encountered any barriers. In other words once they had decided to do the work thereby overcoming any motivational barriers, which they may or may not have been recognized, the majority of householders who had fitted cavity wall insulation did not report any barrier. Conversely where home owners had not filled their cavity walls, all interviewees in Macclesfield 006 reported a barrier and in only one case, concerning a householder's time constraints, did the barrier appear to be motivational.

Table 12-2 *Primary barriers to cavity wall insulation, Macclesfield 006*

Barrier To Cavity Wall Retro-fitting	Cavity insulated by existing owner		H'hold in home with un-insulated cavity	
	Count	% of total	Count	% of total
No barriers	13	64%	0	0%
Barriers identified (listed below)	9	36%	10	100%
Poor value	(1)		(3)	
Access issues	(1)		(2)	
Time constraints	(1)		(0)	
Knowledge	(2)		(0)	
Aesthetic issues	(1)		(1)	
Building construction	(1)		(0)	
Technical concerns	(1)		(2)	
Age and payback concerns	(1)		(0)	
Age, waiting for subsidy	(0)		(2)	

Weighted by age

A finding that residents who had not filled their cavities were more likely to identify technical or financial reason why they had not carried out the work may reasonably have been expected. As more cavities are filled, the proportion of householders with, say, technical concerns about moisture transfer, will tend to increase in the group of householders with un-insulated cavity walls.

However the contrast in responses in the Macclesfield 006 survey between those who had voluntarily fitted cavity wall insulation, where two thirds of the sample did not report a retro-fit barrier, to those householders who had not retrofitted where all householders reported a barrier, suggests that motivational issues may be more significant than indicated by the survey responses summarised in Table 12-2.

This observation, that householders who have not retro-fitted are less likely to report that their motivation is a barrier, is supported by the analysis of the data from Kirklees 051, where residents who had accepted the offer of freely fitted insulation were asked why they had not done the work sooner. Their answers are summarized in Table 12-3.

Table 12-3 *Primary reasons why residents had not retro-fitted before the free insulation offer*

<table>
<tr><td></td><td colspan="2">Loft insulation fitted FOC by Kirklees Warm Zone</td><td colspan="2">Cavity wall insulation fitted FOC by Kirklees Warm Zone</td></tr>
<tr><td></td><td>Count</td><td>% of total</td><td>Count</td><td>% of total</td></tr>
<tr><td colspan="5">Non-motivational issues</td></tr>
<tr><td>Up front cost</td><td>0</td><td rowspan="2">0%</td><td>5</td><td>50%</td></tr>
<tr><td>Technical concerns</td><td>0</td><td>2</td><td>20%</td></tr>
<tr><td colspan="5">Motivational issues</td></tr>
<tr><td>Hadn't thought about it</td><td>13</td><td rowspan="3">100%</td><td>2</td><td rowspan="3">30%</td></tr>
<tr><td>Too much hassle</td><td>2</td><td>0</td></tr>
<tr><td>Not got around to it</td><td>5</td><td>1</td></tr>
<tr><td>Total</td><td>20</td><td>100%</td><td>10</td><td>100%</td></tr>
</table>

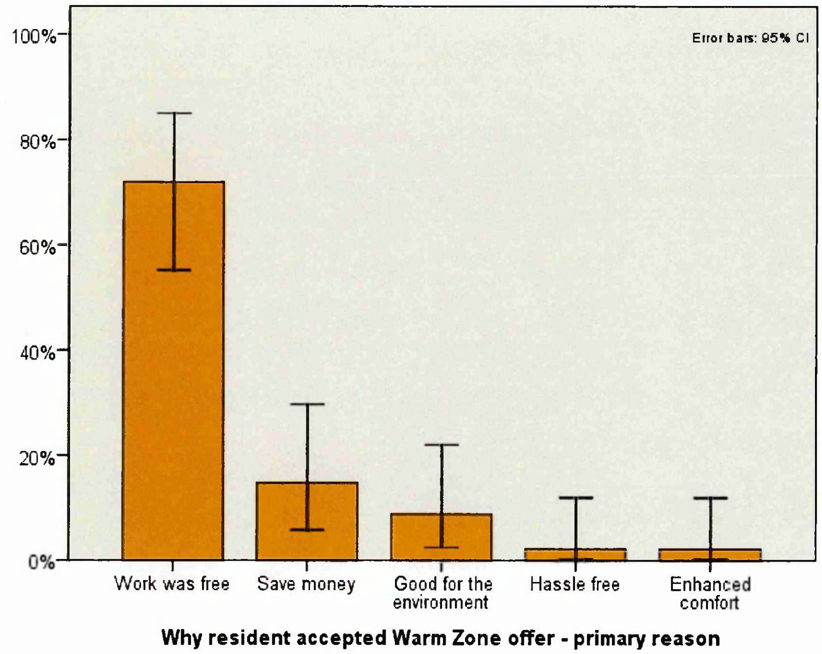
Weighted by age

Once again the sample is relatively small and any relationships inferred are indicative rather than statistically significant, but in the sample of ten home owners in Kirklees 051 who had accepted the offer of free cavity wall insulation, motivation appeared to have been the principal barrier for about a third who advised that prior to the Warm Zone offer, *'they had not got around to it'*, or *'they hadn't thought about it'*. This rose to 100% when householders were asked why they had delayed topping up their loft insulation until the work was done for them. Therefore once the work had been carried out, respondents appeared more willing to indicate that motivation had been their principal retro-fit barrier. In which case, some of the literature into retrofit barriers, for example Thornton (2009) is likely to under-estimate the importance of the motivational barrier, because their studies were based upon households who had not yet retro-fitted their homes with insulation. The finding also implies that retro-fit strategies which are based upon awareness raising and market forces, but which do not also take steps to also make energy efficiency more valuable, are likely to be limited by householder apathy to energy efficiency, particularly in the most affluent homes.

12.5 Factors Which Motivated Residents To Retro-fit

Households who had retro-fitted either cavity wall or loft insulation were asked to identify the primary and secondary factors which had motivated them to carry out the work. Because of the different retro-fitting environment in each town, the results for Macclesfield 006 and Kirklees 051 are illustrated separately in Figure 12-1 and Figure 12-2.

Figure 12-1 *Why Kirklees 051 residents accepted free insulation (N= 33, weighted by age)*



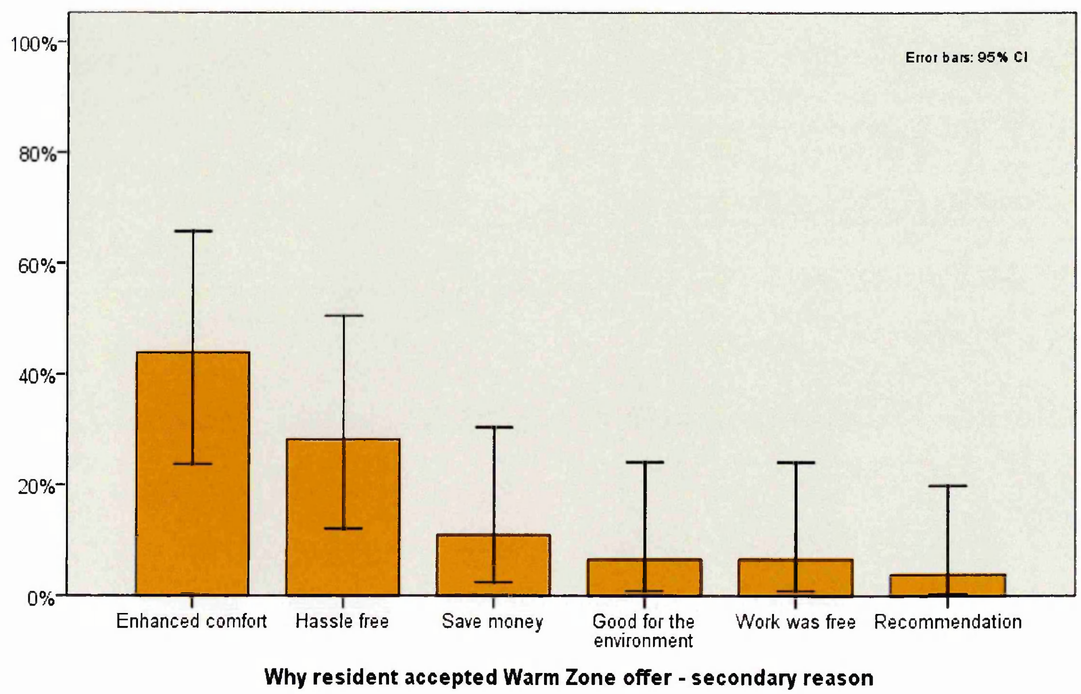
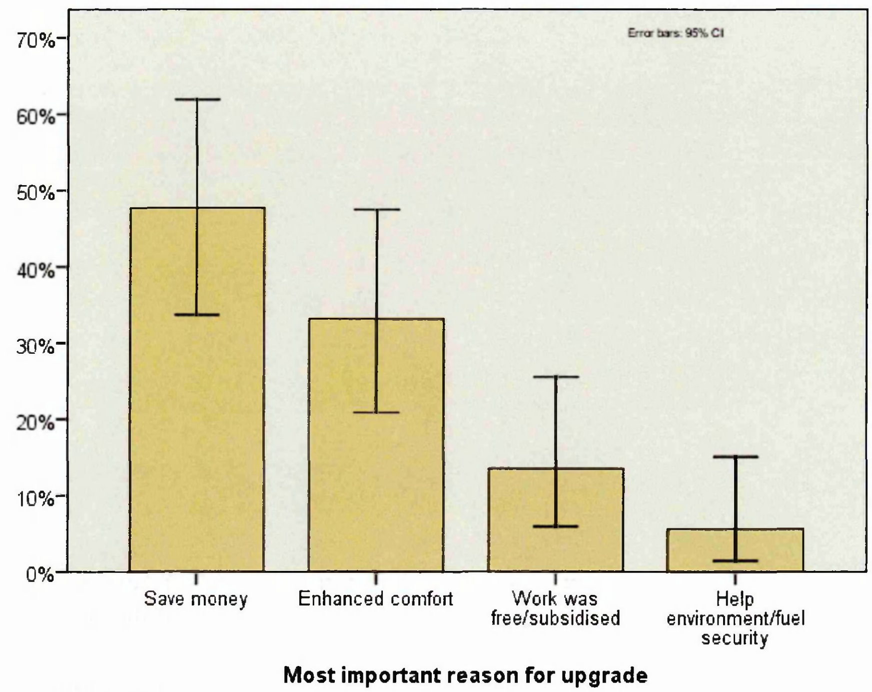
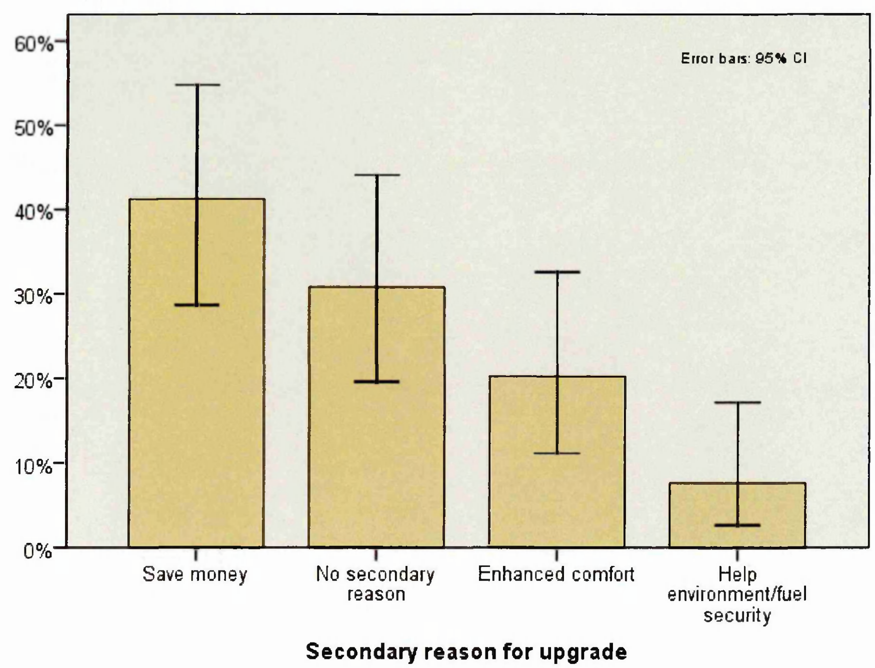


Figure 12-2 *Why Macclesfield 006 residents had upgraded their insulation (N=46, weighted by age)*





Kirklees 051 residents reported that their primary motivating factor for accepting the retro-fit work was financial, but linked to the more tangible up-front cost savings, rather than the less tangible and longer term benefits which could accrue from lower fuel bills. The importance of the up-front cost, or in this case, the absence of a charge, is illustrated by data supplied by Kirklees Borough Council (Appendix 20) and a second Warm Zone which supplied data for this study, North Staffordshire (Appendix 20). North Staffordshire Warm Zone asked those judged able to pay to contribute £99 per measure and they found that the take-up rate of insulation measures was approximately one third of that achieved in Kirklees.

Kirklees 051 residents reported that enhanced comfort and hassle free installation were also important motivating factors. Less than one in five reported that they accepted the free insulation to save money, although some may have felt that they had indicated their financial motivation by highlighting the importance of the free offer. Only approximately one in ten advised that they were primarily motivated by the prospect of helping the environment.

In Macclesfield 006, where the majority of residents had to organize and finance their own retro-fit schemes, the prospect of saving money on fuel bills was the most common driver, followed by a desire for a cosier home. In common with residents in Kirklees 051, approximately one in ten households in Macclesfield 006 reported that they were primarily motivated by their environmental concerns.

The work of the Warm Zone in Kirklees (Appendix 20) suggests that if the up-front cost and hassle is removed, a well-coordinated, well-publicized retro-fit offer is likely to encourage the majority of householders in affluent districts to take-up additional basic insulation to make their homes more comfortable. However Kirklees Borough Council data indicates that approximately 20% of Kirklees 051 householders rejected, or failed to take-up, the offer, which suggests that more robust policies are likely to be required at some point to achieve the energy efficiency targets for the housing stock discussed in Section 1.3.

12.6 **Attitudes Towards The Green Deal**

The Green Deal concept was explained to home owners and their opinions recorded. One third of householders (34%, 95%CL 43%, 27%) reported an interest in a Green Deal loan. However, only 5% (95%CL 2%, 9%), reported that they were *'very interested'*. The cross tabulated survey results disaggregated by age, income and estimated fuel consumption are summarized in Table 12-4 to Table 12-6.

Table 12-4 *Green Deal interest and income (weighted by age)*

Interest in Green Deal	Income Quintile						Total	
	Missing		Q1 to Q3		Q4 and Q5			
'Very interested', 'Interested', or *'Interested, depending upon details'*	1	6%	11	28%	28	46%	40	34%
'Not too interested'	4	22%	5	13%	13	21%	22	19%
'Not interested at all'	13	72%	23	59%	20	33%	56	47%
Total	18	100%	39	100%	61	100%	118	100%

Note. Statistically significant, p= .04, excluding those who don't know: chi square = 6.6, V=0.26.

Table 12-5 *Green Deal interest and energy expenditure (weighted by age)*

Interest in Green Deal	Income Quintile						Total	
	Missing		Q1 to Q3		Q4 and Q5			
'Very interested', 'Interested', or *'Interested, depending upon details'*	8	30%	23	41%	9	26%	40	34%
'Not too interested'	4	15%	10	18%	7	21%	21	18%
'Not interested at all'	15	56%	23	41%	18	53%	56	48%
Total	27	100%	56	100%	34	100%	117	100%

Note. Not statistically significant, p= .58, excluding those who don't know: chi square = 2.9, V = 0.16.

Table 12-6 *Green Deal interest and age (weighted by age)*

Interest in Green Deal	Age of household reference person								Total	
	35 - 44		45 - 54		55 - 64		65 +			
'Very interested', 'Interested', or 'Interested, depending upon details'	12	46%	18	56%	6	26%	4	11%	40	34%
'Not too interested'	8	31%	2	6%	6	26%	6	16%	22	19%
'Not interested at all'	6	23%	12	38%	11	48%	27	73%	56	47%
Total	26	1	32	1	23	1	37	1	118	1

Note. Statistically significant $p< .000$, chi square = 26.6, V = 0.34.

The analysis suggests that, collectively, higher income households, that is Income Quintile 4 and 5 households, may potentially be more interested in the Green Deal. This could be a meaningful finding, because as mentioned previously, these households tend to use disproportionately large amounts of fuel (Figure 2-10) and Income Quintile 5 households have been relatively disengaged from the retro-fitting programme (Chapter 8).

However DEFRA (2008a) reported that household groups willing to take 'environmental friendly' actions, including insulation retro-fitting, tended to have disproportionately high incomes, be educated to higher standard and come from ABC socio-economic groups. Therefore, an indication that higher income homes may be more interested in The Green Deal, may well be insufficient to redress the income related retro-fit imbalance discussed in Chapter 8, because there is evidence of earlier mis-matches between attitudes and actions in this group.

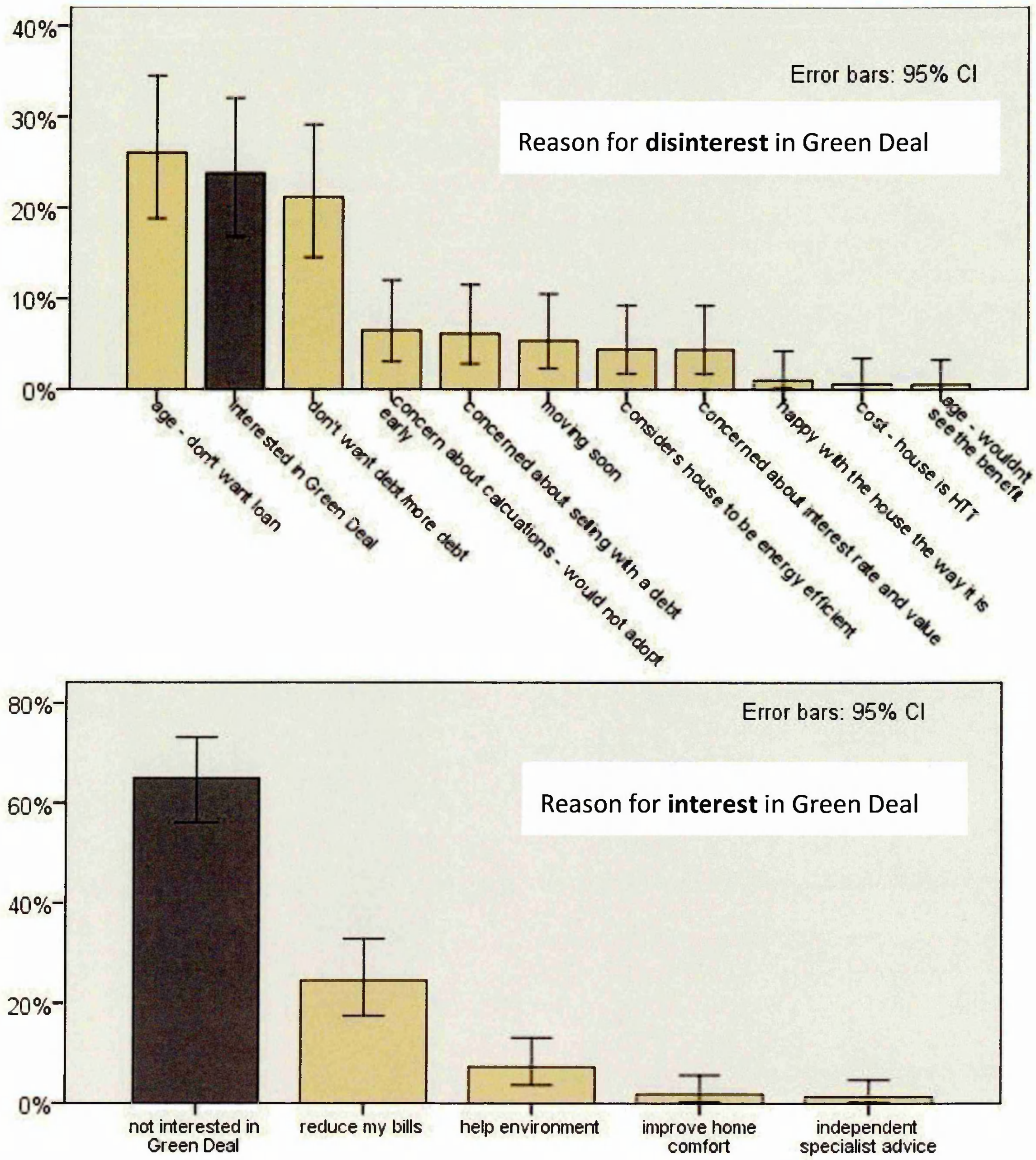
Also, as indicated in Table 12-5, the relationship between fuel demand and Green Deal interest is not statistically significant, which coupled with the evident pro-environmental attitude bias, particularly in the sample of 45-54 year olds (Appendix 24), suggests that any correlation should be viewed cautiously, until corroborated.

The correlation between a householders age and interest in the Green Deal fell was statistically significant (Table 12-6). Those over 55 years old tended to be much less likely to express an interest in The Green Deal and, as illustrated in Figure 12-3, this is primarily because older householders advised that do not want a debt or additional debt. The survey suggests that 35 to 54 year olds are more likely than most to express an interest in the concept of a Green Deal loan and notably the study of the EHCS suggested that this demographic group tends to work full time and to have been left behind by current retro-fit initiatives (Chapter 8). However this finding should also be treated with caution at this stage, because of the pro-environmental bias mentioned previously.

The Green Building Council (GBC, 2010) based upon an on-line YouGov survey of just over 2300 adults, also reported that those over 55 years old tended to be less attracted to the Green Deal. GBC reported that 44% (weighted) of those over 55 years old found the Green Deal proposition *'attractive'*, in comparison to 65% of interviewees between 18 and 44 years old and 55% for the population as a whole. GBC suggested that the age related differential was because many more in the older age group had already taken action to improve the energy efficiency of their home, although it is not clear from the reference that this conclusion was the result of a question, or was inferred from the data. Figure 12-3 suggests that a desire to avoid additional debt could be alternative, or contributory, explanation.

In Macclesfield 006 and Kirklees 051, approximately one third (95%CL, 45%, 23%) of households expressed an 'interest' in a Green Deal loan, or at least willingness to consider the option further. As indicated, GBC (2010) reported that over half of interviewees found the Green Deal 'attractive'. The question on the attractiveness of The Green Deal in this study was purposefully closely copied from the GBC survey to enable the answers in both surveys to be compared. This survey was focussed upon affluent households, the YouGov survey for GBC was national and intended to be nationally representative. Therefore the difference in the proportion of households interested by the Green Deal reported by each survey, could be a reflection on the different attitudes held by disproportionately affluent householders in comparison to the general population. In which case, this comparison suggests that the Green Deal is less attractive to older householders and contrary to the relationship suggested in Table 12-4, as household affluence increases.

Figure 12-3 *Primary reason for interest or disinterest in a Green Deal loan (weighted by age)*



Overall this survey and the earlier GBC survey, suggest that there is the potential to market the Green Deal to the under 55's, but that interest in the Green Deal is 'soft' and that action is required to firstly encourage early adopters and then to build momentum and trust. As indicated in Figure 12-3, for the majority of householders in Macclesfield 006 and Kirklees 051 who expressed an interest in a Green Deal loan, the primary driver is to reduce their bills. However once loan repayments and any fuel prices are factored in, it may be difficult for householders who have taken out a loan to identify any savings. In which case, careful and informative billing may be important. Additionally a mechanism which delivers a clearly identifiable short term or one-off benefit, could also help to develop a positive impression of the Green Deal concept.

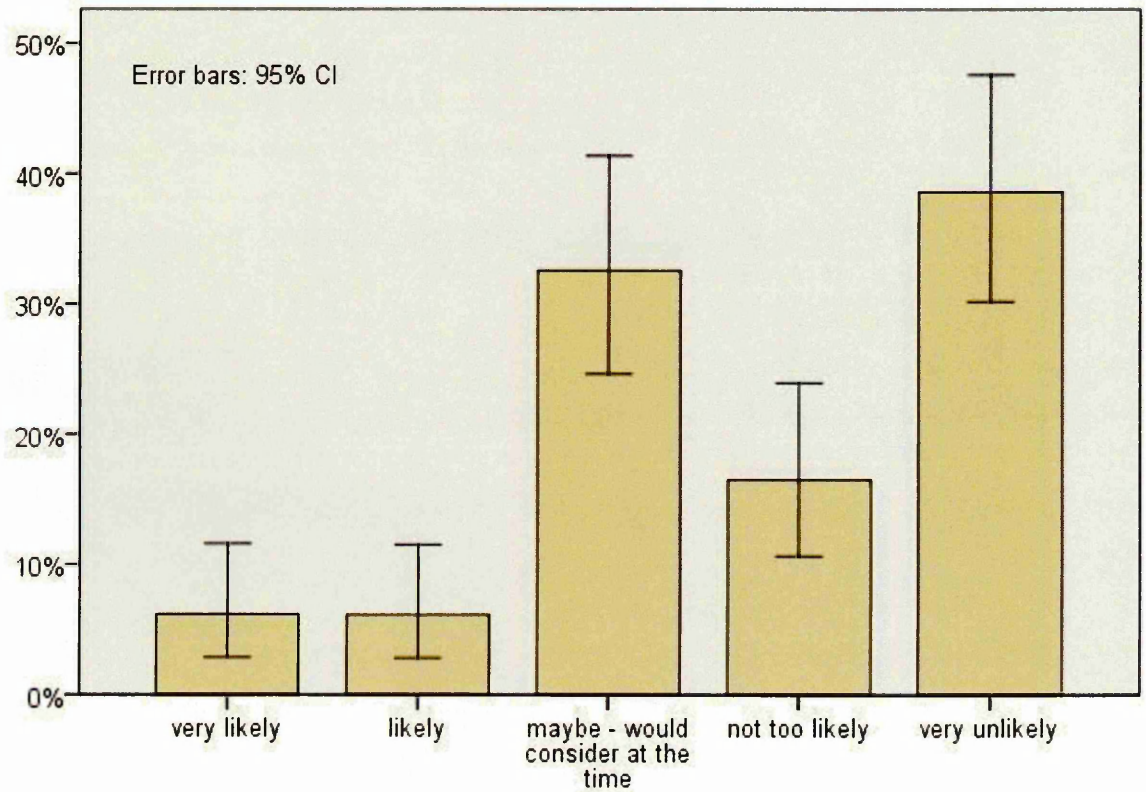
12.7 **Attitudes Towards A Minimum Standards Strategy**

In 2007 Boardman et al published *"Hometruths: a Low Carbon Strategy To Reduce UK Housing Emissions By 80% By 2050"*. Various emission reduction proposals were developed, but in the view of Boardman et al *"the most important measure, in the whole Low-carbon Strategy, is the introduction of minimum standards* [of energy efficiency for existing homes]*"*. Boardman suggested progressively raising minimum standards, described by Energy Performance Certificate (EPC) classifications, so that in stages, it becomes no longer possible to sell or let properties in the lowest energy efficiency rating bands.

Boardman suggested that once a milestone has been passed, a property which does not meet prescribed minimum standards could only be sold once, until it had been upgraded. Their argument was that in addition to forcing the buyer or seller to carry out the work, the buyer will also expect to pay less, potentially creating a source of capital to fund the work. And, although not stated explicitly in the report, such a strategy would also take advantage of the change of ownership, a key retro-fit trigger point (Energy Saving Trust, 2011).

In this survey residents were asked *"if new regulations meant that anybody buying your home after 2015 could not resell it until specific insulation measures had been fitted, how likely is it that you would get the work done before putting the property on the market?"* Their answers are illustrated in Figure 12-4.

Figure 12-4 *Is it likely that you would retro-fit before selling if minimum standards were compulsory for the purchaser? (weighted by age)*



The mean residence time per property is 16 years (DCLG, 2010c). Consequently it would take until nearly 2050, the date when all properties are to be effectively zero carbon (Section 1.3) for such a policy to be reasonably certain of raising the energy efficiency of some 50% of the most energy inefficient homes in the housing stock, to standards below the 2050 target. Therefore on the face of it, such a proposal does not appear likely to have a meaningful impact upon the 2020 emission reduction targets.

However approximately 50% of householders reported that they would consider getting the work done before putting the property on the market. Cross tabulations indicate that a householder's answer was independent of either, their age, their income or their household fuel demand. The reasons why certain householders would contemplate taking pre-sale energy efficiency enhancements were not systematically explored, but could inform further research questions. For example '*is an owner's reluctance to sell a property which does not meet minimum standards linked to their pride in their home and if so could this be exploited by policy makers attempting to reduce national household fuel demand*'?

12.8 **Summary and Implications of Task 3 Findings**

Behind the research questions articulated in Chapter 6 is the idea that non-financial barriers are particularly important for affluent householders because the financial returns delivered by retro-fitting are proportionally less for this group. However in the literature, the cost of retrofitting was the most commonly quoted barrier to retro-fit, even in affluent households. This research suggests that householders frequently under-play the motivational barrier, which becomes much more widely acknowledged once householders have fitted insulation into their homes. Hence apathy appears potentially to be a more significant issue than inferred from the literature which is based upon surveys of householders who have not yet retro-fitted additional insulation in their homes.

Pay-As-You-Save schemes, such as The Green Deal scheme, could encourage retro-fit, but the evidence from this survey is that the take-up of loans is likely to be limited and most householders, particularly older home owners, appear reluctant to take on a debt or be an early adopter.

Kirklees Borough Council data indicates that coordinated, free, retro-fit programmes can increase the proportion of homes with insulation and accelerate a retro-fit programme. However even when retro-fit is offered free of charge, with third party installation managed by the local authority, some 20% of households living in potentially suitable homes, failed to take-up the offer. In which case, simply giving retro-fit away will not deliver the targets discussed in Section 1.3, even if this were a financial viable option in view of the scale of the challenge.

It appears that energy efficiency is not valued particularly highly. Potential policy options to address this issue are discussed in Chapter 13, but in this survey interviewees were questioned about only one, the introduction of minimum energy efficiency standards for housing, enforced at the point of sale, once removed. The survey answers were illuminating in so much as they indicated that many affluent householders may act to pre-empt their home being classified as 'failing' to meet a Minimum Standard and that a householder's pride in their home, or their desire to keep as much control as possible during sale negotiations, could be employed as policy tools to drive retro-fit.

Overall the Task 3 survey has reinforced the Task 1 conclusions. Affluent householders are generally willing to accept freely installed insulation, but for many, the value of energy efficiency is insufficient motivation in itself to trigger an action.

13IMPLICATIONS OF THE RESEARCH FINDINGS

13.1 Introduction

This chapter considers the implications of the principal research findings. Initially the five research questions set out in Chapter 6 are reconsidered and then other conclusions which may be drawn from the data, summarized. The second half of the chapter broadens the debate and includes discussions on the implications of the research findings for existing and alternative energy efficiency strategies.

13.2 Research Questions Reconsidered

The central thesis of this research has been that energy efficiency policies and household socio-economics have together acted as a *de facto* barrier to retro-fit in the most affluent homes. Five research questions were developed and the principal conclusions from the research into each question are summarized below.

1) *What are the principal demographic characteristics of the homes and households in the Priority and Non-Priority Groups?*

In general terms, Priority Group households are more likely to live in more modern, more energy efficient homes. Collectively, Non-Priority households tend to live in larger homes. The Non Priority Group also tend to earn more and use more fuel. Consequently residential energy efficiency strategies have taken account of social objectives and social policies by focusing upon the Priority Group, but did not account for the distribution of energy demand in society. Consequently those who collectively use most fuel are the least likely to have received prioritized assistance and the least likely to have responded to price signals by reducing the level of energy services purchased or by making their homes more energy efficient.

2) *Has the level of retro-fitting by Priority Group and Non-Priority householders differed? And if so, how are these differences expressed in the retro-fitting statistics?*

During the Energy Efficiency Commitment period, a Priority Group householder was approximately twice as likely as a Non-Priority home owner to have retro-fitted cavity wall insulation and over 40% of loft insulation retro-fits were carried out in Priority Group households, when they occupied approximately one third of the housing stock. In groups ineligible for assistance, voluntary retro-fitting has not kept pace with the measures fitted under the prioritization programmes. The failure of Non Priority households to retro-fit in high numbers is potentially significant because they include over two thirds of English households and they use disproportionately large quantities of fuel.

3) *Non-Priority households have largely been responsible for organizing and financing the retro-fit of basic insulation measures into their homes. Within this group of voluntary retro-fitters, has retro-fitting been differentiated by the characteristics of the homes and the householders?*

The 60% of households living on 'middle incomes', albeit a broad definition of middle incomes encompassing Income Quintiles 2, 3 and 4, were more willing to voluntarily insulate their homes, than high income or low income householders. Age was also a meaningful differentiating factor. During the Energy Efficiency Commitment period, those over 65 years old have been the age group most willing to retro-fit without state assistance. Voluntary retro-fitting was carried out least by householders between 45 and 65 years old and those living in homes over $90m^2$.

4) *If retro-fitting has been socially differentiated, what impact, if any, has the differentiation had upon changes in residential fuel demand?*

The rate of total insulation retro-fitting per income quintile, i.e. the sum of assisted and voluntary retro-fits, was broadly comparable in the 80% households who earned Quintile 1 to 4 incomes, but declined sharply in the highest earning quintile. These variations are reflected in the energy expenditure data which suggests that 15% to 20% of fuel demand changes in households with Quintile 1 to 4 incomes were due to more efficient use of energy (Table 10-7). However in the 20% of households earning the most, any effects from using energy more efficiently were undetectable in the expenditure statistics.

5) *Why have affluent householders been more disengaged from the retro-fit programme?*

When the motivational barriers to retro-fit were removed, for example where high income households qualified for Priority Group assistance, affluent householders appeared to be just as willing as on low incomes to accept freely installed measures. Indeed there is some evidence to indicate that they were more willing to accept free retro-fit assistance when it was available to them. However affluent householders were reluctant to voluntarily carry out the work, indicating that many did not value the potential benefits sufficiently to overcome their motivational barriers to retro-fit, preferring instead to simply pay more for their energy services.

13.3 **Other Conclusions**

13.3.1 The Green Deal

The Green Deal should make advice and support available to affluent householders who were previously unlikely to have been prioritized for retro-fit assistance. Additionally with the introduction of ECO (Section 3.8), financial assistance to retro-fit is available, irrespective of income, to home owners who previously were unlikely to recoup their energy efficiency investment, because they live in hard-to-treat properties. However this research suggests that the voluntary basis of The Green Deal is a potential weakness because it does not counter the relatively low value of energy efficiency in affluent households.

13.3.2 Income, Fuel Expenditure and Price Controls

Rising fuel prices reduce fuel demand (Summerfield et al, 2010), but fuel price inflation can also stimulate the market for energy efficient goods and services (Bernstein and Griffin, 2005). Therefore price controls could be used to drive energy efficiency programmes. Fiscal policies are also necessary to control indirect rebound (Section 2.9). However such measures have a number of drawbacks: they are potentially inflationary; they interfere with the energy market; and, they can be extremely unpopular with voters faced with higher fuel bills. Of particular concern are potential equity issues for householders least able to purchase adequate energy services.

A system of 'rising block tariffs' offers a potential, but partial, solution to the equity issue and also provides a mechanism to reduce demand in high income households which consume the most fuel, whilst rewarding moderate consumption. As such rising block tariffs are consistent with the long held regulatory principal, that the 'polluter pays' (Section 1.1).

Under rising block tariffs, the national level of fuel expenditure would be maintained as far as practicable, but fuel would cost less below a defined level of consumption and the discount would be paid for by charging a supplement on fuel purchases once this level of consumption had been exceeded. Gradually as homes became more energy efficient, the tariffs could be adjusted to reward greater efficiency and maintain the viability of the energy network and the supplier's margins.

OfGEM (2009) reviewed the viability of rising block tariffs to promote energy efficiency and concluded that *"there could be serious welfare effects for a significant minority of consumers with a low income / high consumption profile"*. However OfGEM (2009) relied upon research (Roberts et al, 2007) based upon the EFS and as discussed in Appendix 5, the EFS based energy expenditure statistics appear to over-estimate the range of fuel expenditure in different income groups because researchers did not account for seasonal variations in energy expenditure or bulk buying of fuel oil.

Analysis of the expenditure and income statistics in the EFS also suggests that the income data for households ostensibly categorized in Income Decile 1 is less reliable than for other income groups (Figure 6-2), which is a meaningful point, because low income, high fuel demand households are most at risk from any mechanism which adjusts fuel price according to demand.

The Committee on Climate Change appeared to welcome further consideration of fuel price controls to promote energy efficiency. In March 2009, Lord Turner, Chairman of the Committee on Climate Change advised the House of Commons Energy and Climate Change Committee that adjusted fuel tariffs send *"a price stimulus to higher income, higher energy using households to do something about their energy efficiency while fully protecting the lower income households"*.

The Committee on Climate Change commissioned Hulme and Summers (2009) to consider the impact of rising block tariffs and they opted to carry out the assessment using standardised fuel expenditure data from the EHCS. In this way they avoided the Case specific expenditure issues in the EFS (Appendix 5). However as Hulme and Summers themselves point out, it is difficult to understand the actual cost implications for suppliers or consumers from standardised data, because standardised expenditure does not represent actual consumption (Figure 10-5).

This research suggests that relationships between income, fuel price and household fuel demand are not yet sufficiently well understood to permit policy makers to reliably assess the potential impacts of, or benefits from, fiscal mechanisms such as rising block tariffs.

13.3.3 The Application of Minimum Standards

This thesis tested attitudes to proposals developed by Boardman et al (2007a, 2012), that minimum energy efficiency standards for housing become enforceable when a property changes hands for the second time, and the research suggests that a minority of householders may pre-empt such regulations and retro-fit their properties before they sold for the first time.

Additionally approximately 1% of householders per year are granted planning permission for major improvement works (DCLG, 2011) and analysis of the EHCS suggests that major home improvement projects, such as fitting new kitchens or bathrooms, are carried out every 15 to 20 years. The prospect of minimum standards is likely to encourage householders to use these opportunities to improve the energy efficiency of their home, potentially boosting the take up of Green Deal loans.

However it is far from clear what proportion of home owners who would act in advance of the introduction of minimum standards and how quickly the market would respond to such an approach. This uncertainty is the basis for the second research proposal discussed in the next chapter.

14STUDY REVIEW & RECOMMENDATIONS

14.1 Introduction

This review considers firstly whether the research hypothesis has been proven. The research methods are reviewed in Section 14.3, and recommendations for further research are summarized in Section 14.6.

14.2 Review of the Research Outcomes

The research findings support the hypothesis that affluent householders have been more reluctant than lower income householders to retro-fit basic insulation into their homes. The study also provides an explanation why this has been the case. However the question that arises is whether support for the hypothesis constitutes a proof.

Statistical proof typically requires a demonstration that a relationship could have arisen by chance less than 5% of the time. In normally distributed data this may be calculated from the standard error on the mean. However the analyses of the links between income and retro-fitting discussed in Chapter 8 were not based upon the number of homes which were retro-fitted in any one year. Rather the annual changes in the numbers of homes with un-insulated cavity walls, or less than 125mm of loft insulation, were used as proxy measures for the number of retro-fits. Additionally the data was derived from a serial, cross sectional, cluster sample rather than a true longitudinal study. These factors contributed to the variability evident in the annual retro-fitting estimates and the use of best-fit trend lines to describe average retro-fitting rates over the Energy Efficiency Commitment period (Appendix 14).

Therefore statistically it appears inappropriate to consider the hypothesis proven. However it is reasonable to conclude that all lines of evidence considered indicate that retro-fitting rates were meaningfully different between the Priority Group and Non-Priority households. Consistent differences within each group were also evident, as factors such as income and age influenced the value, desirability and practicality of retro-fitted insulation.

14.3 Contribution

Studies in the literature established that factors such as income (Druckman and Jackson, 2008, Gough et al, 2011), tenure (Utley and Shorrock, 2008) or household composition (Boardman, 2010, Palmer and Cooper, 2011) are linked to fuel demand, although the correlation between income and fuel demand is contested (Section 2.7 and Appendix 5). Other lines of research in the literature have calculated notional demand reductions attributable to greater residential energy efficiency (Utley and Shorrock, 2008, Palmer and Cooper, 2011) or estimated the impact of variations in fuel prices and ambient temperatures on fuel demand (Summerfield et al, 2010).

This study has added to the literature, or in some cases challenged the existing position. The research has uncovered several lines of evidence which suggest that household income is linked to not only the fuel demand, but how household fuel demand has changed and provided possible explanations for this. This research has also found evidence to support DECC (2011d), who reported that greater energy efficiency had reduced household demand and whose results initially appeared to contradict the regression analysis by Summerfield et al, 2010 who reported that 99% of household demand changes can be explained by changes in the fuel price and external temperature.

But this research also supports Summerfield et al, who acknowledged the potential for fuel price rises to act as a proxy for greater energy efficiency and concludes that approximately 85% of the demand reductions between 2002 and 2008 cannot be explained by greater energy efficiency. Rather it appears that the majority of the demand changes were caused by variations to other demand drivers, including variations the fuel price and average winter temperatures.

This research has also indicated that the UK studies into the correlation between income and household fuel demand are unreliable when considering demand and expenditure at the household level (Appendix 5). The correlation between both variables appears likely to be stronger than indicated in the literature and this study suggests that further research is required in this area.

14.4 Review of the Methods

The external validity of the study was enhanced by using large secondary databases which also allowed the study findings to be readily contrasted to the literature. However the secondary analyses were dependent upon the reliability of the ONS weighting systems.

Task 2 involved the development of a research method and although the findings from several lines of research appear to align closely, a critical review of the method, together with further studies of the linkages between energy efficiency and fuel demand could usefully support, or repudiate, the research findings.

The re-use of questions employed by earlier researchers in the two primary household surveys was useful to calibrate the samples in Task 3. However the large confidence intervals attached to the results highlighted a particular issue of using a Simple Random Sample in a resource constrained project.

14.5 Dissemination and Personal Development

The research results have been presented at several conferences and a paper is being prepared for submission to a peer reviewed journal. Details of the publications and the accredited training received during this thesis are presented in Appendix 25.

14.6 Further Research

The majority of recent papers on the drivers for, and barriers to, residential energy efficiency appear to have focused upon measures which will 'nudge' householders into making changes to the way that they consume energy. However, when viewed in terms of the progress achieved to date; and, the scale of the financial, logistical, political, technical and temporal challenges, the arguments for compulsory change appear difficult to resist, if the Transition Plan (Section 1.3) is to be realised.

Therefore two lines of research linked to more robust measures to promote energy efficiency are proposed. The first is to reconsider the relationship between income and fuel expenditure and then re-model the impacts and benefits of fiscal measures designed to reduce fuel demand and develop the market for more energy efficient homes. The second proposal is a study of policies which demand minimum energy efficiency standards for housing.

1) Both of these research proposals would consider policies which involve some form of compulsion. A third line of research is proposed into a policy option which is based upon enhancing the benefits which accrue from greater energy efficiency, using a study of social differentiation in the take up of PV panels following the introduction of the Feed in Tariff (FITS) in 2010. *Income and fuel expenditure*

This thesis has highlighted that; the existing expenditure data in the EFS can only be relied upon to identify average fuel spending and does not accurately reflect the range of fuel expenditure; and, any impact assessment which solely relies upon standardised fuel expenditure data cannot realistically assess the financial impacts of an altered fuel tariff, because consumers do not purchase standardised fuel services.

This research suggests that the benefits and impacts of fuel price controls are not well understood and OfGEM (2009) highlighted that there is insufficient information available to allow an evidence based policy to be developed. If the Green Deal does not deliver the market transition hoped for, alternative, or complimentary, policies will be needed and fuel price control may be an important option.

Therefore additional research into the relationships between income, fuel price and fuel demand would be timely and valuable. OfGEM (2009) suggest that research in this area *"would* [ideally] *go beyond the aggregate demand level to examine various consumer groups and household types to get a better picture of the differences in customers' price sensitivity…. Additional analysis could also consider the pricing ratios or differentials that trigger household investment in efficiency measures."*

2) Minimum housing standards

This thesis has indicated that a proportion of householders will react pre-emptively to prevent their homes being classified as failing a minimum standard and research could seek to determine the likely energy efficiency outcomes of alternative minimum standard strategies. Additionally it would be useful to consider how housing standards could be introduced progressively, so that they minimized the potential for social impacts, for example, negative equity in the housing market.

3) On-site renewables and social differentiation

The methods employed in this thesis could be extended and augmented to examine any social differentiation in the take-up of PV panels after the introduction of FITS in 2010. The research could consider whether the FITS model could inform insulation retro-fit policy. Specifically could the idea of post installation inducements, such as linking insulated homes to a different fuel tariff, mobilize more affluent households to make their homes more energy efficient?

14.7 **Comment**

Previous research established that high income households collectively use the most fuel. This research has extended the literature by providing evidence that these social divisions are also evident in insulation retro-fitting. Consequently the energy demand gap between the most affluent and least affluent English households has been widening.

This study suggests that to reverse this trend, complimentary, but politically challenging, polices, which increase the value of energy efficiency in affluent households, are required to support policies such as The Green Deal and ECO. In common with all sectors of the economy, difficult decisions must be taken to drive the transition to a low carbon, more energy efficient housing sector. In the words of Maria van der Hoeven, International Energy Agency Executive Director, speaking to the European Council for an Energy Efficient Economy on 13 November 2012:

"energy efficiency is just as important as unconstrained energy supply. But energy efficiency will not happen by itself. Strong policies are needed".

Approximately 41,000 words in the body of the report and 15,000 words in the appendices

BIBLIOGRAPHY

The bibliography includes sources referenced in the appendices.

Aleklett, K., Hook, M., Jakobsson, K., Lardelli, M., Snowdon, S. & Soderbergh, B. 2010, "The Age Of Peak Oil - Analyzing world oil production. Reference Scenario in World Energy Outlook 2008", *Energy Policy,* vol. 38, pp. 1398-1414.

Barker, G. 2011 speaking to You and Yours, BBC Radio 4, July 2011. BBC. London.

Bentley, R.W. 2002 " Global oil and gas depletion: an overview" *Energy Policy,* vol. 30, pp. 189-205.

Bernstein, M. & Griffin, J. 2005, *Regional Differences in the Price-Elasticity of Demand for Energy* , RAND Corporation, http://www.rand.org/pubs/technical_reports/2005/RAND_TR292.pdf.

Boardman, B. 2012, *Achieving Zero*, Oxford, Environmental Change Institute.

Boardman, B. 2010, *Fixing Fuel Poverty*, 1st ed, London, Earthscan.

Boardman, B. 2007a, *Hometruths: A Low Carbon Strategy to Reduce UK CO2 Emissions By 80%*, Oxford, Environmental Change Institute

Boardman, B., Darby, S., Killip, G., Hinnels, M., Jardine, C., Palmer, J. & Sinden, G. 2007b, "Examining the carbon agenda via the 40% House scenario", *Building Research & Information*, vol. 35, no. 4, pp. 363.

Boonekamp, P. 2009, *Energy efficiency trends and policies in the household and tertiary sectors in the EU 27*, Intelligent Energy Europe, http://www.odyssee-indicators.org/publications/PDF/brochures/buildings.pdf.

Cheng, V. & Steemers, K. 2011, "Modeling domestic energy consumption at district scale: A tool to support national and local energy policies", *Environmental Modeling & Software*, vol. 26, no. 10, pp. 1186-1198.

Committee On Climate Change 2012, *Meeting Carbon Budgets. 2012 Progress Report to Parliament*. London. [Online] www.theccc.org.

Committee On Climate Change 2011a, *Meeting Carbon Budgets. Third Progress Report to Parliament*. London. [Online] www.theccc.org.

Committee On Climate Change 2011b, *Household energy bills - impacts of meeting carbon budgets*. London. [Online] www.theccc.org.

Committee On Climate Change 2010, *Meeting Carbon Budgets 2nd Progress Report To Parliament*. London. [Online] www.theccc.org.

Committee On Climate Change 2008, *Building a low carbon economy - the UK's contribution to tackling climate change*, The Stationary Office. London

Crockett, A, 2011, *Weighting the Social Surveys*, Version 1.9. based upon proceedings of the Weighting and Social Surveys conference at the Royal Statistical Society, 2004. Economic and Social Data Service. www.esds.ac.uk.

Davis Langdon and Inbuilt Ltd 2010, *"Study on hard to fill cavity walls in domestic dwellings in Great Britain"*. At study undertaken for DECC, reference CESA EE0211. London. Department of Energy & Climate Change

Day, T, 2006, *Degree-days: theory and application,* TM41:2006, London, The Chartered Institute of Building Services Engineers.

Department For Communities & Local Government, 2011, *Live Table* 100 Dwelling Stock, last up dated Feb 2010. [Online]. Last accessed at 14 September 2012 at: www.communities.gov.uk/documents/housing/xls/table100.xls.

Department For Communities & Local Government, September 2010a Live *Table 401: Household projections* [Online]. Last accessed at 14 September 2012 at: www.communities.gov.uk/documents/housing/xls/table401.xls].

Department For Communities & Local Government 2010b, *Table 111 Conversions and demolitions: estimated annual gains and losses, England, from 1991/92* [Online]. Last accessed on 15 May 2012 at: www.communities.gov.uk/documents/housing/xls/table-111.xls.

Department For Communities & Local Government 2010c, *English Housing Survey Housing Stock Report 2007*. London. HM Government.

Department For Communities & Local Government 2010d, "Housing and Planning Statistics 2010". London. HM Government.

Department For Communities & Local Government 2009a, *English House Condition Survey 2007 Annual Report*, London. HM Government.

Department For Communities & Local Government, 2009b *Housing in England, 2007-08*. London. HM Government.

Department For Communities & Local Government 2008c, "*Housing Statistics 2008*", London. HM Government.

Department For Communities & Local Government 2007, *English House Condition Survey Technical Report* (2005 Edition), Communities and Local Government Publication Centre. London. HM Government.

Department For Communities & Local Government (various years), *English House Condition Survey Annual Report*, Communities and Local Government Publication Centre. London. HM Government.

Department For Environment Food & Rural Affairs 2008a, "*A Framework For Pro Environmental Behaviors*". London. HM Government.

Department For Environment Food & Rural Affairs 2008b, "*The UK Fuel Poverty Strategy 6th Annual Progress Report*". London. HM Government.

Department For Environment Food & Rural Affairs 2006a, *The Energy Efficiency Commitment April 2008 to March 2011, Initial Consultation.* London. HM Government.

Department For Environment Food & Rural Affairs 2006b, *Energy Efficiency Commitment - Social and Equity Issues,* A consultation document issued by The Sustainable Energy Policy Division. DEFRA. London. HM Government.

Department For Environment Food & Rural Affairs 2004 , *Fuel Poverty In England: The Government's Plan For Action*, DEFRA. London. HM Government.

Department of Business, Innovation and Skills 2010, *Low Carbon Construction. Final Report*, London. HM Government.

Department of Energy & Climate Change 2012a, *2010 UK Greenhouse Gas Emissions, Final Figures*, London. HM Government.

Department of Energy & Climate Change 2011a, *The Carbon Plan: Delivering our low carbon future.* London. HM Government.

Department of Energy & Climate Change 2011b, *Annual report on fuel poverty statistics 2011.* London. HM Government. .

Department of Energy & Climate Change 2011c, *Energy Consumption UK.* London. HM Government.

Department of Energy & Climate Change 2011d, *National Energy Efficiency Data-Framework Report on the development of the data-framework and initial analysis*, DECC report reference URN 11D/703. London. HM Government.

Department of Energy & Climate Change 2011e, *Quarterly Energy Prices*, [on-line] http://www.decc.gov.uk/en/content/cms/statistics/publications/prices/prices.aspx. London. HM Government.

Department of Energy & Climate Change 2011f, *Amendments to the Carbon Emission Reduction Targets*. London. HM Government.

Department of Energy & Climate Change 2011g, *The Green Deal and Energy Company Obligation - Impact Assessment 1A*. London. HM Government.

Department of Energy & Climate Change 2011h, *Estimates of home insulation levels in Great Britain: April 2011*. London. HM Government.

Department of Energy & Climate Change 2011i - continually up dated energy statistics. [on-line] Last accessed at 23 November 2011 at : http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/en_effic_stats/en_effic_stats.aspx.

Department of Energy & Climate Change 2010a, *Warm Homes, Greener Homes A Strategy for Household Energy Management Supporting Papers*. London. HM Government.

Department of Energy & Climate Change 2010b, *Digest of United Kingdom Energy Statistics*, London. The Stationary Office.

Department of Energy & Climate Change 2010c, *Estimates of home insulation levels in Great Britain*: *July 2010*. . London. HM Government.

Department of Energy & Climate Change 2010a, *Fuel Poverty Methodology Handbook*, URN10D/825 edn, . London. HM Government.

Department of Energy & Climate Change 2009a, The Transition Plan, National strategy for energy and climate change. HM Government. London

Department of Energy & Climate Change 2009b, *The UK Fuel Poverty Strategy 7th Annual Progress Report*. . London. HM Government.

Department for Work and Pensions 2012 *Households below average incomes. An analysis of income distribution 1994/95 to 2010/11.* London. Department of Work and Pensions.

Dresner, S. & Ekins, P. 2006, "Economic instruments to improve UK home energy impacts without negative social impacts", *Fiscal Studies*, vol. 27, no. 1, pp. 47-74.

Dresner, S. & Ekins, P. 2004 "*Economic Instruments for a Socially Neutral National Home Energy Efficiency Programme*", Policy Studies Institute, London. Research Discussion Paper.

Druckman, A., Chitnis, M., Sorrell, S. & Jackson, T. 2011, "Missing carbon reductions? Exploring rebound and backfire in UK households", *Energy Policy*, vol. 39, pp. 3572-3581.

Druckman, A. & Jackson, T. 2008, "Household Energy Consumption In The UK. A Highly Geographically Disaggregated Model", *Energy Policy*, vol. 36, no. 8, pp. 3177-3192.

European Council for an Energy Efficient Economy [on-line] last accessed on 13 November 2012 atwww.eceee.org.

Energy Saving Trust, 2012, [on-line] last accessed on 6th February 2012 at www. energysavingtrust.org.uk.

Energy Saving Trust 2011, *Trigger Points: a convenient truth*, London. Energy Saving Trust

Energy Saving Trust 2010, *Sheffield Eco Terrace: A refurbishment case study.* London. Energy Saving Trust.

Energy Saving Trust 2008, *Roadmap to 60%: eco-refurbishment of 1960s flats*, London. Energy Saving Trust

English Heritage, 2010, “Energy Efficiency and Historic Buildings”. english.heritage.org.

Ernst & Young (2011) *Green Deal Insight from recent customer research.* Available on-line httppe://www.ey.com/publication/vwluassets/green_deal_consumer/$file/green_deal_consumer.pdf

European Commission 2011, [on- line] last accessed on 29th December 2011 at http://ec.europa.eu/energy/efficiency/action_plan/action_plan_en.htm].

Fawcett, T. 2011, "*Home time: An exploration of the time dimensions of eco-renovation of housing*", UKERC Energy and people conference, October 2011. Oxford.

Friedman, K. & Cooke, A. 2012, "*Is UK Planning a barrier to energy efficient heritage retrofit: a comparative analysis of a selection of London Boroughs*", Retrofit 2012, University of Salford, 24-26 January.

Galvin R, 2009, *Thermal upgrades of existing homes in Germany: The building codes, subsidies and economic efficiency.* A CSERGE Working paper EDM 09-11. University of East Anglia.

Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J. & Smith, C. 2011, *The distribution of total greenhouse gas emissions by households in the UK, and some implications for social policy*, Centre for Analysis of Social Exclusion, London School of Economics.

Green Building Council 2010, *Green Deal - public appetite market research*. [on-line] La\st accessed on 17 July 2012 at thttp://www.greatbritishrefurb.co.uk/images/pdfs/gbr-greendealmarketresearch.pdf.

Green Fiscal Commission, 2009, *Doing what it takes to reduce carbon emissions: The case for Green Fiscal Reform.* Briefing Paper 4. London

Green, G. & Gilbertson, J. 2008, *Health Impact Evaluation of The Warm Front Scheme*, Centre for Regional, Economic and Social Research, Sheffield Hallam University.

Harvey, F. 2012, *Chris Huhne: UK must invest in energy infrastructure to keep the lights on*, The Guardian, 12 July 2012

Herring, H. 1998, *Does Energy Efficiency Save Energy: The Implications of accepting the Khazzoom-Brookes Postulate*, Open University.

HM Government 25 Oct 2011a-last update, www.parliment.uk. [on-line] Last accessed on 13 Jan 2012 at http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1065/106506.htm. London.

HM Government 12 December 2011b-last update, *Household earnings estimates: Model-based estimates of income for MSOAs* [Homepage of HM Government], [Online]. Last accessed on 17 March 2011 at http://data.gov.uk/dataset/household_earnings_estimates_-_model-based_estimates_of_income_for_msoas].

HM Government Public Accounts Committee 2010, Twenty first report. *The Decent Homes Programme*, [Online]. Last accessed on a5 February 2012 at http://www.publications.parliament.uk/pa/cm200910/cmselect/cmpubacc/350/35002.htm.

Hulme, J. & Summers, C. 2009, *An investigation of the effect of rising block tariffs on fuel poverty* , London. Committee For Climate Change.

Hunt, L.C., Judge, G. & Ninomiya, Y. 2003, "Underlying trends and seasonality in UK energy demand: a sectoral analysis", *Energy Economics*, vol. 25, no. 1, pp. 93-118.

Intergovernmental Panel on Climate Change, 2007, 4th Report, Summary for Policy Makers. Available at www.IPCC.ch/

Jackson, T. 2009, *Prosperity Without Growth*, 2nd, 2011 edn. London, Earthscan

Jenkins D.P. 2010, "The value of retrofitting carbon-saving measures into fuel poor social housing", *Energy Policy*, vol. 38, no. 2, pp. 832-839.

Kelly, S. 2011, *Do homes that are more energy efficient consume less energy* ?, Cambridge. Electricity Policy Research Group.

Kirklees Borough Council, 2012 Instant Atlas [on-line]. Last accessed on 28 November 2012 at http://www.kirklees.gov.uk/community/statistics/areaprofiles/report/atlas.html

Kirklees Borough Council 2011 *Warm Zone retrofitting statistics.* Pers comm.

Lees, E. November 2011-last update, *Do energy efficiency obligations work*? [Homepage of European Council for an Energy Efficient Economy], [Online]. Last accessed on 28 November 2011 at: http://www.eceee.org/columnists/Eoin_Lees/Do_Obligations_Work].

Lowe, R. & Oreszczyn, T. 2008, "Regulatory standards and barriers to improved performance for housing", *Energy Policy*, vol. 36, no. 12, pp. 4475-4481.

Mallaband, B., Haines, V. & Mitchell, V. 2012, "*Barriers to domestic retrofit- learning from past home improvement experiences*", Retrofit 2012, University of Salford, January 2012.

Milne, G. & Boardman, B. 2000, "Making cold homes warmer. The effect of energy efficiency programmes in low income homes", *Energy Policy*, vol. 28, pp. 411-424.

National Audit Office 2010, *The Decent Homes Programme*. A report by the comptroller and auditor general to the House of Commons, HC 212, Session 2009 to 2010, 21 January 2010.

National Audit Office 2009, *The Warm Front Scheme*. A report by the comptroller and auditor general to the House of Commons, HC 126, Session 2008 to 2009, 4 February 2009.

Northern Ireland Department For Social Development 2006, Northern Ireland Housing Statistics 2005 to 2006. HM Government.

Oakdene Hollins 2011, *The Further Benefits of Business Resource Efficiency*, London, Department for Environment, Food and Rural Affairs.

Office For National Statistics 2012a, *Annual Survey of Hours and Earnings* (ASHE). [on-line] last accessed 3 October 2012 at www.ons.gov.uk/ons/datasets-and-tables/index.html?pageSize=50&newquery=hours+and+earnings+2004 .

Office For National Statistics 2012b, [on-line] last accessed 23 November 2012 at ww.ons.gov.uk.

Office For National Statistics 2011, *Living Costs & Food Survey 2009*, Newport. Office for National Statistics.

Office For National Statistics 2008, *English Housing Survey*. Newport. Office for National Statistics.

Office For National Statistics 2003 to 2008 inclusive, *Expenditure and Food Survey* (EFS). Data and User Manuals. Newport. Office for National Statistics.

Office For National Statistics 2003 to 2007 inclusive, *English House Condition Survey*. Data and User Manuals. Newport. Office for National Statistics.

OfGEM 2009, *Can Energy Charges Encourage Energy Efficiency*? A Discussion Paper To Prompt Debate. London. Office of the Gas and Electricity Markets.

OfGEM 2008a, *CERT Update Issue 1*, OfGEM. London. Office of the Gas and Electricity Markets.

OfGEM 2008b, *EEC 2005-2008, Report to Secretary of State*. London. Office of the Gas and Electricity Markets.

OfGEM 2005, *EEC1, Report to Secretary of State*. London. Office of the Gas and Electricity Markets.

OfGEM 2003, *A review of the Energy Efficiency Standards of Performance 1994 – 2002*. London. Office of the Gas and Electricity Markets.

Palmer, G., MacInnes, T. & Kenway, P. 2008, *Cold and Poor: An analysis of the link between fuel poverty and low income*, London. New Policy Institute.

Palmer, J. & Cooper, I. 2011, *Great Britain's housing energy fact file*. London. Department of Energy & Climate Change.

Palmer, J. & Cooper, I. 2012, *United Kingdom housing energy fact file*. London. Department of Energy & Climate Change.

Peacock, A., Jackson, T., Berry, A., Masini, G., Ahadzi, M., 2009, *Market development potential of residential refurbishment packages.* A conference organized by the European Council for an Energy Efficient Economy and available at http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.093/paper

Pelanur, M and Cruickshank, H. 2012, *The social barriers to adopting energy efficiency measures and behaviors in the home: a Manchester and Cardiff case study.* A paper at Retrofit 2012, The University of Salford, January 2012.

Powells, G. 2009 *Warming homes, cooling the planet,* a PhD thesis submitted to Durham University.

Power, A. & Zulauf, M. 2011, *Cutting carbon costs: learning from Germany' energy saving program*, London School of Economics, London.

Public Accounts Committee 2010, *The Decent Homes Programme*. [on-line] Last accessed on 21 September 2012 at: http://www.publications.parliament.uk.

Read, S. 22 June 2012, *Regional energy prices vary by £92 a year and 'hit poorest hardest*', 8019th edn, The Independent, London.

Reinders, A.H.M.E., Vringer, K. & Blok, K. 2003, "The direct and indirect energy requirement of households in the European Union", *Energy Policy*, vol. 31, no. 2, pp. 139-153.

Richards, P. 2012 *The Green Deal,* Ref SN/SC/5763. House of Commons library. London.

Roberts, S. 2008a, "Altering existing buildings in the UK", *Energy Policy*, vol. 36, pp. 4482-4486.

Roberts, S., White, V., Preston, I. & Thumin, J. 2007, *Assessing the Social Impacts of a Supplier Obligation* A study for DEFRA, Bristol. Centre For Sustainable Energy.

Rosenow, J. 2011, "*Different paths of change: Home energy efficiency policy in Britain and Germany*" A conference organized by European Council for an Energy Efficient Economy, available at http://proceedings.eceee.org/, 6-11 June 2011.

Sanders, C. & Phillipson, M. 2006, *Review of Differences between Measured and Theoretical Energy Savings for Insulation Measures*. Centre for Research on Indoor Climate and Health. Glasgow Caledonian University.

Sefton, T. & Chesshire, J. 2005, *Peer Review of the Methodology for Calculating the Number of Households in Fuel Poverty in England*, London. Department of Business, Environment and Regulatory Reform. Available at www.berr.gov.uk/files/file16566.pdf.

Sefton, T. 2004, *Aiming High - An evaluation of the potential contribution of Warm Front towards meeting the Government's fuel poverty target in England*. Centre for Analysis of Social Exclusion. London School of Economics

Shorrock, L.D. 2011, *Energy efficiency first: The foundation of a low-carbon society* A conference organized by European Council for an Energy Efficient Economy, available at http://proceedings.eceee.org/, 6-11 June 2011..

Sorrell, S., Spiers, J., Bentley, R., Brandt, A. & Miller, R. 2009a, *An assessment of the evidence for a near-term peak in global oil production*, Oxford. UK Energy Research Centre.

Sorrell, S., Dimitropoulos, J. & Sommerville, M. 2009b, "Empirical estimates of the direct rebound effect: A review", *Energy Policy*, vol. 37, no. 4, pp. 1356-1371.

Statistics For Wales 2010, *Dwelling Stock Estimates* 2008-2009. Reference SDR 2010. Cardiff. Welsh Assembly Government.

Summerfield, A.J., Lowe, R.J. & Oreszczyn, T. 2010, "Two models for benchmarking UK domestic delivered energy", *Building Research & Information*, vol. 38, no. 1, pp. 12-24.

Sustainable Development Commission 2007, *Domestic energy bills and costs of implementing environmental measures*, Sustainable Development Commission. Available [on-line] at http://www.sd-commission.org.uk/publications/downloads/DomesticEnergyPriceAnalysis.pdf

The Carbon Trust 2006, *The carbon emissions that we generate in all that we consume*, Carbon Trust, London.

The Scottish Government, Housing Statistics Branch August 25, 2010 (last modified), "*Housing Statistics for Scotland - Key Information and Summary Tables*". Edinburgh.

Thornton, A. 2009, *Public attitudes and behaviours towards the environment - tracker survey: A report to the Department for Environment, Food and Rural Affairs.* TNS. DEFRA, London.

Thumin, J., Fahmy, E. & White, V. 2011, *The distribution of UK household carbon dioxide emissions*: Interim report for the Joseph Rowntree Foundation programme Climate Change and Social Justice. York. Joseph Rowntree Foundation.

Thurlwell, J., Davis, C. & Mohamed, S. 2011, *British Gas Home Energy Report 2011 - An assessment of the drivers of domestic natural gas consumption*, London. Centre for Economics and Business Research Limited.

UK Green Building Council 2008, *Low Carbon Existing Homes*. London. UK Green Building Council.

Utley, J.I. and Shorrock, L.D. 2008, *Domestic Energy Fact File*. Milton Keynes. Building Research Establishment.

Weber, C.L. & Matthews, H.S. 2008, "Quantifying the global and distributional aspects of American household carbon footprint", *Ecological Economics*, vol. 66, no. 2–3, pp. 379-391.

Fuel Poverty

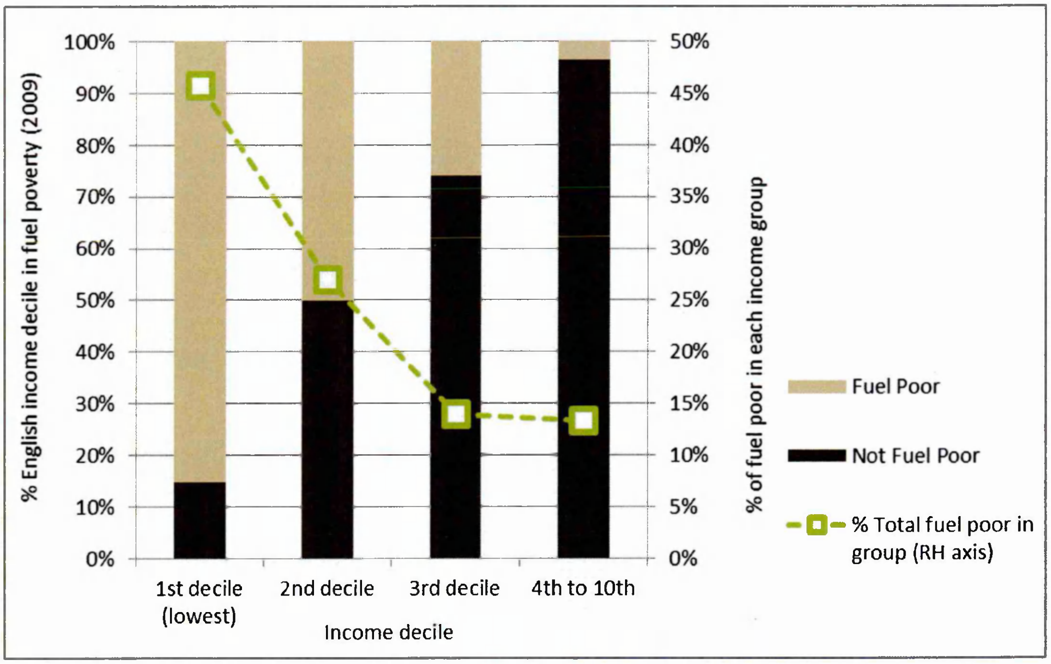
Under the Warm Homes and Energy Conservation Act (2000), the government is legally obliged to ensure that, by 2016 in England and 2018 in Wales, 'as far as is reasonably practicable', people do not live in fuel poverty.

Actions under WHECA are devolved and the definition of fuel poverty varies slightly between the devolved administrations. In England a household is fuel poor if they would have to spend more than 10% of their full income, which is net household income plus income from housing benefits and any mortgage interest protection insurance and regular interest from savings (DECC 2010b) to maintain their living room at 21^{0}C and the remaining rooms at 18^{0}C for 16 hours per day, for those likely to be at home and nine hours per day for households where all members work or full time education. In addition to purchasing warmth, the fuel poverty assessment also allows for buying a basket of energy services based upon average household demand for such services

The Act lead to the UK Fuel Poverty Strategy 2001, and an interim target, that by 2010 fuel poverty in households will have been eliminated in homes occupied by older householders, those with children, the disabled and those with long term illnesses, a group collectively referred to as the 'vulnerable fuel poor'.

The 2001 strategy lead to the development of specific programmes to reduce, address or eliminate fuel poverty, such as Warm Front (see Chapter 4). The Strategy was also evident in the social elements of residential energy efficiency initiatives such as the Energy Efficiency Commitment and The Carbon Emission Reduction Target. The programmes were designed so that a disproportionate element of the energy efficiencies were achieved in the homes a predominantly low income sub-group – see Figure 1.

Figure 1 *Proportion of households in fuel poverty by income group, 2009*

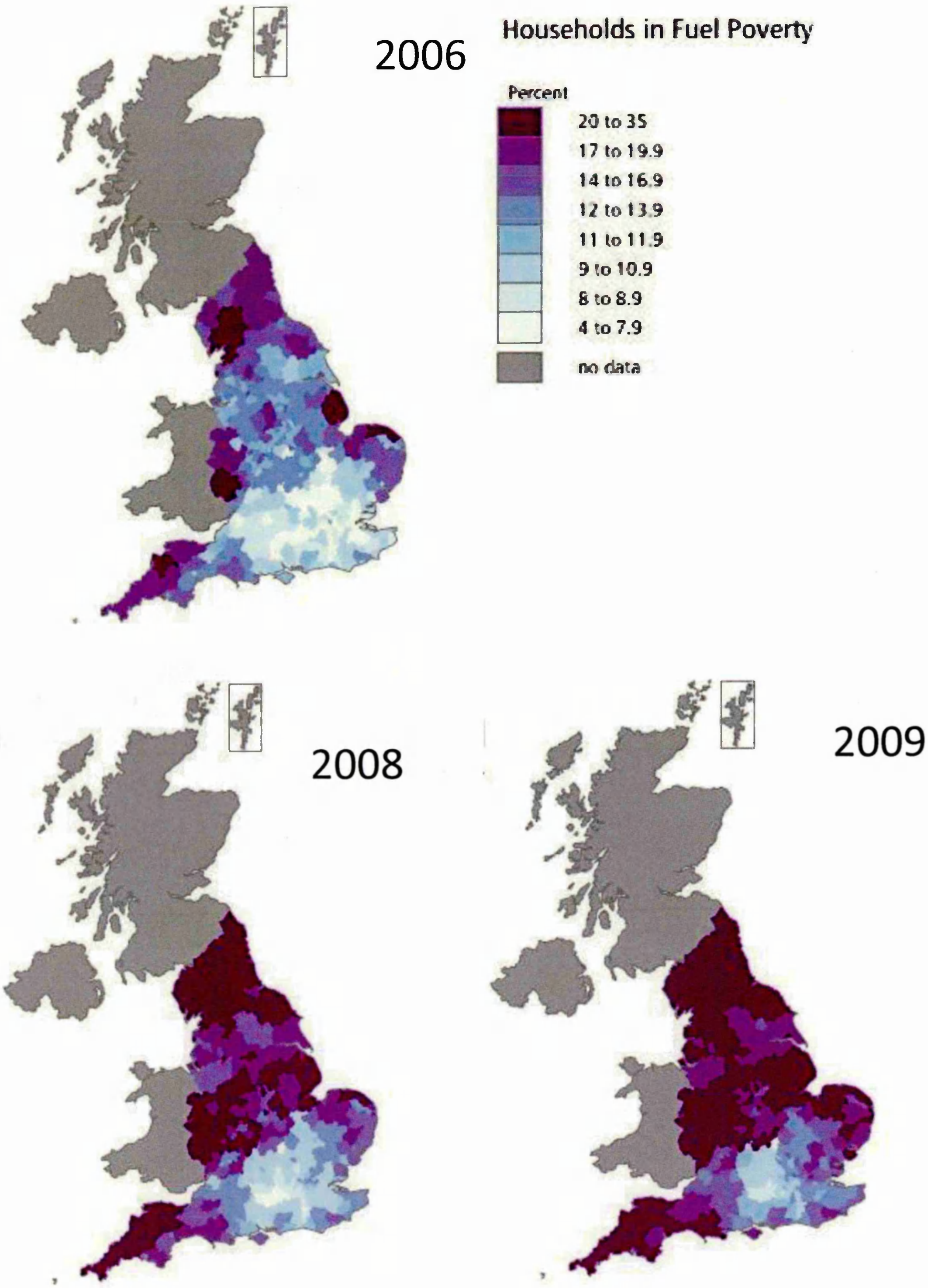


Source DECC, 2011b

As a result of decreasing fuel costs, additional income support and to a lesser extent enhanced residential energy efficiency (Boardman, 2010), the number of households in fuel poverty fell between 2000 and 2003. However the energy efficiency programmes, coupled with poor targeting of fuel poverty spending (Sefton, 2004) has meant that the fuel poverty programmes have been unable to off-set the effects of fuel price rises. The number of English households in fuel poverty has risen from 1.2million in 2003 to 4 million in 2009 (DECC, 2011b)

As illustrated in Figure 2, fuel poverty is unevenly distributed around the country. In 2009, the highest percentage of fuel poor homes was in the West Midlands (DECC, 2011b), but as illustrated, by 2009 over 20% of households in the north and south west were also considered fuel poor.

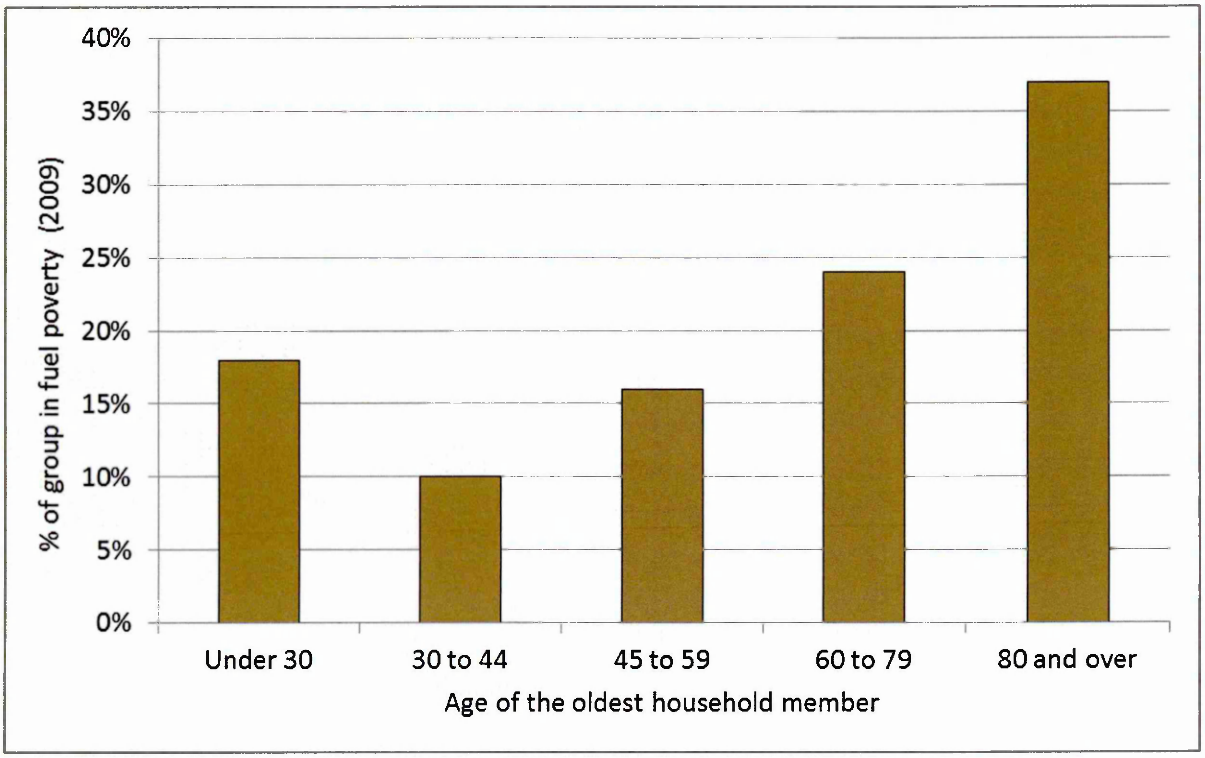
Figure 2 *Proportion of English homes in fuel poverty*



Source DECC, website Nov 2011

The number of fuel poor households and their proportion increases by age group and as indicated in Figure 3, in nearly two thirds of cases, the oldest member of a fuel poor household is over 60 years old and the majority of households in this group have at least one household member who is over 80.

Figure 3 *Proportion of households in fuel poverty by age of the oldest member of the household*



Source DECC,2011b

Preston (2008) estimated that 22% of fuel poor, who owned their home outright, could be lifted out of fuel poverty by moving to a smaller house.

The Costs Of Thermal Renovation

The costs and approximate pay-back periods for basic insulation measures and solid wall insulation is summarised in Table 1.

Table 1 *Approximate costs and pay back times for retrofit measures*

	Loft insulation		Cavity wall insulation	Solid wall insulation		Floor insulation - timber floor
	0 to 270mm	100 to 270mm		Internal	External	
Approximate saving per year	Up to £175	£25	Up to £135	Around £445	Around £475	Around £60
Installation cost (subsidised)	£100 to £350	£100 to £350	£100 - £350	£5,500 to £8,500	£9,400 to £13,000	£100 (DIY) to around £770 (professional)
Time taken to pay for itself (subsidised)	Up to two years	From four years	Less than a year - 3 years			Around two years (DIY)
Installation cost (unsubsidised 2011)		£300-£500	£500-£600			

Source: Energy Saving Trust website, accessed 2 February 2012 and DECC, Green Deal Impact Assessment, 2011g

The Energy Saving Trust modeled the refurbishment cost to reduce carbon dioxide emissions by 60% from a two bed flat (EST, 2008). EST concluded that the average cost would be over £10,000 and the cost could vary by a factor of three depending upon the storey the flat occupied, the wall type, the nature of the existing heating system and the type of glazing. Jenkins (2010) reported the findings of two other modeling projects, which predicted thermal refurbishment costs of £21,300 for a 1945-64 semi to achieve a 48% emissions reduction, to £31,900 to reduce emissions by 57% in a pre-1919 detached house. PRP Architects reported spending £15,000 to £25,000 per home to reduce emissions by approximately 50% (Daily Telegraph, 5 July 2012) by a combination of better insulation and more efficient heating systems. The architects concluded that the costs could be reduced if multi-skilled retrofit companies developed.

These studies however do not take into account the cost of installing micro-renewables which researchers, for example Shorrock (2011) have concluded will be required to reduce household emissions by 80%. In 2009 the EST, Sheffield City Council and their contractors Kier, carried out an energy efficiency refurbishment of a 2 bed terrace, with solid walls, in Sheffield. Household emissions were reduced by 76% by a combination of energy efficiency measures and micro-renewables. However allowing for labour for energy efficiency measures only, the refurbishment cost was approximately £45,000 (EST, 2010b).

Killip (2011) suggests that the cost for additional energy efficiency measures during major renovation work is likely to be in the range £12,000 to £25,000 for an 80% reduction in emissions, although he notes that costs could be greater in specific circumstances or where thermal renovation is carried out in isolation. Enseling and Hinz, 2006, monitored the costs for a single firm to renovate 850 similar apartments in a single block, to differing thermal standards. The results are summarized in Table 2.

Table 2 *Costs to Thermally Renovate Flats in a German Apartment Block*

Reduction in energy demand	**30%**	**75%**	**86%**	**90%**
Refurbishment cost (€/m^2 of floor area)	36	122	235	314

Source: Enseling and Hinz, 2006 reproduced by Galvin, 2010

DECC (2011g) estimate that the cost of internal wall insulation alone is likely to be between £7500 and over £15,000 for each solid wall property.

Table 3 *Estimate of fixed costs for internal wall insulation*

	Large detached house	**Small flat**
Installation	£8147	£3830
Materials	£6247	£1930
Fixed costs (average)	£1900	£1900
Capital cost sub total	£16294	£7660

Source DECC 2011g Green Deal Risk Assessment Table 24

Based upon these studies it appears reasonable to conclude that average retrofit costs per household are likely to be approximately two orders of magnitude greater than those incurred by householders voluntarily fitting basic insulation measures such as cavity wall insulation and additional loft insulation.

The Energy Saving Trust (2008) modeled the refurbishment cost to reduce carbon dioxide emissions by 60% from a two bed flat. Variables included the storey the flat occupied, the wall type, the nature of the existing heating system and the type of glazing. The study results are summarized in Table 4. EST concluded that the average cost would be over £10,000 and the cost could vary by a factor of three depending upon the storey the flat occupied, the wall type, the nature of the existing heating system and the type of glazing – the size and layout of the flat was kept constant.

Table 4 *Cost estimates to reduce CO_2 emissions from a two bed flat by 60%*

	Number of scenarios	Minimum (£)	Maximum (£)	Average (£)
Refurbishment cost	54	7050	20200	12271

Source: Energy Saving Trust, 2008

EST developed cost estimates and predicted emissions reductions for three refurbishment scenarios: low, medium and high cost energy efficiency measures (see Table 5)

Table 5 *Measures included in the cost estimates for the energy efficiency refurbishment of a two bedroom flat (Source EST, 2008)*

Low cost	Medium cost	High cost
low energy lighting, draught proofing, loft insulation, cavity wall insulation	Low cost measures plus: internal wall insulation, replacement front door, new boiler and controls, new radiator where flats previously had electric heating	Medium cost measures plus: external insulation, floor insulation, new windows, new hot water cylinder, solar hot water heating

Under these scenarios refurbishment costs varied between £550 and £10500 and emission reductions ranged from 2% to 68%. As illustrated in Figure 1, to achieve the higher percentage emission reductions reflected in the Transition Plan, it will be necessary to invest in more expensive refurbishment options. But significantly the average marginal abatement costs for the scenarios modeled do not increase with the project costs see Table 6. And because marginal abatement costs are directly linked to fuel costs and pay-back periods it must therefore also be the case that pay-back periods are not necessarily connected to the amount invested in the original refurbishment.

Table 6 *Cost estimates and emission reduction predictions, for energy efficiency refurbishment of a two bed flat (Source Energy Saving Trust, 2008)*

Emission reduction	Number of cases	Refurbishment cost (£)			Marginal abatement cost (£/tonne CO_2)		
		Min	Max	Average	Min	Max	Average
>60%	31	4700	10500	9075	2136	6563	3820
50%-59%	25	4500	10500	6471	1456	6563	3417
40%-49%	31	1600	8600	6122	762	8125	4595
30%-39%	20	1150	6500	3253	762	6833	3577
20%-29%	17	550	4700	3273	917	8200	4483
10%-19%	20	550	1150	809	458	3833	1877
<10%	18	550	1150	800	2750	11500	5370

Figure 1 *Cost estimates and emission reduction predictions, for energy efficiency refurbishment of a two bed flat (Energy Saving Trust, 2008)*

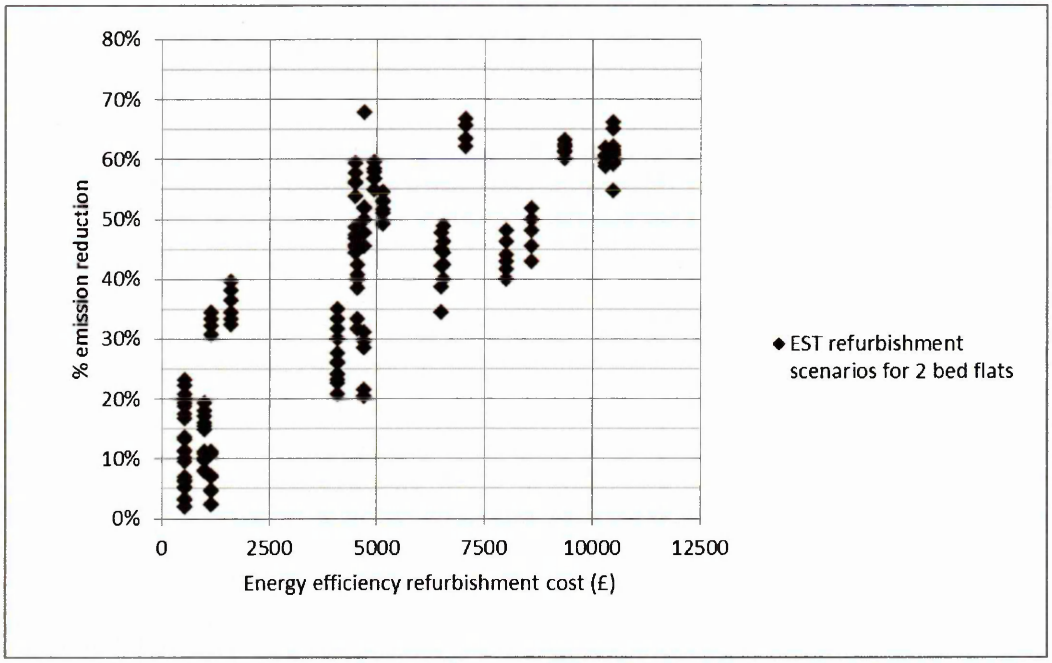
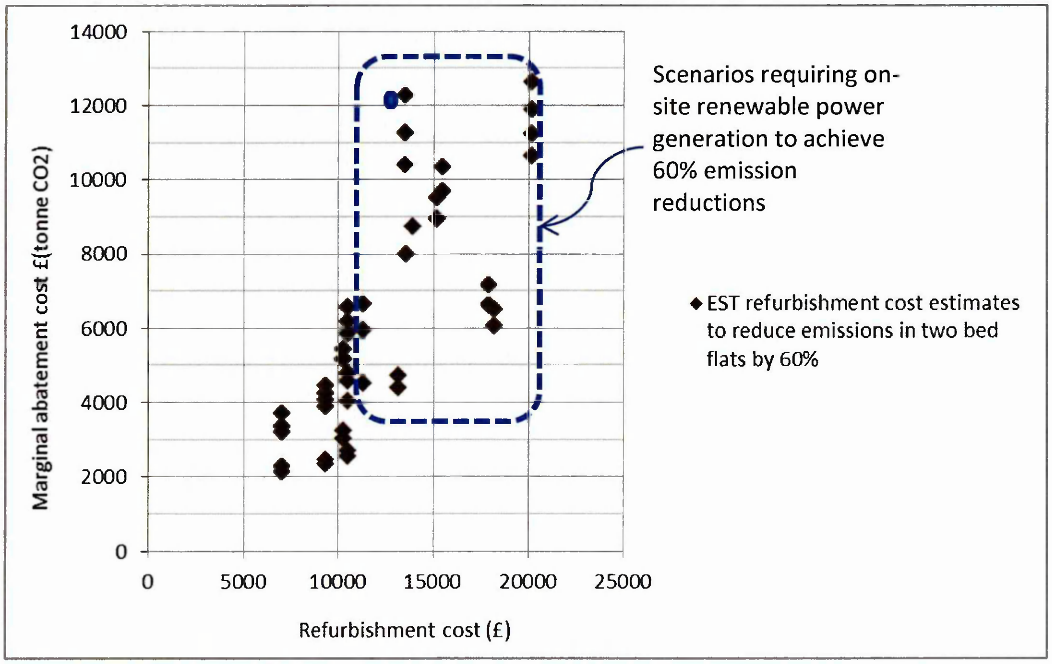


Figure 2 *Cost estimates to reduce emissions from a two bed flat by 60%*



In general, case studies suggest that energy efficiency renovation becomes more expensive, per unit of demand reduced, as the proportional fall in demand increases. Galvin (2010) reported on studies from Germany which reported that renovating to 193kWh/m^2/yr could cost as little as three eurocents per kWh of consumption theoretically saved, rising to around 20 cents per kWh when renovating to 40kWh/m^2/yr and 40 cents or more for 15kWh/m^2/yr, the German '*Passivhaus*' standard. These figures should be treated with care because they will depend upon whether the energy efficiency measures were part of a larger renovation project, or whether the costs describe the installation of measures only.

Enseling and Hinz, 2006, monitored the costs for a single firm to renovate 850 'very similar' apartments in Ludwigshaven, to differing thermal standards. The results are in illustrated Figure 3. As set out Table 7, Enseling and Hinz found that marginal abatement costs increased sharply as the thermal standard of the renovation increased.

Figure 3 *Costs to renovate flats in a German apartment block to various thermal standards (data from Enseling and Hinz, 2006, Galvin, 2010)*

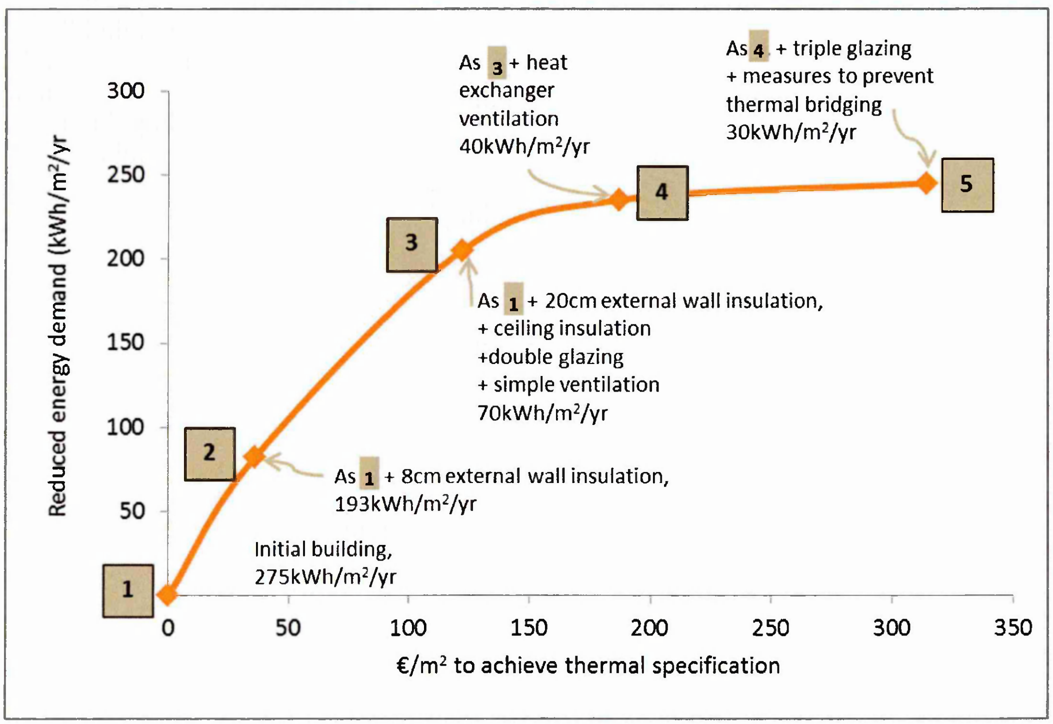


Table 7 *Costs to renovate flats in a German apartment block to various thermal standards (data from Enseling and Hinz, 2006, Galvin, 2010)*

Scenario – see Figure 3	2	3	4	5
Reduction in energy demand	30%	75%	86%	90%
Refurbishment cost (€/m^2 of floor area)	36	122	235	314

Table 7, of course does not convey the entire picture because providing a resident continues to benefit from the higher thermal standards, they should be compensated over time by reduced fuel bills. However Galvin calculated that even after 25 years, a resident refurbishing their flat to 30kWh/m^2/yr and thereby reducing there fuel demand by 90%, would have paid nearly three times as much per unit of energy saving as a resident who reduced their emissions by 30%.

The scenarios requiring on-site generation are all associated with higher refurbishment costs and in the majority of cases, higher marginal abatement costs, which in turn mean longer pay-back periods.

Appendix 3 Household Numbers

Table 401: Household projections, United Kingdom, 1961-2033

Thousands of households

	England[1]	Wales[2]	Scotland	Great Britain	Northern Ireland[3]	United Kingdom[4]	Average hhold size **England**
1972	16,107	931	..	..	..	..	2.85
1973	16,251	943	..	..	..	..	2.83
1974	16,352	954	..	..	..	..	2.81
1975	16,455	963	..	..	..	..	2.79
1976	16,561	972	..	..	..	..	2.78
1977	16,680	980	..	..	..	..	2.76
1978	16,800	989	..	..	..	..	2.74
1979	16,929	998	..	..	..	..	2.72
1980	17,068	1,007	..	..	..	..	2.70
1981	17,362	1,025	1,884	20,271	456	20,727	2.65
1982	17,453	1,027	1,895	20,375	..	..	2.63
1983	17,585	1,033	1,908	20,526	..	..	2.62
1984	17,757	1,042	1,929	20,728	..	..	2.60
1985	17,942	1,053	1,945	20,940	..	..	2.58
1986	18,131	1,065	1,963	21,159	..	..	2.56
1987	18,335	1,079	1,978	21,392	..	..	2.53
1988	18,551	1,097	1,995	21,643	..	..	2.51
1989	18,778	1,113	2,014	21,905	..	..	2.49
1990	18,970	1,124	2,032	22,126	..	..	2.47
1991	19,166	1,113	2,043	22,322	541	22,863	2.45
1992	19,284	1,124	2,059	22,467	..	..	2.44
1993	19,391	1,134	2,076	22,601	..	..	2.44
1994	19,494	1,144	2,094	22,732	..	..	2.43
1995	19,630	1,153	2,112	22,895	..	..	2.42
1996	19,756	1,162	2,126	23,044	..	..	2.41
1997	19,874	1,172	2,139	23,185	..	..	2.40
1998	20,000	1,183	2,153	23,336	..	..	2.40
1999	20,156	1,192	2,166	23,514	..	..	2.39
2000	20,335	1,202	2,177	23,714	..	..	2.38
2001	20,523	1,212	2,195	23,930	627	24,557	2.37
2002	20,691	1,224	2,211	24,126	..	..	2.36
2003	20,831	1,235	2,230	24,296	..	..	2.35
2004	20,969	1,249	2,249	24,467	..	..	2.35
2005	21,170	1,259	2,271	..	..	..	2.34
2006	21,344	1,271	2,291	24,906	673	25,579	2.34
2007	21,527	1,284	2,314	25,125	..	..	2.33
2008	21,731	1,297	2,331	25,359	689	26,048	2.33
2013	22,868	1,366	2,440	26,674	733	27,407	2.29
2018	24,108	1,440	2,550	28,098	772	28,870	2.25
2023	25,320	1,509	2,645	29,474	810	30,284	2.22
2028	26,472	1,569	2,732	30,773	848	31,621	2.19
2033	27,536	1,620	2,813	31,969	880	32,849	2.16

1. Figures for England to 2008 are based on ONS mid-year population estimates and projected rates of household formation from trends in Census and Labour Force Survey data. Other data sources, such as the Labour Force Survey, provide direct sample survey estimates of the number of households in each year and therefore may differ from the model based figures shown here. Figures from 2002 to 2008 have been revised to be consistent with revised mid year population estimates for these years, and figures from 1991 have been updated in line with the methodology used for the 2008-based projections.

2. Household estiamtes for Wales from 1991 to 2007 were revised in August 2009 to provide a backseries consistent with the methodology changes adopted for the 2006-based projections.

3. Northern Ireland figures are Census counts from 1961 to 2001, 2008-based projections for 2008 onwards

4. All projections are 2008-based. Data for earlier years may not follow consistent definitions.

.. Data unavailable

Source: DCLG, Welsh Assembly Government, Scottish Executive, NISRA

Contact:

Telephone: 0303 444 2276

Email: housing.statistics@communities.gsi.gov.uk

Latest update	Nov-10
Next update	tbc

File:hhep1-gb

Relative Energy Efficiency Of UK Housing Stock

Figure 1 and Figure 2 indicate that in 2006, the energy efficiency of UK homes was close to the EU-27 average.

Figure 1 *Energy use[1] (kg oil equivalent/m²) for space heating per m² floor area*

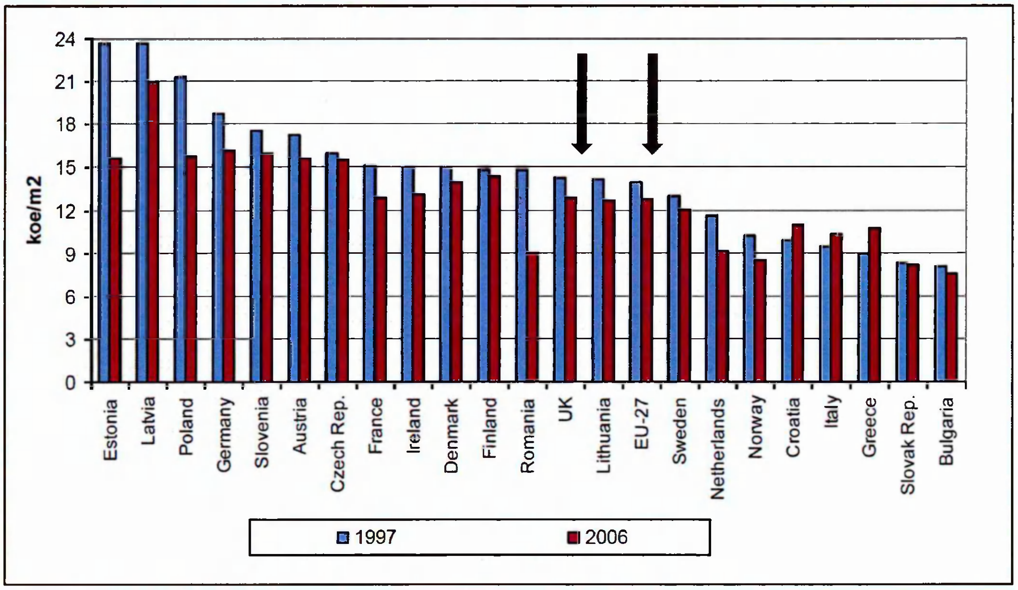
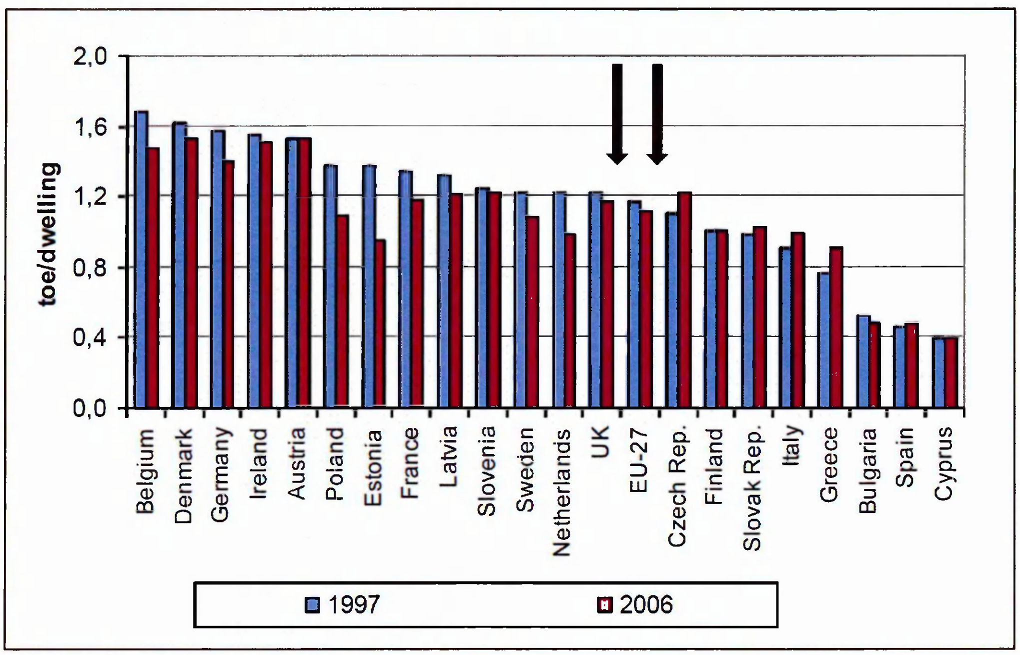


Figure 2 *Energy use[2] for space heating per dwelling (tonnes oil equivalent[3]/household/year).*



Courtesty of Boonekamp, (2009)

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[1] Adjusted to the EU average climate.
[2] Adjusted for the average climate of the country.
[3] 1 toe = 11630kWh

UK homes were collectively more energy efficient than homes in countries with similar climates, for example Ireland or Belgium (Boonekamp, 2009). Since 2003, and more particularly after 2006, the reference date for both figures, considerable resources have gone into improving the energy efficiency of the UK housing stock and the SAP rating of UK housing has increased by SAP 4.4 since 2006. Therefore, taking into account the UK's position in 2006, the rapid expansion of retro-fit since 2003 and a more demanding thermal specification for new build, it is quite likely that energy efficiency of the average UK home is actually above the EU average.

Household Income And Fuel Demand

1.0 Context and Structure

The UK literature on the correlation between income and fuel demand referenced in this thesis was all based upon secondary analysis of two databases, published by the Office for National Statistics (ONS). The most widely referenced data source is the Expenditure and Food Survey (EFS, now renamed the Living Costs and Food Survey), but a number of studies also referred to the English House Condition Survey (EHCS, now the Survey of English Housing).

As indicated in Chapter 2, the literature appears to be ambivalent about the strength of the correlation between income and household fuel demand and research by this author, suggests that these two variables are likely to be much more closely correlated than indicated in UK based studies. This observation has significant implications for energy efficiency and emission reduction policies.

This appendix is divided into six sections: the background is set out in Section 2; Sections 3 and 5 discuss how expenditure data is collected for the EFS and EHCS respectfully. Examples of when the expenditure data appears to have been incorrectly applied to examine the correlation between income and fuel demand, are discussed in Sections 4 and 5; and, the conclusions are summarised in Section 6. The bibliography for this appendix has been incorporated into the thesis bibliography.

2.0 Background

A positive correlation between income and fuel demand is well established (Utley and Shorrock, 2008, Druckman and Jackson, 2008, Kelly, 2011). However there appears to be considerable disagreement over the strength of the correlation. Weber and Matthews, (2008), Cheng (2011) report that income and expenditure are the most important predictors of residential fuel demand. Other researchers, for example, Dresner & Ekins, (2006), Roberts et al (2007) conclude that the correlation between household energy use and income is relatively weak.

Dresner and Ekins (2004) studied the 1996 EFS and the 1996 EHCS and reported a correlation between energy use and household income of r=0.17, leading them to conclude that "*household energy use and expenditures depend largely on factors other than income*".

Thumin (2011), working with Equivalized Income from the EFS (see Chapter 8 for a discussion on the drawbacks of this approach), found that the income effect size upon carbon emissions from domestic fuel was .05, that is 5% of the variation in emissions is linked to variations in Equivalised Income. In separate papers Dresner and Ekins reported that the correlation between energy use and Equivalised Income was 0.08 (2004) and 0.019 (2006). Gough (2011), also working with the EFS, reported that Equivalised Income, household composition and employment status together explained 21% (R^2=0.21) of the variations in residential emissions.

However these correlations are lower than reported in the US, where Weber and Matthews (2008) found that the correlation between household carbon emissions and income in four studies ranged from 0.46 to 0.49. Herendeen et al (1981); Lenzen et al, (2006); and Reinders et al (2003) studied energy consumption in societies as varied as India, Brasil, the USA, Denmark and Japan and collectively reported that expenditure and income were the strongest predictors of household energy requirements.

Similarly Cheng (2011) found that estimated total energy consumption from a study of the EHCS is "*significantly and substantively correlated with household income*" (r_s=0.96, $p<0.01$). Although Kelly (2011) also studying the EHCS, reported a correlation of r=0.37, $p<0.01$ between household income and household energy expenditure.

Clearly there is a contradiction in the literature over the strength of the correlation between income and residential fuel demand and the contrary conclusions, coupled with the importance of income as a policy tool and in policy impact assessment, lead to this review of the UK studies.

3.0 Income And Fuel Expenditure Statistics in the Expenditure & Food Survey (EFS)

The EFS lists UK wide, weekly, household expenditure. The information is collected by the Office For National Statistics (ONS) in household surveys and from a two week expenditure diary. The surveys are carried out throughout the year. Typically some 12,000 to 13,000, randomly selected households per year are invited to take part in the survey and the response rate is about 50% (ONS, 2009). ONS weight the database using 2001 Census information to allow for the under representation of particular socio-economic and geographical groups.

ONS (pers comm) confirmed that weekly fuel expenditure data is generated by dividing the most recent fuel bill by the billing period. In Cases where the most recent bill covered part of the 'heating season', the weekly expenditure will be greater than the annualised average of weekly fuel spending for that Case. Conversely when surveying in Autumn and early Winter, the last fuel bill is likely to cover the summer months, and the database will indicate that the fuel expenditure in that household is less than the annualised average weekly fuel spending on fuel.

Consequently the database will exaggerate the range of household fuel consumption. But because the survey is carried out throughout the year, averaged data will correct for the seasonal variations and the ONS (pers comm) recommended using averaged data when working with fuel expenditure data to address this factor.

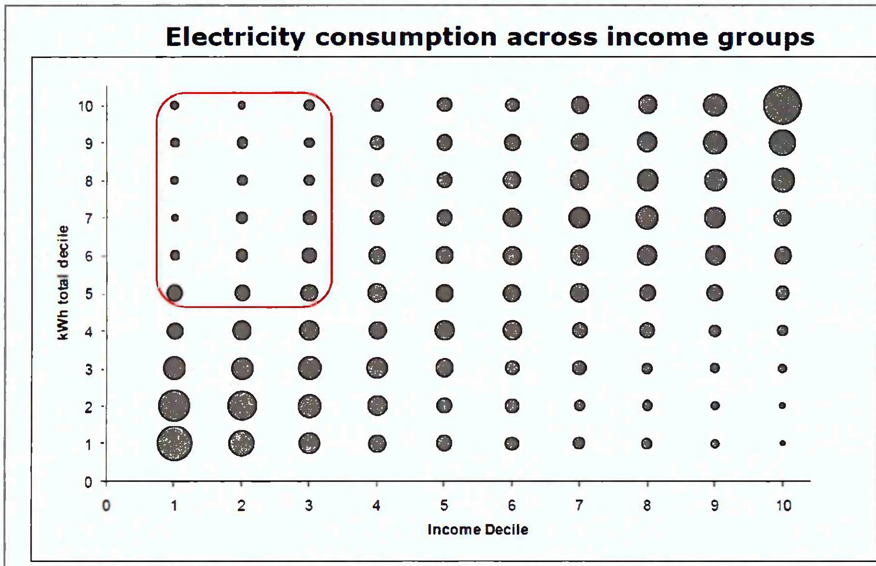
However, irregular fuel payments also distort the data. The reported weekly bill for fuel oil is derived by dividing any payment made in the last three months by 13 (ONS, pers comm). Coal and coke is accounted for in the expenditure diary and any fuel bills received in that fortnight, divided by two. Households using pre-payment meters are recorded as spending nothing on fuel, if no payment is made during the two week diary period.

Therefore households which did not buy fuel in the period specified by the ONS, or where households used their order over longer than the periods than assumed by ONS, will make the range of fuel expenditure appear greater and may enhance the distortion caused by seasonal variations in expenditure. Evidence that households which use fuel oil are distorting the expenditure range in the database is presented in Addendum 1 to this appendix, but is not focused upon further in this discussion paper.

4.0 Mis-Use Of Fuel Expenditure Data in the EFS

As a result of the distortions caused by seasonal variations in fuel expenditure and bulk buying of fuel, relatively few of the Cases reported in the EFS actually record the average weekly fuel expenditure. Therefore working with un-corrected expenditure data, as appears to be the case in the work of Dresner & Ekins[4], (2006), Roberts et al (2007), Gough et al (2011) and Thumin et al (2011), will suggest that the correlation between income and fuel expenditure is weaker than is actually the case. This is likely to be part of the reason why studies of the EFS suggest that the correlation between household income is weaker than studies based upon overseas expenditure databases, or alternative sources of UK data, such as the English House Condition Survey (EHCS).

Figure 1 *Electricity demand by income group reported by OfGEM in 2009*



Source: Centre for Sustainable Energy (2008) *Assessing the social impacts of a supplier obligation: report to DEFRA*

Source OfGEM, 2009

The apparent mis-use of the EFS to identify household fuel demand also appears in Government papers and publications. Figure 1 shows the relationship between income and electricity demand. The graph was taken from an OfGEM discussion paper

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[4] Dresner and Ekins used expenditure data from the 1996 EHCS, but prior to 2001 the EHCS fuel expenditure records were based upon household bills, rather than modelled, standardised levels of spending.

entitled *"Can energy charges encourage energy efficiency"* (OfGEM, 2009), but OfGEM had taken the graph directly from Roberts et al (2007).

The graph shows the electricity demand of households in each income decile, where a decile is one tenth of the population and Decile 1 includes the 10% of households earning the least. The width of each circle is proportional to the number of households in that particular income decile and electricity demand decile. The electricity demand deciles were calculated using fuel expenditure statistics in the EFS. However because the graph has been constructed using Case data, rather than averaged data, there will be a tendency to increase the population of the extremes.

In their 2009 discussion paper, OfGEM highlighted that the introduction of Rising Block Tariffs (see Chapter 15) would have a particularly significant impact upon low income households with high fuel demand. The 'At Risk' group is picked out by the rectangle in Figure 1. However the EFS is likely to over-estimate both, the size of this population and their fuel demand. Consequently they are likely to over-estimate the potential impact upon this group of measures which control residential demand by penalizing high consumption and rewarding energy efficiency. Figure 2 is a further example where a mis-interpretation of the EFS appears to have crept into HM Government's statistics.

Figure 2 *Fuel expenditure statistics reported by DCLG, 2008*

Table 9.2: Household expenditure: household expenditure on electricity, gas and other fuels, England, 2006-07

	Owner Occupiers		Social Renters		Private renters	All Tenures
Proportion of disposable income	Owned ouright	Buying with mortgage	Council	HA		**Total**
						thousands of households
0 - 3%	2,731	5,727	917	652	1,480	11,506
4 - 6%	2,240	1,948	554	348	467	5,556
7 - 9%	896	336	350	185	234	2,001
10% or more	725	266	345	185	246	1,768
All	**6,592**	**8,277**	**2,165**	**1,370**	**2,427**	**20,831**
						percentage
Median percentage of disposable income	4	3	4	4	3	3
						£ per week
Median expenditure	15	16	10	8	10	14

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Source:
Expenditure and Food Survey, ONS

Live table 903

Next update: September 2009

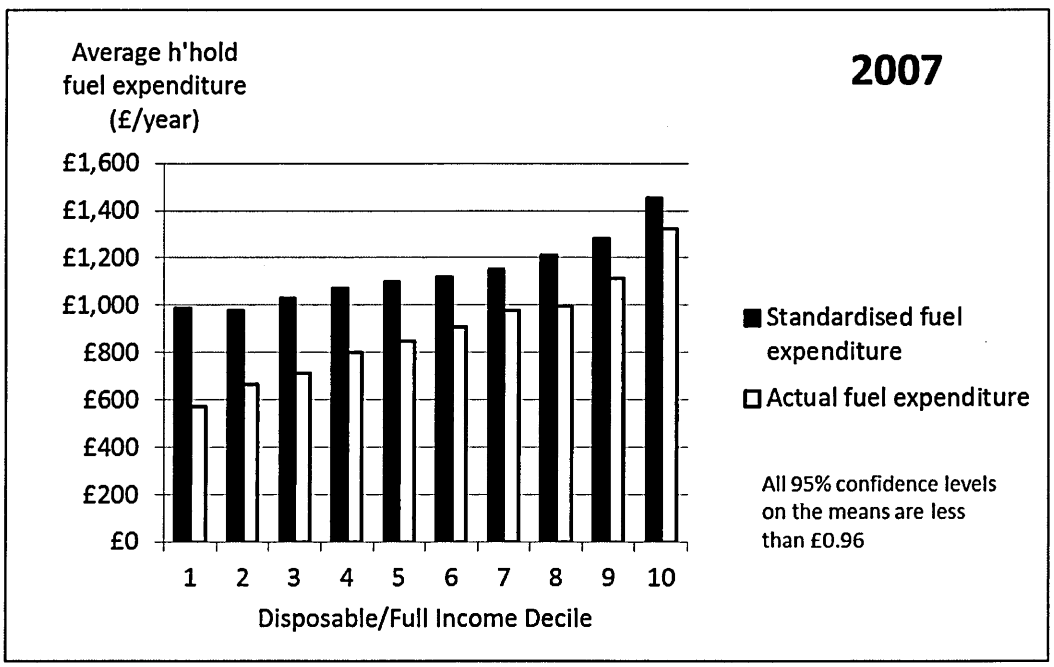
Source: DCLG, 2008c

The table in Figure 2 was copied directly from a DCLG housing paper (DCLG, 2008c). For the reasons explained previously, the extremes of the distribution are likely to have been enhanced. However in this example the use of a '10% of more' category to define the highest consuming group, makes it difficult to assess how the extremes of the distribution have been exaggerated and it is difficult to be sure how significant the distortion in the database is likely to have been.

5.0 Correlating Income And Fuel Expenditure Using The EHCS

The EHCS is a survey of some 8500 households annually, carried out throughout the year, to identify the characteristics of the housing stock. The ECHS includes fuel expenditure statistics, but the data is based upon calculations of how much energy would be required to heat and power each home surveyed to achieve a standard condition, rather than actual fuel bills. The database has been used by Cheng (2011) and Kelly (2011) to estimate the correlation between fuel demand and income. Hulme & Summers (2009) analysed the EHCS to predict the impact of Rising Block Tariffs upon low income households.

Figure 3 *Actual vs standardized fuel expenditure*



Sources: Standardised fuel expenditure from the EHCS 2007 (ONS, 2009). Actual fuel expenditure statistics from the EFS 2007 (ONS, 2009).

The contrast between standardized fuel expenditure, reported in the EHCS and actual fuel spending, recorded in the EFS, are illustrated in Figure 3. As illustrated, collectively householders do not warm their homes to standard conditions and in general, when comparing actual fuel spending to standardised fuel bills, the less a household earns, the greater the proportional underspend, in comparison to standardised fuel expenditure. Therefore, studies into the correlation between income and fuel expenditure which rely upon the EHCS, such as those by Cheng or Kelly, are also likely to under-estimate the strength of the correlation between household income and fuel spending.

6.0 Conclusions

Studies into the relationship between household income and household fuel demand using fuel expenditure data from the EFS and EHCS, under estimate the strength of the correlation between household income and spending on fuel. This conclusion has several important policy implications.

- Firstly, the demand reduction potential of policies which use fuel price controls to reduce fuel consumption and to drive the demand for energy efficient homes and products, are likely to be under-estimated. Rising Block Tariffs for domestic fuel are an example of such a policy, where the outcome is likely to be under-estimated;
- Secondly, the severity and the scale of the impact of fuel price controls upon low income, high fuel demand households, is likely to be over-estimated because the group is likely to be smaller, with lower fuel demands, than indicated by the statistics. Consequently the cost of supporting such households, is likely to be over-estimated in the event that fuel tariffs which promote energy efficiency were introduced.

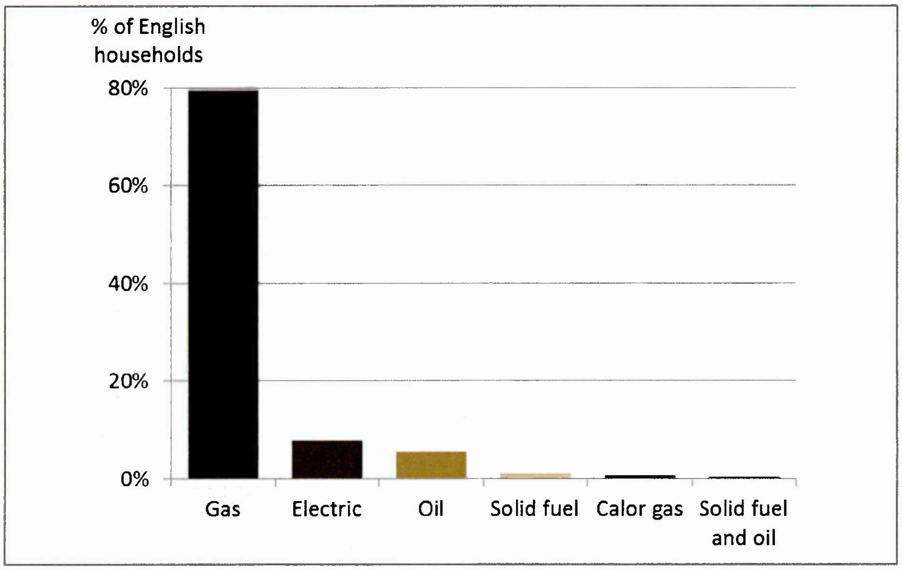
Addendum 1 to Appendix 5

FUEL OIL AND OUTLYING FUEL EXPENDITURE

Fuel Expenditure & Fuel Type

The ONS assume that boiler fuel payments cover a 13 week period, but if the fuel is used over a longer period, the data will suggest that weekly fuel expenditure on boiler fuel is greater than is the case. In which case, there is likely to be more outlying cases of households using boiler fuel than other fuels.

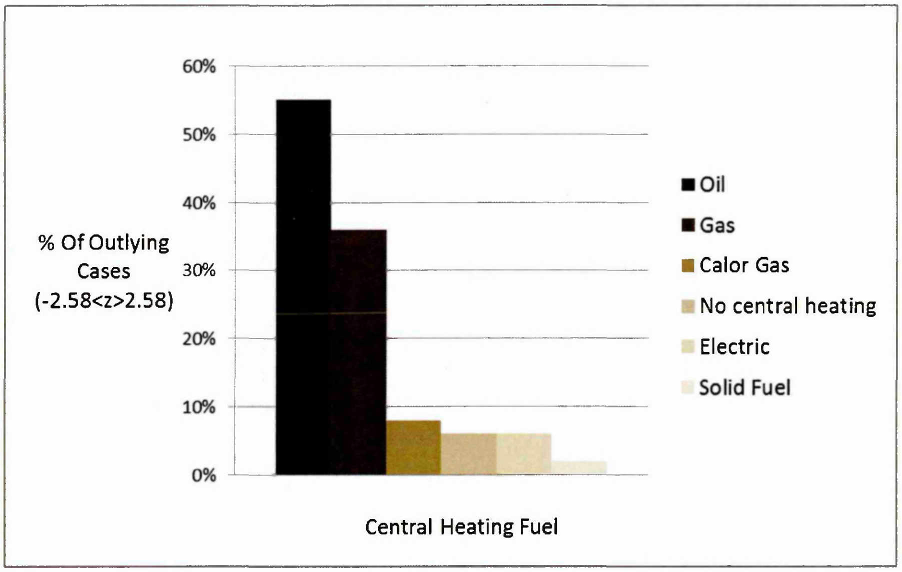
Figure A1 *Proportion Of Homes Heated By Different Central Heating Fuels*



Source: 2007 Expenditure and Food Survey (ONS, 2009)

Figure A1 shows the relative proportions of the different central heating fuels in UK homes. Gas is used in four out of five central heating systems and fuel oil in approximately 5% of homes.

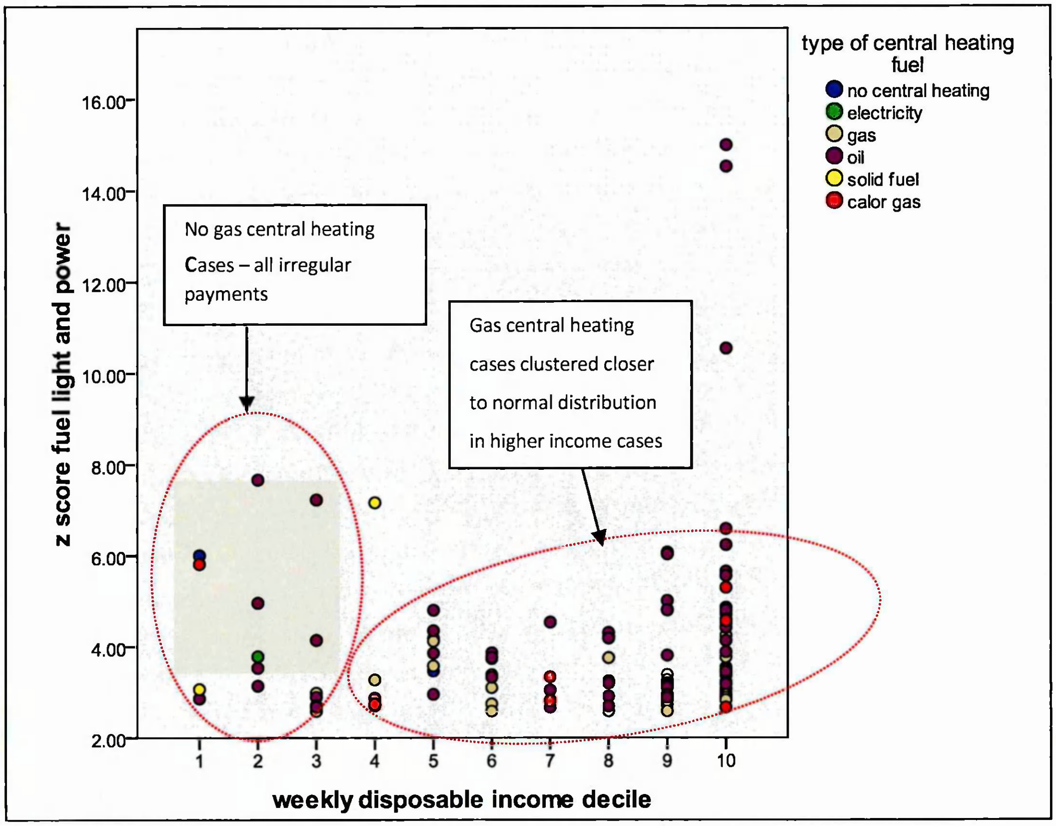
Figure A2 *Fuel Type For Cases With Outlying (z>2.58) Fuel Expenditure*



However as shown in Figure A2, households buying fuel oil make up nearly 50% of outlying cases, where z=2.58. Once calor gas and solid fuel are included, households which buy fuel irregularly make up nearly 60% of outlying cases, but these fuels are used to centrally heat less than 10% of homes. Conversely, although gas is the fuel of choice for nearly 80% of homes with central heating, only one third of cases, where fuel expenditure is outside a normal distribution, have gas central heating.

Figure A3 illustrates the how in outlying cases, those that use fuel oil are over represented and that for low income groups, none of the outlying cases are associated with gas central heating. Outlying gas expenditure tends to be associated with higher income cases and lies closer to a normal distribution.

Figure A3 *Central Heating Fuel And Fuel Expenditure z-Score (z>2.58)*



Appendix 6

Warm Front and Energy Efficiency Commitment Passport Benefits

Passport Benefits For Warm Front & The Energy Efficiency Commitment

The passport benefits are summarized in Table 1, followed by detailed supporting information from the 2001 Order. Table 3 lists the EHCS variables which record receipt of these benefits and were used to derive the Priority Group variable.

Table 1 List or Warm Front and EEC Passport Benefits

Warm Front	EEC**
• Working Tax Credit (with an income of less than an income threshold –see Schedule 2, which must include a disability element) • Disability Living Allowance • Child Tax Credit (with an income of less than an income threshold, see Schedule 2) • Housing Benefit (which must include a disability premium) • Income Support (which must include a disability premium) • Council Tax Benefit (which must	• The householder receives one of the following benefits: a) council tax benefit, b) housing benefit, c) income support, d) an income-based jobseeker's allowance under the Jobseekers Act, e) an attendance allowance under section 64 of the 1992 Act, f) an attendance payment made under the 1983 Scheme, g) a disability living allowance under

** Criteria set out in Schedule 2 The Electricity and Gas (Energy Efficiency Obligations) Order 2001

Warm Front

include a disability premium)

- War Disablement Pension (which must include a mobility supplement or Constant Attendance Allowance)
- Industrial Injuries Disablement Benefit (which must include a mobility supplement or Constant Attendance Allowance),

or, householders aged 60 or over; or householders with a child under 16; or pregnant women with a maternity certificate in receipt of one or more of the following benefits:

- Income Support,
- Council Tax Benefit,
- Housing Benefit,
- Job Seekers Allowance (income based),
- Pension Credit,
- Income-related Employment and Support Allowance.

EEC**

section 71 of the 1992 Act,

h) working families tax credit or disabled persons tax credit (2002-2003 only),

i) a war disablement pension and a mobility supplement, or constant attendance allowance; and industrial injuries disablement benefit where it includes constant attendance allowance,

j) state pension credit, 2006 onwards; or

k) receiving a working tax credit or a child tax credit, with an income less than a threshold (see Schedule 2).

Appendix 6 Passport Benefits

The following is text of Schedule 2 of the Energy Efficiency Order upon which this table was based followed by details on how income is calculated for the purposes of assessing eligibility for working tax credits and child tax credits and hence eligibility for Priority Group status.

The Electricity and Gas (Energy Efficiency Obligations) Order 2001

Schedule 2

Benefits relevant to qualifying action

The benefits relevant for the purposes of articles 6 and 10 are—

(a) council tax benefit (**d**);

(b) housing benefit;

(c) income support;

(d) an income-based jobseeker's allowance within the meaning of the Jobseekers Act 1995(**e**);

(e) an attendance allowance, that is to say—

(i) an attendance allowance under section 64 (entitlement) of the 1992 Act;

(ii) an increase of an allowance which is payable in respect of constant attendance under a scheme under, or having effect under, paragraph 4 of Part I of Schedule 8 to the 1992 Act;

(iii) a payment made under article 14, 15, 16, 43 or 44 of the 1983 Scheme or any analogous payment;

(iv) any payment based on need for attendance which is paid with a war disablement pension; or

(v) any payment intended to compensate for the non-payment of a payment, allowance or pension mentioned in any of paragraphs (i) to (iv) of this sub-paragraph;

(f) a disability living allowance under section 71 (disability living allowance) of the 1992 Act;

(g) working families tax credit or disabled persons tax credit(**f**);

(h) a war disablement pension within the meaning of section 139 (arrangements for council tax benefits) of the Social Security Administration Act 1992(**g**) or under article 10 of the 1983 Order(**h**), so far as that Order is made otherwise than under the Air Force (Constitution) Act 1917(**i**), together with—

> (i) a mobility supplement under article 26A of the 1983 Order(**m**) (including such a supplement payable by virtue of the application of that article by any other scheme or order) or under article 25A of the 1983 Scheme (including that article as applied by article 48A of that Scheme)(**n**), or a payment intended to compensate for the non-payment of such a supplement, or
>
> (ii) a payment under regulations made under paragraph 7(2)(b) of Schedule 8 to the 1992 Act (constant attendance allowance); and
>
> (i) industrial injuries disablement benefit under sections 103 to 105 of the 1992 Act where it includes constant attendance allowance.

In 2003 Schedule 2 was amended so that it included two credits which were introduced in that year, the working tax credit and the child tax credit. The Amendment Order (2003) is reproduced below:

Amendment of the Electricity and Gas (Energy Efficiency Obligations) Order 2001

2.—(1) The Electricity and Gas (Energy Efficiency Obligations) Order 2001(**1**) is amended as follows.

(2) In article 6 (qualifying action)—

(a) in paragraph (2), for the words following "domestic consumers" there are substituted—

"who are in receipt of—

(a) at least one of the benefits described in paragraph 2 of Schedule 2 to this Order; or

(b) at least one of the benefits described in paragraph 3 of that Schedule and whose relevant income is less than £14,200."; and

(b) there is added after paragraph (2) the following paragraph—

"(3) For the purpose of paragraph (2)(b) "relevant income" has the same meaning as in Part 1 of the Tax Credits Act 2002.".

(3) In paragraph (2)(d) of article 10 (information as to compliance) for the words "in receipt of a benefit described in Schedule 2" there is substituted "referred to in article 6(2)".

(4) In paragraph (1)(a) and (b) of article 12 (enforcement of energy efficiency obligations) for "Part II" in each case there is substituted "Part I".

(5) In Schedule 2 (benefits relevant to qualifying action)—

(a) in paragraph 2—

(i) for the words "The benefits relevant for the purposes of articles 6 and 10" there are substituted "The benefits relevant for the purpose of article 6(2)(a)"; and

(ii) for all after sub-paragraph (h) there is substituted—

"(i) industrial injuries disablement benefit under sections 103 to 105 of the 1992 Act where it includes constant attendance allowance; and

(j) state pension credit(**2**)."; and

(b) at the end there is added—

"**3.** The benefits relevant for the purpose of article 6(2)(b) are child tax credit and working tax credit(**3**).".

(**1**) S.I. 2001/4011.

(**2**) State pension credit is provided for in the State Pension Credit Act 2002 (c. 16).

(**3**) Child tax credit and working tax credit are provided for in Parts 1 and 3 of the Tax Credits Act 2002 (c. 21).

Working tax credit and child tax credit confer eligibility for passport benefits when relevant household income is below specific thresholds. The Priority Group income thresholds for eligibility for Priority Group status via child tax credits and working tax credits, are listed in the Table 2.

Table 2 Income Thresholds For Priority Group Status Via Child Tax Credits and Working Tax Credits

Year	Income Threshold (£/yr)	Source
2008	15460	national audit office
2007	15050	http://webarchive.nationalarchives.gov.uk/20070708092740/direct.gov.uk/en/moneytaxandbenefits/benefitstaxcreditsandothersupport/on_a_low_income/dg_10018661
2006	15050	http://webarchive.nationalarchives.gov.uk/20061211095958/direct.gov.uk/en/moneytaxandbenefits/benefitstaxcreditsandothersupport/on_a_low_income/dg_10018661
2005	14625	estimate
2004	14200	http://bromsgrovelabour.org.uk/news/local-news/60-warm-front.html
2003	14200	www.can.uk.net/.../sept_heca_forum_warm_front_presentation.ppt

Appendix 6 Passport Benefits

Table 3 EHCS Variables Which Record Receipt of Passport Benefits

HM Government Programme				Benefit available dates	EHCS Files & Variables					
Warm Front	Energy Efficiency Commitment	Decent Homes	CERT		Interview/Income.sav		Derived/Interview.sav		Derived/General.sav	
					Variable Name	Variable Label	Variable Name	Variable Label	Variable Name	Variable Label
Working Tax Credit (with an income of less than threshold (see below), which must include a disability element)				2003-2009	bnwtc	State benefits: g working tax credit				
	Working families tax credit or disabled persons tax credit,			2002-2004	bnwftc	State benefits: c working families tax credit				
Disability Living Allowance	A disability living allowance under section 71 of the 1992 Act,			2002-2009	bndlacc	Benefits: j disability living allowance (care component)				
				2002-2009	bndlamc	Benefits: l disability living allowance (mobility component)				

Appendix 6 Passport Benefits

HM Government Programme					EHCS Files & Variables					
Warm Front	**Energy Efficiency Commitment**	**Decent Homes**	**CERT**	**Benefit available dates**	**Interview/Income.sav**		**Derived/Interview.sav**		**Derived/General.sav**	
					Variable Name	**Variable Label**	**Variable Name**	**Variable Label**	**Variable Name**	**Variable Label**
Child Tax Credit (with an income of less than threshhold, see below)				2003-2009	bnctc	State benefits: h child tax credit				
Housing Benefit (which must include a disability premium)	Housing benefit,			2002-2009			housbenx	Household receives any housing benefit		
Income Support (which must include a disability premium)	Income support,			2002-2009	bnincsup	State benefits: a income support				
				2002-2009	bndisp	Benefits: m a disability premium with income support/housing benefit				
Council Tax Benefit (which must include a disability premium)	Council tax benefit,	missing								
War Disablement Pension (which must include a mobility supplement or Constant Attendance	A war disablement pension and a mobility supplement, or constant attendance allowance;			2002-2009	bnwardp	Receiving benefits: c war disablement benefit				

Appendix 6 Passport Benefits

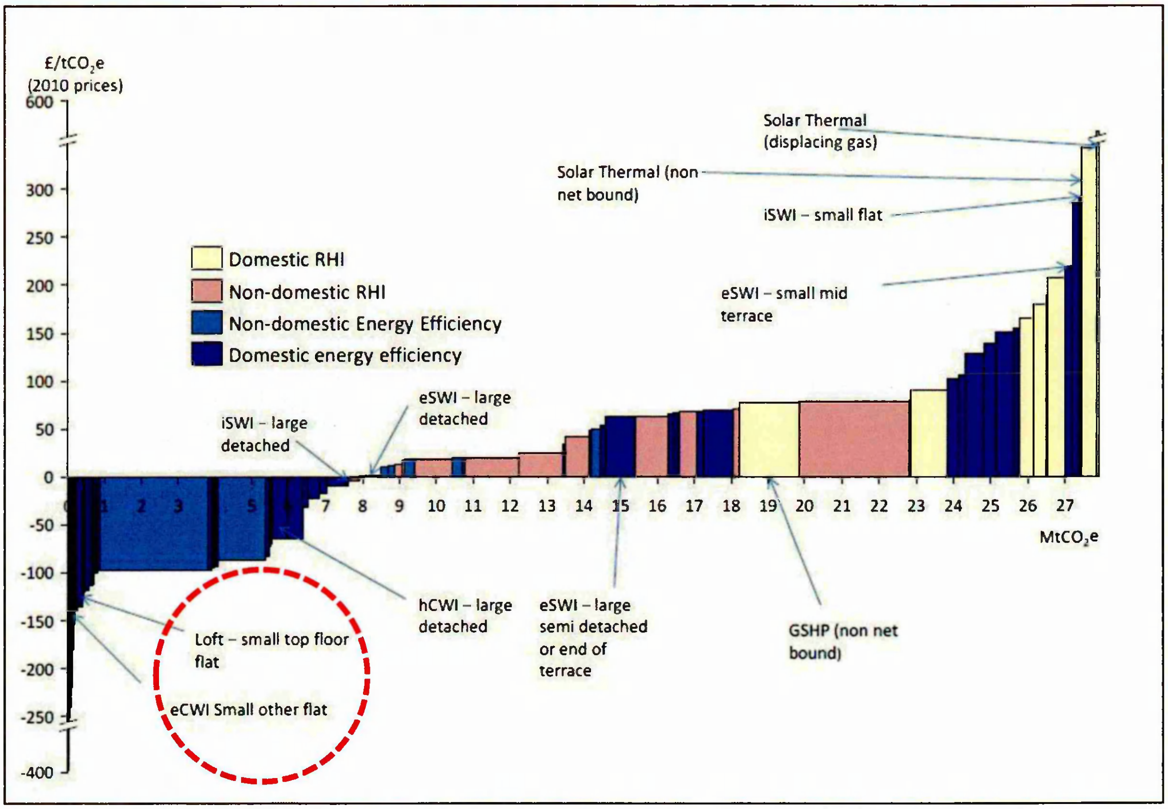
HM Government Programme				Benefit available dates	EHCS Files & Variables					
Warm Front	Energy Efficiency Commitment	Decent Homes	CERT		Interview/Income.sav		Derived/Interview.sav		Derived/General.sav	
					Variable Name	Variable Label	Variable Name	Variable Label	Variable Name	Variable Label
Allowance)	and industrial injuries disablement benefit where it includes constant attendance allowance,									
Industrial Injuries Disablement Benefit (which must include a mobility supplement or Constant Attendance Allowance),or, householders aged 60 or over; or householders with a child under 16; or pregnant women with a maternity certificate in receipt of one or more of the following benefits:				2002-2009	bniidb	Receiving benefits: f industrial injuries disablement				
▯ Income Support,				2002-2009	bnincsup	State benefits: a Income support				

Appendix 6 Passport Benefits

HM Government Programme				Benefit available dates	EHCS Files & Variables					
Warm Front	Energy Efficiency Commitment	Decent Homes	CERT		Interview/Income.sav		Derived/Interview.sav		Derived/General.sav	
					Variable Name	Variable Label	Variable Name	Variable Label	Variable Name	Variable Label
Council Tax Benefit,	Council tax benefit,	missing								
Housing Benefit,	Housing benefit,			2002-2009			housbenx	Household receives any housing benefit		
Job Seekers Allowance (income based),	An income-based jobseeker's allowance under the Jobseekers Act,			2002-2009	bnjsa	State benefits: b jobseekers allowance				
Pension Credit,				2006-2009	BnPenCrd	State benefits: b pension credit				
Income-related Employment and Support Allowance.				2008-2009	bnesa	Employment support allowance				
	An attendance allowance			2002-2009	bnaa	Receiving benefits: g attendance allowance				
		Social tenant		2002-2009					tenure4x	Tenure

Appendix 6 Passport Benefits

HM Government Programme				Benefit available dates	EHCS Files & Variables					
Warm Front	Energy Efficiency Commitment	Decent Homes	CERT		Interview/Income.sav		Derived/Interview.sav		Derived/General.sav	
					Variable Name	Variable Label	Variable Name	Variable Label	Variable Name	Variable Label
			Householder over 70	2008-2009	ageoldx	Age of oldest person in household				



Source DECC (2011g) Green Deal Impact Assessment

Figure 1 *Marginal Abatement Cost Curve (MACC), residential energy efficiency measures*

The y –axis illustrates the investment cost for each technology in £ per tonne of carbon dioxide emissions abated. The x-axis represents the total emission reductions anticipated, in Mt of carbon dioxide (equivalent) from each technology option.

Cavity wall insulation and loft insulation have been highlighted in the figure because the marginal cost of these measures is negative, that is they are predicted to save more in fuel bills than they cost to install. This is not because such measures are disproportionately effective at enhancing the thermal characteristics of a building, but because they are highly cost effective.

Appendix 8

Measures claimed under the Energy Efficiency Commitment

and CERT Supplier Obligations

Supplier Obligation Retrofit Statistics

Energy companies above a certain size are mandated to deliver specific, theoretical energy demand, or carbon dioxide emission reductions in UK homes within specified periods. The obligations for each supply company are set by OfGEM. Suppliers are free to choose how to meet their obligations. Measures adopted can include information campaigns as well as physical retrofits, although the energy efficiency measures must be approved by OfGEM. A key feature of the obligation is that suppliers are not required to spend a fixed amount (OfGEM, 2005). Consequently the policy structure promotes energy efficiency measures which deliver maximum energy efficiencies, or emission reductions, per investment.

The UK is not alone in adopting a Supplier Obligation, although the UK scheme is the largest and longest running operational programme (Lees, 2011). Italy, Denmark, Flanders and France have Supplier Obligations, and Poland and Ireland are reported to be introducing their own versions shortly (Lees, 2011).

The type of measures delivered under the Energy Efficiency Committment (2002 to 2008) and their proportional contributions to the Supplier Obligation are listed in Table 1. Table 2 provides more detail on the type of measures installed and as to be expected, low cost retro-fit options, such as loft insulation and cavity wall insulation predominate, although the EEC also funded or contributed towards over two million replacement boilers. Summary information on installations during the first three years of the four year CERT Supplier Obligation is presented in Table 3.

Table 1 *Proportion of energy savings claimed under EEC1 and EEC2, by type of measure*

Measure	EEC1[6]		EEC 2[7]		EEC 1 and 2 Combined	
	% of energy efficiencies	TWh/year	% of energy efficiencies	TWh/year	% of energy efficiencies	TWh/year
Appliances	11%	10	6%	9	19	8%
Heating	9%	8	9%	14	21	9%
Insulation	56%	49	70%	106	154	65%
Lighting	12%	10	15%	23	33	14%
Total claimed	100%	87	100%	151[8]	238	100%

Source: OfGEM, 2005 and 2008b

Table 2 *Number of measures claimed by energy suppliers under EEC1 and EEC2*

Measure	Number installed ('000's) EEC1	EEC2
Cavity wall insulation	792	1,761
Loft insulation (virgin)	226	491
Loft insulation (top-up)	528	1,297
DIY loft insulation (m^2)	15,979	31,983
Solid wall insulation	24	41
Hot water tank jackets	196	232
Draught stripping	23	30
Radiator panels (m^2)	39	62
Other insulation (m^2)	3	1,460
Compact fluorescent lamps (CFLs)	39,738	101,876
Other lighting	..	373
Energy efficiency cold and wet appliances	6,508	8,346
TVs	..	9,450
Standby savers	..	2,914
Other appliances	94	2,145
All boilers	279	2,083
Heating controls	2,366	2,236
Heating controls and replacement boilers	87	109
CHP[5]/ Communal heating	<1	10
Other heating	<1	200
Fuel switching	41	78

Source: Energy Consumption UK, DECC, 2011c [9]

[6] Ofgem (2005) Review of EEC 2002 to 2005
[7] Ofgem (2008) Review of EEC 2005 to 2008
[8] Excludes 36 TWh carried over from EEC1

[9] Office of Gas and Electricity Markets (OfGEM) - Energy Efficiency Commitment reports and issued as Table 3.20,

Table 3 *Number of measures ('000's) installed in UK homes using funding generated by CERT (Years 1-3 of a four year programme)*

CERT phase	Cavity wall	Loft (inc DIY)	Solid wall	Fuel switching	CFLs	Ground source heat pumps	Solar water heating ('000's m²)
2008-2011 (12 quarters)	1,583	3,306	37	70	297,003	5	2

Source: Energy Consumption UK, DECC, 2011[10])

[10] DECC referenced Office of Gas and Electricity Markets (OfGem) - Quarterly CERT reports and issued as Table 3.21

Appendix 9

Energy Efficiency Measures and Household Characteristics, 2007

Cross Sectional Data for Basic Energy Efficiency Measures, 2007

The data in Tables 1 to 3 is expressed negatively, for example, tables refer to the number of homes where the cavity walls remain unfilled, or the number of homes without at least 125mm of loft insulation. By reporting the negative, the data shows where most retro-fit work is required and by counting the number of cases where a measure is absent, the influence of new homes, where such energy efficiency measures are incorporated as standard, is controlled for when retro-fitting trends are studied in greater detail in later chapters.

Some of the statistics in this chapter are based upon the number of English dwellings and others are based upon the number of English households. The two are similar but not the same. In 2007 there were 22,189,000 dwellings and 21,380,000 households (DCLG, 2010a).

Table 1 Tenure, floor area, household composition and income in homes with lofts and ***less than 100mm of loft insulation****, England, 2007*

	Homes with lofts	Dwellings <100mm loft insulation ('000's)	Dwellings <100mm loft insulation (%)
Tenure			
owner occupied	14833	4184	28%
private rented	2167	939	43%
local authority	1451	255	18%
Registered social landlord (RSL)	1457	188	13%
Total dwellings	19908	5565	28%
Floor area			
less than $50m^2$	1383	398	29%
50 to $69m^2$	4338	1149	26%
70 to $89m^2$	6159	1797	29%
90 to $109m^2$	3170	920	29%
$110m^2$ or more	4859	1301	27%
Total dwellings	19908	5565	28%
Household composition			
couple under 60	3689	1037	28%
couple 60 or over	3600	930	26%
couple with children	4845	1299	27%
lone parent	1289	359	28%
multi-person h'hold	1370	450	33%
one person under 60	1811	560	31%
one person 60 or over	2633	688	26%
Total households	19328	5323	28%
Income quintile			
1st quintile (lowest)	3735	1031	28%
2nd quintile	3862	995	26%
3rd quintile	3835	1100	29%
4th quintile	3823	1136	30%
5th quintile (highest)	3983	1061	27%
Total households	19238	5323	28%

Source DCLG (2010c) EHCS Report Table SS6.4

Table 2 Tenure, floor area, household composition and income in homes with ***un-insulated cavity walls****, England, 2007*

Tenure	***Dwellings with cavity walls (000's)***	***Un-insulated dwellings ('000's)***	***Un-insulated dwellings (%)***
owner occupied	11046	5894	53%
private rented	1451	991	68%
local authority	1489	660	44%
RSL	1541	717	46%
Total dwellings	15527	8260	53%
Floor area			
less than $50m^2$	1684	948	56%
50 to $69m^2$	301	2005	56%
70 to $89m^2$	4524	2386	53%
90 to $109m^2$	2323	1173	50%
$110m^2$ or more	3396	1748	51%
Total dwellings	15527	8260	53%
Household composition			
couple under 60	2821	1623	58%
couple 60 or over	2872	1276	44%
couple with children	3500	1919	55%
lone parent	1002	568	57%
multi-person h'hold	917	503	55%
one person under 60	1578	954	60%
one person 60 or over	2355	1104	47%
Total (households)	15044	7949	53%
Income quintile			
1st quintile (lowest)	2975	1472	49%
2nd quintile	3187	1656	52%
3rd quintile	3061	1632	53%
4th quintile	2959	1593	54%
5th quintile (highest)	2862	1596	56%
Total (households)	15044	7949	53%

Source DCLG (2010c) EHCS Report Tables SS6.4 and SS6.6

*Table 3 Tenure, floor area, household composition and income in homes with **non-condensing boilers**, England, 2007*

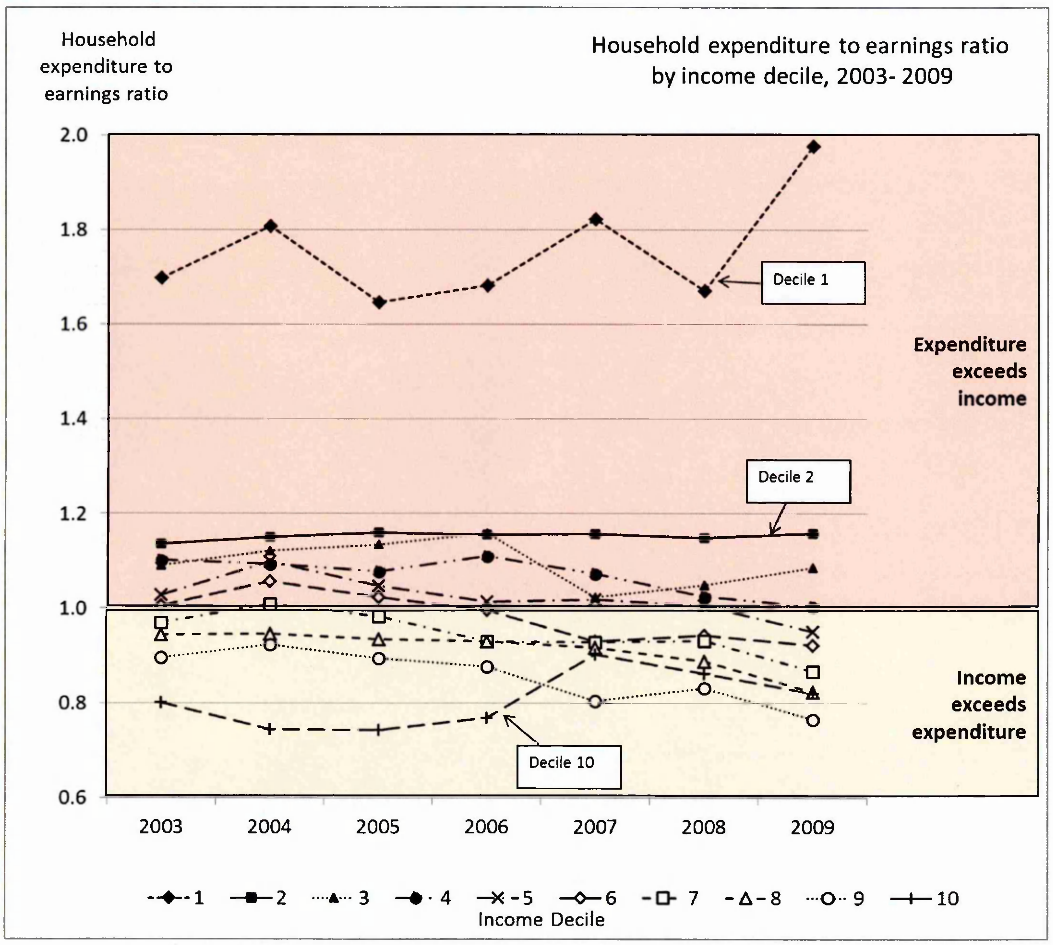
	Dwellings with boilers (000's)	***Non-condensing boilers (000's)***	***Non-condensing boilers (%)***
Tenure			
owner occupied	14225	12425	87%
private rented	2121	1872	88%
local authority	1672	1401	84%
RSL	1529	1315	86%
Total	19547	17012	87%
Floor area			
less than $50m^2$	1467	1247	85%
50 to $69m^2$	4384	3803	87%
70 to $89m^2$	5877	5140	87%
90 to $109m^2$	3063	2735	89%
$110m^2$ or more	4757	4088	86%
Total	19547	17012	87%
Household composition			
couple under 60	3656	3181	87%
couple 60 or over	3418	2974	87%
couple with children	4792	4154	87%
lone parent	1329	1157	87%
multi-person h'hold	1366	1184	87%
one person under 60	1915	1678	88%
one person 60 or over	2494	2214	89%
Total (households)	18970	16542	87%
Income quintile			
1st quintile (lowest)	3683	3221	87%
2nd quintile	3761	3307	88%
3rd quintile	3727	3260	87%
4th quintile	3758	3310	88%
5th quintile (highest)	4040	3445	85%
Total (households)	18970	16542	87%

Source DCLG (2010) EHCS Report Table SS6.4 and SS6.6

The Relationship Between Household Expenditure and Income, 2003 to 2009

Income and expenditure data from the Food and Expenditure Survey, later renamed the Living Costs and Food Survey, from 2003 to 2009 are illustrated in Figure 1. The figure shows total annual expenditure divided by annual income. The data is divided by income decile, where Income Decile 1 is the 10% of households which earn the least. Where the ratio exceeds 1, the average annual household expenditure exceeded the annual average income. Generally average reported incomes were less than average spending in Income Deciles 1 to 5.

Figure 1 *Household expenditure to income ratios by income group, 2000 to, 2009, UK*

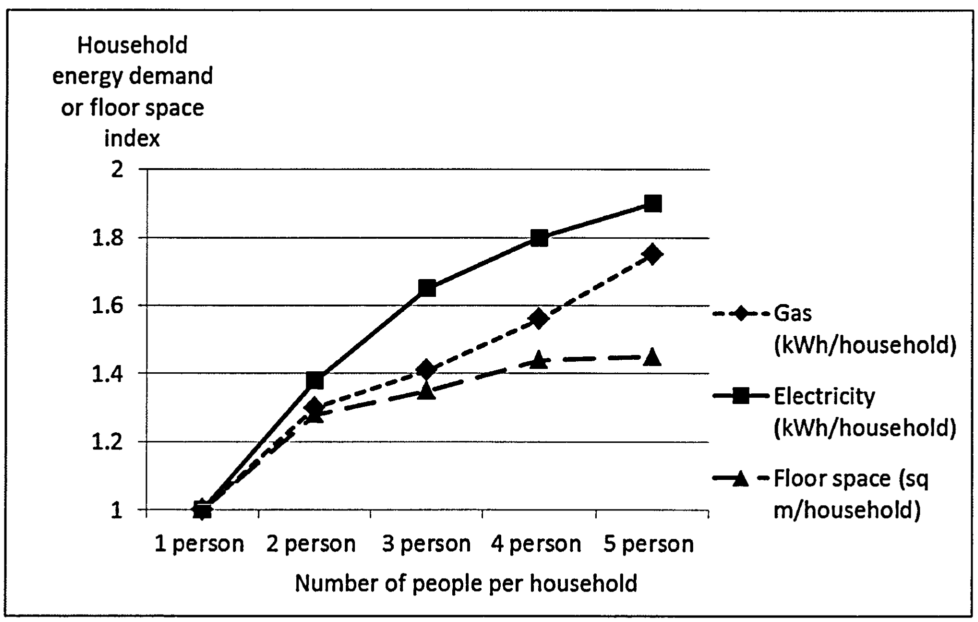


Fuel Demand and Household Characteristics

The characteristics of the property determine how much energy is required to deliver a certain level of energy services, but the householder controls the level of consumption. Consequently Fawcett (2011) argued that energy efficiency initiatives need to consider the householder, as well as the home, because people living in similar or identical homes, can have very different energy fuel demand and consumption patterns.

In average homes, the higher the headcount, the more fuel is used and the larger the area of the home. However as illustrated below the relationship between these variables is neither linear, nor is it the same for each. The additional energy used by an extra person diminishes as the household grows. The figure is based upon Fawcett's indices, reproduced by Boardman (2010), and the graph illustrates the diminishing demand for fuel and space per capita, as the number of heads per household rises. Typically a five person household lives in a house which is 50% bigger than a single occupancy property, but they will consume nearly 100% more electricity.

Household fuel demand and floor space by household headcount



Source: Boardman (2010) quoting Fawcett, Lane and Boardman (2000)

Chapter 9

Treatment of incomes

Modelling of incomes for 2004-05 and 2005-06 data sets

9.1 Household net income in this report refers to the annual net income of the Household Reference Person (HRP) and any partner from wages, pensions, savings and benefits. It does not include any council tax benefit, housing benefit, Income Support Mortgage Interest (ISMI) or any payments made under a Mortgage Payment Protection Insurance policy (MPPI). This net income is modelled from raw data collected on gross incomes with missing data imputed as described below.

9.2 The interview survey collected information on the main components of income for the HRP and any partner. These include:

- Earnings from main job as employee or as self-employed
- Earnings from other work
- Earnings from Government schemes
- State benefits including state pensions
- Occupational pensions, private pensions and annuities
- Income from savings and investments
- Any other regular income such as rent from lodgers, maintenance payments etc.

9.3 The data were thoroughly checked for inconsistencies and errors although they were only corrected where it was totally implausible. Where respondents said that they were in receipt of benefits but were unable to specify the amount, an estimate was inserted using basic allowances where possible. Households were only allocated income from benefits that they said that they received. If they were entitled to other benefits but were not claiming them, then estimates for these were not included.

9.4 Where respondents were working and amounts were missing, data from ASHE; the Annual Survey of Hours and Earnings (previously known as the New Earnings Survey) on average incomes by sex, age and socio-economic group were used to fill these missing values. Where such respondents were receiving a private or occupational pension, mean amounts from respondents who did provide data were calculated by age, sex and socio-economic group and used to fill in missing data. From 2005, averages were calculated using medians instead of means as this better reflects the characteristics of skewed distributions such as are common with income data.

9.5 Tax and national insurance payable was calculated, where appropriate, and these amounts were deducted to give total net annual household income. Where the calculated annual net income was lower than the household's basic calculated income support, the amount was changed as follows. Where these households were receiving one or more of the main benefits (excluding child benefit) they were allotted their basic income support plus any disability premiums that they might qualify for. Where they were not in receipt of any of these benefits, their income was reset to missing (as it was assumed key components had been missed or seriously under-reported). For households where income data were missing, these data were filled in using the mean (median for 2005/06) for households as defined by working status, socioeconomic group and whether HRP had a partner. Table 1 illustrates the number and percentage of cases having different types of data imputed.

Table 1: Type of imputation used in EHCS income modelling

	Frequency	Percent
None, all data OK	11,036	68.7
Some private sources imputed	535	3.3
Some benefit amounts imputed or changed	1,695	10.6
Some private and some benefits imputed	173	1.1
Household total imputed using group mean	668	4.2
Was below basic IS – imputed using group mean	298	1.9
Was below basic IS – imputed using basic IS	1,498	9.3
Was below basic IS – imputed using basic IS plus disability premiums	156	1.0
Total	**16,059**	**100.0**

9.6 Information was also collected on savings for HRP and partner. Some 8% of cases had missing information on savings. A model developed using segmentation analysis of 2001 data and updated using the latest 2004 data was applied to attribute missing amounts. Information was also collected on the total income of any additional benefit units in the household and on housing benefit, council tax benefit, ISMI and MPPI, but none of these are included in the income variable described in this report.

Comparisons with data from other sources

9.7 Comparisons carried out with incomes reported in the Expenditure and Food Survey (EFS) showed close agreement apart from households containing additional adults (Table 2). For these households, the EHCS incomes used in this report are lower because the amount assessed as household income just includes that of the HRP and any partner, whereas the EFS household income includes all household members. Other differences in the definition used do exist, for example treatment of Winter Fuel Payment, however, where EHCS incomes include other benefit units in the households, the figures are much closer.

Table 2: Comparisons between EHCS and EFS net weekly income

Household Composition	EFS 2005 weekly disposable income (£)	EHCS 2005 income of HRP and partner (£)
One adult	257	247
One adult, one child	274	246
One adult, two or more children	294	265
One man and one woman	538	502
Two men or two women	512	316
One man, one woman, one child	647	617
One man, one woman, two children	706	677
One man, one woman, three children	687	614
Two adults, four or more children	680	509
Three adults	712	448
Three adults, one or more children	753	564
Four or more adults	974	443
Four or more adults, one or more children	866	529
Total	**500**	**441**
Tenure		
Owner Occupied	579	506
Private Rented	415	377
Local Authority	255	214
RSL	260	234
Total	**500**	**441**
Age of HRP		
Less than 30	432	369
30 to 49	613	546
50 to 64	549	456
65 to 74	350	325
75 or over	260	247
Total	**500**	**441**

Screening to identify Independent Variables

To identify independent variables for more detailed assessment, the strength of association between a series of independent variables and whether a home had fitted cavity wall insulation was studied in owner occupied households. The association between the variables listed below and cavity wall insulation was tested using Chi Squares and Cramer's V.

- Useable floor area
- Quintiles of the value of private homes
- Appearance of the area
- Age of Household Reference Person (HRP)
- Employment status (primary) of HRP
- Ethnic group of HRP
- Net household income quintiles
- BHC equivalised income quintiles
- Length of home ownership
- Receives means tested benefits
- The level of householder equity in home
- How likely to move in next five years
- Level of demand in the area
- How easy is it to meet fuel bills (2005 onwards)
- How easy is it to meet mortgage costs (2005 onwards)

The screening variables with the strongest association with homes with cavity wall insulation are listed in Table 1 and Table 2 lists the variables where the strength of the association increased the most between 2003 and 2007.

Appendix 13

Table 1 Variables With Strongest Association With CWI In Private Homes In 2007

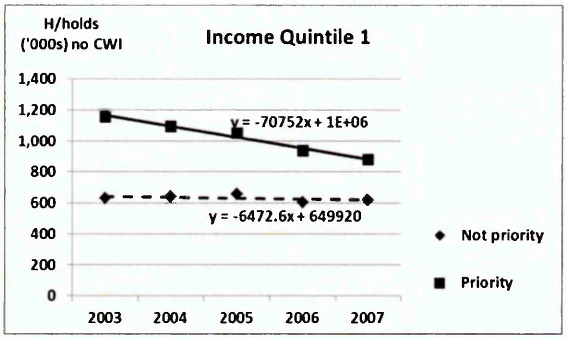
Independent Variable	P of Chi Square	Cramers V	Most significant difference with expected situation
Age of Household Reference Person (HRP)	<0.005	0.102	230,000 (4%) fewer working age (25 to 54 yrs) owners and 219,000 (7%) more 65yrs+ with CWI.
HRP employment	<0.005	0.101	220,000 (4%) fewer f/t workers, 220,000 (7%) more retired with CWI.
Floor area	<0.005	0.071	140,000 (6%) fewer smaller homes (<70m^2) with CWI.
Ethnicity of householder	<0.005	0.064	75,000 (14%) fewer non-white owners with CWI.
Equity in home	<0.005	0.058	<c£180,000 equity, the likelihood that CWI is installed decreases. 60,000 (7%) fewer owners with <£50k equity with CWI

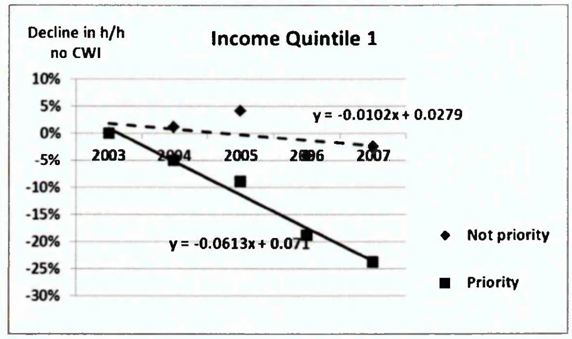
Table 2 Variables With The Strongest Increases In Association With CWI

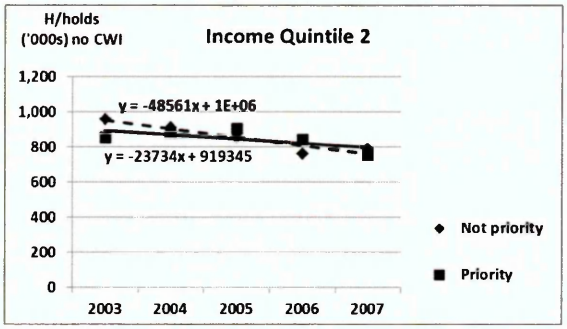
Variable	Cramers V		Trend
	2003	2007	
HRP age	0.053	0.102	125,000 (6% of group) fewer 45 to 54 year old home owners than would be expected have fitted CWI. Young and old home owners more likely to have installed CWI.
HRP employment	0.053	0.101	Those without CWI are increasingly likely to be of working age and a disproportionate number are unemployed.
Receives means tested benefits	0.005	0.053	An increasing proportion of homes without CWI do not receive benefits
Ethnicity of householder	0.047	0.064	An increasing proportion of homes without CWI are owned by non-whites (5% of homes are owned by non-whites)
Equivalised (BHC) income	0.026	0.043	An increasing proportion of homes without CWI are owned by high earning families (Quintiles 3, 4 and Highest).

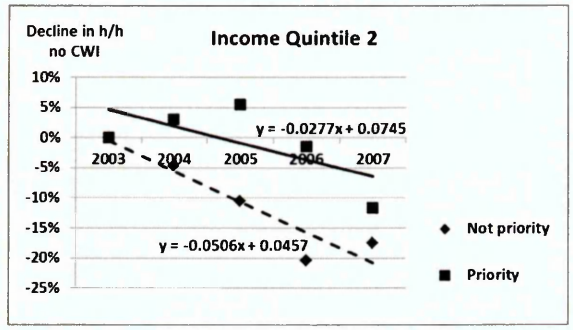
Appendix 14 – Retrofitting Trends

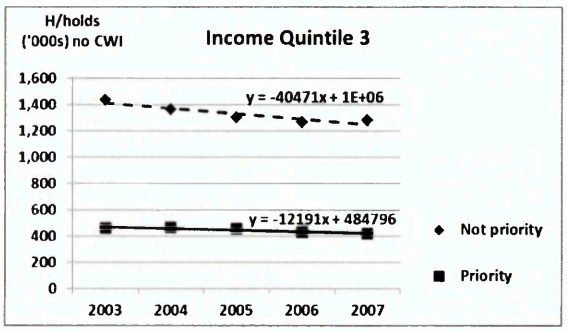
Decline In Un-insulated Cavity Walls By Income And Priority Group Status

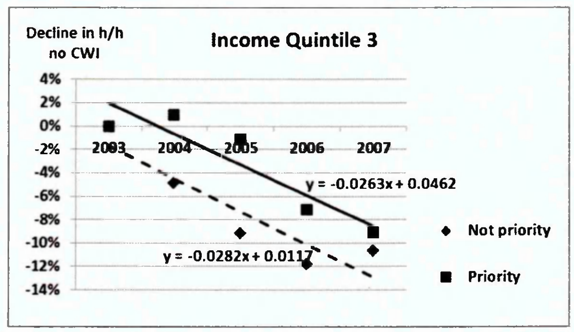


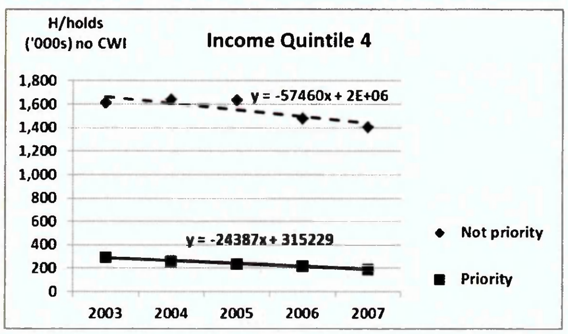


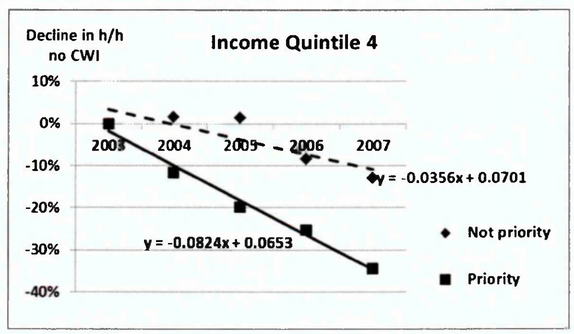


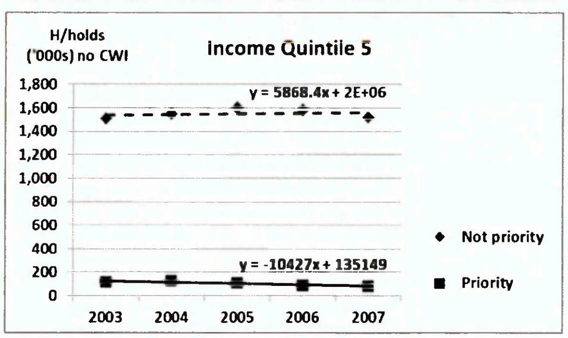


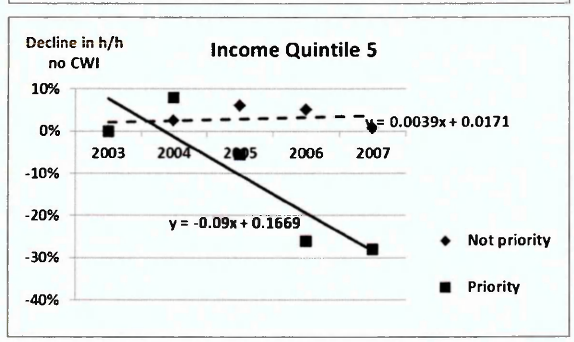






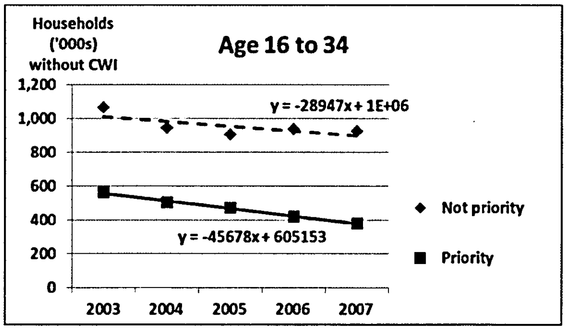


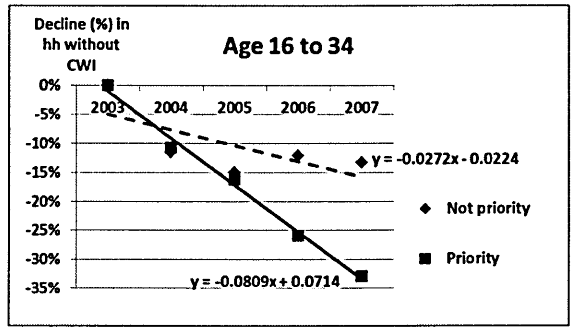


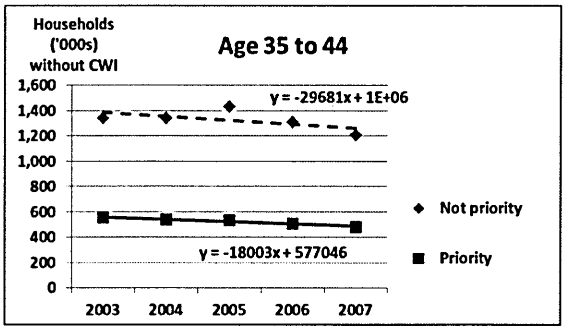


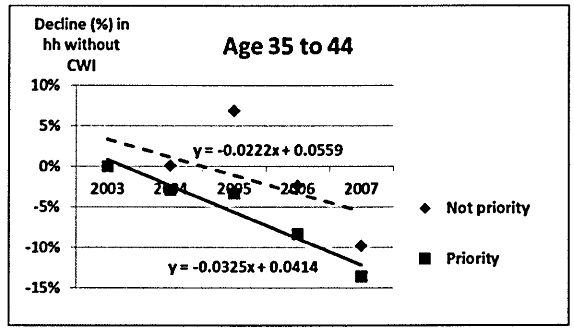
Source: English House Condition Survey and English Housing Survey (various years)

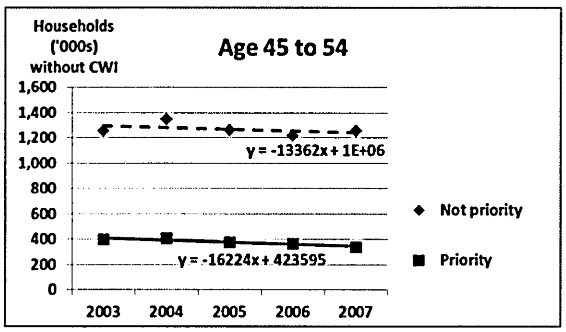
Decline In Uninsulated Cavity Walls By Age And Priority Group Status

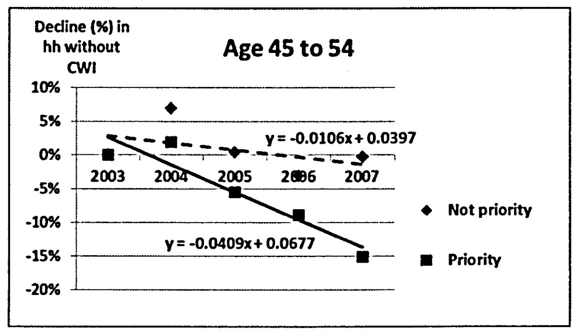


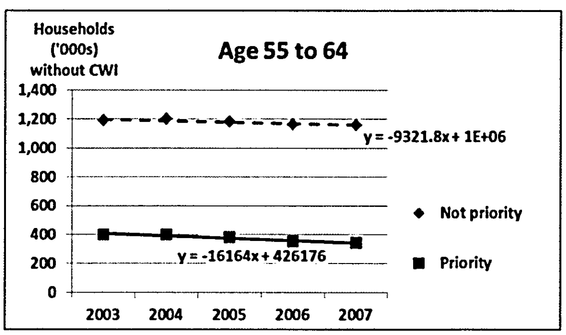


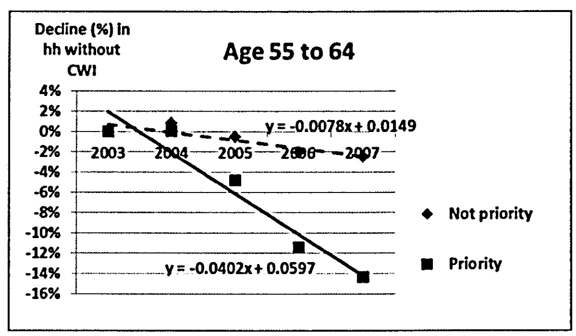


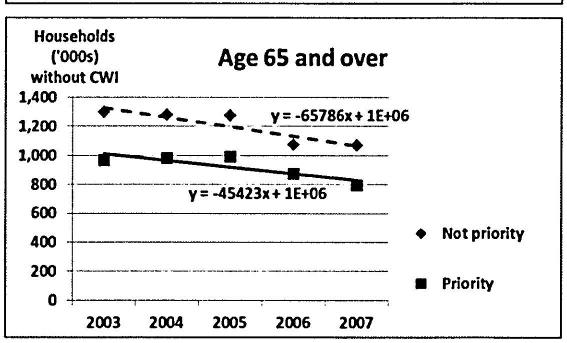


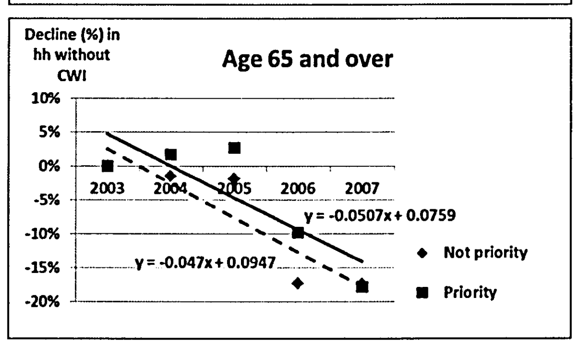






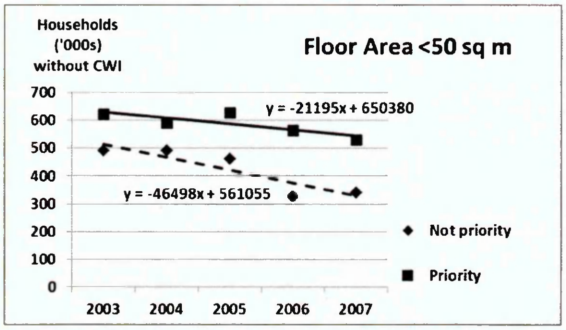


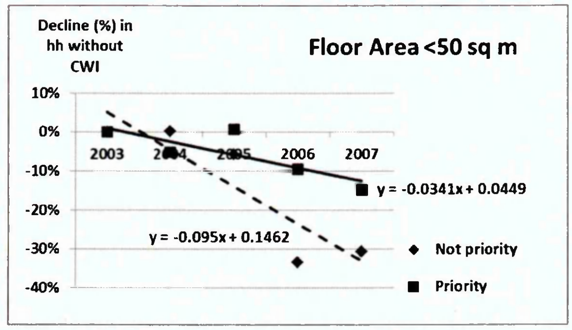


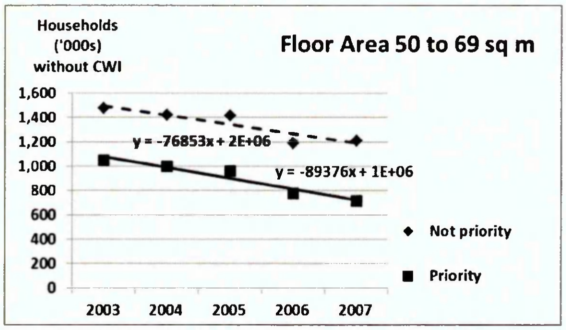


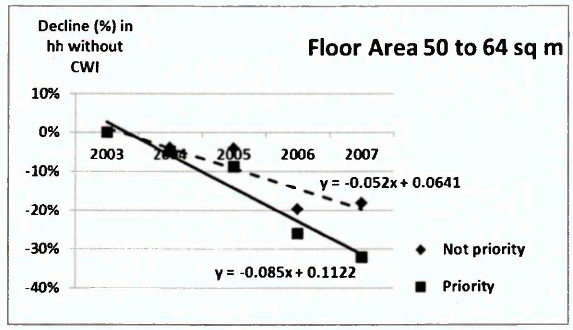
Source: English House Condition Survey and English Housing Survey (various years)

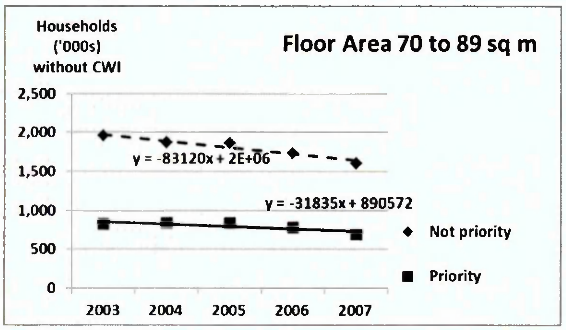
Decline In Uninsulated Cavity Walls By Floor Area And Priority Group Status

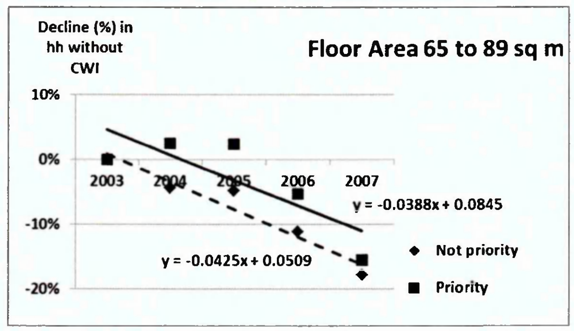


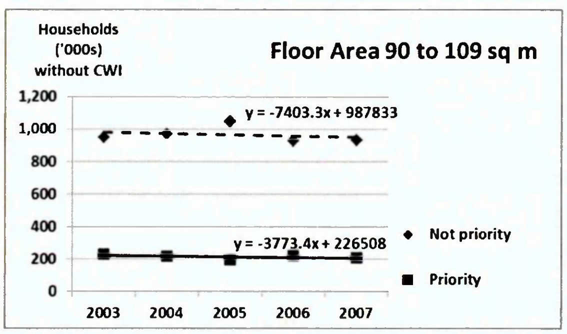


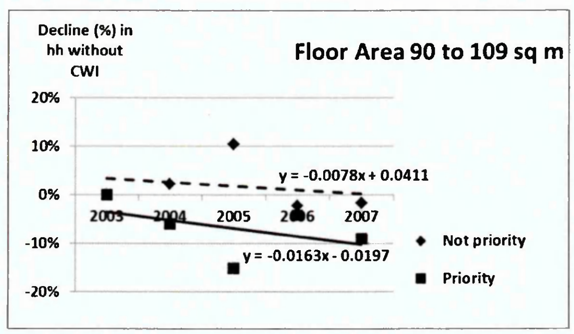


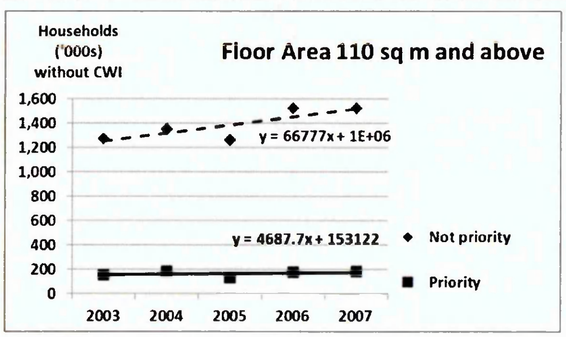


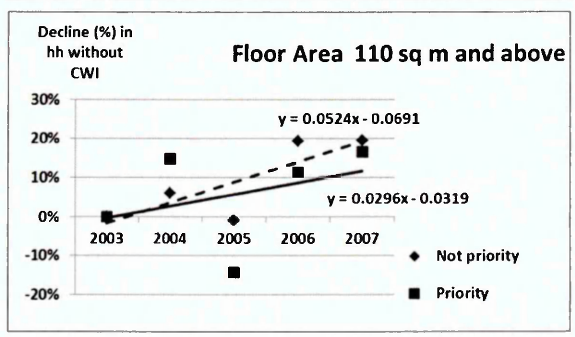






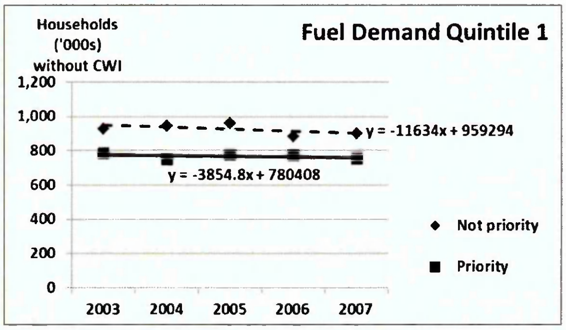


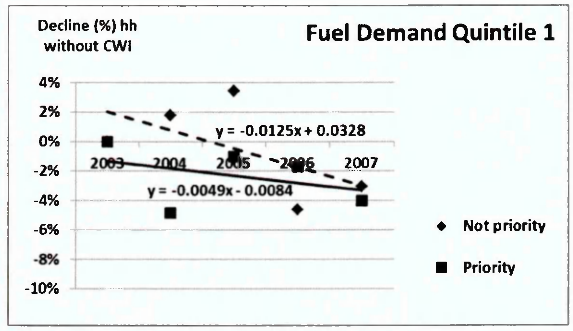


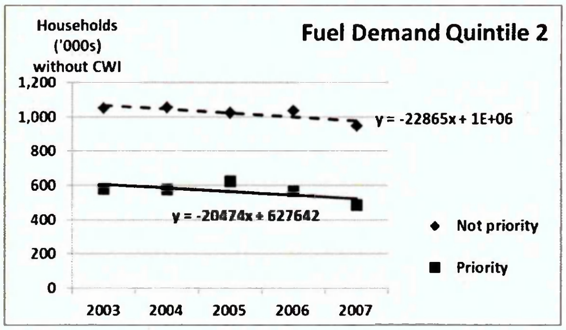


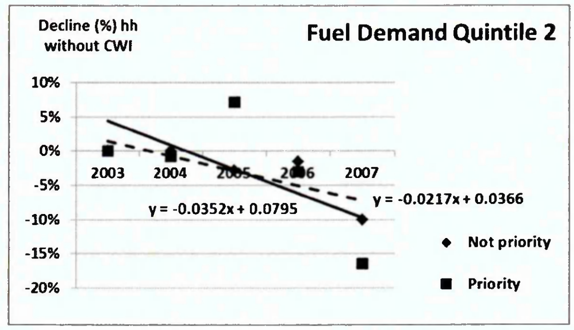
Source: English House Condition Survey and English Housing Survey (various years)

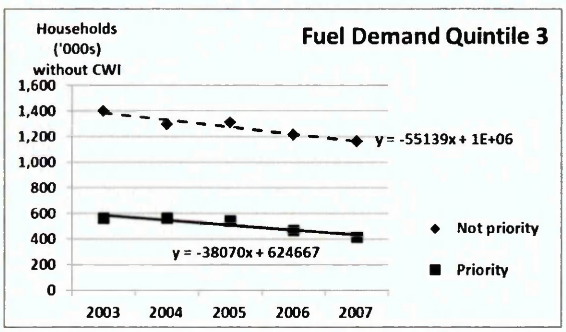
Decline In Uninsulated Cavity Walls By Standard Fuel Expenditure And Priority Group Status

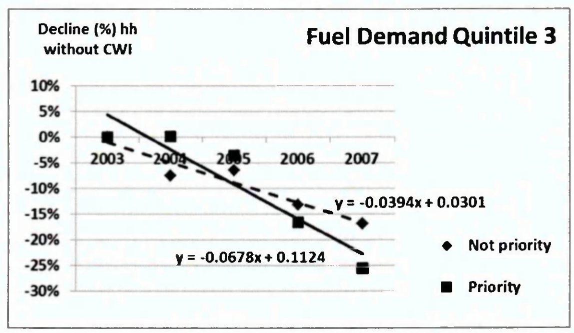


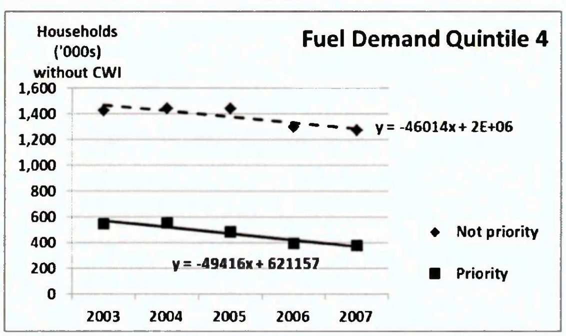


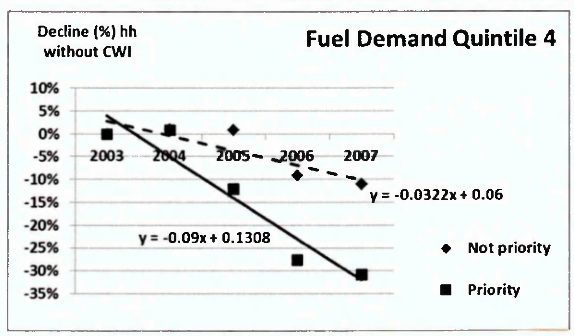


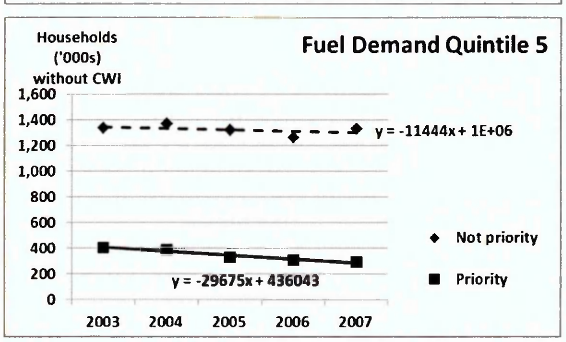


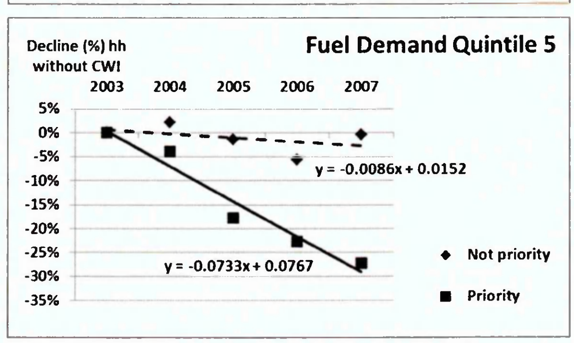






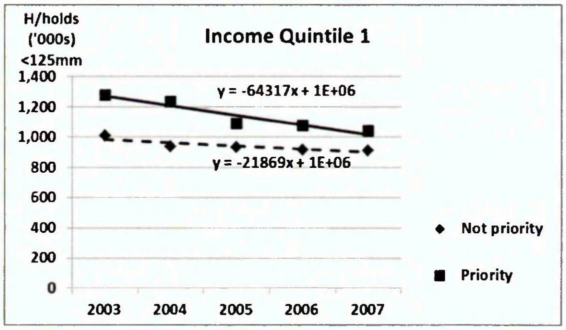


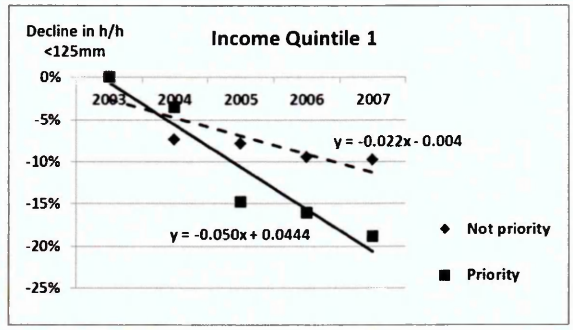


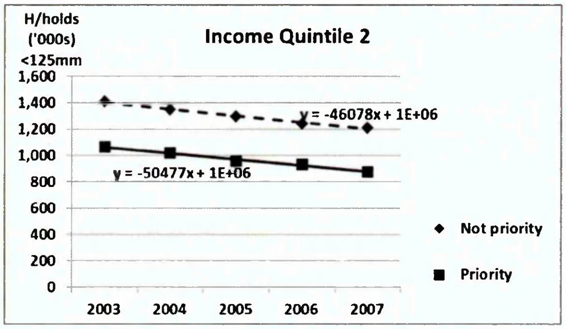


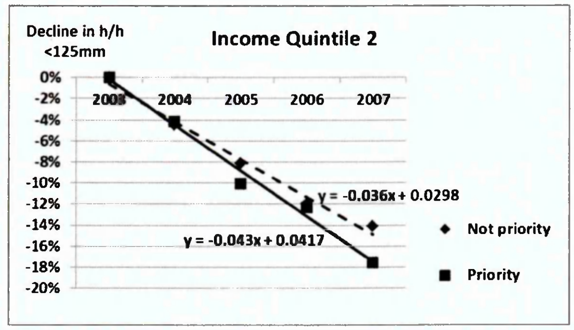
Source: English House Condition Survey and English Housing Survey (various years)

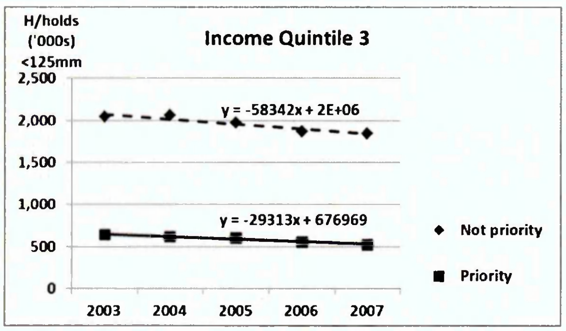
Decline (%) In Under Insulated Lofts By Income And Priority Groups

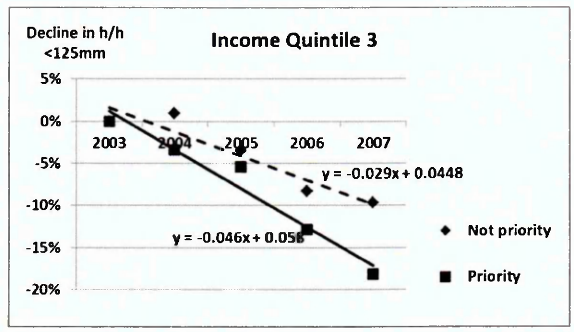


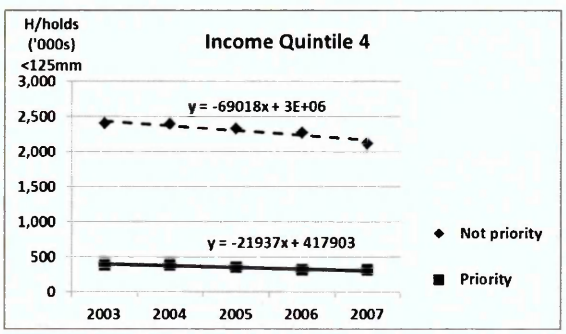


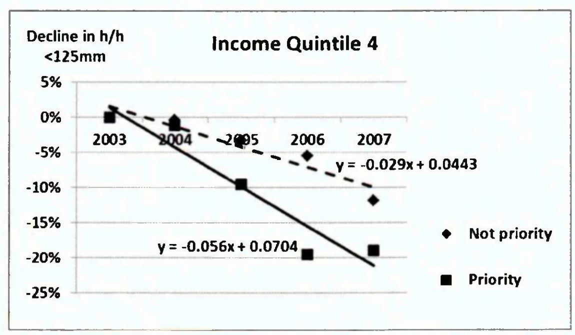


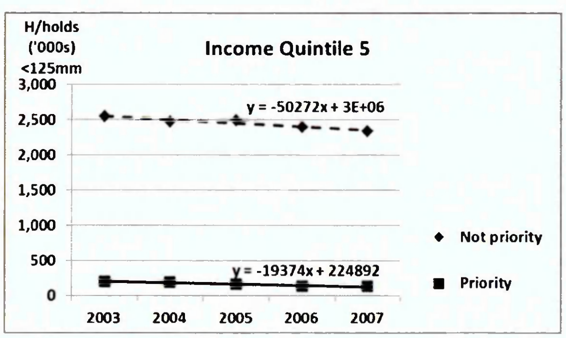


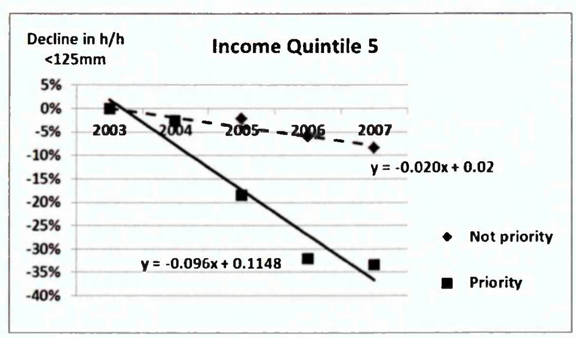




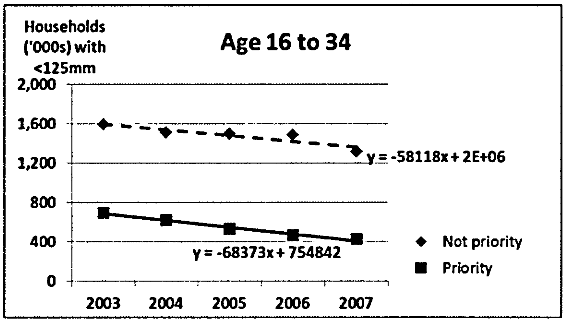


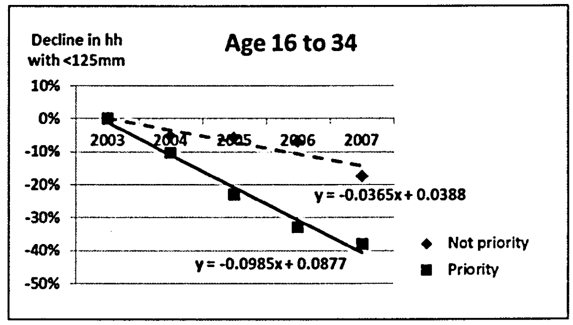


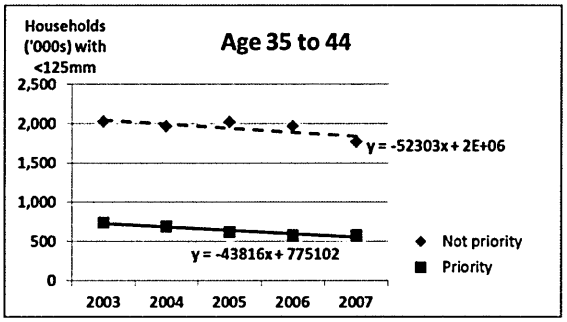


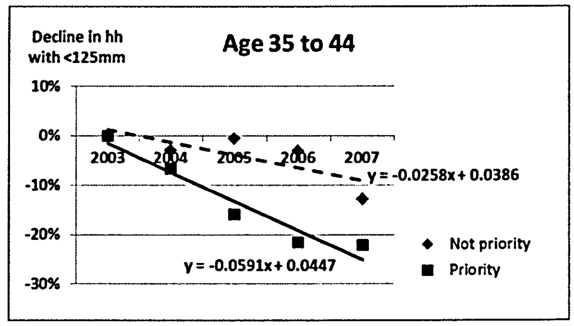


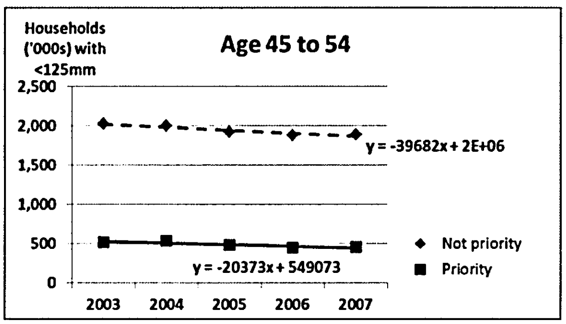
Decline (%) In Under Insulated Lofts By <u>Age</u> And Priority Groups

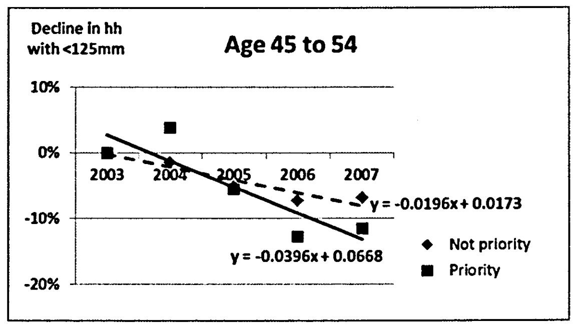


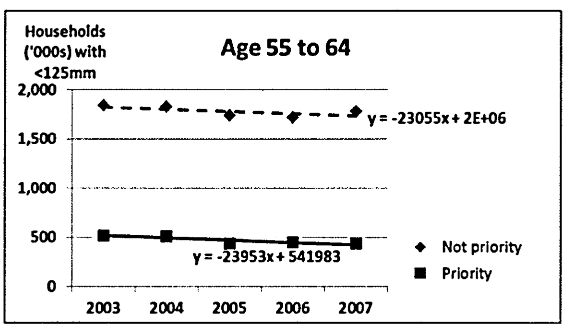


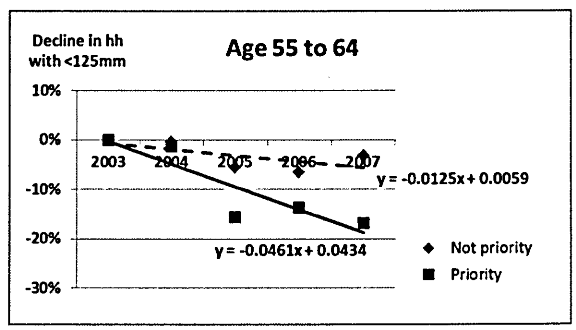


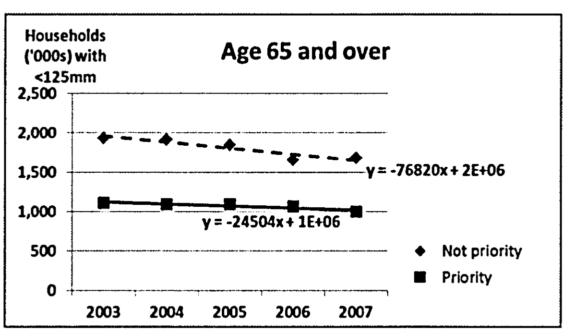


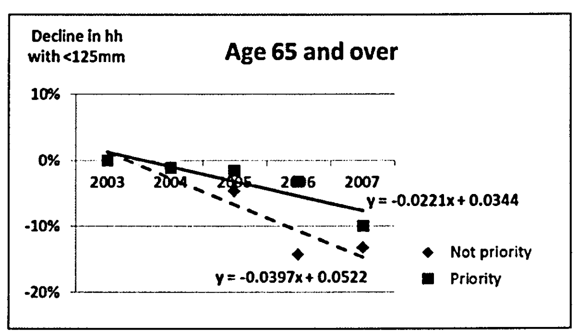






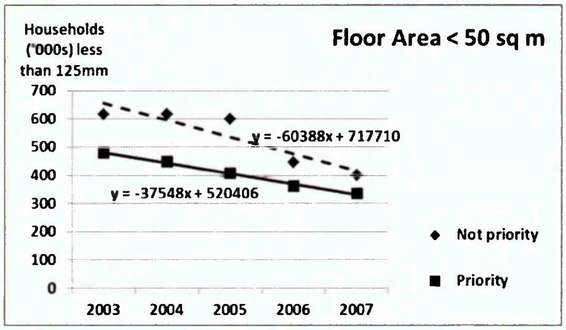


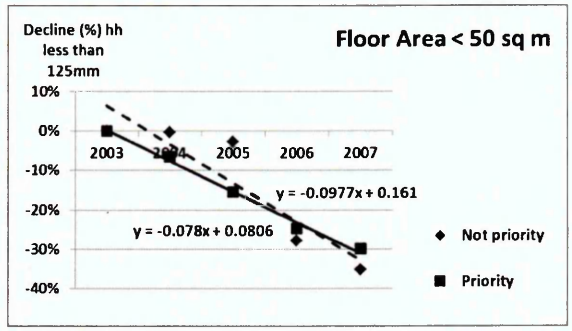


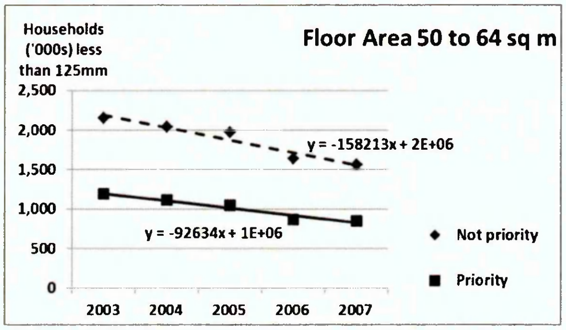


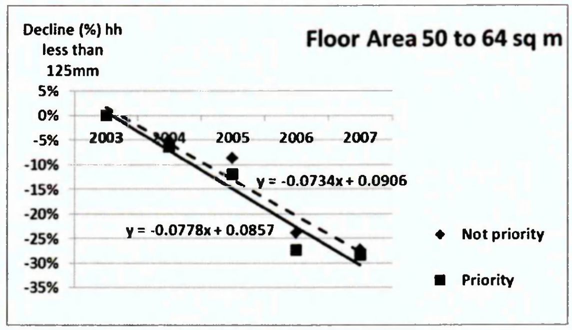
Source: English House Condition Survey and English Housing Survey (various years)

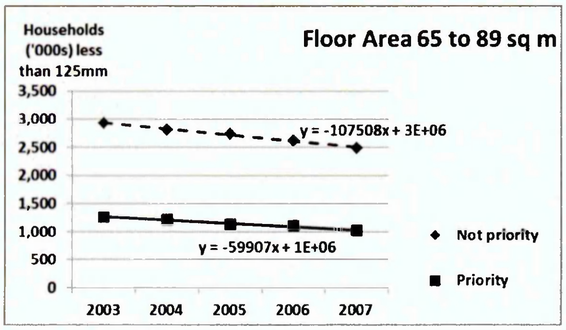
Decline (%) In Under Insulated Lofts By Floor Area And Priority Groups

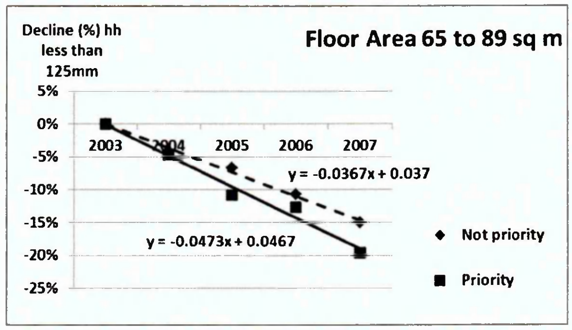


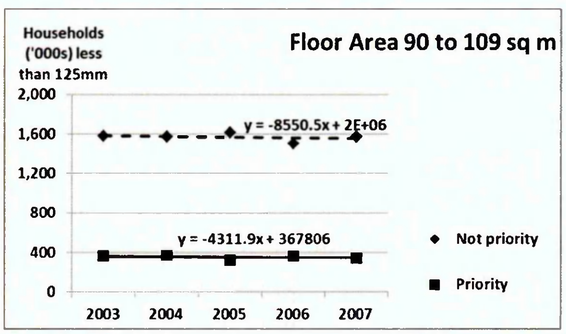


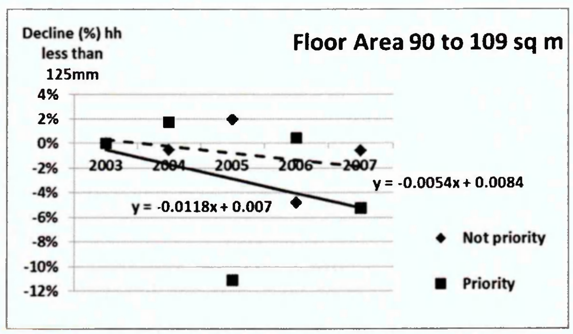


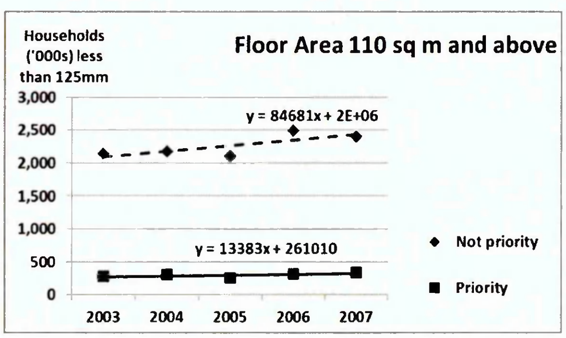


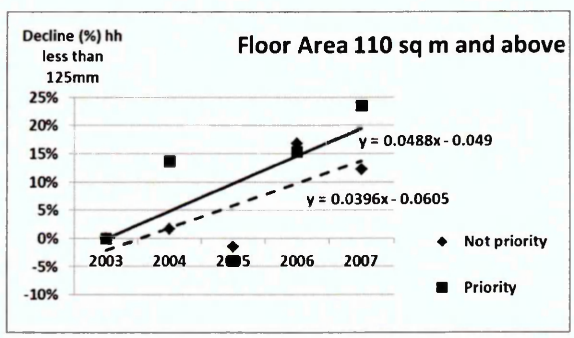




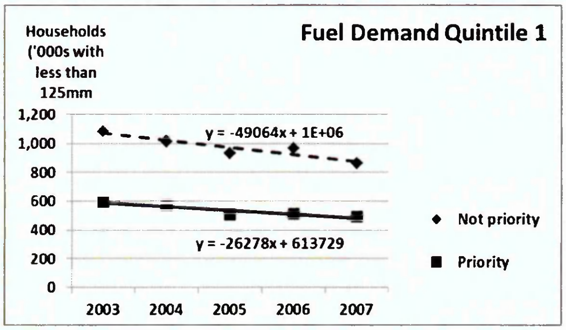


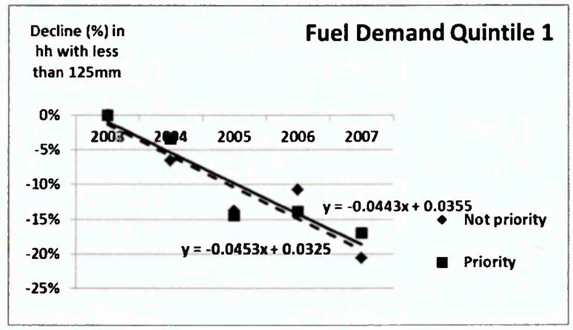


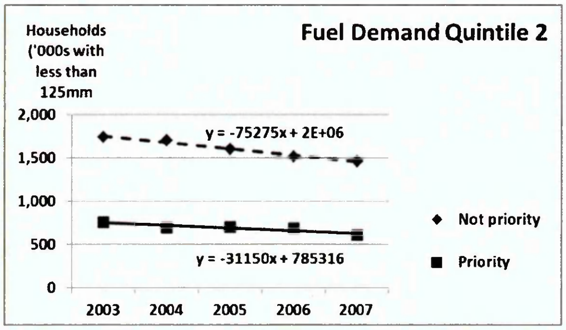


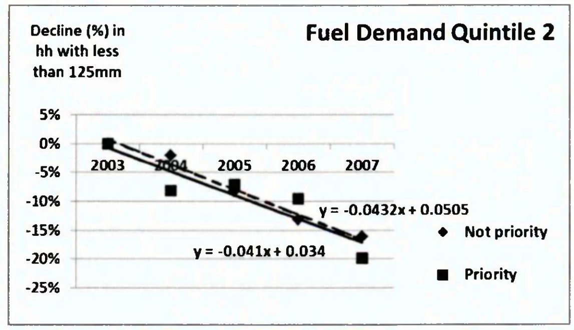


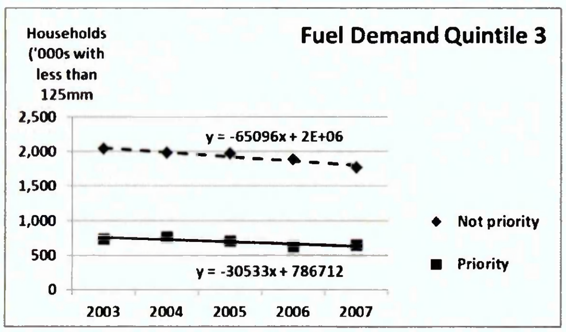
Decline (%) In Under Insulated Lofts By <u>Standard Fuel Expenditure</u> And Priority Groups

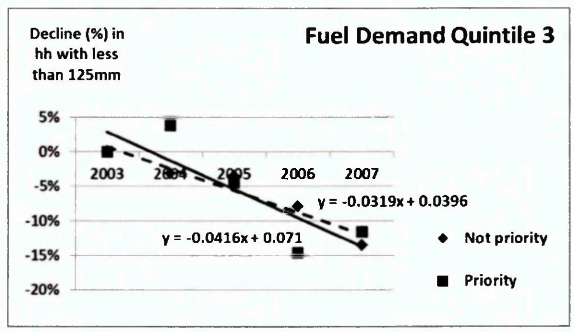


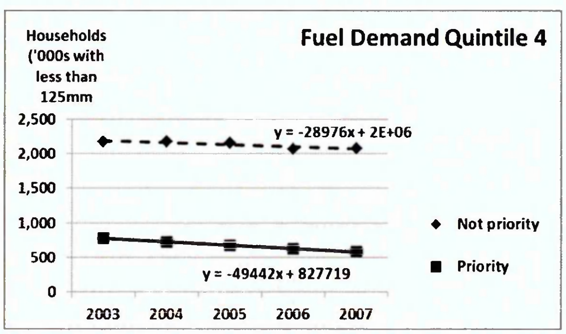


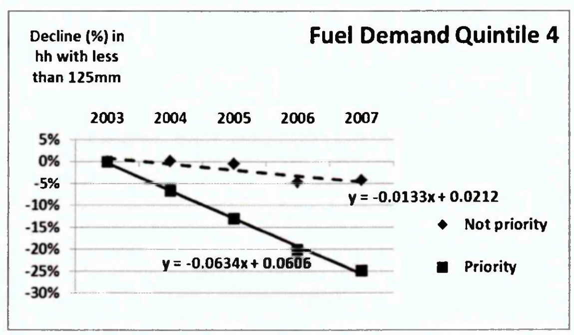


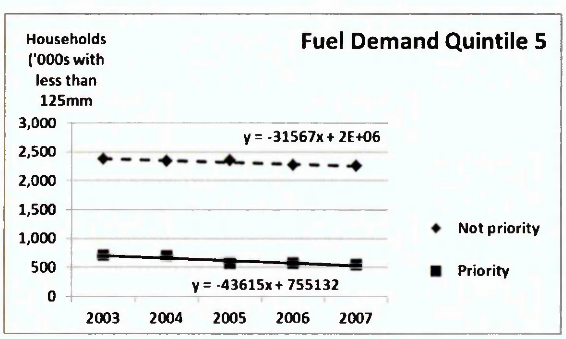


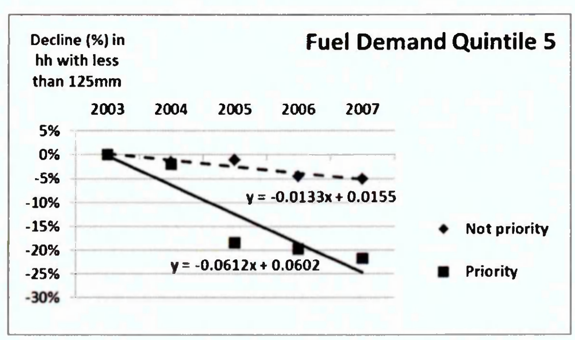












Appendix 15

Task 1 - Retrofitting During The CERT Supplier Obligation

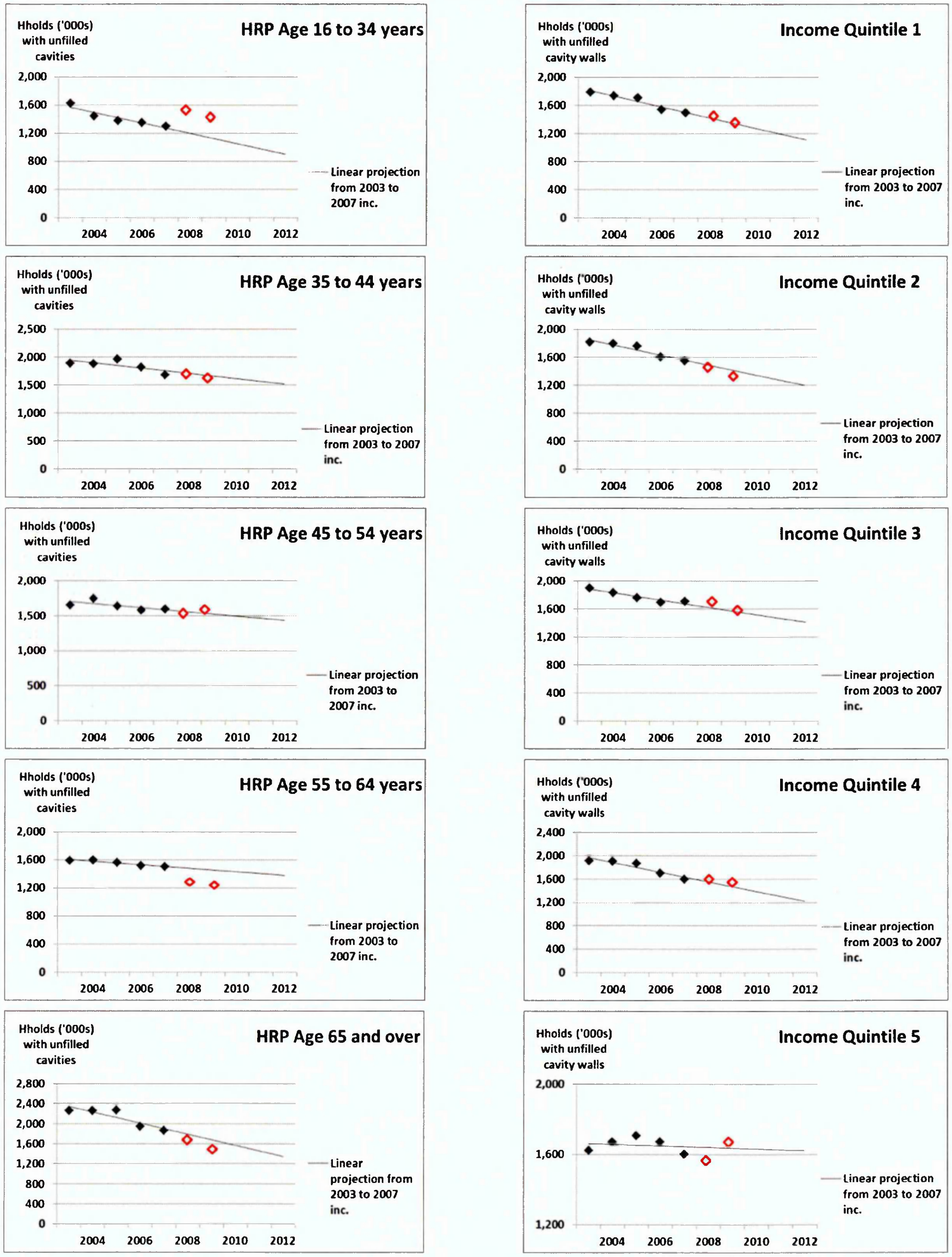
Retrofitting Under CERT

Two years of English Housing Survey data, the successor of the EHCS, are available for the CERT Supplier Obligation and the additional data provides an insight into whether the retrofit trends which developed during the period of the Energy Efficiency Commitment were maintained under the changed regime.

Figure 1 and Figure 2 illustrate the changes in the number of potentially suitable homes with cavity wall insulation, with data for the first two years of CERT highlighted separately. The trend lines added to the graphs are based upon the data from 2003 to 2007 inclusive, which represent the full six years of the Energy Efficiency Commitment. The data has not been disaggregated by priority group status because under CERT the Priority Group was enlarged from approximately 28% (DECC, 2006a) of households to 42% (DECC, 2011f) by adding all homes where a member of the household was over 65. At this stage loft insulation data has not been analyzed but could be considered if this research is extended.

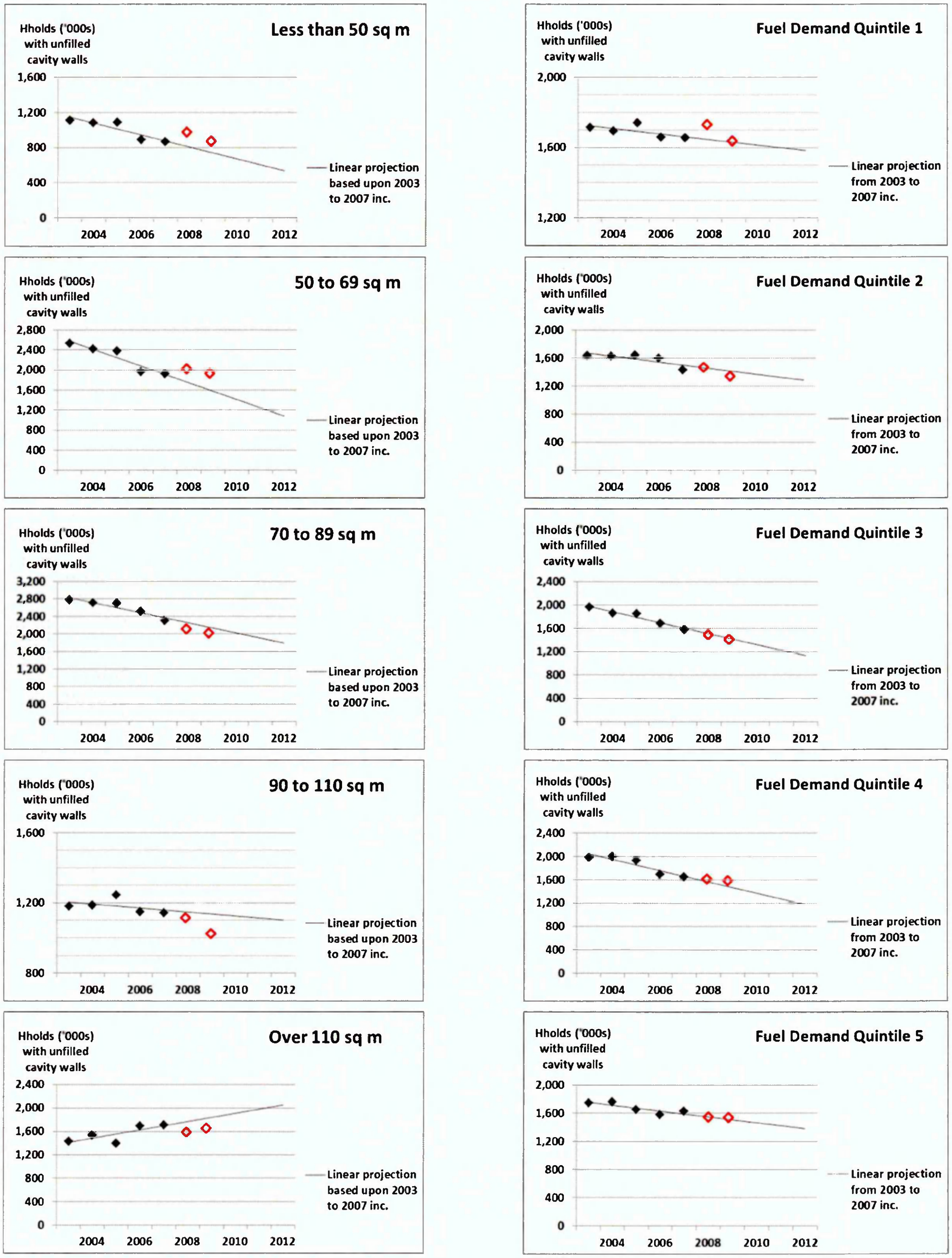
Figure 1 and Figure 2 indicate that many of the trends identified under the Energy Efficiency Commitment were retained during the first two years of CERT: householders between 35 to 54 years old and Income Quintile 5 householders continued to retrofit cavity wall insulation in disproportionately low numbers. However, during the first two years of CERT, the rate of cavity wall filling markedly increased in homes with a floor area of $90m^2$ to $110m^2$ and in the largest homes, the rate of cavity wall filling appears to have been sufficient to off-set the rising number of households in this category.

Figure 1 *Households with un-insulated cavity walls by age and income, 2003 to 2009*



Source: English House Condition Survey and English Housing Survey (various years)
Linear projections to 2012 are based upon data from 2003 to 2007 inclusive.
◇ Estimates of unfilled cavity walls for 2008 and 2009. Source English Housing Survey

Figure 2*Households with un-insulated cavity walls by area and std fuel demand, 03 to 09*



Source: English House Condition Survey and English Housing Survey (various years)
Linear projections to 2012 are based upon data from 2003 to 2007 inclusive.
◇ Estimates of unfilled cavity walls for 2008 and 2009. Source English Housing Survey

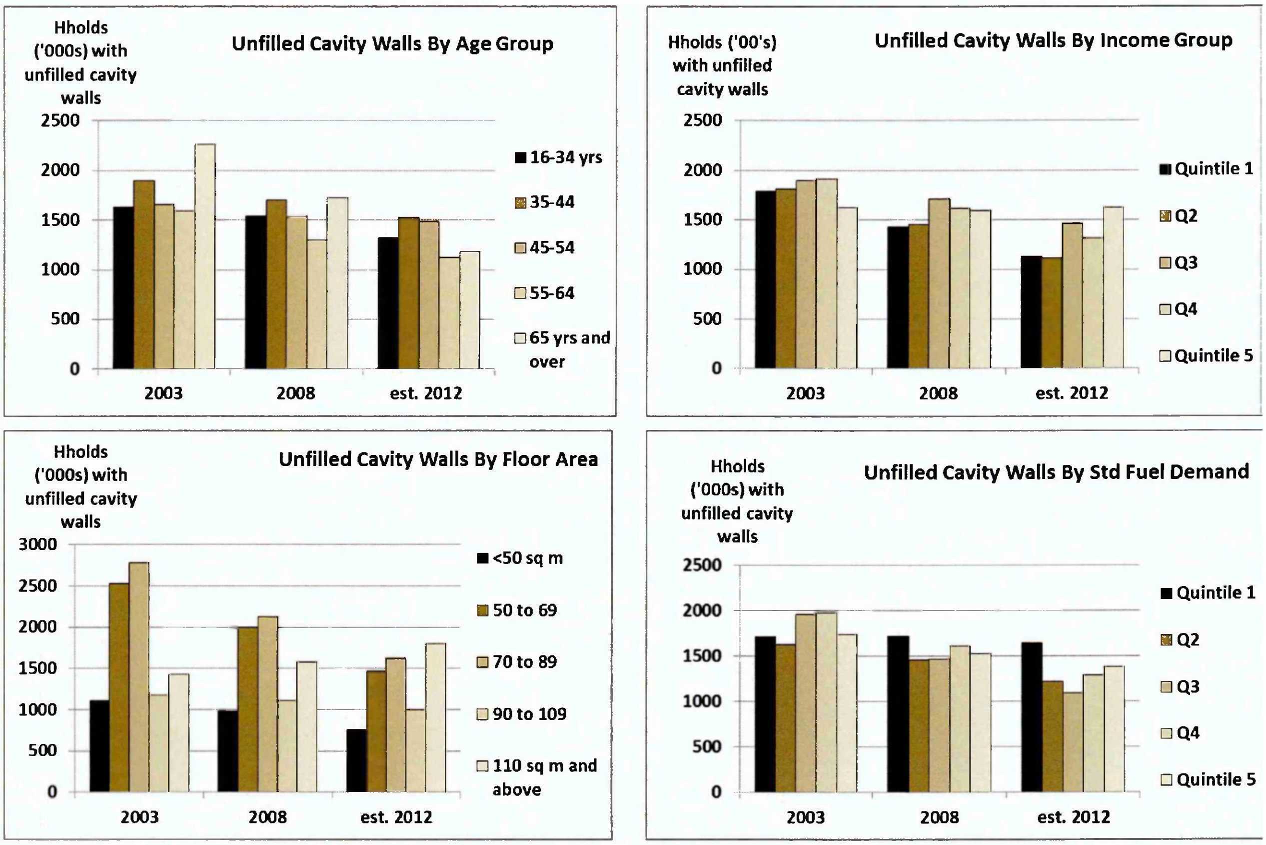
Retrofitting appears to have increased where a householder was over 65. Retrofitting also increased in the 55 to 64 year old group, possibly because many in this group live with somebody who is over 65. The introduction of an age based passport criteria to a system which was previously defined by eligibility for income related benefits and credits, made prioritized assistance more widely available to relatively affluent householders and the higher retrofitting rates in the older age categories could be linked to the rising number of retrofits in larger properties, a point which could be tested by further research into CERT.

Other potential changes to the trends identified under the Energy Efficiency Commitment include reductions in cavity wall retrofitting in small homes (less than $70m^2$) and in households with Quintile 4 incomes or Quintile 4 fuel demands. When total retrofit activity is accounted for, that is assisted and voluntary retrofitting, Income Quintile 4 households were the most active income based group of retrofitters during the Energy Efficiency Commitment. A reduction in retrofitting in this group may point towards a 'saturation point', as the proportion of householders in this income category, willing to accept assistance or retrofit privately, diminishes.

In 2012, CERT is to be replaced by The Energy Company Obligation (ECO), which is to accompany a 'Pay As You Save' retrofit initiative known as The Green Deal. The Green Deal and ECO mark a change of direction away from funding simple retrofit measures, towards subsidies and loans for more complex and costly energy efficiency initiatives, aimed particularly at homes with 'hard to treat' solid and cavity walls.

As a pre-cursor to later discussions on policy options, Figure 3 is an extrapolation of the data illustrated in Figure 1 and Figure 2 and illustrates the predicted number of homes with unfilled cavity walls in 2012, the point when CERT gives way to the Green Deal and ECO. The graphs highlight several points. Firstly at a point when the focus is shortly to move towards 'hard to treat' properties, there are likely to be approximately 6.5 million homes with unfilled cavity walls which probably continue to offer the best 'return on investment', in terms of emissions abated per £ invested, providing that the cost of identifying and driving change in these households remains acceptable.

Figure 3 *Estimates of the number of homes with un-insulated cavity walls in 2012, based upon linear projections from 2003 to 2009*



Source: English House Condition Survey and English Housing Survey 2003 to 2009

Secondly Income Quintile 5 householders did not fit cavity wall insulation during the Energy Efficiency Commitment in meaningful numbers and as the CERT obligation draws to a close it is likely that the number of Income Quintile 5 households living in homes with un-insulated cavity walls is similar to the number of such households at the beginning of the Energy Efficiency Commitment. Thirdly the number of homes over 110m^{2}, with un-insulated cavities, the group of homes which collectively use the most fuel per property, is almost certainly higher in 2012 than in 2003, when the first major supplier obligation was introduced.

Appendix 16

Task 2 - Calculations To Study Energy Efficiency and Fuel Demand

Calculating The Relative Contribution Of Energy Efficiency Enhancements, Ambient Temperature Changes, Increasing Floor Area And The Relative Price Of Fuel, On Household Fuel Expenditure, 2003 to 2007

The fuel demand of the average English household fell by 15% over the six years of the Energy Efficiency Commitment Supplier Obligation, which was operational between April 2002 and March 2008. The fall in demand coincided with energy efficiency enhancements in existing homes and more energy efficient new homes; rising fuel prices; changes to ambient temperatures ; and, increases in average floor areas . The calculations set out below are an assessment of the relative importance of all these factors upon declining household fuel demand during this period. The assessment is based upon the contrast between average household fuel bills in 2007 and fuel bills which would have been incurred, based upon 2003 expenditure, if energy efficiency, ambient temperature , fuel prices and average floor areas in 2007 had remained unchanged between 2003 and 2007.

The tables below summarise the fuel expenditure data by income quintile over the study period. Expenditure data is from the English House Condition Survey (EHCS) which records the expenditure which would have been required to purchase sufficient energy services to heat the householder's living room to 21C, the remainder of the house to 18C, and meet average power needs - a fuel demand referred to as 'standard conditions'. The EHCS data is not influenced by the price of fuel. The second source of fuel expenditure data is the Expenditure and Food Survey (EFS) which records actual household spending and consequently EFS data includes the householder's response to rises in fuel prices.

A. Fuel expenditure data (£/year) to operate under standard conditions (21C in living room, 18C throughout remainder of home. Expenditure includes VAT and supplementary environmental charges added to fuel bills between 2003 and 2007 (see below)

Source: English House Condition Survey

Income Quintile	Units	1	2	3	4	5
2003	£/year	610	652	680	724	802
2004		619	672	704	751	852
2005		697	756	814	866	1003
2006		875	936	1009	1069	1249
2007		981	1052	1109	1181	1366
all 95% confidence levels on mean expenditures < +/-£1.00						

B. Actual fuel expenditure data (£/year). Expenditure includes VAT and supplementary environmental charges

Source: Expenditure and Food Survey

Income Quintile	Units	1	2	3	4	5
2003	£/year	448	538	587	671	796
2004		448	552	621	677	816
2005		466	570	655	714	855
2006		514	643	710	772	968
2007		647	771	859	997	1185
all 95% confidence levels on mean expenditures < +/-£1.00						

C. Expenditure adjusted to remove VAT @ 5%

Source: English House Condition Survey

Income Quintile	Units	1	2	3	4	5
2003	£/year	579	620	646	688	762
2004		588	639	669	713	809
2005		662	718	774	823	953
2006		831	889	958	1016	1187
2007		932	999	1053	1122	1298

Source: Expenditure and Food Survey

Income Quintile	Units	1	2	3	4	5
2003	£/year	426	511	558	637	756
2004		425	524	590	643	775
2005		443	541	623	679	813
2006		489	611	674	733	920
2007		615	733	816	947	1126

D. Retail fuel bill inflation 2003 to 2007

Sources: Index of fuel prices , DECC, 2011, Quarterly Energy Price, Table 2.1.1, Dec, 2011. Share of fuel market from DECC, 2011, DUKES, Table 1.1.5 .

Method: Identify inflation rate for individual fuels and then combine into a composite fuel inflation rate by their relative contribution of individual fuel in meeting the national residential fuel demand .

C:\Users\Rob Ashby\Documents\work\Sheffield Hallam\References\Data Library\Energy\energy bills\QEP 2011 nov.pdf

(i) Index of fuel inflation (QEP, 2011)

Year	Units		Gas	Elec	Heating oil
2003	Index (2005=100)		81.2	85.3	68.5
2004			87.1	90.4	77.9
2005			100	100	100
2006			131.9	121.7	113.2
2007			142.1	131.4	114.2
Price inflation 03 to 07			75%	54%	67%

(ii) Fuel demand (TOEq) and proportion of residential energy market (DUKES, 2011, Table 1.1.5)

Year	Coal	Coke and breeze	Other solid fuels	Natural gas	Electricity	Heat sold	Renewable	Petroleum
2003	813	92	255	33,232	10,576r	11	247	3,068
2004	733	36	230	34,085	10,679r	52	252	3,265
2005	474	24	199	32,836	10,809	52	318	3,092r
2006	426r	16	200	31,550	10,723r	52	358	3,249r
2007	487	11	182	30,341	10,583r	52	400	2,875r
Sum	2,933	179	1,066	162,044	53,370	219	1,574	15,551
Market share (%)	1%	0%	0%	68%	23%	0%	1%	7%

(iii) Calculation of composite fuel price inflation 2003 to 2007 (renewables and coal inflated as gas)

Fuel	Market share (DUKES, 2011) 03 to 07	Fuel Inflation (QEP, 2011) 03 to 07	Fuel inflation 03 to 07
Gas	70%	0.75	53%
Elec	23%	0.54	12%
Heating oil	7%	0.67	5%
Composite fuel inflation factor			70%

(iv) Average floor areas in 2003 and 2007 EHCS surveys and calculation of the effect of increases in average floor area on average household fuel demand

Method: Average floor area determined from EHCS. Regression analysis of the EHCS data indicates that the proportional increase in fuel demand is 40% of the proportional increase in floor area, i.e. a 10% increase in average floor area increased the average fuel demand by 4%

Income quintile	Year	Units	1	2	3	4	5
Average floor area (EHCS)	2003	m^2	67.52	74.72	81.75	90.31	110.87
	2004		67.59	74.87	81.72	90.57	115.83
	2005		67.56	74.70	81.13	89.75	115.48
	2006		72.22	78.56	86.00	94.28	124.04
	2007		73.40	78.89	86.57	97.17	125.54
	2003-07		5.87	4.17	4.81	6.86	14.67
	2003-07	%	8.7%	5.6%	5.9%	7.6%	13.2%
Floor area to fuel demand factor					0.40		
Floor area inflation factor	Adjusted 2003-07	%	3%	2%	2%	3%	5%
all 95% confidence levels on mean areas <0.1m^2							

E. Calculation of Residential Energy Underspend Against Expenditure To Purchase Standard Conditions

Method: Contrast actual fuel bills (from the EFS) with expenditure to purchase standard conditions (from the EHCS) in 2003 and 2007. 2007 data adjusted to remove £39.80 charge for environmental programmes (SDC, 2007) so that it may be compared to 2003 data

Income Quintile	Units	1	2	3	4	5
Average fuel bill to purchase standard conditions, 2003 (EHCS ex VAT)	£/year	579	620	646	688	762
Average fuel bill, 2003 (EFS ex VAT)		426	511	558	637	756
Under-spend to purchase standard conditions, 2003		153	109	88	51	6
Under-spend to purchase standard conditions, 2003	%	26%	18%	14%	7%	1%

Income Quintile	Units	1	2	3	4	5
Average fuel bill to purchase standard conditions, 2007 (EHCS ex VAT)	£/year	932	999	1053	1122	1298
Average fuel bill, 2007 (EFS ex VAT)		615	733	816	947	1126
2007 EHCS minus environmental supplement		897	964	1018	1087	1262
2007 EFS minus environmental supplement		579	697	781	912	1091
Under-spend to purchase standard conditions, 2007		318	267	237	175	172
Under-spend to purchase standard conditions, 2007	%	35%	28%	23%	16%	14%

F. Calculating fuel expenditure inflation and deflation factors

i) Fuel price and floor area

Income Quintile	1	2	3	4	5
Fuel price inflator	0.70	0.70	0.70	0.70	0.70
Floor area adjustment 2003 to 2007 (from EHCS)	0.04	0.02	0.02	0.03	0.05
Fuel price inflation and floor area adjustment factor	0.74	0.72	0.72	0.73	0.75

ii) Temperature changes between 2003 and 2007

Climatic correction 2003 to 2007	Degree days calculated using the Hitchins formula (Day, 2006) and mean monthly air temperatures (DUKES, 2011) for Apr 2002 to March 2004 and Apr 2006 to Mar 2008			Temperature correction factor (ratio)
	Year	2003	2007	2007:2003
	Degree days	3808.1	3582.9	0.94

iii) Fuel bill changes 2003 to 2007

Environmental supplement (£/year) to fuel bills for Energy Efficiency Commitment 1 & 2, Renewables Obligation and EU Emissions Trading System (Sustainable Development Commission, 2007)	35.5

G. Calculating expenditure savings due to all factors (fuel price inflation, floor area adjustment, ambient temperatures and enhanced energy efficiency

Method:

1. Remove VAT at 5% from the EFS expenditure data for 2003 and 2007.
2. Adjust 2003 data to 2007 climate by multiplying by the temperature correction factor.
3. Inflate 2003 EFS expenditure data to 2007 by multiplying 2003 expenditure (exc. VAT) by the price and floor area inflator and add on the Environmental Charge
4. Difference between 2007 EFS expenditure and inflated 2003 expenditure is the result of all factors which influence fuel demand including fuel price increases, large r floor area, warmer weather and more energy efficient properties in 2007.

Income Quintile	Units	1	2	3	4	5
a) Average fuel bill, 2007, before VAT @5%		615	733	816	947	1126
Average fuel bill, 2003, EFS, before VAT @5%		426	511	558	637	756
b) Average fuel bill, EFS 2003 before VAT inflated to 2007 by adjusting for inflated fuel price, floor area plus environmental supplement		775	915	997	1138	1360
c) Savings from all factors = b) minus a)		160	183	181	191	234

H. Calculating proportion expenditure savings by income quintile

Income Quintile	Units	1	2	3	4	5
Average fuel bill, 2007, before VAT @5% and environmental supplement	£/year	579	697	781	912	1091
c) Savings from all factors		160	183	181	191	234
Proportional saving		28%	26%	23%	21%	21%

I. Calculating expenditure savings due to changes in ambient temperature only

Method:

1. Remove VAT at 5% from the EFS expenditure data for 2003 .
2. Adjust 2003 data to 2007 climate by multiplying by the temperature correction factor
3. Inflate climate adjusted 2003 EFS expenditure data to 2007 by multiplying by the fuel price and floor area inflator and add on the Environmental Supplement
4. Difference between c) adjusted bills taking account climate and b) adjusted bills without taking into account the climate factor is the expenditure savings attributable to less degree days in 2007

Income Quintile	Units	1	2	3	4	5
2003 average fuel bill (EFS), before VAT		426	511	558	637	756
2003 average fuel bill (EFS), before VAT, adjusted to 2007 climate	£/year	401	481	525	600	711
d) Climate adjusted 2003 fuel bills, before VAT, adjusted to 2007 to take into account relative fuel price, floor area adjustment and environmental supplement		731	863	940	1073	1282
e) Savings from fewer degree days in 2007 = b) minus d)		44	52	57	65	78

J. Calculating expenditure savings due to improved energy efficiency

Method:

1. Remove VAT at 5% from the EHCS expenditure data for 2003 and 2007.
2. Adjust 2003 data to 2007 climate by multiplying by the temperature correction factor.
3. Inflate 2003 EHCS expenditure data to 2007 by multiplying 2003 expenditure (exc. VAT) by the price and floor area inflator and then add the Environmental Charge.
4. Difference between 2007 expenditure and inflated 2003 expenditure is the contribution of more fuel efficient properties if households purchased standard conditions
5. To adjust fuel efficiency contribution to take into account sub-standard purchasing multiply by the ratio of actual spending (EFS) to standardized spending (EHCS)

Income Quintile	Units	1	2	3	4	5
2007 Average expenditure to purchase standard conditions (EHCS) inc VAT	£/year	981	1052	1109	1181	1366
e) 2007 Average expenditure to purchase standard conditions (EHCS) exc VAT @5%		932	999	1053	1122	1298
2003 Average expenditure to purchase standard conditions (EHCS) inc VAT		610	652	680	724	802
2003 Average expenditure to purchase standard conditions (EHCS) exc VAT @5%		579	620	646	688	762
2003 EHCS (ex VAT) adjusted to 2007 climate		545	583	608	647	717
f) climate adjusted 2003 EHCS expenditure, inflated to 2007 by applying floor area and price inflation factors plus environmental supplement		981	1039	1082	1155	1292
g) Savings due to energy efficiency only (at standard conditions) = f) minus e)		49	40	29	33	-6
h) Adjusted energy efficiency savings adjusted from underspending g) multiplied by EFS (2007 ex VAT / EHCS(2007 ex VAT)		32	29	22	28	-5

K. Combining the data

Income Quintile	Units	1	2	3	4	5
c) Savings from all factors affecting residential fuel demand, including fuel price, ambient temperature, property size and the energy efficiency of the property	£/year	160	183	181	191	234
h) Savings due to energy efficiency, once changes in average floor area have been accounted for		32	29	22	28	-5
g) Savings from fewer degree days in 2007		44	52	57	65	78

L. Proportional effect of downward pressures on fuel demand, 2003 to 2007

Income Quintile	Units	1	2	3	4	5
Average household fuel expenditure reductions as a result of energy efficiency enhancements between 2003 and 2007, once variations in floor area have been taken into account	%	20%	16%	12%	15%	-2%
Average household fuel expenditure reductions resulting from changes in degree days between 2003 and 2007		27%	28%	31%	34%	33%
Average fuel expenditure reductions due to other factors, including rising fuel prices and the relative cost of fuel		52%	56%	56%	51%	69%

Appendix 17 Degree Day Calculations

Average monthly temp (DUKES Table 1.1.8)

	January	February	March	April	May	June	July	August	September	October	November	December
2004	5.5	5.6	6.6	9.6	12.1	15.3	15.7	17.4	14.8	10.6	8.0	5.7
2005	6.4	4.5	7.2	8.8	11.2	15.4	16.6	16.1	15.0	13.0	6.4	4.8
2006	4.5	4.2	5.0	8.5	11.8	15.8	19.3	16.2	16.4	12.8	8.1	6.4
2006	4.5	4.2	5.0	8.5	11.8	15.8	19.3	16.2	16.4	12.8	8.1	6.4
2007	6.9	6.0	7.1	11.2	11.9	14.9	15.2	15.5	13.9	11.0	7.5	5.0
2008	6.4	5.4	6.1	7.9	13.0	14.0	16.3	16.2	13.5	9.8	7.0	3.7
2009	3.3	4.4	6.9	9.7	11.9	14.8	16.2	16.6	14.2	11.5	8.4	3.1

$$D_m = \frac{N_m (\theta_b - \bar{\theta}_{o,m})}{1 - e^{-k(\theta_b - \bar{\theta}_{o,m})}} \qquad (2.4)$$

where D_m is the monthly degree-day value, N_m is the number of days in the month, $\bar{\theta}_{o,m}$ is the mean monthly temperature, and k is a location specific constant given by:

Days in month

	January	February	March	April	May	June	July	August	September	October	November	December
2002	31.0	28.0	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0

Numerator 2005 15.5

	January	February	March	April	May	June	July	August	September	October	November	December
2002				178	105	6	-6	-59	22	152	225	304
2003	283	308	256	200	133	4	-34	-19	14	77	273	331
2004	340	317	327									

Appendix 17 Degree Day Calculations

Denominator function 2005	k=	-0.71							
		1.05688E-55	3.3576E-33	0.01681	64.74265	1.09355E+18	2.07597E-07	9.83632E-48	4.78551E-70	2.51626E-94

Degree Days 2003 (Apr 2002 to Mar 2004)

	January	February	March	April	May	June	July	August	September	October	November	December
2002				178	105	6	0	0	22	152	225	304
2003	283	308	256	200	133	4	0	0	14	77	273	331
2004	340	317	327									

Degree Days 2007 (Apr 2006 to Mar 2008) 15.5

	January	February	March	April	May	June	July	August	September	October	November	December
2006				130	112	17	8	-1	49	140	239	326
2007	283	284	292	227	76	44	-24	-22	59	178	256	365
2008	378	312	266									

MSOA Removed From the Fuel Demand Assessment

All potentially outlying data, where the % reduction in fuel demand was more than two standard deviations from the mean % reduction were checked to see whether local circumstances, such as very low number of gas meters or large changes in the number of gas meters, could have contributed to the extreme result. Where outlying data could be the result of changes to the number of meters or the small sample size, the data was excluded from the study. Excluded outlying data points are listed in the table below.

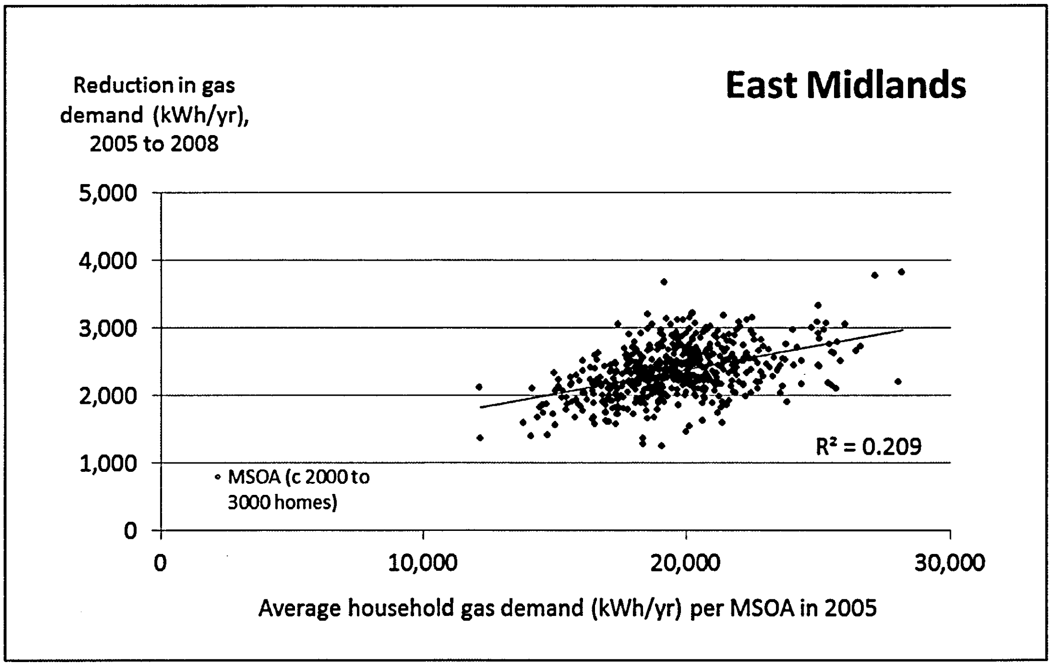
Government Office Region	MLSOA Reference	Reason for data exclusion
East Midlands	E02005440	
	E02005849	
	E02005687	
East of England	E02006242	
	E02005538	
	E02006293	
	E02006237	
	E02006240	
	E02005606	
London	E02000935	1706 meters added
	E02000756	1993 meters lost
North East	No outliers removed from the database	
North West	No outliers removed from the database	
South East	E02005921	Number of gas meters increased from 13 to 141 (+985%)
	E02003388	Number of gas meters decreased from 1493 to 739 (-51%)
	E02004822	Number of gas meters decreased from 117 to 49 (-58%)

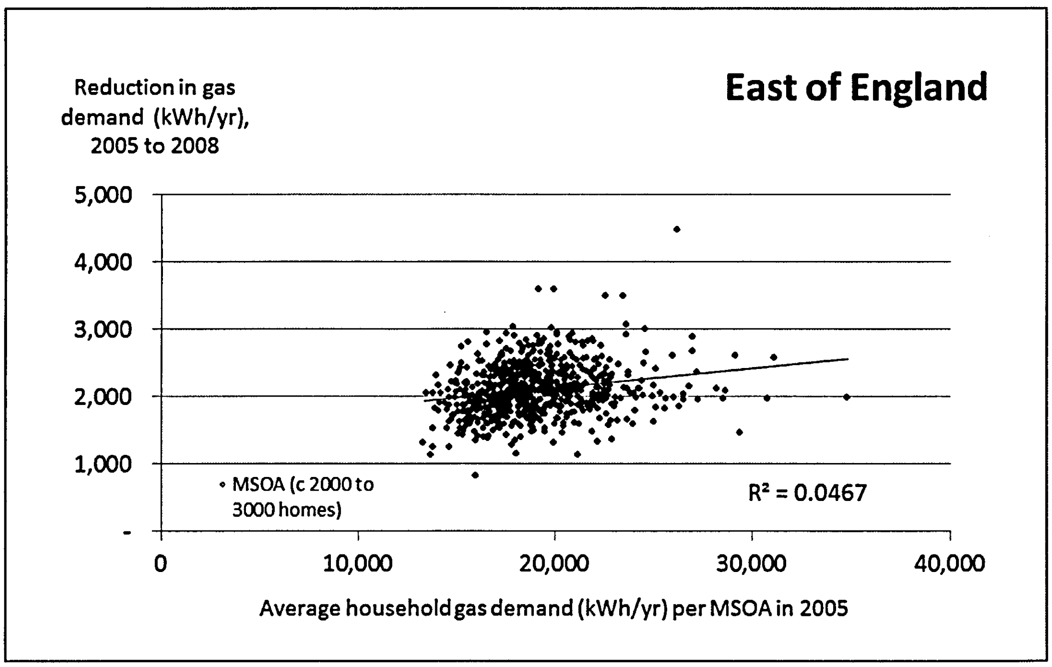
	E02005172	Only 24 meters
	E02004677	Number of gas meters increased from 75 to152 (+103%)
	E02005947	Number of gas meters decreased from 3007 to 1958 (-35%)
South West	E02006695	Number of gas meters increased from 20 to 28 (40%)
	E02003956	Number of gas meters increased from 10 to 19 (90%)
	E02003893	Only 8 gas meters
	E02003935	Number of gas meters increased from 2157 to 2785 (29%)
	E02003926	Number of gas meters increased from 207 to 253 (22%)
	E02003927	Number of gas meters increased from 581 to 672 (16%)
	E02003907	Only 7 meters
	E02003940	Only 89 meters
	E02004199	Only 10 meters
West Midlands	E02006027	Number of meters increased from 39 to 100 (156%)
	E02006014	Number of meters increased from 989 to 1209 (22%)
	E02002905	Only 63 meters
	E02001894	Number of meters increased from 2396 to 2869 (20%)
	E02006754	Number of meters increased from 99 to 179 (81%)
	E02006131	Number of meters decreased from 1443 to 931 (-35%)
	E02002924	Only 84 meters
Yorkshire	E02005796	Number of meters decreased from 1043 to 709 (-34%)
	E02002430	Number of meters decreased from 2911 to 2642 (-13%)

This appendix includes charts showing absolute gas demand changes per region and the proportional demand per region.

Absolute Gas Demand Reductions

Appendix 19 - Absolute Gas Demand Changes





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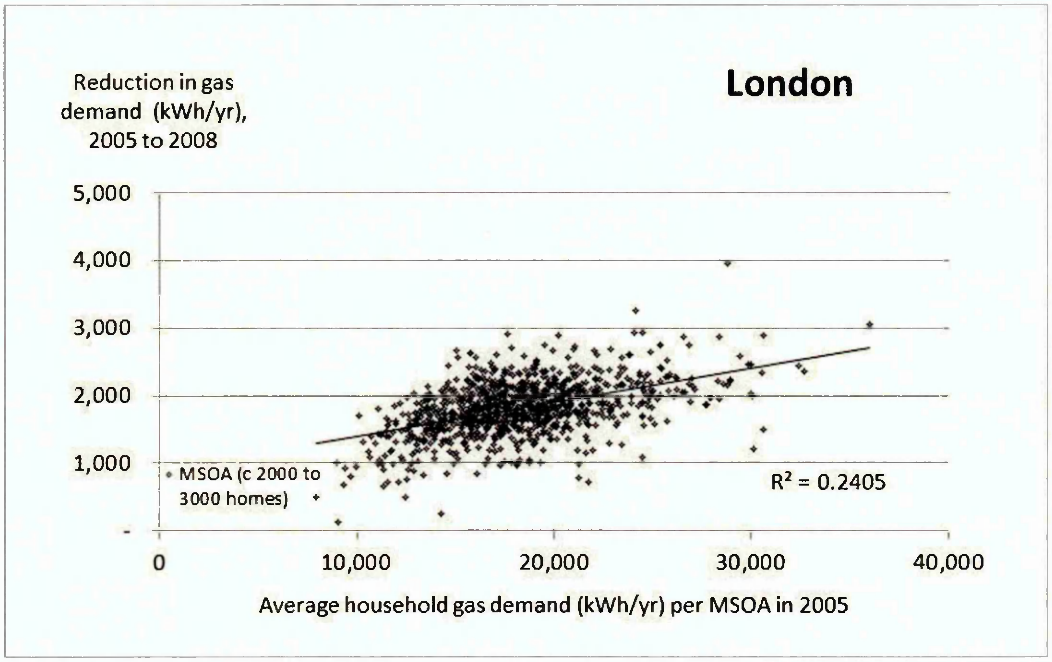

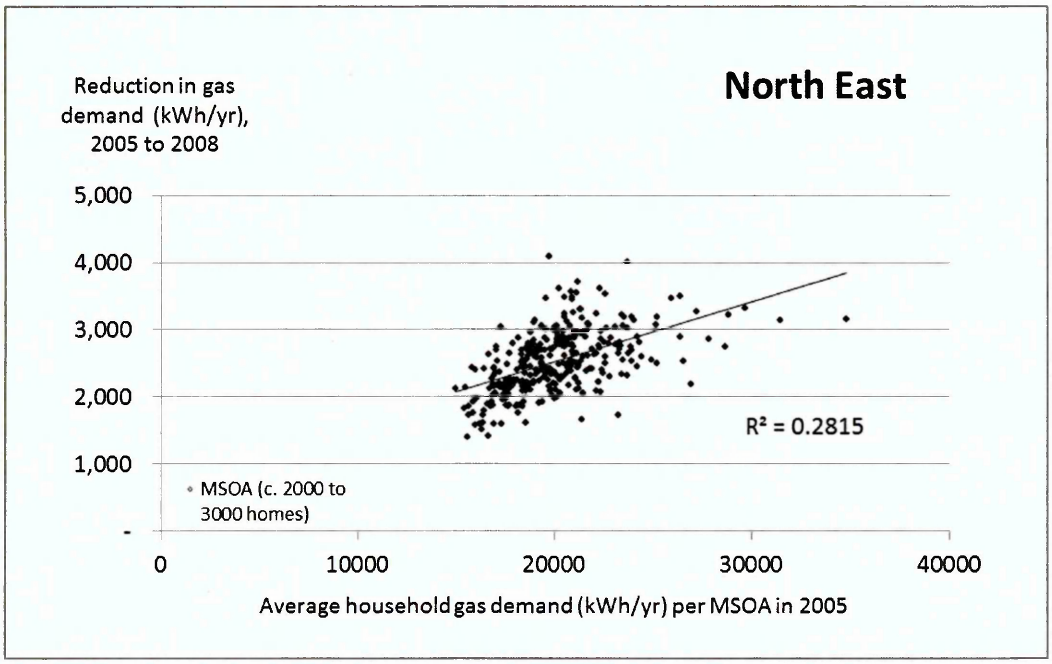

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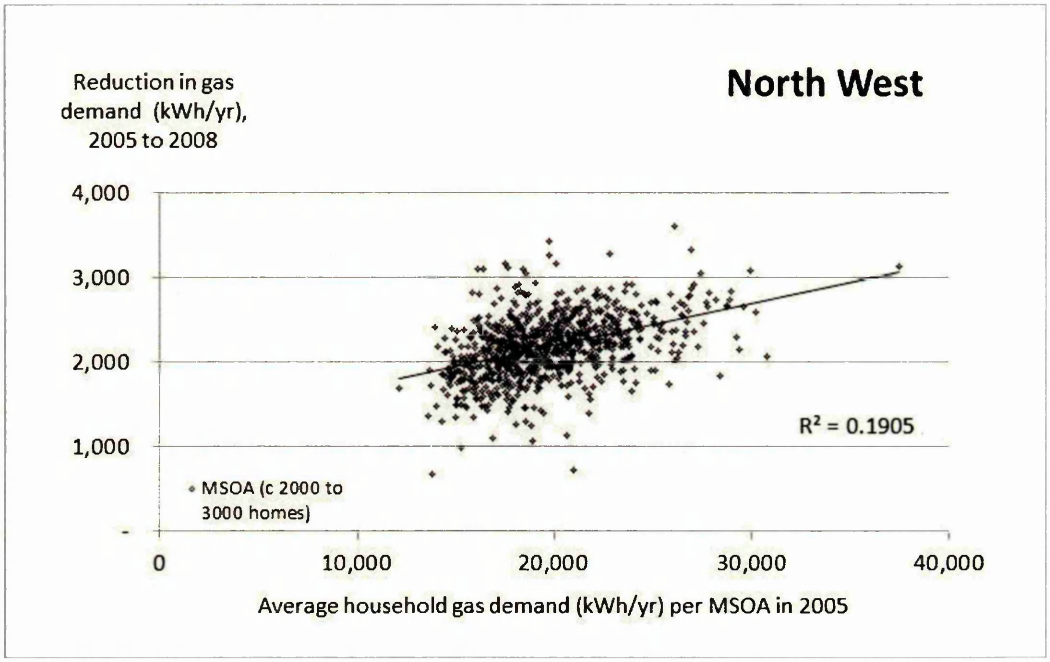

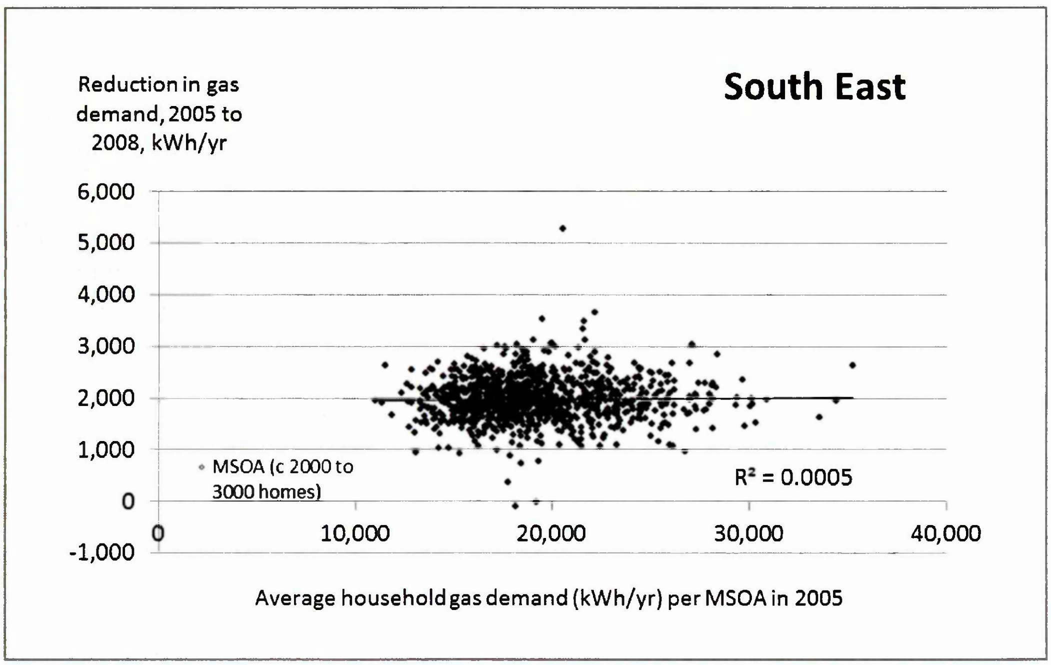

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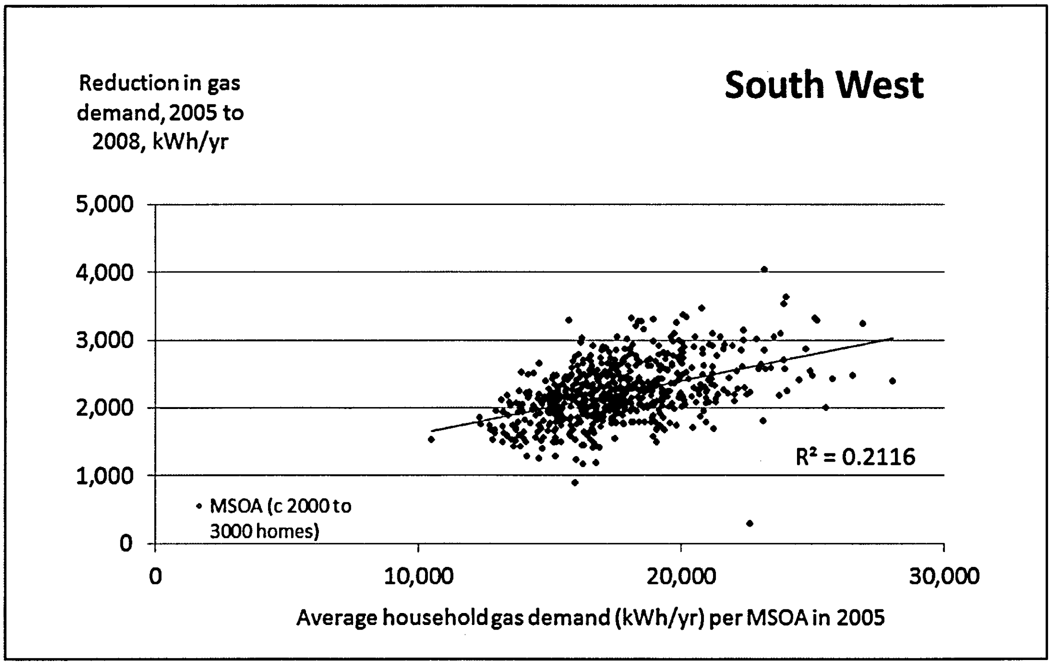
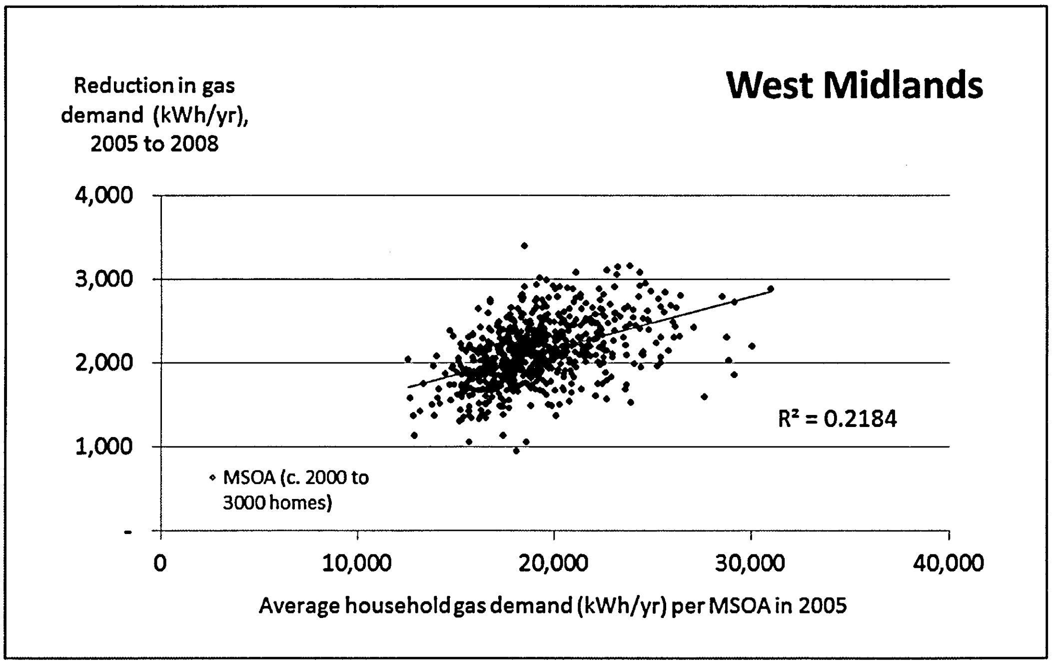
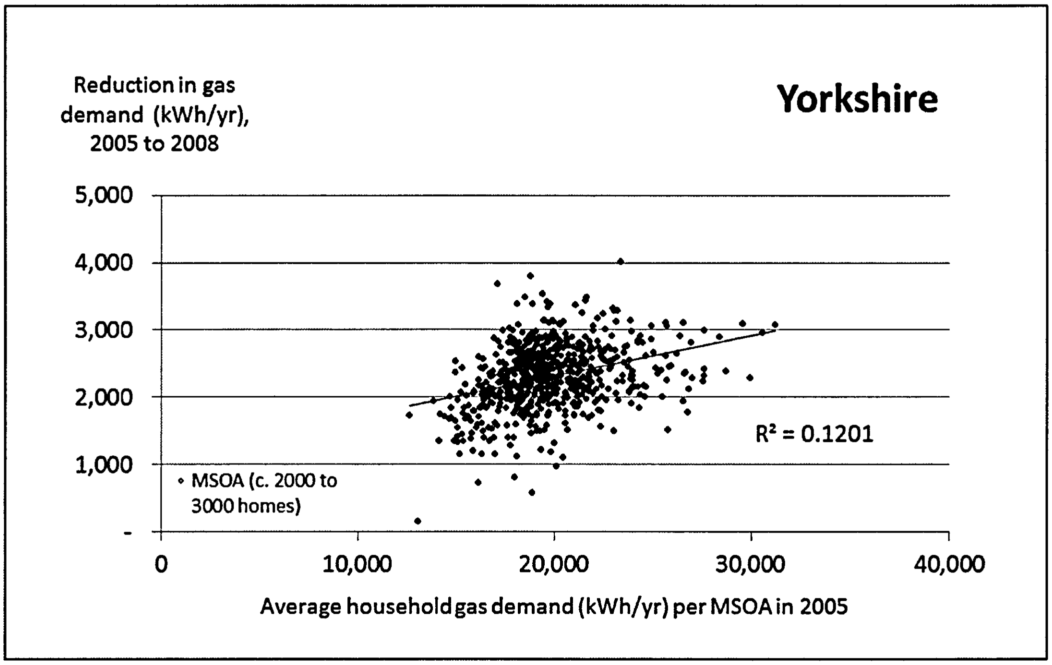
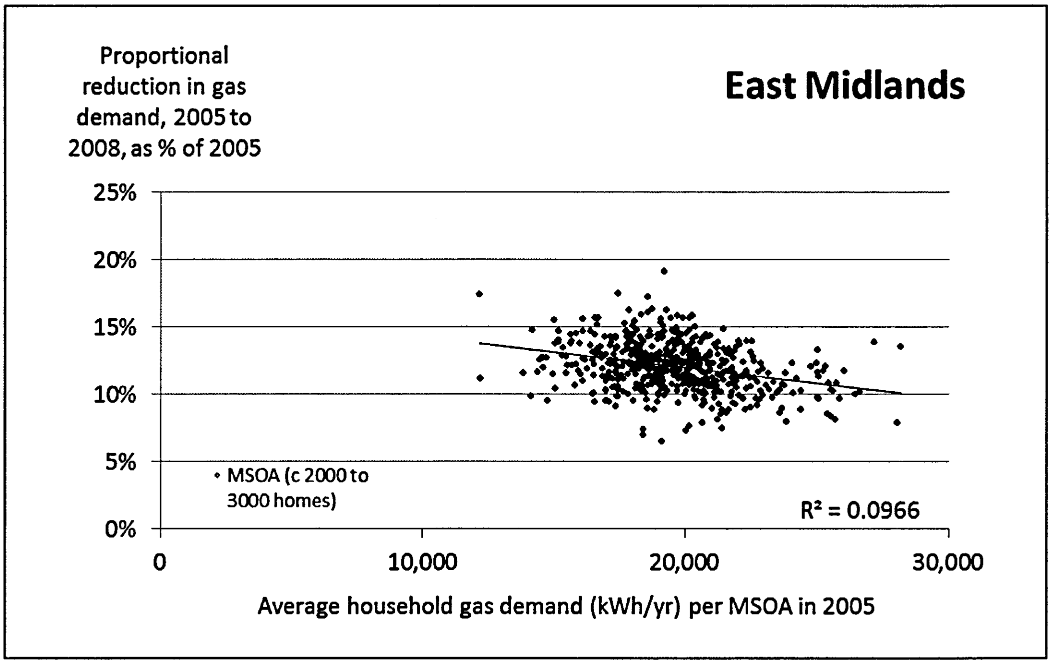


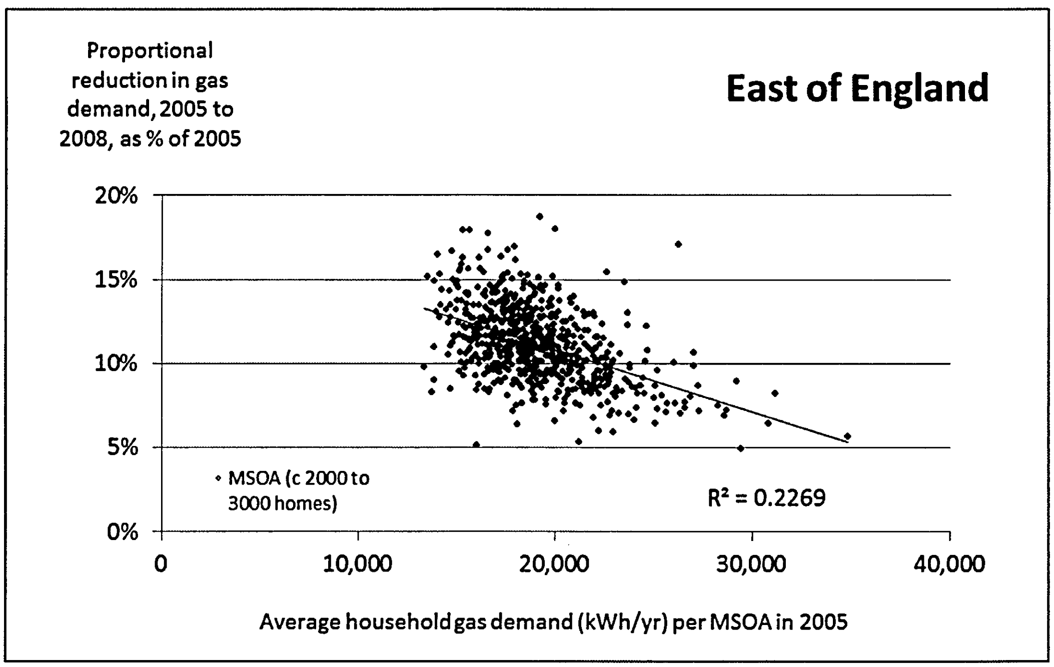


Appendix 19 - Absolute Gas Demand Changes

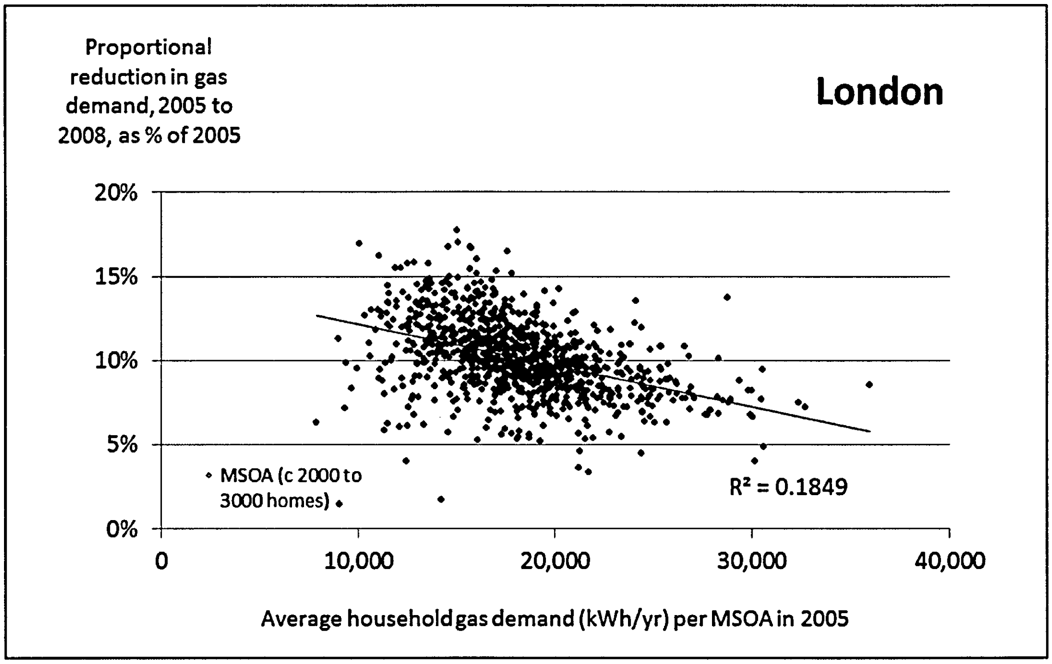


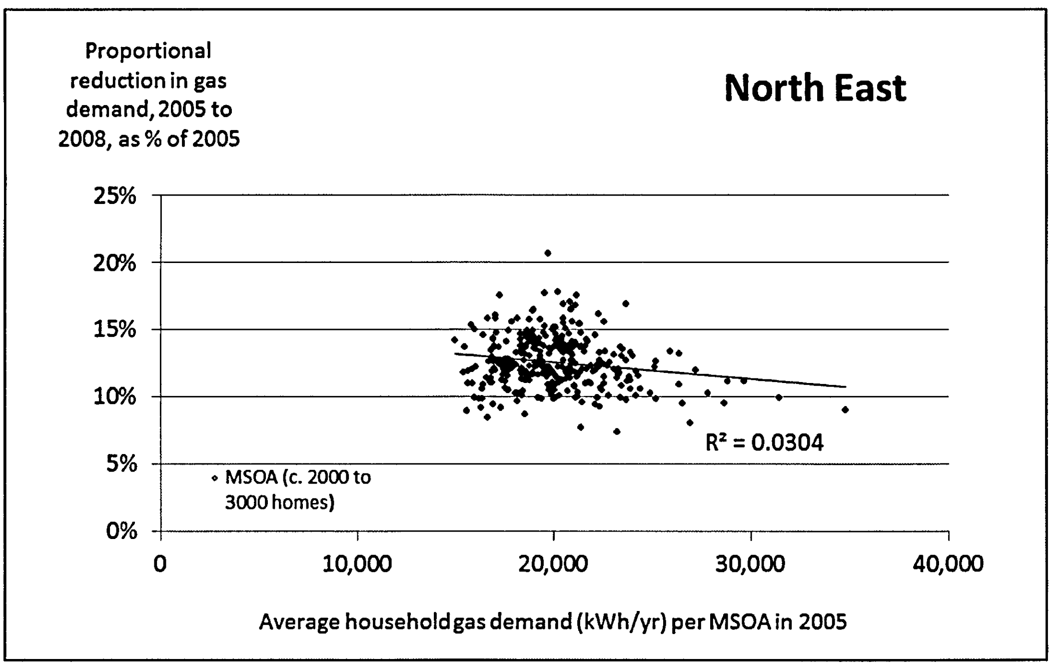
Proportional Gas Demand Reductions


Proportional reduction in gas demand, 2005 to 2008, as % of 2005
East Midlands
25%
20%
15%
10%
5%
0%
• MSOA (c 2000 to 3000 homes)
R² = 0.0966
0
10,000
20,000
30,000
Average household gas demand (kWh/yr) per MSOA in 2005

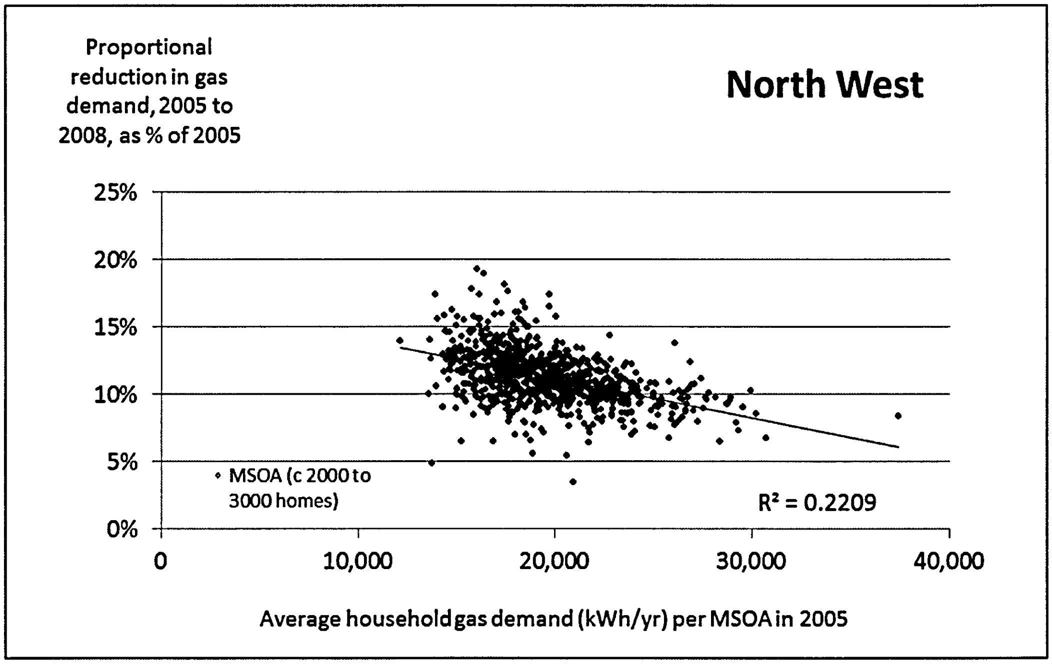

Proportional reduction in gas demand, 2005 to 2008, as % of 2005
East of England
20%
15%
10%
5%
0%
• MSOA (c 2000 to 3000 homes)
R² = 0.2269
0
10,000
20,000
30,000
40,000
Average household gas demand (kWh/yr) per MSOA in 2005

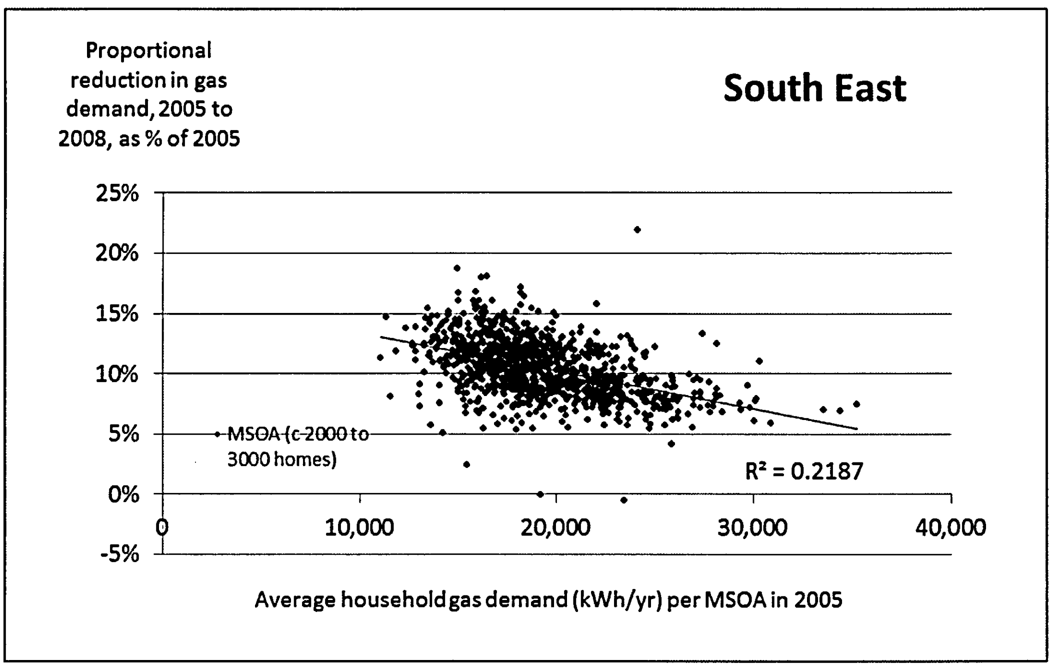
Appendix 19 - Proportional Gas Demand Changes



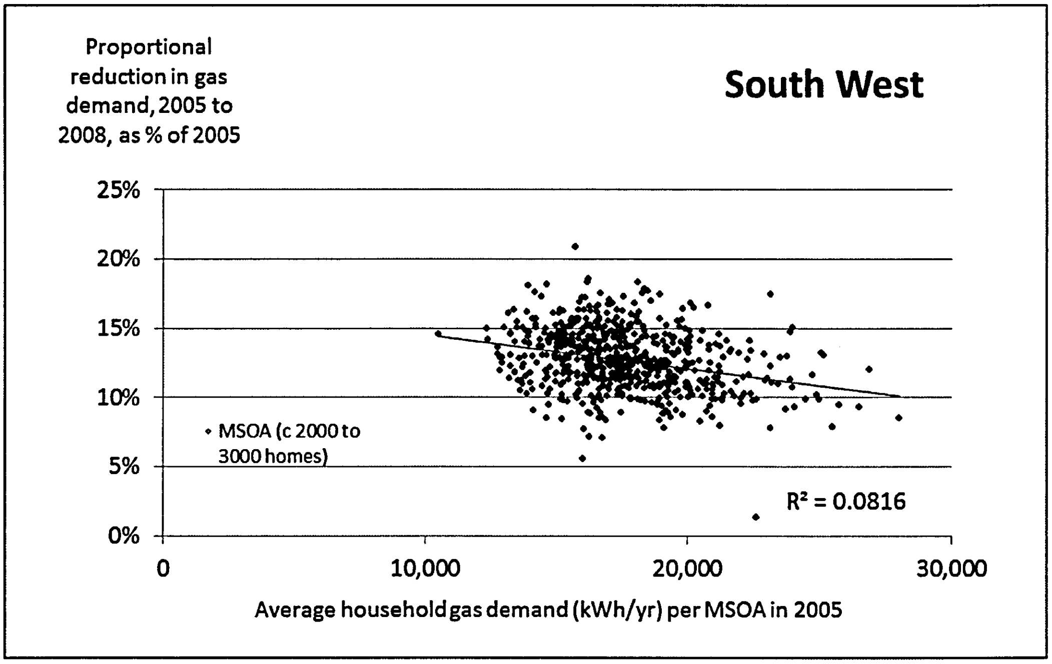


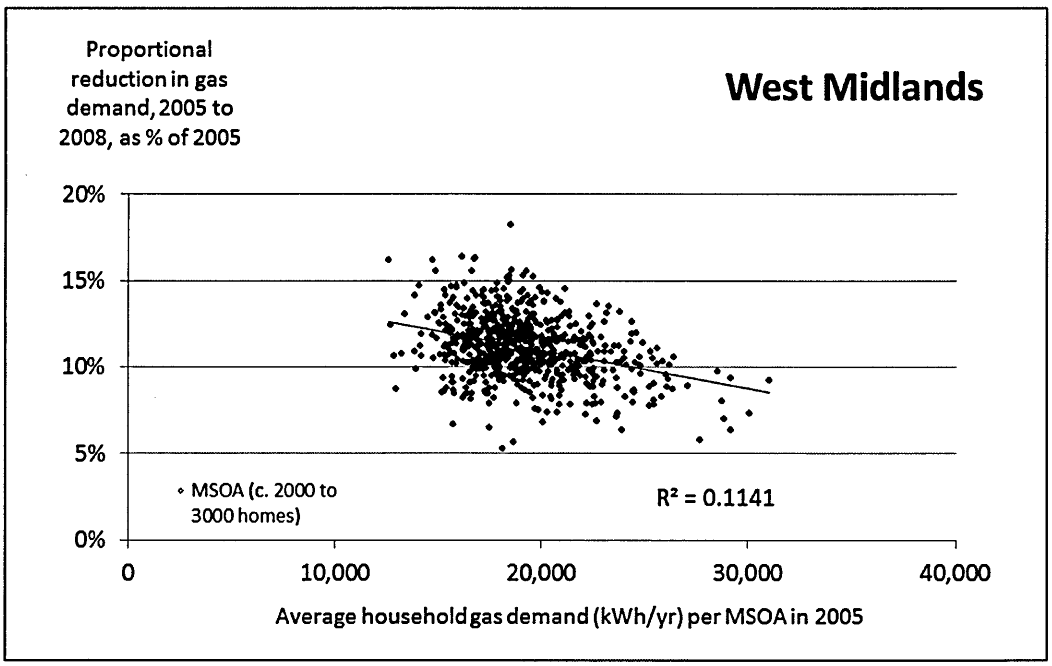
Appendix 19 - Proportional Gas Demand Changes



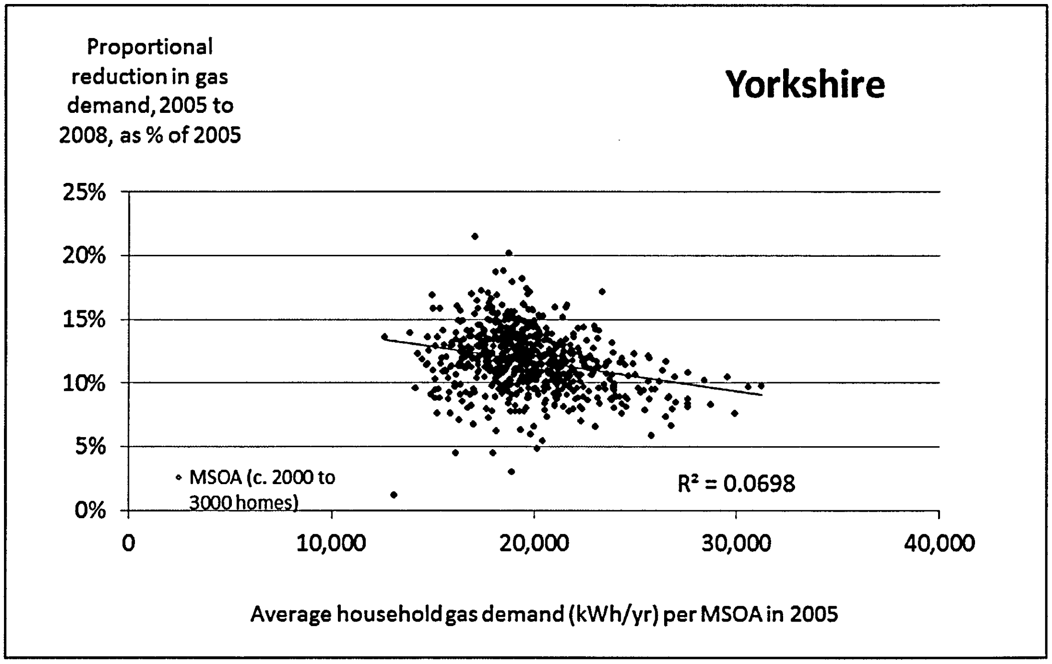


Appendix 19 - Proportional Gas Demand Changes





Appendix 19 - Proportional Gas Demand Changes



Appendix 20

Task 3 - Kirklees and Staffordshire Warm Zone Retro-Fit Statistics

Appendix 20 Warm Zone Data

Retro-fit Data Supplied By Kirklees Warm Zone

Ward	No of homes in ward	No homes who have refused Warm Zone (up to end July 2010) Weekly data - 30th July	No private homes surveyed	No of private houses with adequate insulation at survey	No private homes suitable for measures	No of private homes where measures were fitted (4th Oct 2010)
Holme Valley South	7593	532	4288	906	3030	2627
Kirkburton	6023	444	3733	871	2777	2412
Mirfield	8336	256	4972	1225	3662	3262
Colne Valley	7378	322	3767	830	2426	2164
Cleckheaton	7239	481	4023	960	2891	2497
Holme Valley North	7027	530	3805	937	2681	2366
Denby Dale	6560	322	3377	880	2457	2213
Birstall & Birkenshaw	7399	600	3673	971	2769	2338
Dalton	8135	441	4035	1055	2819	2496
Liversedge & Gomersal	7661	503	3674	1028	2665	2281
Heckmondwike	6963	429	3537	990	2473	2179
Lindley	7742	632	4701	1342	2903	2606
Newsome	8059	359	3526	896	2010	1687
Ashbrow	8171	414	3962	1243	2729	2317
Greenhead	7982	482	3517	1013	2170	1802
Golcar	7906	404	4567	1318	2643	2332
Batley West	6945	368	3532	1155	2290	1990

Appendix 20 Warm Zone Data

Ward	No of homes in ward	No homes who have refused Warm Zone (up to end July 2010) Weekly data - 30th July	No private homes surveyed	No of private houses with adequate insulation at survey	No private homes suitable for measures	No of private homes where measures were fitted (4th Oct 2010)
Crosland Moor & Netherton	7525	716	4187	1267	2514	2175
Dewsbury East	7604	453	3772	1229	2409	2019
Dewsbury South	6643	331	2984	988	1754	1532
Almondbury	7612	452	4648	1625	2676	2293
Batley East	6880	345	3434	1226	1848	1537
Dewsbury West	7140	317	2866	1180	1588	1393
Average						

Statistics Derived From The Kirklees Warm Zone Data

Ward	Proportion of private households refusing Warm Zone	Proportion of private households failing to take up Warm Zone	Proportion of surveyed households suitable for measures accepting measures	Proportion of potentially suitable private homes with adequate insulation at survey	Proportion of potentially suitable surveyed private homes with adequate insulation after offer	Number of refusing homes likely to be suitable for measures (based upon survey statistics)	Proportion of potentially suitable private homes (all) with adequate insulation after offer	Number of refusing households and households failing to take up measures	Private homes [potentially suitable] refused Warm Zone or did not accept measures
Holme Valley South	11%	8%	87%	21%	82%	376	82%	779	16%
Kirkburton	11%	9%	87%	23%	88%	330	83%	695	17%
Mirfield	5%	8%	89%	25%	90%	189	88%	589	11%
Colne Valley	8%	6%	89%	22%	79%	207	86%	469	11%
Cleckheaton	11%	9%	86%	24%	86%	346	82%	740	16%

Appendix 20 Warm Zone Data

Ward	Proportion of private households refusing Warm Zone	Proportion of private households failing to take up Warm Zone	Proportion of surveyed households suitable for measures accepting measures	Proportion of potentially suitable private homes with adequate insulation at survey	Proportion of potentially suitable surveyed private homes with adequate insulation after offer	Number of refusing homes likely to be suitable for measures (based upon survey statistics)	Proportion of potentially suitable private homes (all) with adequate insulation after offer	Number of refusing households and households failing to take up measures	Private homes [potentially suitable] refused Warm Zone or did not accept measures
Holme Valley North	12%	7%	88%	25%	87%	373	83%	688	16%
Denby Dale	9%	7%	90%	26%	92%	234	87%	478	13%
Birstall & Birkenshaw	14%	10%	84%	26%	90%	452	79%	883	21%
Dalton	10%	7%	89%	26%	88%	308	85%	631	14%
Liversedge & Gomersal	12%	9%	86%	28%	90%	365	82%	749	18%
Heckmondwike	11%	7%	88%	28%	90%	300	84%	594	15%
Lindley	12%	6%	90%	29%	84%	390	85%	687	13%
Newsome	9%	8%	84%	25%	73%	205	83%	528	14%
Ashbrow	9%	9%	85%	31%	90%	285	84%	697	16%
Greenhead	12%	9%	83%	29%	80%	297	81%	665	17%
Golcar	8%	6%	88%	29%	80%	234	87%	545	11%
Batley West	9%	8%	87%	33%	89%	239	85%	539	14%
Crosland Moor & Netherton	15%	7%	87%	30%	82%	430	82%	769	16%
Dewsbury East	11%	9%	84%	33%	86%	289	83%	679	16%
Dewsbury South	10%	7%	87%	33%	84%	195	86%	417	13%
Almondbury	9%	8%	86%	35%	84%	260	86%	643	13%
Batley East	9%	8%	83%	36%	80%	186	85%	497	13%
Dewsbury West	10%	6%	88%	41%	90%	176	87%	371	12%
Average	10%	8%							15%

Appendix 20 Warm Zone Data

Retro-fit data Supplied By North Staffs Warm Zone (i)

Stoke-on-Trent											
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	No. homes potentially suitable for CWI*	No. with CWI already	No. homes potentially suitable for LI**	No. with LI already	Cav Wall Installed By WZ	Loft Installed By WZ	DoorstepVisit Ward Start Date***
01	Longton South	4898	4432	2848	843	562	1408	850	259	341	08/01/2007
03	Burslem North	4399	4001	2889	812	612	1558	841	234	337	19/02/2007
05	Bentilee and Townsend	2917	2881	2126	782	813	1011	878	180	206	02/04/2007
07	Blurton	3539	3104	2339	882	1105	969	1181	234	178	14/05/2007
09	Tunstall	5046	4113	3218	710	966	1229	1468	126	200	11/06/2007
11	Chell and Packmoor	3730	3330	2361	897	932	895	1233	188	186	23/07/2007
12	Fenton	5062	4499	3288	691	689	1249	1368	106	187	13/08/2007
13	Abbey Green	3358	3130	2268	790	916	848	1146	171	162	17/09/2007
15	Weston and Meir North	3958	3732	2655	775	1174	956	1230	181	175	15/10/2007
16	Berryhill and Hanley East	3484	3387	2507	569	677	880	867	110	127	05/11/2007
18	Norton and Bradeley	3616	3418	2429	665	1148	745	1354	164	153	26/11/2007
20	Longton North	4915	4489	2697	724	1143	877	1308	187	176	17/12/2007
21	Stoke and Trent Vale	4651	4055	2659	530	513	1005	954	94	177	03/03/2008
23	Hanley West and Shelton	3460	3109	2340	259	244	700	561	39	107	07/04/2008
25	Burslem South	4922	3902	3457	458	712	935	1203	106	189	02/06/2008
28	Meir Park and Sandon	4374	4372	2206	614	1089	587	1254	212	189	03/11/2008
31	East Valley	4601	4587	2452	564	1182	570	1526	201	162	12/01/2009

Appendix 20 Warm Zone Data

Stoke-on-Trent												
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	No. homes potentially suitable for CWI*	No. with CWI already	No. homes potentially suitable for LI**	No. with LI already	Cav Wall Installed By WZ	Loft Installed By WZ	DoorstepVisit Ward Start Date***
35	Northwood and Birches Head	4921	4921	2749	471	883	748	1500	129	176	11/05/2009
40	Hartshill and Penkhull	5394	5387	2156	387	649	877	1162	95	178	24/08/2009

Appendix 20 Warm Zone Data

Retro-fit data Supplied By North Staffs Warm Zone (ii)

Newcastle-under-Lyme											
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	No. homes potentially suitable for CWI*	No. with CWI already	No. homes potentially suitable for LI**	No. with LI already	Cav Wall Installed By WZ	Loft Installed By WZ	DoorstepVisit Ward Start Date***
02	Cross Heath	1579	1104	1106	432	314	616	328	111	133	05/02/2007
04	Knutton and Silverdale	1176	1074	830	330	210	426	335	73	82	19/03/2007
06	Holditch	1239	1238	919	263	389	368	487	46	62	30/04/2007
08	Silverdale and Parksite	1271	955	828	249	325	375	406	55	64	04/06/2007
10	Chesterton	2183	1761	1505	481	617	579	775	57	93	09/07/2007
14	Butt Lane	1766	1380	1192	265	421	427	578	92	102	12/10/2007
17	Town	1684	1156	1089	128	104	342	410	30	51	26/11/2007
19	Bradwell	2114	1780	1384	402	792	371	916	154	116	11/02/2008
22	Kidsgrove	2416	2141	1580	322	1014	275	1176	64	61	28/04/2008
24	Thistleberry	1833	1832	1285	363	560	496	629	141	142	28/07/2008
26	Talke	1335	1329	913	199	571	240	599	78	70	29/07/2008
27	Porthill	1683	1682	955	262	281	372	392	67	93	28/07/2008
29	May Bank	2508	2507	1410	328	576	415	728	139	142	01/12/2008
30	Wolstanton	2204	2235	1261	360	348	633	593	85	131	16/02/2009
32	Clayton	1479	1474	701	163	402	191	431	82	63	23/02/2009
33	Seabridge	2158	2158	1076	295	638	258	707	101	109	23/02/2009
34	Westlands	2281	2279	1116	364	566	357	640	102	105	13/04/2009
36	Newchapel	1410	1400	838	233	443	313	510	61	65	13/04/2009

Appendix 20 Warm Zone Data

37	Ravenscliffe	1632	1626	867	218	408	353	361	52	43	15/06/2009
38	Audley and Bignall End	2174	2172	1155	233	354	436	495	83	100	15/06/2009
39	Halmerend	1466	1447	871	151	253	394	314	54	70	20/07/2009
41	Madeley†	1665	1659	382	149	120	261	115	54	77	28/09/2009
42	Loggerheads and Whitmore	2649	2642	674	221	240	401	234	68	106	14/09/2009
43	Keele	346	345	71	11	31	53	9	3	19	28/09/2009

Statistics Derived From The Staffs Warm Zone Data (i)

Stoke-on-Trent							
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	% of target responding to WZ	% of potentially suitable homes where WZ fitted CWI	% of potentially suitable homes where WZ fitted LI
01	Longton South	4898	4432	2848	64.3	31%	24%
03	Burslem North	4399	4001	2889	72.2	29%	22%
05	Bentilee and Townsend	2917	2881	2126	73.8	23%	20%
07	Blurton	3539	3104	2339	75.4	27%	18%
09	Tunstall	5046	4113	3218	78.2	18%	16%
11	Chell and Packmoor	3730	3330	2361	70.9	21%	21%
12	Fenton	5062	4499	3288	73.1	15%	15%
13	Abbey Green	3358	3130	2268	72.5	22%	19%
15	Weston and Meir North	3958	3732	2655	71.1	23%	18%
16	Berryhill and Hanley East	3484	3387	2507	74.0	19%	14%
18	Norton and Bradeley	3616	3418	2429	71.1	25%	21%

Appendix 20 Warm Zone Data

Stoke-on-Trent							
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	% of target responding to WZ	% of potentially suitable homes where WZ fitted CWI	% of potentially suitable homes where WZ fitted LI
20	Longton North	4915	4489	2697	60.1	26%	20%
21	Stoke and Trent Vale	4651	4055	2659	65.6	18%	18%
23	Hanley West and Shelton	3460	3109	2340	75.3	15%	15%
25	Burslem South	4922	3902	3457	88.6	23%	20%
28	Meir Park and Sandon	4374	4372	2206	50.5	35%	32%
31	East Valley	4601	4587	2452	53.5	36%	28%
35	Northwood and Birches Head	4921	4921	2749	55.9	27%	24%
40	Hartshill and Penkhull	5394	5387	2156	40.0	25%	20%

Statistics Derived From The Staffs Warm Zone Data (ii)

Newcastle							
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	% of target responding to WZ	% of potentially suitable homes where WZ fitted CWI	% of potentially suitable homes where WZ fitted LI
02	Cross Heath	1579	1104	1106	100.2	26%	22%
04	Knutton and Silverdale	1176	1074	830	77.3	22%	19%
06	Holditch	1239	1238	919	74.2	17%	17%
08	Silverdale and Parksite	1271	955	828	86.7	22%	17%
10	Chesterton	2183	1761	1505	85.5	12%	16%

Appendix 20 Warm Zone Data

Newcastle							
No.	Ward	Total No of homes	WZ Target	No. homes responding to WZ	% of target responding to WZ	% of potentially suitable homes where WZ fitted CWI	% of potentially suitable homes where WZ fitted LI
14	Butt Lane	1766	1380	1192	86.4	35%	24%
17	Town	1684	1156	1089	94.2	23%	15%
19	Bradwell	2114	1780	1384	77.8	38%	31%
22	Kidsgrove	2416	2141	1580	73.8	20%	22%
24	Thistleberry	1833	1832	1285	70.1	39%	29%
26	Talke	1335	1329	913	68.7	39%	29%
27	Porthill	1683	1682	955	56.8	26%	25%
29	May Bank	2508	2507	1410	56.2	42%	34%
30	Wolstanton	2204	2235	1261	56.4	24%	21%
32	Clayton	1479	1474	701	47.6	50%	33%
33	Seabridge	2158	2158	1076	49.9	34%	42%
34	Westlands	2281	2279	1116	49.0	28%	29%
36	Newchapel	1410	1400	838	59.9	26%	21%
37	Ravenscliffe	1632	1626	867	53.3	24%	12%
38	Audley and Bignall End	2174	2172	1155	53.2	36%	23%
39	Halmerend	1466	1447	871	60.2	36%	18%
41	Madeley†	1665	1659	382	23.0	36%	30%
42	Loggerheads and Whitmore	2649	2642	674	25.5	31%	26%
43	Keele	346	345	71	20.6	27%	36%

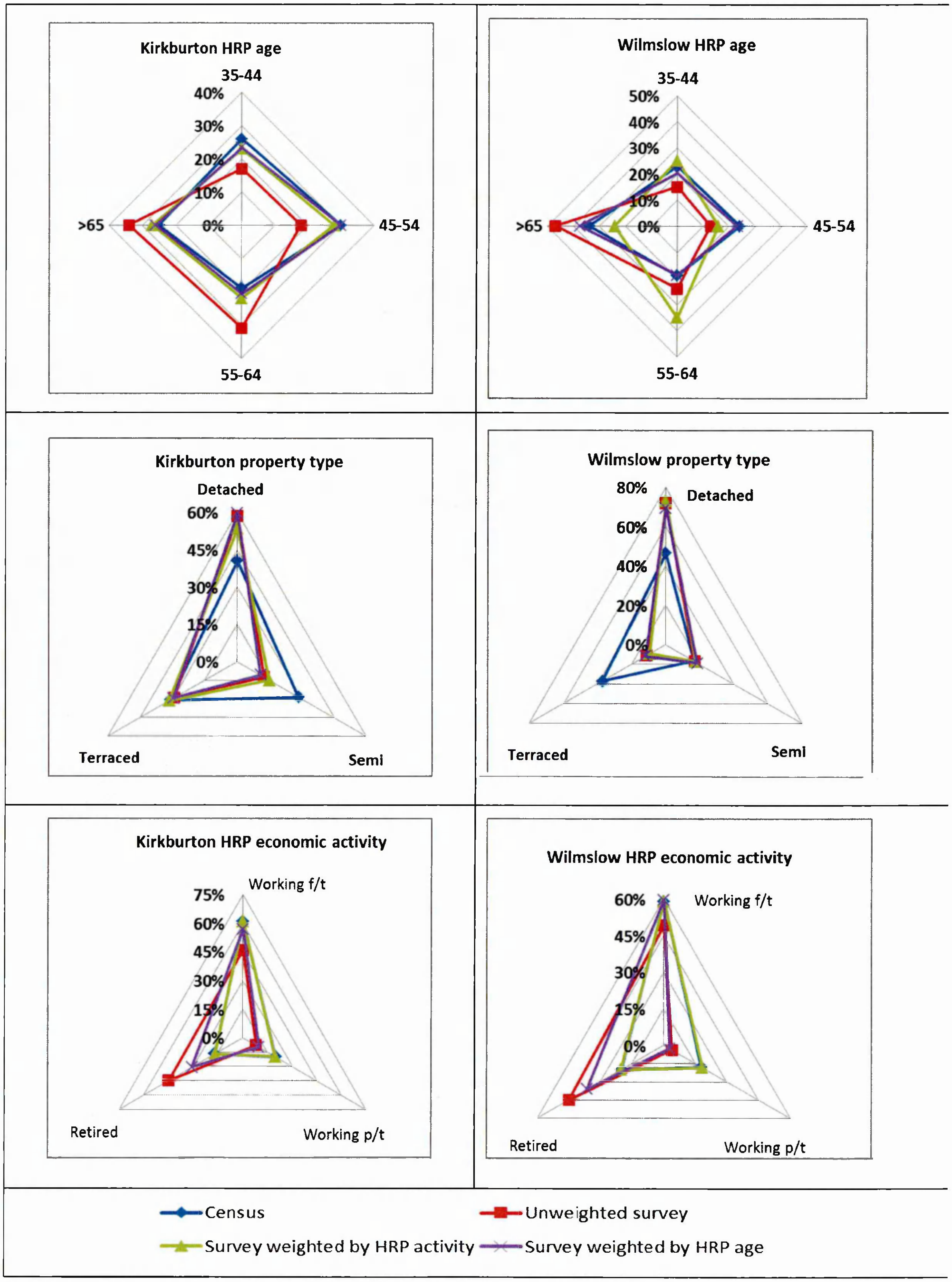
Appendix 22 Weighting Assessment

Variable	2001 Census				Survey 2011				Weight	
	Kirkburton	Wilmslow	Kirkburton	Wilmslow	Kirkburton	Wilmslow	Kirkburton	Wilmslow	Kirkburton	Wilmslow
House Type (UV56)	No households		% households		No households		% households			
House or Bungalow: Detached	954	1359	41%	46%	38	38	58%	72%	0.69	0.65
House or Bungalow: Semi-detached	672	482	29%	16%	8	9	12%	17%	2.32	0.97
Terraced (including end-terrace) and flats	728	1085	31%	37%	19	6	29%	11%	1.06	3.28
Flat, Maisonette or Apartment										
Total	2354	2926	100%	100%	65	53	100%	100%		
Average weight when scaled									1.00	1.00
Economic Activity (UV28)	No people		% population		households where HRP is...					
Economically active: Employee: Full-time	2087	2130	61%	59%	30	26	46%	49%	1.33	1.20
Economically active: Employee: Part-time	665	668	20%	18%	5	2	8%	4%	2.54	4.89
Economically active: Unemployed	82	82	2%	2%	1	1	2%	2%	1.56	1.20
Full-time Students	1445	254								
Economically inactive: Retired	576	737	17%	20%	29	24	45%	45%	0.38	0.45
Economically inactive: Looking after home / family	197	319								
Economically inactive: Permanently sick / disabled	135	78								
Economically inactive: Other	71	90								
Total	3171	2228								
Total p/t, f/t, unemployed and retired	3410	3617	39%	41%	65	53	100%	100%		
Average weight when scaled									1.00	1.00
Age Group (UV04)	No people		% population (35+)		households where HRP is...					
16-24	1661	454								
25-34	620	678								
35-44	877	934	26%	23%	11	8	17%	15%	1.54	1.55
45-54	1010	937	30%	24%	12	7	18%	13%	1.63	1.78
55-64	646	758	19%	19%	20	13	31%	25%	0.62	0.78
>65	831	1352	25%	34%	22	25	34%	47%	0.73	0.72
Total 35->65	3364	3981	100.00%	100%	65	53	100%	100%		
Average weight when scaled									1.00	1.00

Method

- Remove 16-24 age group becuase none in survey.
- Weight = Census number divided by survey number
- Scaled weights have a mean of 1.00

Appendix 22 Weighting Assessment



Appendix 23 Weighted and Un-weighted Analysis

Table 1 *Summary of Wilmslow and Kirkburton Samples (Counts)*

		Wilmslow		Kirkburton	
		Un-weighted	Age Weighted	Un-weighted	Age Weighted
Age	35 - 44	8	11	11	15
	45 - 54	7	12	12	20
	55 - 64	13	10	20	13
	65 or over	25	20	22	17
	Total	53	53	65	65
Household Income (gross)	Less than £11,500	1	1	7	6
	£11,500 to £16,500	1	1	2	2
	£16,500 to £23,500	4	3	6	4
	£23,500 to £35,500	11	11	13	12
	Over £35,500	25	29	27	33
	Total	42	44	55	56
	Missing	11	9	10	9
Energy demand	Lowest 20%	1	1	3	4
	Quintile 2	2	2	8	5
	Quintile 3	5	4	13	12
	Quintile 4	17	17	11	12
	Quintile 5	17	18	15	16
	Total	42	41	50	50
	Missing	11	12	15	15

The weighting sensitivity analysis indicated that in majority of cases, the percentage occurrence of a variable was changed by less than a few percentage points and the study conclusions would be the same using weighted or un-weighted data. Two study findings were identified where weighting had a potentially meaningful effect including:

a) The proportion of households who had fitted loft insulation in the last five years, rose from 21% (un-weighted) to 29% (weighted). The EHCS indicates that home owners over 55 years old are less likely to have topped up their loft insulation unless assisted to do so, and age weights are likely to improve the external validity of this estimate.

b) The proportion of households potentially interested in a Green Deal loan to improve the energy efficiency of their home increased from 28% to 34%. Interviewees over 55 years old were more reluctant to go into debt and therefore age weights are likely to make the Green Deal data more valid externally.

A Review of the External Validity of the Sample

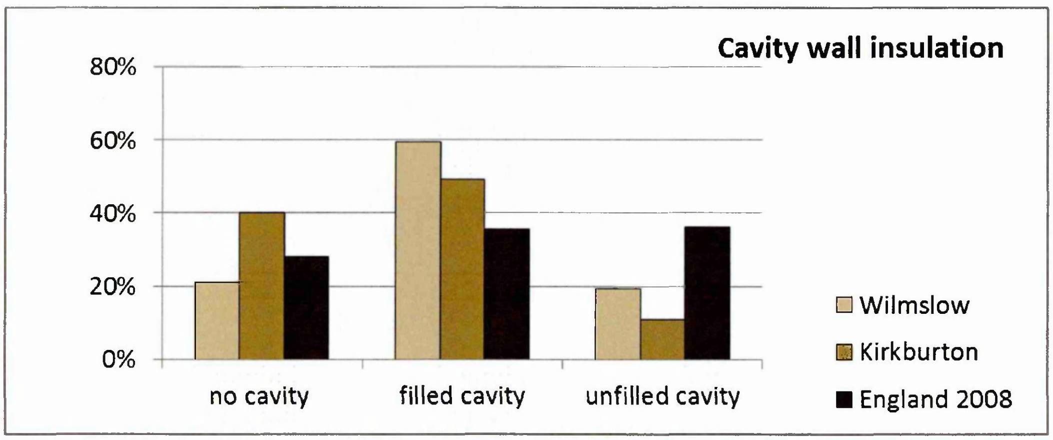
Introduction

Although the survey was based upon a random sample, interviewees were free to decline to participate, exposing the survey to a degree of *self-selection, which in turn could have created a pro-energy efficiency or pro-environmental attitude bias in the sample. To examine the data for such a possibility three lines of evidence were considered: the proportion of surveyed homes with insulation; interviewee's opinions; and, home improvements carried out in the past five years.*

Validity review taking account of the level of insulated homes in the survey

The samples from Macclesfield 006 and Kirklees 051 suggest that the proportion of properties with filled cavities is meaningfully and significantly ($p<.05$) greater than the English average, derived from the 2008 EHCS , see Figure 1

Figure 1 *Proportion of filled cavity walls in Macclesfield 006 and Kirklees 051surveys (weighted by age)*



Source: Data for England from EHCS, 2008. Data for owner occupiers, over 35 years old only

The relatively high frequency of filled cavities in the samples was contrary to expectations for several reasons. Firstly Income Quintile 5 households are disproportionately common and in Macclesfield 006 at least, gas demand changed little between 2005 and 2008.

Therefore the contrast between the sample and national statistics suggests that there may have been a bias in the sample towards those who have insulated their homes. Such a bias does not necessarily appear unreasonable in Kirkburton, where the Council were disproportionately active, retrofitting cavity wall insulation and/or loft insulation free of charge in 2424 homes in 2009 and 2010 (pers comm), equivalent to 40% of the houses in the Ward.

Kirklees Borough Council records (pers comm) indicate that by August 2010, approximately 83% of potentially suitable homes in Kirklees 051had filled their cavity walls with insulation. In the survey, 87% (weighted) of homes with suitable cavity walls had insulated cavities. The correlation between the Council and the survey data suggests that the weighted Kirklees 051sample may have been reasonably characteristic of this population.

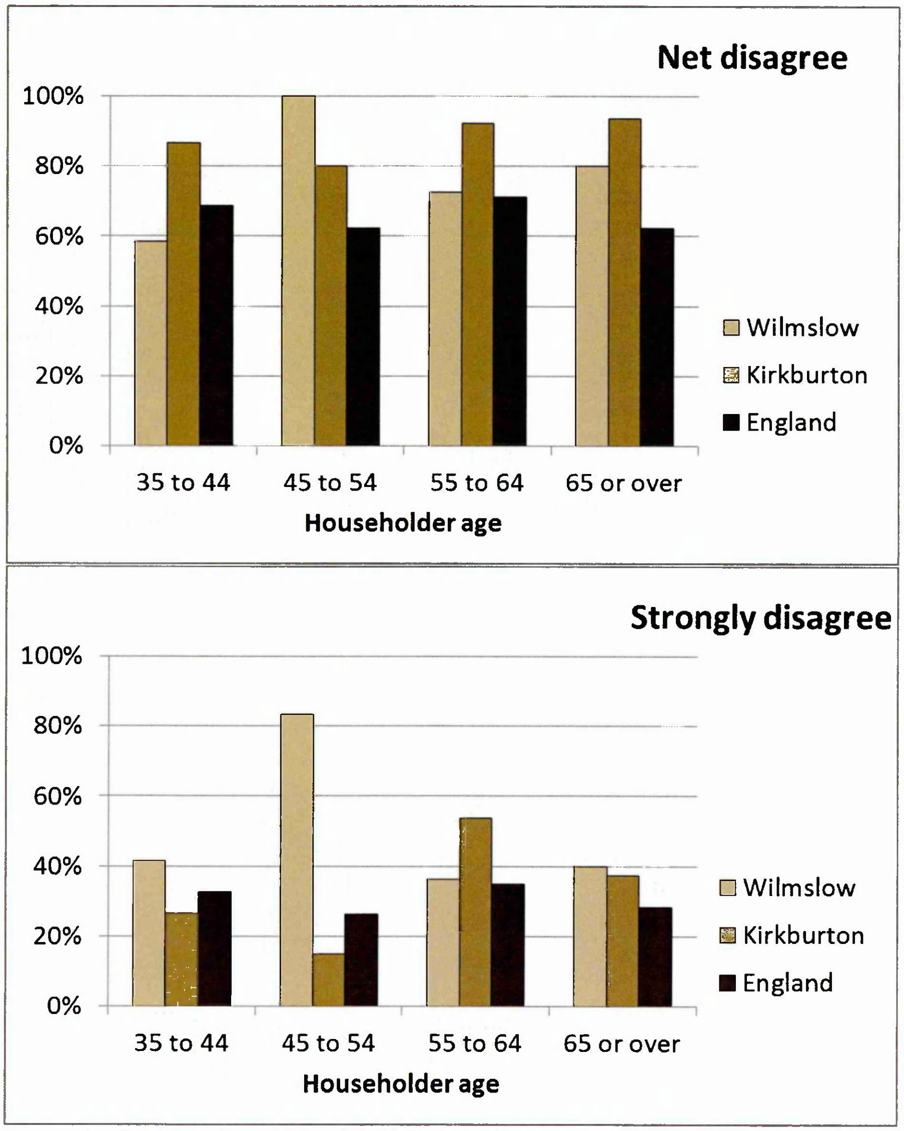
However one in ten private householders in Kirklees 051refused the offer of a survey to determine whether their homes were suitable for insulation measures (see Appendix 13) and a further 9% of householders whose homes were surveyed and identified as potentially suitable, subsequently rejected or failed to take up the free insulation. This group was under-represented in the sample - two householders in the 65 strong sample reported that they missed the Council's surveyor and two reported that they agreed to the retrofit, but missed the Council's retrofit contractors.

A young housing stock would offer a possible explanation for the unexpectedly high incidence of filled cavity walls in Macclesfield 006 because cavity wall insulation became mandatory in new homes in 1976. However only approximately 12% of cavity wall homes sampled in the town had been built after the mid-1970s, which is less than half of the national average in 2008 (EHCS, 2008). Therefore the age of the properties cannot explain the apparent pro-insulation bias in the Macclesfield 006 sample and without information to support the relatively high frequency of filled cavity walls in this sample, the comparison suggests that the Macclesfield 006 sample was biased towards residents who had retrofitted their homes with cavity wall insulation.

Validity review taking into account interviewee's environmental attitudes

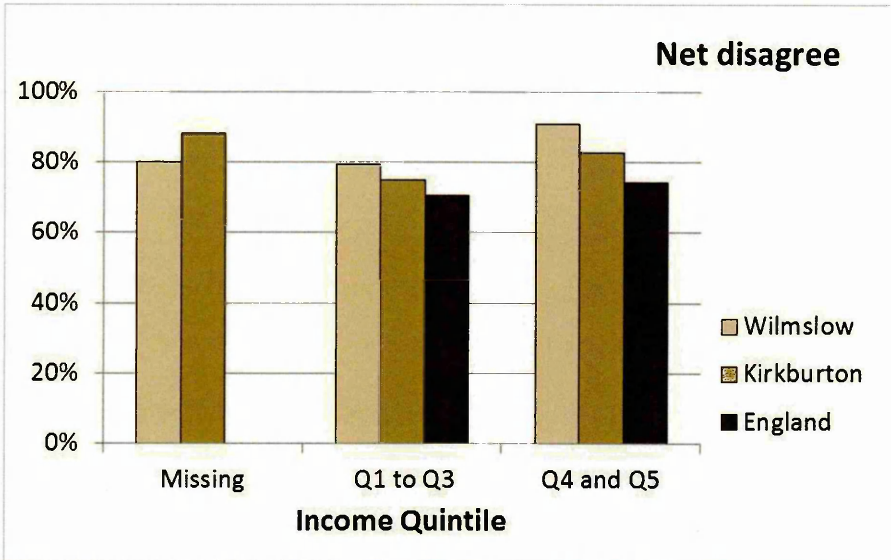
A pro-retrofitting bias may also indicate a pro-energy or pro-environmental attitude bias in the samples. The potential for such a bias was tested by contrasting the opinions of interviewees with the attitudes of those surveyed by DEFRA (2009). Figure 3 illustrate the proportion householders who disagreed with the statement *"It's not worth doing things to help the environment if others do not do the same"*.

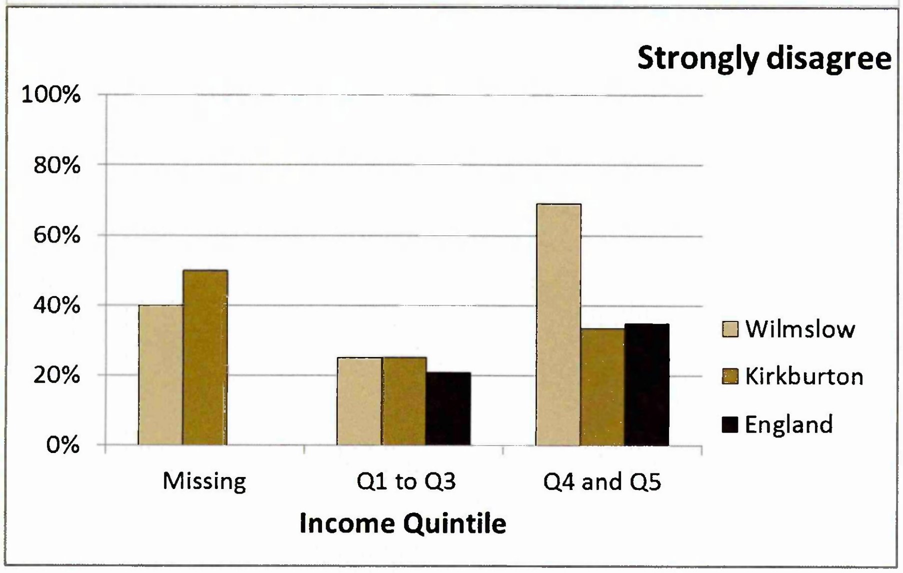
Figure 3 ***"****It's not worth doing things to help the environment if others do not do the same" (disaggregated by age)*



Source: England data from DEFRA (2009) Table Q66k

Figure 4 *"It's not worth doing things to help the environment if others do not do the same" (weighted by age and disaggregated by income)*





Source: England data from DEFRA (2009) Table Q66k. English Income Quintiles 4 and 5 data is a proxy based upon a threshold of £40,000pa.

The data illustrated in Figure 3 and Figure 4 suggests a general pro-environmental bias in both surveyed towns. However, the limited sample size means that once the data is disaggregated, the differences between the sample and the national results are not statistically significant (at $p<.05$) except for home owners between 45 and 54 years old in Macclesfield 006. This proportion of the population was under-represented in the sample and it appears that householders in this group who participated in the survey had disproportionately strong pro-environmental views.

Age weights increased the influence of this group, but as noted previously, the weighting effect has been relatively marginal. For example age weights increased the proportion of Quintile 4 or 5 income households from Macclesfield 006 who 'strongly disagreed' with the statement, from 64% to 69%, whereas for England as a whole, 35% of householders earning over £40,000pa strongly disagreed with the statement (DEFRA, 2009). Weighted, or un-weighted, the difference between the Macclesfield 006 sample and the national sample is statistically significantly ($p<.05$) for those between 45 and 54 years old.

Comparable results were obtained to the question *'it's only worth doing environmentally friendly things if they save you money'*. As illustrated in Figures 5 and 6, homeowners from Macclesfield 006, particularly those between 35 and 55 years old, or those receiving Quintile 4 or 5 incomes in either district, displayed a willingness to undertake environmentally friendly actions which was greater than was anticipated from the results of a national study.

Figure 5 *It's only worth doing environmentally friendly things if they save you money" (disaggregated by age)*

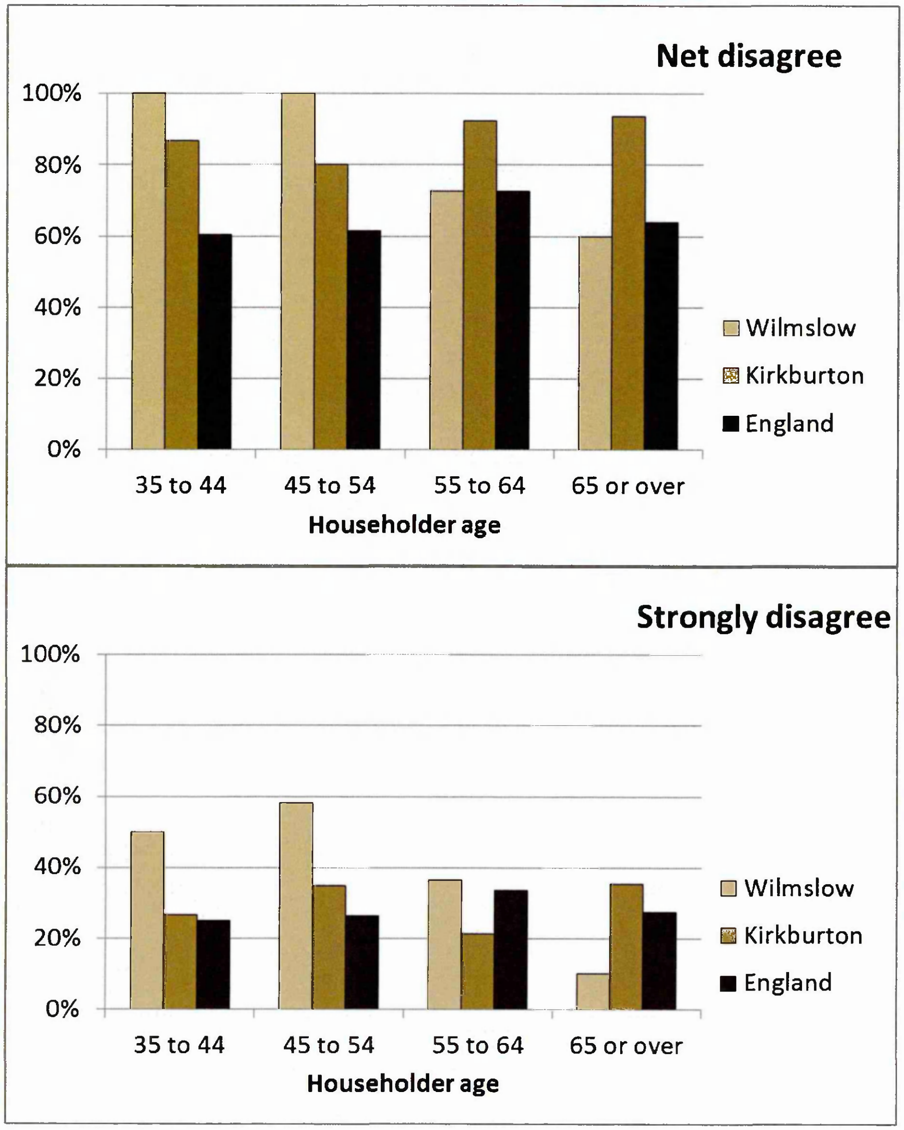
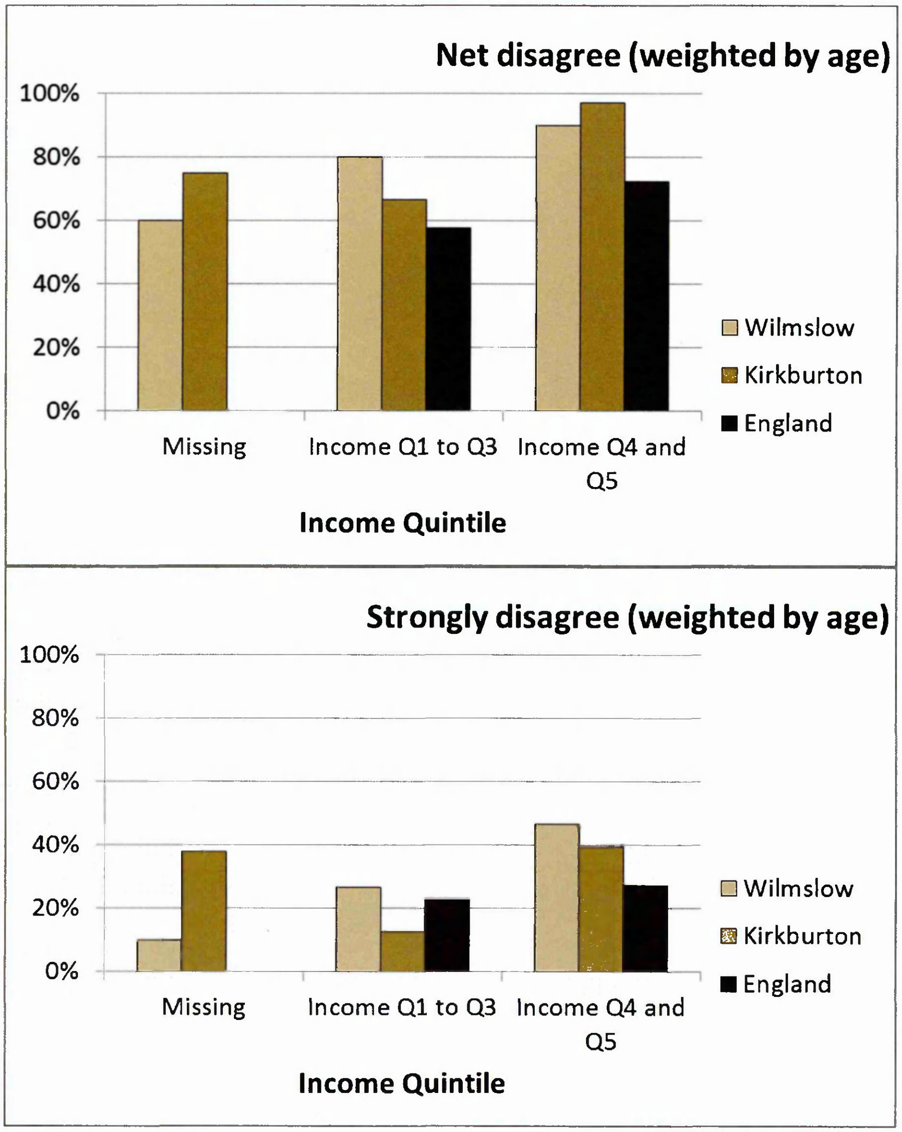


Figure 6 *"It's only worth doing environmentally friendly things if they save you money" (weighted by age and disaggregated by income)*



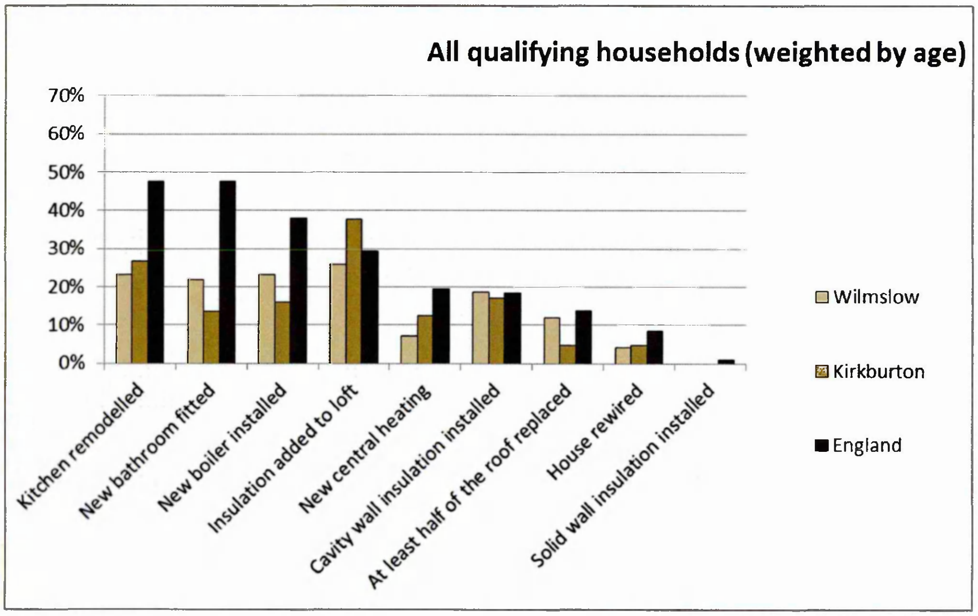
Source: England data from DEFRA (2009) Table Q66m

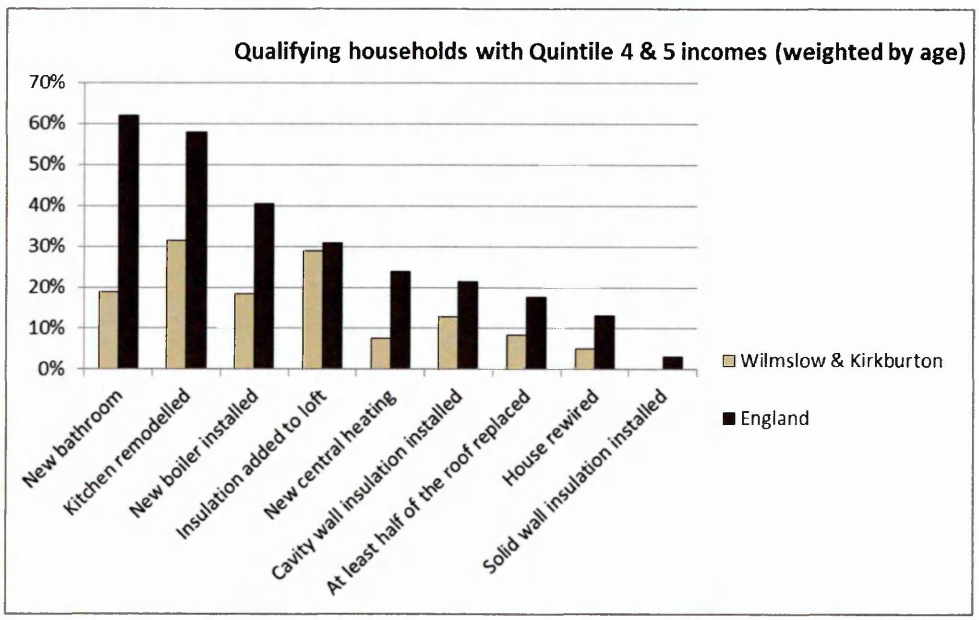
Validity review taking into account the level of home improvements

In addition to being more likely than the English average to live in a home with filled cavities and to hold relatively pro-environmental opinions, the sample displayed disproportionately low levels of discretionary spending on their homes.

As illustrated in Figure 7, interviewees purchased new kitchens, bathrooms, central heating, rewires, or new roofs at approximately half the English average for home owners over 35 years old. Insulation retrofitting on the other hand had proceeded in line with expectations, based upon the national data. The English averages illustrated in Figure 7 were based upon the 2008 EHCS, extrapolated for five years. Therefore the estimates are not precise, as spending on maintenance and refurbishment will be linked to other factors such as the housing market and availability of credit. Nevertheless the statistics are considered sufficient to highlight a meaningful and statistically significant difference between the sample and expectations, based upon national statistics.

Figure 7 *Proportion of household undertaking home improvement actions in last five years*





Source: Data for England from EHCS, 2008. Data for owner occupiers who are over 35 years old. Macclesfield 006 and Kirklees 051survey data weighted by age to Census 2001.

Summary of the validity review

The review suggests that the sample was disproportionately older than the true populations of either Macclesfield 006 or Kirkburton. There also appears to be a pro-environmental attitudes bias in the samples from both areas which is reflected in the interviewees' opinions and the strength of those opinions. Such a bias affects the external validity of the results but does not invalidate the survey. Rather the validity review indicates that the general population in both districts is likely to hold less environmentally friendly opinions on the topics discussed in this chapter, than is suggested by the survey data.

Conference Proceedings

Ashby R and Pitts A. (2012) *"The legacy of energy efficiency prioritization programmes and the implications for The Green Deal"*, Retrofit 2012, January 2012, The University of Salford. Available at: http://www.energy.salford.ac.uk/cms/resources/uploads/File/Retrofit%20Papers/008%20Ashby.pdf

Ashby R and Pitts A. (2011) *"Homework -a study of the relationships between income, energy consumption and home insulation installation"* presented at Energy and people: futures, complexity and challenges, UK Environmental Research Centre, Oxford University, October 2011. Available at http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=1930&display

Papers In Preparation

Ashby R., Pitts A. & Escott, K. *"The effects of social prioritization on the outcome of the Energy Efficiency Commitment Supplier Obligation"*

Ashby R., Pitts A. & Escott, K. *"The contribution of a more energy efficient housing stock to falling household fuel demand during the Energy Efficiency Commitment Supplier Obligation"*

Other Presentations

"Trends in residential insulation retrofitting and household fuel demand" presented to The Royal Town Planning Institute, Yorkshire Conference Series 2011/12, Renewable energy and climate adaptation, 22 March 2012

"The response of English home owners to residential energy efficiency programmes" presented at the Faculty Research Conference, Faculty of Development & Society, Sheffield Hallam University, 20th June 2011

Accredited Training Programmes

Associate lecturer training workshops, Sheffield Hallam University, 2012

Statistical Methods (MRES module), Sheffield Hallam University, 2010 (Good Pass)

Research Principles (MRES module), Sheffield Hallam University, 2009 (Distinction)